e-ISSN: 2735-1084

VOLUME 1
ISSUE 2 | 2020

ADVANCES IN AGRICULTURAL & FOOD RESEARCH JOURNAL

MSAE
MALAYSIAN SOCIETY OF AGRICULTURAL AND FOOD ENGINEERS
Est. 1982

HH PUBLISHER

Editorial Board

Table of Contents

EDITORIAL NOTE

ORIGINAL RESEARCH ARTICLE

Table of Contents

Table of Contents

MSAE MALAYSIAN SOCIETY OF AGRICULTURAL AND FOOD ENGINEERS Est. 1962

ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

HH PUBLISHER

Editorial Note

1-Year Journey: An Insight

Rosnah Shamsudin

Department of Process & Food Engineering, Faculty of Engineering, Universiti Putra Malaysia, Serdang, 43400 Serdang Malaysia; rosnahs@upm.edu.my

Received: 29th December 2020

Accepted: 30th December 2020

Available Online: 31st December 2020

Citation: Shamsudin R. 1-year journey: An insight. Adv Agri Food Res J 2020; 1(2): a0000163. https://doi.org/10.36877/aafrj.a0000163

Main Text

On behalf of the Editorial Board Members of the ***Advances in Agricultural and Food Research Journal —(AAFRJ)*** (https://journals.hh-publisher.com/index.php/AAFRJ/index), I am glad to present the Volume 1, Issue 1 and Issue 2 of the journal for year 2020. The journal which was established in April 2020 has now published 2 issues; twice in a year. ***AAFRJ*** is a Gold open access journal and is also indexed in Google Scholar, Crossref and Malaysian Citation Centre (MyJurnal).

During the year of 2020, ***AAFRJ*** received a total of 66 papers, out of which 33 papers will be published in Volume 2 Issue 1 for the year 2021. During 2020, 53 articles were accepted for publication after being evaluated in the peer review process. In the Volume 1 Issue 1, around 10 articles were published whereas for Volume 1 Issue 2, a total of 23 articles were published from authors around the world. A number of 105 research scientists and academics from all over the world reviewed the 33 articles published in Volume 1 Issue 1 and 2.

In another aspect, the average view per article is 37 and it is increasing as the year moves on. ***AAFRJ*** has reached this stage through the constant support of its respected Board Members, the readers and also the contributors, authors and reviewers alike.

AAFRJ is a refereed, scholarly journal publishing original research and review papers on any subject related to science and engineering in agricultural and food, particularly those of relevance to industry. These include, but are not limited to, applied agriculture, biology and environment, natural resources, food, and livestock farming with the intention of solving problems in complex living systems. In addition to science and engineering topics, we also welcome articles related to agriculture and food service extension, management and business both at local and international level.

I would like to take this opportunity to acknowledge the contributions of the Editorial Board Members, Senior Editors and the publisher during the final editing of all articles until they were published. I also would like to express my deepest appreciation to all our valuable authors, reviewers, readers and the Advisory Board Members for their interest, support and contributions to ***AAFRJ***.

Celebrating the coming new year is exciting for everyone despite the ongoing COVID-19 pandemic. Year 2021 represents a new chapter. The calendar will change but the commitment would never waver. The hope is for a better year than the previous one. We, the ***AAFRJ*** editorial team, will continuously work hard to better service our authors and readers.

We hope that all could achieve their goals and let it be the best year of our life. Happy new year 2021!

ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

MALAYSIAN SOCIETY OF AGRICULTURAL AND FOOD ENGINEERS

HH PUBLISHER

Original Research Article

Effect of Heat Treatment on Rheological Properties of Bambangan (*Mangifera Pajang Kosterm*) Fruit Juice

Jumardi Roslan[1]*, Hay Chye Ling[1], Mohd Dona Sintang[1], Suryani Saallah[2]

[1]Faculty of Food Science and Nutrition, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, jumardi@ums.edu.my, haychyeling@gmail.com, donasintang@ums.edu.my

[2]Bioetchnology Research Institute, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, suryani@ums.edu.my

*Corresponding author: Jumardi Roslan, Faculty of Food Science and Nutrition, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, jumardi@ums.edu.my

Abstract: Bambangan (*Mangifera pajang Kosterm*) is an indigenous fruit that can be found in Borneo Island including Sabah and Sarawak (Malaysia), Kalimantan (Indonesia), and Brunei. Besides being eaten fresh, the pulp of bambangan fruit can be processed for juice production and expand its market potential. During the fruit juice processing, application of heat treatment such as pasteurization and sterilization might influence their rheological behavior. Thus, the present study aims to investigate the effect of heat treatment on the rheological properties of bambangan fruit juice (BFJ). The freshly squeezed BFJ was subjected to different heat treatment conditions; sterilization (121°C, 3 minutes), mild temperature long time (MTLT) pasteurization (65°C, 15 minutes), and high temperature short time (HTST) pasteurization (90°C, 1 minute). Rheological analysis of the heat-treated BFJ was performed using a rheometer at a shear rate ranging from 1 to 250 s^{-1} and a temperature between 5°C to 70°C. Pasteurization at 90 °C for 1 minute (HTST) was found to be the most suitable heat treatment for the BFJ. At this condition, the BFJ exhibited a non-Newtonian pseudoplastic fluid behavior ($n < 1$), fitted well with the Herschel-Bulkey model. The value of parameters obtained from Herschel-Bulkley equation for HTST treatment of bambangan juice were n = 0.83, k = 0.32 and yield stress = 3.96. The viscosity values of HTST bambangan juice at the temperature of 5, 20, 40 and 70 °C were 3.53, 2.33, 1.53 and 1.76 Pa.s respectively. This rheological information is of fundamental importance in optimizing equipment design, process control, and sensory evaluation.

Keywords: Bambangan fruit; bambangan fruit juice; heat treatment; rheological properties

Received: 28th August 2020

Accepted: 30th September 2020

Available Online: 14th October 2020

Citation: Roslan J, Ling HC, Sintang MD, *et al*. Effect of Heat Treatment on Rheological Properties of Bambangan (*Mangifera Pajang Kosterm*) Fruit Juice. Adv Agri Food Res J 2020; 1(2): a0000115. https://doi.org/10.36877/aafrj.a0000115

1. Introduction

Bambangan (*Mangifera pajang Kosterm*) is an underutilized fruit endemic to Borneo Island (Sabah and Sarawak of Malaysia, Brunei, and Kalimantan, Indonesia). It is a type of wild mango belongs to the *Anacardiaceae* family. The trees can grow up to 20 m in height and bears up to hundreds of semi-oval shaped fruits. The uniqueness of thee fruits are the size can reach up to three times larger than common mangos (*Mangifera indica*), has a thicker peel, rough-brown skin, big seed size and can weigh up to 2 kg. The fruits consist of pulp which represents 60–65% of the total weight, kernel (15–20% of total weight) and peel (10–15% of the total weight). The fruit pulp has a delightful mango fragrance, highly fibrous, very juicy with a unique aromatic flavor and strong smell (Mohd Fadzelly & Jeffrey, 2013).

Several scientific studies have discovered the health-promoting benefits of bambangan fruit attributed to its rich Vitamin C content and superior antioxidant properties. Usually, the fruits are eaten fresh, pickled or used as an ingredient in local dishes. Production of juice from bambangan fruit is an ideal solution to expand its potential market (Mohd Fadzelly & Jeffrey, 2013). Although, the fruit juice is highly susceptible to microbial, enzyme, chemical, and physical degradations but affect the product quality and shelf-life during cool and room temperatures storage. Various approaches have been investigated to overcome this problem, but thermal treatment such as pasteurization and sterilization remains the most cost-effective strategy to prolong the shelf-life of juice product by inhibiting microorganisms and enzymes that can cause fruit juice deterioration (Aguilo-Aguayo *et al*., 2009; Rawson *et al*., 2011; Jimenez-Sanchez *et al*., 2017).

During the processing of fruit juice, thermal treatment may affect the fruit juice attributes, particularly on rheological behavior (REFs). Rheology attempts to define the relationship between stress acting on given materials and the resulting shear strain developed in this material. When stress is applied to any food material like liquid food, a strain develops in the materials causing the deformation of materials as in the flow of juices through pipes or movement of semi-solid foods (Rosnah *et al*. 2007). Therefore, this rheological information is useful for prediction of heat and mass transfer coefficient where they can be applied in food handling and processing, quality control, sensing and for the design or development of equipment in the fruit juice industry (Rosnah *et al.*, 2013; Sinemobong & Emediong, 2016).

Several studies have been conducted to investigate rheological properties of fruit juice under the influence of heat treatment including grape juice (Mauricio *et al.*, 2017), pineapple juice (Sinemobong & Emediong, 2016), white carrot juice (Zbigniew *et al*., 2015), Yankee pineapple juice (Rosnah *et al.*, 2013), mango juice (Manish *et al*., 2007), and strawberry juice (Juszczak & Fortuna, 2003). Generally, fruit juices exhibited a non-Newtonian flow behavior known as shear-thinning behavior, a typical pseudoplastic fluid, which can be explained by several models such as the Newtonian, Herschel-Bulkley, Bingham, and Power Law models (Quek *et al.*, 2013). However, to date, no rheological information is available for juice made from bambangan fruit. Therefore, the study was undertaken to investigate the rheological behavior and temperature-viscosity relationship of bambangan fruit juice under different heat treatment conditions.

2. Materials and Methods

2.1. Preparation of bambangan fruit juice (BFJ)

Bambangan fruits (*Mangifera pajang*) were bought from Ranau market, Sabah and brought to the laboratory. Upon arrival at laboratory, the fruits were washed, and the peel was manually removed to get the pulp. The pulp maturity was evaluated according to the total soluble solid (°Brix) using refractometer (Atago, Germany) with the matured bambangan fruit was considered approximately around 15°Brix of total soluble solid. The pulp was then cut into smaller pieces followed by blending using a food processor (Dito Sama, Italy) and filtered to get the juice. The juice was prepared with a ratio of 1:1 (water and flesh) and then placed in 500 mL Schott bottle.

2.2. Heat treatments of BFJ

The bambangan fruit juice (BFJ) was then treated at three different heat treatment conditions denoted as high temperature short time (HTST) for pasteurization at 90°C/1 minute, mild temperature long time (MTLT) for pasteurization at 65°C/15 minutes (Pareek *et al.*, 2011; Wang *et al.*, 2018) and sterilization at 121°C/3 minutes using horizontal retort (CY-3000H, China) (Chen *et al.*, 2015). BFJ without treatment were used as control. All samples were stored in a cold room at the temperature of -20°C until further use.

2.3. Rheological characterizations

Rheometer (TA Instruments AR1500EX, USA) with computer software (Rheology Advantage Data Analysis Program, TA, New Castle, DE) was used to determine the rheological properties of BFJ. Measurement of the rheological properties was carried out using cone and plate system. Calibration steps were carried out before operating the rheometer. Cone-plate geometry with a diameter of 60 mm and an angle of 2° was used. A total of 3.5 mL sample from each of the treatments was tested at a shear rate within the range of 1 - 250 s^{-1} (Mauricio *et al*. 2017). Sample temperature was controlled and regulated at 5°C, a common storage temperature for fruit juice. The rheological models were fitted to the experimental shear stress and shear rate data according to the rheological models as follow: Newtonian, Bingham, Casson, Power Law, and Herschel-Bulkley. The best rheological model that fitted the experimental data was selected according to the lowest relative error (Equation 1) between observed and predicted values.

$$\text{Relative error (\%)} = [(\text{Observed value} - \text{predicted value}) / \text{Observed value}] \times 100 \qquad (1)$$

After that, rheological data obtained was fitted into pseudoplastic fluid *(Herschel-Bulkley)* model (Equation 2) in which τ is shear stress (Pa), γ is shear rate (s^{-1}), τ_0 is yield stress (Pa) , K is consistency coefficient ($Pa^{1/2}s^n$), and n is flow behaviour index.

Herschel-Bulkley, $\tau = \tau_0 + K(\gamma)^n$ (2)

Different *n* value indicates the fluid behavior. For Newtonian behavior, $n = 1$ while $n < 1$ indicate pseudoplastic behavior and $n > 1$ for dilatant behavior. Viscosity measurement was further carried out using Peltier control system with temperature ramp from 5 to 70°C. Perimeter of the exposed sample was covered with metal solvent trap to minimize evaporation of sample at a higher temperature. Experiments were performed in triplicate.

2.4. Statistical Analysis

Statistical Package for the Social Science (SPSS) version 25 was used for statistical analysis. Mean and standard deviation was calculated for triplicate and one-way analysis of variance (ANOVA) followed by Tukey's B test was used to evaluate the differences among treatment at significant level of 5% ($p < 0.05$).

3. Results and Discussions

3.1. Selection of Rheological Model

Bambangan fruit juice (BFJ) was subjected to three different heat treatment conditions; medium temperature-long time (MTLT), high temperature-short time (HTST), sterilization and no heat treatment as control. All the treated BFJ samples were tested using the existing rheological models including Newtonian, Bingham, Casson, Power Law and Herschel-Bulkley. The best fitted model was chosen depending on the lowest relative error. Based on the results presented in Table 1, the lowest relative error was obtained by the Herschel-Bulkley model, indicating that this model was the best to describe the rheological behavior of the treated BFJ.

Table 1. Relative error values of heat treated BFJ at different rheological model

	Relative error (%)				
Treatment/Model	**Newtonian**	**Bingham**	**Casson**	**Power Law**	**Herschel-Bulkley**
No heat treatment	283.0	28.0	13.9	60.8	9.3
MTLT	267.9	76.0	37.5	21.6	9.8
HTST	287.0	73.5	35.2	23.7	9.2
Sterilization	282.3	79.7	40.8	16.6	6.9

3.2. Analysis and modelling of fluid flow behavior using Herschel-Bulkley

All the treated BFJ were further analyzed for their fluid flow behavior using Herschel-Bulkley model. The plot of shear stress and at shear rate ranging from 1–250 s^{-1} for the BFJ is as shown in Figure 1. All samples exhibited a non-Newtonian behavior with a concave downward curve pattern, describing a pseudoplastic behavior. In addition, the flow curves demonstrate a static yield stress, indicating the bambangan pulp structure is sensitive and easily disrupted by fluid movement (Adriano & Sundaram, 2009).

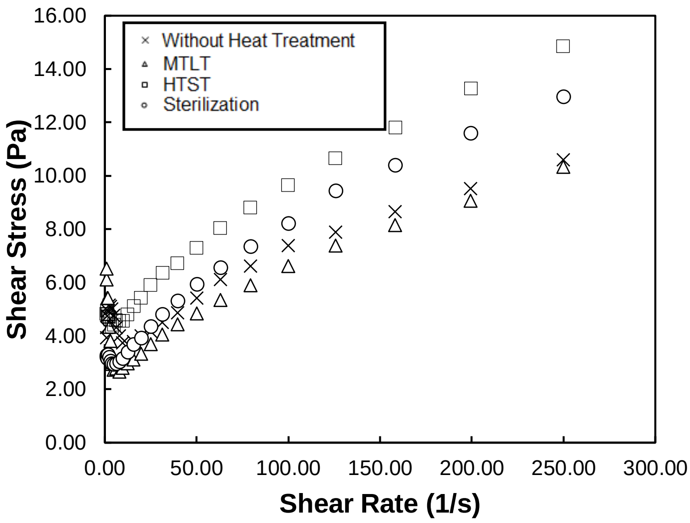


Figure. Flow curves of bambangan juice with different heat treatments

A decreasing in shear stress at the beginning and increases as the shear rate increased is an indication of initial yield stress. This phenomenon occurs due to the presence of entangled pulp that prevents the free flow of the juices at zero shear rates. Therefore, the cross-linking structure needs to be disrupted using appropriate shear rates and temperatures before the flow can occur. A similar pattern was also reported by Rosnah *et al*., (2013) for pineapple juice. BFJ treated using HTST condition has the highest shear stress (4.95–14.86 Pa), followed by sterilization (3.30–12.98 Pa), without heat treatment (4.99–10.59 Pa) and MTLT (6.51–10.33 Pa). A high shear stress value for HTST might be due to the low viscosity of the juice as a result of the heat treatment. This is an agreement with the findings by Hassan and Hobani (1998) where the shear stress is enhanced with the increase in temperature. This might be due to the rearrangement of the particles in parallel directions and their breaking into smaller particles. These particles can flow more easily due to the decrease in the particle-particle interactions, thus reducing the viscosity. This finding demonstrates the notable effect of heat treatments on the flow behavior of the BFJ.

The Herschel-Bulkley model was used to calculate rheological parameters including flow behavior index (n), consistency coefficient (K) and yield stress (σ_0) (Table 2). As expected, the increase in temperature reduces the flow behavior index (n) for all the treatments but have different consistency coefficient (K) and yield stress (σ_0). The highest n value was obtained for BFJ without treatment (1.11) which close to the Newtonian index value of n = 1. The heat-treated BFJ has flow behavior index of less than 1 with values of 0.85, 0.83, 0.77 for MTLT, HTST and sterilization, respectively. This is a clear indication that heat treatment caused the BFJ to show pseudoplastic behavior and deviate from the

Newtonian fluid. However, there was no significant difference ($p > 0.05$) between the n values of all treatments. A high flow behavior index value in the untreated BFJ was probably due to the presence of a significant amount of water where the BFJ was made up of a 1:1 ratio between puree and water. Heat treatment may cause changes in the viscosity as a result of water removal, leading to a decrease in n values. The n value of less than 1 obtained here for the heat-treated BFJ is consistent with the previous finding reported by Manish *et al*. (2007), Chin *et al*. (2009) and Quek *et al*. (2013) on mango, pomelo and soursop juices, respectively.

As for consistency coefficient (*K*), the values were varying with different heat treatment used. The highest *K* value was obtained when BFJ was treated using HTST (0.32) followed by sterilization (0.20), MTLT (0.14) and without heat treatment (0.07), respectively. There was a significant difference ($p < 0.05$) for the *K* value between untreated and HTST but no significant difference for MTLT and sterilization. The variation in consistency coefficient of BFJ might be due to the presence of water which affected by the different temperature and heating time. The values of consistency coefficient are very important in juice processing especially during pasteurization where the increase in consistency coefficient will cause the flowing rate in the pipe to decrease due to more flow resistance (Quek *et al*. 2013).

Table 2. Experimental data fitted to parameters of *Herschel-Bulkley* model for heat-treated BFJ

Treatment	***n***	***K***	**Yield Stress, σ_0**
No heat treatment	1.11±0.34[a]	0.07±0.04[b]	4.18 ±0.79[a]
MTLT	0.85±0.10[a]	0.14±0.02[ab]	2.54 ±0.20[a]
HTST	0.83±0.36[a]	0.32±0.14[a]	3.96 ±1.55[a]
Sterilization	0.77±0.04[a]	0.20±0.08[ab]	2.64 ±1.42[a]

*Data presented in mean ± standard deviation ($n = 3$). Values followed by different superscript within each column indicate significant difference ($p < 0.05$).

The untreated BFJ has the highest yield stress (4.18) followed by the HTST (3.96), sterilization (2.64) and MTLT (2.53). However, there was no significant difference ($p > 0.05$) between the yield stress values of all treatments. The yield stress gives information on the stress that must be applied to the sample before it starts to flow. A high yield stress in untreated BFJ indicates that a higher force requires to flow the juice.

3.3. Effect of Temperature on The Viscosity of The Untreated and Treated BFJ

The untreated and heat-treated BFJ were further analyzed for their viscosity at temperature ramp from 5 to 70 °C (Table 3) to elucidate their temperature-viscosity relationship. A high viscosity was found for the untreated BFJ and thevalue ranging from 4.81 to 2.32 Pa.s, followed by HTST (3.53–1.76 Pa.s), sterilization (2.76–0.97 Pa.s) and MTLT (2.04–0.98 Pa.s). Untreated BFJ would remain viscous due to the presence of suspended compound like pulp fiber (hemicellulose and cellulose), protein, pectin and pectin methyl esterase in the juice. These colloidal suspensions cause the viscous, cloud and turbidity appearance in the juice (Sara & Aman, 2018). As compared to other samples (HTST, MTLT and sterilization), heat treatment was applied first during pasteurization and sterilization causing its viscosity to change due to treatment at different temperatures. The study of the effect of temperature on viscosity can be considered as a second heat treatment on the sample which has resulted in more structure would be breakdown and subsequently reduces the viscosity. When subjected to heat treatment, it could breakdown the colloidal suspensions (Tanaka & Hoshino, 2003) and reduces the juice viscosity, thus reducing the yield stress. Only slight reduction in yield stress is observed for the HTST indicates a lower reduction in viscosity as well as pulp fiber disruption as the heat treatment was carried out at a relatively short time (1 minute). As opposed to that, the BFJ treated under MTLT condition shows the lowest yield stress, high probably due to the longer heat treatment duration (15 minutes). At this condition, the system has sufficient time to break down the bambangan pulp fiber which resulted in a low viscosity as well as yield stress.

Table 3. Viscosity values of heat treated bambangan fruit juice at different temperature

	Viscosity (Pa. s) of bambangan juice versus temperature			
Treatment	**5.5°C**	**20.0°C**	**40.0°C**	**70.0°C**
No heat treatment	4.81 ^{a}±1.35	3.01 ^{a}±0.70	2.13 ^{a}±0.16	2.32 ^{ab}±0.61
MTLT	2.04 ^{a}±0.36	1.39 ^{a}±0.20	1.33 ^{a}±0.06	0.98 ^{b}±0.05
HTST	3.53 ^{a}±0.39	2.33 ^{a}±0.09	1.53 ^{a}±0.03	1.76 ^{a}±0.10
Sterilization	2.76 ^{a}±1.97	1.69 ^{a}±2.27	1.01 ^{a}±0.91	0.97 ^{b}±0.75

*Data presented in mean ± standard deviation (n = 3). Values followed by different superscript within each column indicate significant difference ($p < 0.05$).

It should be noted that the heat treatment applied for the BFJ in the previous section resulted in high viscosity due to water removal. As for the heat-treated BFJ (HTST, MTLT and sterilization), when the samples were subjected to heating at temperature ramp from 5 to 70 °C, the reduction of viscosity occurred due to the breakdown of bambangan pulp fibre. These results clearly supported the values obtained from the flow behavior analysis (Figure 1) and analysis of fitted parameters on Herschel-Bulkley model (Table 2). It is also in agreement with the findings reported by Wijitra *et al*. (2013) where viscosities of fruit juices were varies at different temperature depending on the type of fruit juice used. Lower viscosity value for BFJ treated using MTLT might also be attributed to the hydrolysis reaction by the action of enzymes present in the juice (Solange *et al*. 2009). Changes in viscosity of fruit juice may have a big impact on the process especially those that involve mixing (stirrer dimension, type and pump capacity, reactor liquid circulation, *etc*).

4. Conclusion

The effect of pasteurization (MTLT and HTST) and sterilization of bambangan fruit juice (BFJ) on the rheological behavior is satisfactorily be described by Herschel-Bulkley model that showed a pseudoplastic fluid behavior. The findings that obtained from this study provide useful information for juice manufacturers to design a suitable equipment and transport systems in juice processing.

Author Contributions: Conceptualization, J.R., M.D.S. and S.S.; funding acquisition, J.R.; investigation, H.C.L.; writing—original draft preparation, H.C.L., J.R. and S.S..; writing—review and editing, J.R.D, S.S. and M.D.S

Funding: This work was funded by the Universiti Malaysia Sabah through Acculturation Grant Scheme with grant number SGA0019-2019.

Conflicts of Interest: The authors declare no conflict of interest.

References

Adriano, S. & Sundaram, G. (2009). Yield stress in foods: Measurements and applications. *International Journal of Food Properties*, *12*(1), 70–101.

Aguilo-Aguayo, I., Oms-Oliu, G., Soliva-Fortuny, R., *et al*. (2009). Changes in quality attributes throughout storage of strawberry juice processed by high intensity pulsed electric fields or heat treatments. *Food Science and Technology*, *42*, 813–818.

Chen, X., Qin, W., Ma, L., *et al*. (2015). Effect of high-pressure processing and thermal treatment on physicochemical parameters, antioxidant activity and volatile compounds of green asparagus juice. *LWT — Food Science and Technology*, *62*, 927–33.

Chin, N.L., Chan, S.M., Yusof, Y.A., *et al*. (2009). Modelling of rheological behaviour of pummelo juice concentrates using master-curve. *Journal of Food Engineering*, *93*(2), 134–140.

Hassan, B.H & Hobani, A.I. (1998). Flow properties of rossele (*Hibiscus sabdariffa L.*) extract. *Journal of Food Engineering*, *35*(4), 459–470.

Jimenez-Sanchez, C., Lozano-Sanchez, J., Segura-Carretero, A., Fernandez-Gutierrez, A. (2017). Alternatives to conventional thermal treatments in fruit-juice processing. Part 1: Techniques and applications. *Critical Reviews in Food Science and Nutrition*, 57, 501–23.

Juszczak, L. & Fortuna, T. (2003). Viscosity of concentrated strawberry juice: Effect of temperature and soluble solids content. Electronic Journal of Polish Agricultural Universities. *Food Science and Technology*, *6*(2).

Manish, D., Verma, R.C., & Jaaffrey, S.N.A. (2007). Effect of temperature and concentration on rheological properties of "Kesar" mango juice. *Journal of Food Engineering*, *80*, 1011–1015.

Mauricio, B.M.C., Lilian, F.L.B., Gisandro, R.C., *et al*. (2017). Experimental study of physical and rheological properties of grape juice using different temperatures and concentrations. Part I: Cabernet Sauvignon. *Food Research International*, *100*, 724–730.

Mohd Fadzelly, A.B. & Jeffrey R.F. (2013). A review on underutilized indigenous bambangan (*Mangifera pajang*) fruit as a potential novel source for functional food and medicine. *Journal of Medicinal Plants Research*, 7(45), 3292–3297.

Pareek, S., Paliwal, R., & Mukherjee S. (2011). Effect of juice extraction methods and processing temperature-time on juice quality of Nagpur mandarin (*Citrus reticulata Blanco*) during storage. *Journal of Food Science and Technology, 48*, 197–203.

Quek, M.C., Chin, N.L., & Yusof, Y.A. (2013). Modelling of rheological behaviour of soursop juice concentrates using shear rate–temperature–concentration superposition. *Journal of Food Engineering, 118*(4), 380–386.

Rawson, A., Patras, A., Tiwari, B.K., *et al*. (2011). Effect of thermal and non-thermal processing technologies on the bioactive content of exotic fruits and their products: review of recent advances. *Food Research International, 44*, 1875–1887.

Rosnah S., Wan, R.W.D., Mohd. Sobri, T., *et al*. (2007). Physical properties of the josaphine variety of pineapple fruit. *International Journal of Food Engineering*, *3*(5), Art 9.

Rosnah S., Chia, S.L., Noranizan, M.A., *et al*. (2013). Rheological properties of ultraviolet-irradiated and thermally pasteurized Yankee pineapple juice. *Journal of Food Engineering, 116*, 548–553.

Sara, A. & Aman, M.Z. (2018). A review of pectin methylesterase inactivation in citrus juice during pasteurization. *Trends in Food Science & Technology*, *71*, 1–12.

Sinemobong, O.E. & Emediong, U.U. (2016). Effect of temperature on the rheological properties of pineapple juice (*Ananascomosus*). *International Journal of Latest Research in Science and Technology*, *5*(2), 86–90.

Solange, V., Mara, G.N.Q., José, A.R.de.S., *et al*. (2009). Temperature effect on the rheological behaviour of carrot juice. *Journal of Food Engineering, 92*, 269–274.

Tanaka, A. & Hoshino, E. (2003). Similarities between the thermal inactivation kinetics of *Bacillus amyloliquefaciens* α-amylase in an aqueous solution of sodium dodecyl sulphate and the kinetics in the solution of anionic-phospholipid vesicles. *Biotechnology and Applied Biochemistry*, *38*, 175–181.

Wang, Y., Li, W., Ma, Y., *et al*. (2018). Effect of thermal treatments on quality and aroma of watermelon juice. *Journal of Food Quality*, https://doi.org/10.1155/2018/9242675.

Wijitra, L., Nathalie, D.C., Vera, V.H., *et al*. (2013). Impact of thermal treatment on physicochemical, antioxidative and rheological properties of white-flesh and red-flesh dragon fruit (*Hylocereus* spp.) purees. *Food Bioprocess Technology*, *6*, 416–430.

Zbigniew, K., Rafał, N., Tomasz, G., *et al*. (2015). Effect of pasteurization on rheological properties of white carrot juice. *Agriculture and Agricultural Science Procedia*, *7*, 99–102.

ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

Original Research Article

Usage of Seaweed Base Organic Fertilizer as Yield Booster at Volcanic Soil: Effect on Soil Quality and Yield of Patchouli (*Pogostemon Cablin*)

Sures Narayasamy[1]*, Mohamadu Boyie Jalloh[2]

[1]Department of Agrotechnology and Bioindustry, Politeknik Sandakan Sabah, Jalan Sungai Batang, 90000, Sandakan Sabah, Malaysia, sures@pss.edu.my

[2]Department of Crop Production, Faculty of Sustainable Agriculture, Universiti Malaysia Sabah, Locked 3, 90509 Sandakan Sabah, Malaysia, m.boyiej@gmail.com

*Corresponding author: Sures Narayasamy, Department of Agrotechnology and Bioindustry, Politeknik Sandakan Sabah, Jalan Sungai Batang, 90000, Sandakan Sabah, Malaysia, sures@pss.edu.my

Abstract: Patchouli (*Pogostemon cablin Benth*.) is a bushy herb and native to tropical region of Asia, and now cultivated for its essential oil which usually used in perfume productions. It is also widely been used throughout the world to treat skin conditions, relieving depression, controlling appetite, and antifungal agents. It is cultivating commercially in Tawau, Sabah for export purposes and the average oil production is up to 26–29 mt per acre in 2016. As they enter the second and third harvesting cycle, the production starts to decline and reach 2.6 mt of oil per acre. This drop-in yield is thought to be either due to soil variabilities, low nutrient levels in volcanic soil, and diseases. Soil nutrient analysis and leaf coloration patterns are studied before conducting the study. Seaweed extract, banana peel, the mixture of Seaweed extract and banana peel, and pre-formulated 12-12-12 (N-P-K) organic fertilizer (PFF) fertilizer treatments were engaged in the Patchouli plot field experiment. Besides, the agronomical practice for the cultivation of Patchouli is well documented. The pre-study showed that the study plot has a very low conductivity level, a very low organic Carbon level and low Cation Exchange Capacity (CEC) level. Meanwhile, there were no diseases or nematode occurrences in the area. Plant height, soil pH, and soil conductivity were studied with all the four treatments that have shown a positive significant impact compared with standard estate practice. The treatments using seaweed and seaweed mixture had the highest significant level with a slight reduction in soil pH. Whereas plant height data analysis showed that the seaweed mixture was significantly different compared with other treatments at a 0.05 level. Hence, we recommend the Patchouli plantation to use organic fertilizers including the mixture of seaweed since it is cheap and easily available in Sabah.

Keywords: Seaweed extract; banana peel; soil pH; soil CEC and organic fertilizer.

Received: 14th September 2020

Accepted: 14th October 2020

Available Online: 24th October 2020

Citation: Narayasamy S & Jalloh MB. Usage of seaweed base organic fertilizer as yield booster at volcanic soil: Effect on soil quality and yield of patchouli (*Pogostemon cablin*), Adv Agri Food Res J 2020; 1(2): a0000120. https://doi.org/10.36877/aafrj. a0000120

1. Introduction

Volcanic soils cover 1% of the Earth's surface yet support 10% of the world's population, including some of the highest human population densities. This is usually attributed to their high natural fertility. However, this is true only in part. Such soils represent the surface areas of our planet that are being replenished with new minerals escaping from the interior of the Earth (Neall, 2009). The land around volcanoes is intermittently attacked by pyroclastic flows, volcanic ash deposition, lahar deposition, and others. This volcanic ejecta or tephra contains various silicates and other minerals of different sizes such as volcanic glass, feldspars, quartz, hornblende, hypersthene, augite, magnetites, biotites, and apatites. After tephra deposition, soil formation starts, the tephra element and mineralogical composition changes, and volcanic ash soils or andisols having unique properties are formed. Many plant nutrient elements are provided to the soil environment during soil formation (Nanzyo, 2002). Volcanic soils are considered fertile soils and suitable for agriculture activities as it contains carbon and minerals, yet it is not as fertile as claimed previously. Volcanic soils are lacking in micronutrients such as Copper (Cu), Zinc (Zn), and Carbon Monoxide (CO). This is due to the availability of these micronutrients in volcanic ash and on their release rates by chemical weathering (Shoji & Takahashi, 2002) Moreover, the percentage of readily mineralizable organic nitrogen (N) in the pool of organic N is rather small in volcanic ash soils. The previous study done by Moritsuka and Saito (2019) comparing the N mineralization potential (NO) to the pool of total organic nitrogen (N) between volcanic ash soils and non-volcanic soils from north-eastern Japan, showed that the percentage of mineralizable of volcanic ash soils is less than that of non-volcanic soils. According to (Kim & Stoecker, 2006), the use of chemical fertilizers has increased significantly to increase the agricultural productivity, and one of the purposes of using chemical fertilizers is to help nutrient-deficient volcanic soils. Liquid organic base fertilizers are an alternative fertilizer that can be used to reduce the usage of chemical fertilizers since chemical fertilizers can cause pollution and degeneration the soil quality (Lin, *et al*., 2019). Therefore, the use of organic fertilizer is a good solution to avoid harmful effects and risks either to the environment or to humans (Chandini, *et al*, 2019).

Other than that, excessive usage of chemical fertilizers in agriculture, resulting in many environmental pollutions due to the heavy metal contents such as cadmium and chromium (Savci, 2012). While chemical fertilizers have been claimed as the most important contributor to the increase in agricultural productivity, it will negatively affect both the environment and humans (Kashi & Olfati, 2012). Chemical fertilizers cause water pollution, soil pollution, air pollution, and bring health issues (Iberdrola, 2020). Nitrogen in agricultural areas reaches the water environment in three ways such as drainage, leaching, and flow. The second effect is the effect on soil pollution. According to previous research, the impact of chemical fertilizers on land is not very clear. However, the effects of chemical fertilizers suggest that the emergence of pollution, reduced soil fertility, and soil degradation reactions occur in the soil. The third effect is affecting air pollution where chemical fertilizers too much applied, it causes air pollution by nitrogen oxides (NO, N_2O, NO_2) emissions (Savcı, 2012) According to (Sharma & Singhvi, 2017), agrochemicals or chemical fertilizers are cause serious hazards to humans that cause endocrine, immune systems, may promote the development of cancer, and causes the escalation of deadly the disease like chronic kidney disease. Therefore, we should consider using organic fertilizer since it is can produce healthy vegetables and plants for consumption. Fruit peels are the best-known source of macronutrients and micronutrients. These are the cheapest and harmless materials are used for plant growth (Jariwala & Syed, 2016). Furthermore, food waste is an inevitable problem everywhere, restaurants, residential houses, food service providers, and so on. Food waste is an issue that is mostly neglected or disseminated. Although, it is a concern for many farmers, not everyone is ready to take it seriously. Food waste usually occurs at the retail and consumer levels in the food value chain. This is due to negligence or conscious decision to remove food. According to Hussein (2019), the banana peel extract enhances the seed germination rate of tomato and fenugreek to 97%.

Seaweed is macroscopic algae which form an essential element of marine renewable resources. These nutrient-rich algae have washed up on seashores throughout the world that can be dried for simple transportation, or integrated wet into compost. It is also an excellent supply of plant nutrients, such as Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca) and Magnesium (Mg) (Gardening Channel, 2020). Seaweed also contains all the 19 essential elements needed for plant growths as well as the trace elements (Andrew, *et al*., 2015) (Nedumaran, 2017). Seaweed extract is widely used in agriculture especially in the horticulture industry. When applied to fruit, vegetable, and flower crop, it improves the nutrient uptake, expands resistant towards diseases and insects, and increase seed germination rate (McHugh, 2003). Moreover, seaweed also acts as a bio stimulant to surge the yield and growth of vegetables and leafy trees (Mohanty *et al*., 2013).

The objectives of the study were to used seaweed as an alternative organic fertilizer at Patchouli plantation in the volcanic area, and to reuse the banana peels as fertilizer which will reduce agricultural waste. The parameters studied were soil pH and plant height with all the parameters were analyzed using SPSS v24 at α 0.05 significant level.

2. Materials and Methods

2.1. Seaweed Extract Preparation

The organic seaweed and banana extract plant booster were developed using the method recommended by Bhosle *et al*., (1975). in which chopped seaweed was boiled with distilled water and then filtered. The ratio of seaweed and distill water for boiling is 1:1 (1 kg seaweed: 1 liter water). The filtrate was taken as a 100% concentration of the seaweed extract. Finally, the seaweed extracts were stored in a covered tank to avoid contamination (Figure 1).

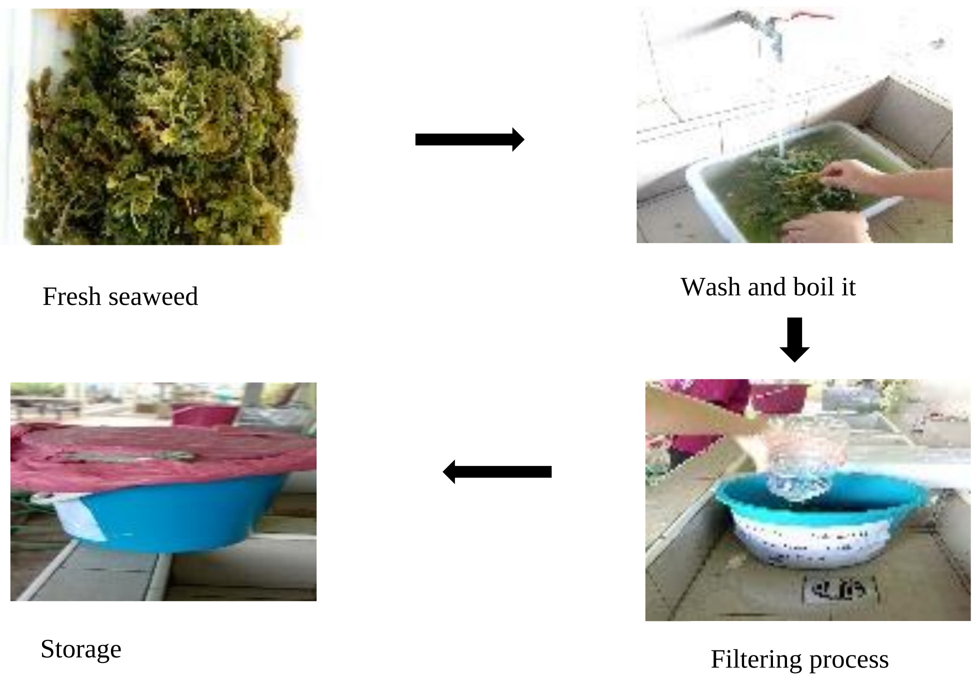
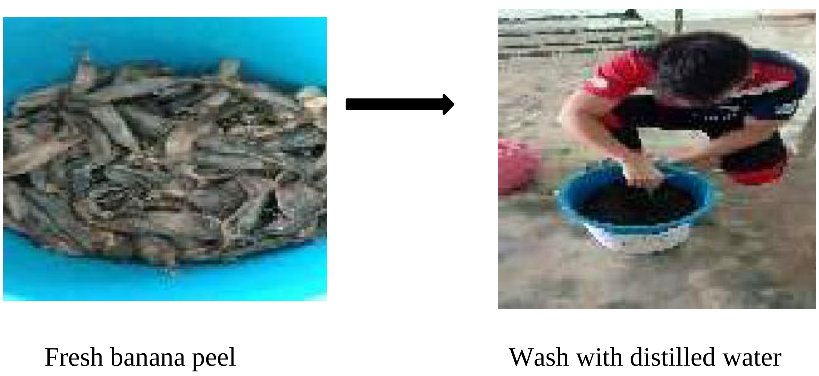
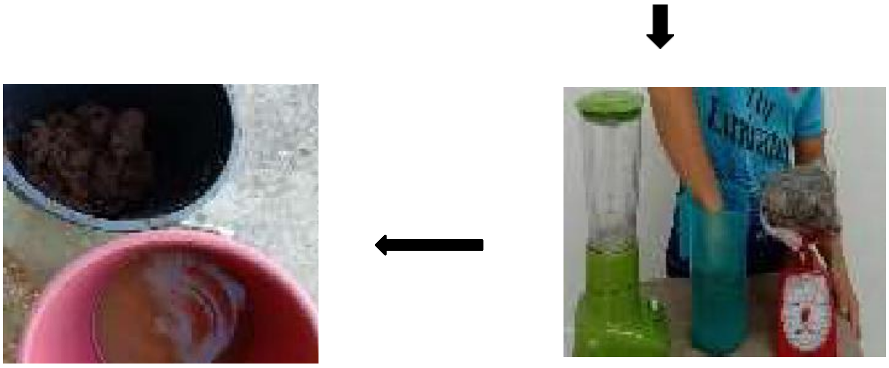


Figure 1. The seaweed extract preparation process.

2.2. Banana Peel Preparation

Meanwhile, the banana peel extract was prepared to wash the peel using distilled water followed by mash/grind it is using the grinder to prepare a banana peel puri. The puri can store in the refrigerator for more than 2 months while it can keep much longer in cold storage. It was prepared in such a way that we can mix it in distilled water when needed (Figure 2).





Storage in puri form

Banana puri preparation

Figure 2. The banana peel extract preparation process.

2.3. Nutrient Analyst of Seaweed and Banana Peel Extract

The extracts were analyzed for nitrogen (N) and phosphorus (P) contents before diluting it with distilled water using La Motte SMART3 colorimeter. The reading of the colorimeter was recorded to determine the level of N and P in both the extracts.

2.4. Testing at Patchouli Plot

After the nutrient test both the extracts were diluted using distilled water (Figure 3) at the rate of 10% since it contains a very high level of N and P. The prepared organic seaweed and banana peel extract were tested on patchouli shrubs that cultivated in volcanic soil (Figure 4). A total of 4 treatments involved in this study with the first plot applied with seaweed extract alone (100 ml), the second plot tested with banana extract alone (100 ml), the third plot tested with both seaweed and banana (1:1) (50 ml:50 ml) and the last plot was treatment with commercial organic fertilizer (100 g) at the frequency of 30 days for 3 rounds before data collection. Experimental design used for the study were RCBD with each plot covers an area of 16m x 10m with an average of 30 Patchouli plants per plot. Each treatment has 5 replicates for plant height and 4 replicates for soil pH. All the plant boosters were supplied via hand spraying methods (Figure 5). Randomized samplings were done each time before application.

Figure 3. Extract of seaweed and banana peel after dilution

Figure 4. The Patchouli plot.

Figure 5. Hand spraying and tagging of Patchouli plant.

3. Results

3.1 Plant Height

A total of 4 treatments were conducted with the difference in plant height, before and after treatment was recorded after 90 days.

Table 1. The patchouli plant height before treatments and after treatments with 5 replicates.

	Highest of Plant (Cm)											
R	*PLOT A (S)*			*PLOT B (B)*			*PLOT C (B+S)*			*PLOT D (O)*		
	bfr	*after*	*dif*	*bfr*	*after*	*dif*	*bfr*	*after*	*dif*	*bfr*	*after*	*dif*
1	40.5	43.7	3.2	30.5	31.6	1.1	27.6	28.9	1.3	45.5	47	1.5
2	37	40.1	3.1	33.5	34.1	0.6	46	49.2	3.2	42	42.4	0.4
3	37	38.1	1.1	35.5	35.6	0.1	50	51.3	1.3	41	41.5	0.5
4	21	23.2	2.2	47.3	47.9	0.6	38	39.3	1.3	26.3	27	0.7
5	36.5	36.9	0.4	22.5	24	1.5	22	25.7	3.7	28	28.3	0.3
Ave	34.4	36.4	2	33.86	34.64	0.78	36.72	38.88	2.16	36.56	37.24	0.68

The average height of the selected patchouli plants was 35.39 cm before treatment, and it increased to 36.79 cm within 1 month after the initial treatment. The Patchouli plants treated with the mixture of seaweed and banana show the highest difference in average plant height with 2.16 cm while the treatment with standard organic fertilizer shows a slight increase in plant height with 0.68 cm from the initial height (Table 1). The result obtained was similar to the study done by (Isleib, 2016) where liquid fertilizers are easy to blend in soil, and uniformity of application can be obtained with it compared with granular fertilizers.

3.2. Soil pH

The treatments with seaweed, banana peel, and the mixture of both seaweed and banana peel have increased slightly over the 1 month with the treatment with banana peel have the highest shift in the pH value up to 1.2. meanwhile, both the treatments with seaweed and mixture of seaweed and banana peel have increased the volcanic soil pH value at an average rate of 0.25 and 0.2875 respectively (Chart 1). This is due to the pH value of the fertilizers itself with pH value seaweed is 6.7 while the pH value of the banana peels was 9.8. This is similar to the study done by Ji (2017) about the effects of liquid organic fertilizers on plant growth and rhizosphere soil characteristics of Chrysanthemum shows that the initial pH value of seaweed extract was 7.1 and the pH value of plant decomposition were 10.4. This is similar to the pH value of the seaweed and banana peel of the treatments. The soil pH of the plot treated with organic NPK shows contrast results as the Nitrogen and Carbon in that fertilizers makes the soil acidic. This finding and statement supported by McCauley *et al*. (2017) where nitrogen base fertilizers such urea (46-0-0) and ammonium phosphates (11-52-0 or 18-46- 0) can slowly lower pH of basic soils.

Chart 1. The soil pH value before and after treatments by seaweed, banana peel, the mixture of banana peel and seaweed and organic NPK fertilizer

TREATMENTS		before	after	dif
PLOT A (Seaweed)	R1	5.4	5.6	0.2
	R2	5.1	5.3	0.2
	R3	5.15	5.45	0.3
	R4	5	5.3	0.3
PLOT B (Banana peel)	R1	5.4	6.6	1.2
	R2	4.9	5.7	0.8
	R3	5.05	5.95	0.9
	R4	4.65	5.75	1.1
PLOT C (banana peel + seaweed)	R1	5.6	5.7	0.1
	R2	5.45	5.75	0.3
	R3	5.7	5.8	0.1
	R4	5.15	5.8	0.65
PLOT D (Organic NPK)	R1	5.4	4.9	-0.5

	R2	5.7	4.9	-0.8
	R3	5.4	5.1	-0.3
	R4	5.85	5.5	-0.35

4. Discussion

Moreover, the statistical analysis also showed that the treatment with the mixture of seaweed and banana were significantly different compared to the treatment with banana and organic pellet fertilizer at significant level $\alpha = 0.05$. Meanwhile, statistically, there are no significant differences between the other treatments as well (Table 2). This is because of the high amount of carbon and nitrogen with trace elements in the seaweed that easily bind with soil. The volcanic soil at Merotai, Tawau is low in Carbon and CEC that makes it difficult to supply nutrients to the Patchouli plants. With the application of seaweed, the carbon content in the soil improves slightly that allow the Patchouli plant uptake nutrients. The result obtained was supported by a study done by Andrew (2015) about seaweed compost for agricultural crop production in which the yield is affected by C: N ratio. Moreover, our findings are similar to study done by Angela, on effects of seaweed on soil quality and yield of sweet corn in 2013 shows that the carbon in soil increases from 492 mg C/kg to 608 mg C/kg after the soil treated with seaweed-based fertilizers. This shows that with the application of seaweed and banana extracts, the carbon level of the soil increases and allowed the nutrients available to the patchouli plant.

Although the volcanic soil pH varied significantly between the treatments (Table 3), two-way ANOVA analysis showed that there are significant differences between the treatment except for the treatment between seaweed, mixture of seaweed and banana peel where the p-value is higher than alpha (0.05).

Table 2. A *t*-test of two samples assuming equal variances analysis of the patchouli plant height.

	Plot A (S)	Plot B (B)	Plot A (S)	Plot C (B+S)	Plot A (S)	Plot D (O)	Plot B (B)	Plot C (B+S)	Plot B (B)	Plot D (O)	Plot C (B+S)	Plot D (O)
Mean	2	0.78	2	2.16	2	0.68	0.78	2.16	0.78	0.68	2.16	0.68
Variance	1.515	0.29	1.515	1.42	1.515	0.23	0.287	1.42	0.287	0.23	1.418	0.23
Observations	5	5	5	5	5	5	5	5	5	5	5	5
Pooled Variance	0.901		1.4665		0.8735		0.8525		0.2595		0.825	
df	8		8		8		8		8		8	
t Stat	2.0322		-0.20891		2.23312		-2.36321		0.31039		2.5763493	
P(T<=t) one-tail	0.0383		0.41987		0.02801		0.02286		0.38210		0.0164010	
t Critical one-tail	1.859548		1.859548		1.859548		1.859548		1.859548		1.859548038	
P(T<=t) two-tail	0.076595		0.8397435		0.0560234		0.0457287		0.7642001		0.032802021	
t Critical two-tail	2.306004		2.3060041		2.3060041		2.3060041		2.3060041		2.306004135	

**P* (two tail) value is higher than alpha 0.05 shows that there are no significant differences between the treatments.

Table 3. Two way ANOVA analysis assuming equal variances analysis of the difference in soil pH.

	PLOT A (S)	PLOT B (B)	PLOT A (S)	PLOT C (B+S)	PLOT A (S)	PLOT D (O)	PLOT B (B)	PLOT C (B+S)	PLOT B (B)	PLOT D (O)	PLOT C (B+S)	PLOT D (O)
Mean	0.25	1	0.25	0.2875	0.25	-0.4875	1	0.2875	1	-0.4875	0.2875	-0.4875
Variance	0.0033	0.0333	0.0033	0.0673	0.0033	0.0506	0.0333	0.0673	0.0333	0.0506	0.0673	0.0506
Observations	4	4	4	4	4	4	4	4	4	4	4	4
Pooled Variance	0.0183		0.0353		0.0270		0.0503		0.0420		0.0590	
df	6		6		6		6		6		6	
t Stat	-7.8335		-0.2822		6.3498		4.4922		10.2673		4.5138	
P(T<=t) one-tail	0.0001		0.3936		0.0004		0.0021		0.0000		0.0020	
t Critical one-tail	1.9432		1.9432		1.9432		1.9432		1.9432		1.9432	
P(T<=t) two-tail	0.0002		0.7873		0.0007		0.0041		0.0000		0.0040	
t Critical two-tail	2.4469		2.4469		2.4469		2.4469		2.4469		2.4469	

5. Conclusion

The results show that the mixture of seaweed and banana works well as plant booster as they increase the plant height and improve volcanic soil pH at a significant rate compared with other treatments. Meanwhile, the organic NPK fertilizers have minor effects on the plant height and reduce the soil pH within the treatment period. Prolong application of organic NPK in the same area will significantly drop the volcanic soil pH at a vigorous rate. This is due to the nitrogen sources in the fertilizer (Ji *et al*., 2017). Therefore, it is recommended that seaweed extract is a good source of plant booster as it improve the plant height without deteriorate the soil quality. At the same time utilizing readily available resources as fertilizer will improve the Gross Domestic product (GDP) of Malaysia and will increase job opportunities to the surrounding community.

Acknowledgments: Politeknik Sandakan Sabah staff and students who help in extracting and hep at the site. The researchers also would like to thank the staff of patchouli plantation at Merotai Tawau, Sabah for their assistance.

Conflicts of Interest: The authors declare no conflict of interest, and also the funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

Andrew J. C., David A. R., Alan L. G., *et al* (2016). Seaweed compost for agriculture crop production. *Journal of Applied Phycology*, 629–642.

Bhosle N., Untawale A., & Dhargalkar V. (1975). Effect of seaweed extract on the growth of Phaseolus vulgaris L. *Indian Journal of Marine Sciences*, 208–210.

Chandini K. R., Kumar R., & Prakash O. (2019). *Research Trends in Environmental Sciences*. Retrieved from Researchgate: https://www.researchgate.net/publication/331132826_The_Impact_of_Chemical_Fertilizers_on_our_Environment_and_Ecosystem

Gardening Channel. (2020). *Gardening Channel*. Retrieved from Gardening Channel Web site: http://www.gardeningchannel.com/seaweed-as-a-natural-fertilizer

Han S. H., An J. Y., Hwang J., *et al*. (2016). The effect of organic manure and chemical fertilizer on the growth and nutrient concentrations of yellow Poplar (Liriodendron tulipifera Lin) in a nursery System. *Forest Science and Technology*, 137–143.

Hussein H., Shaarawy H., Hussien N., *et al*. (2019). Preparation of Nano-fertilizer blend from banana peels. *Bulletin of the National Research Centre*, 1–9.

Iberdrola. (2020). *Soil pollution, its effects on our future and what we can do to reduce it*. Retrieved from

Iberdrola Web site: https://www.iberdrola.com/environment/soil-pollution-causes-effects-solutions

Isleib, J. (2016, December 29). *Pros and cons of granular and liquid fertilizers*. Retrieved from https://www.canr.msu.edu/news/pros_and_cons_of_granular_and_liquid_fertilizers

Jariwala H. J. & Syed H. S. (2016). *Study on Use of Fruit Peels Powder as a Fertilizer*. Retrieved from Researchgate: https://www.researchgate.net/publication/319329572_Study_on_Use_of_Fruit_Peels_Powder_as_a_Fertilizer

Ji R., Dong G., Shi W., *et al*. (2017). Effect of liquid organic fertilizers on plant growth and Rhizosphere soil characteristics of Chrysanthemum. *Sustainability*, 1–16.

Kim, C.-G., & Stoecker, A. (2006). Economic effects of environmental taxation on chemical fertilizers. *International Association of Agricultural Economists* (pp. 1–20). Queensland: EconPapers.

Kashi A., Olfati J., Kochakinezhad H., & *et al* (2012). A comparison of organic and chemical fertilizers for Tomato Production. Journal of Organic Systems, 14–25.

Lin W., Lin M., Zhou H., *et al* (2019). The effects of chemical and organic fertilizer usage on rhizosphere soil in tea orchards. *Plos One*, 1–16.

McCauley A., Jones C., & Olson R. K. (2017). *Soil pH and Organic Matter.* Retrieved from Montana State University Web site: http://landresources.montana.edu/nm/documents/NM8.pdf

McHugh D. J. (2003). *A Guide to The Seaweed Industry.* Rome: Food and agriculture organization of The United Nations.

Mohanty D., Adhikary S., & Chattopadhyay N. (2013). Seaweed Liquid Fertilizer (SLF) and its role in agriculture productivity. *An International Quarterly Journal of Environmental Sciences*, 23–26.

Moritsuka N., Saito H., Tajima R., *et al.* (2019). Farm-scale estimation of total nitrogen content in surface paddy soils by extraction with commercially available hydrogen peroxide. *Agronomy*, 1–15.

Nanzyo M. (2002). Unique properties of volcanic ash soils. *Global Environmental Research*, 99–112.

Neall V. E. (2009). Volcanic soils. In W. H. Verheye (ed.) *Encyclopedia of Land use, Land Cover and Soil Sciences (Soils and Soil Sciences Part 2)* (pp. 23–45). Singapore: Eolss Publishers Co.Ltd.

Nedumaran T. (2017). Seaweed: A fertilizer for sustainable agriculture. *Sustainable Agriculture towards Food Security*, 159–174.

Savci S. (2012). An agricultural pollutant: Chemical fertilizer. *International Journal of Environmental Science and Development*, 77–80.

Sharma N., & Singhvi R. (2017). Effects of chemical fertilizers and pesticides on human health and environment: A review. *International Journal of Agriculture, Environment and Biotechnology*, 675–679.

Shoji S., & Takahashi T. (2002). Environmental and agricultural significance of volcanic ash soils. *Global Environmental Research*, 113–135.

ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

HH PUBLISHER

Original Research Article

Performance Comparison of Experimental IoT Based Drip and Fibrous Capillary Irrigation Systems in The Cultivation of Cantaloupe Plants

Abioye Abiodun Emmanuel[1,2], Mohammad Shukri Zainal Abidin[1]*, Mohd Saiful Azimi Mahmud[1], Salinda Buyamin[1], Mohamad Hafis Izran Ishak[1], Muhammad Khairie Idham Abd Rahman[1], Umar Zangina[1]

[1]Department of Control and Mechatronics Engineering, School of Electrical Engineering, Universiti Teknologi Malaysia (UTM) Skudai, Johor, Malaysia.

[2]Department of Electrical/Electronic Engineering, Akanu Ibiam Federal Polytechnic, Unwana, Ebonyi State, Nigeria.

*Corresponding author: Mohammad Shukri Zainal Abidin, Department of Control and Mechatronics Engineering, School of Electrical Engineering, Universiti Teknologi Malaysia (UTM) Skudai, Johor, Malaysia; shukri@utm.my

Abstract: The demand for freshwater and food is extremely high due to rapid growth in the world's population. the effect of global warming and climate change poses a severe threat on water use and food security. Conventional irrigation system affected due to inefficient management of water and energy, while the insufficient supply of water to plant increases their stress which often affects its growth and development. Hence, there is a need to increase research focus on water use efficiency in irrigated agriculture. This paper aims to investigate the performance of smart drip and subsurface fibrous capillary irrigation experiment for the cultivation of the cantaloupe plant to increase the yield and quality of fruit while decreasing the water and energy usage. An Internet of Things (IoT) approach was used to improve monitoring of soil, weather, plant and control of water application to achieve enhancement of subsurface fibrous capillary and drip irrigation system. The performance comparisons of both methods were evaluated in terms of water-saving in greenhouse cultivation experiment. The results showed that the smart fibrous capillary irrigation has water productivity index (WPI) of 19 kg/m3 with an average fruit sweetness of 13.5 Brix. While drip irrigation has WPI of 4.85 kg/m3 and average sweetness of 10 Brix on the harvested fruit after 90 days of cantaloupe plant cultivation experiment. These have shown that precision irrigation through enhanced smart fibrous capillary irrigation can be used to achieve high water-saving and a good quality yield. It is expected that the research output will help to improve water-saving agriculture towards achieving food security.

Keywords: Water saving; capillary irrigation; drip irrigation; internet of things; water use efficiency

Received: 14th September 2020

Accepted: 14th October 2020

Available Online: 6th November 2020

Citation: Abioye AE, Zainal Abidin MS, Azimi Mahmud MS, *et al*. Performance comparison of experimental IoT based drip and fibrous capillary irrigation systems in the cultivation of cantaloupe plants. Adv Agri Food Res J 2020; 1(2): a0000121. https://doi.org/10.36877/aafrj. a0000121

1. Introduction

As the population grows, urbanization rates and effect of climate change in Asia rise rapidly, stress on the region's water resources is intensifying with an adverse effect on food production, hence the need for increased focus on precision agriculture (Prokurat, 2015; Asia Society, 2019). Precision in agriculture plays an important role in maintaining food security with least labours and energy. At the same time, improving environmental management to ensure improvement in food production efforts and meet up with the increased consumption demand (Saiful *et al.*, 2020). Also, towards achieving food security, proper management of irrigation water using different irrigation techniques such as capillary and drip irrigation system for cultivation of various crops is very important (Oborkhale *et al*., 2015).

Cantaloupe plant is one of the highly valued tropical fruit in Malaysia which form part of a healthy diet with refreshing characteristics. According to Masde and Mohd (2016), achieving fruit quality and yield of cantaloupe plant has become a major issue among farmers and consumers, which largely depends on the water management during the cultivation of cantaloupe plant. This calls for the adoption of smart irrigation technology through the use of Internet of Things (IoT) into the advancement of the different methods of irrigation system commonly used for its cultivation (Rahman *et al*., 2019).

A drip system is one of the methods commonly used for irrigation of cantaloupe fruits. It consists of a network of water pipes with emitters laid on the soil surface through which water is applied towards the root of the plant (Abioye *et al*., 2020). The shortcomings of this method of irrigation system include increased rate of water loss, high cost of the installation, emitters clogging and breakage problems due to the intrusion of roots or the suction of solid particles from the soil matrix, and the difficulty of detecting and repairing potential leakage problems (Martínez & Reca, 2014).

The deficiency of this method needs to be addressed. Subsurface capillary irrigation has the potential of achieving precision irrigation and improves water use efficiency as reported by Li *et al.*, (2018), Zainal Abidin *et al.*, (2014) and Idham *et al.*, (2018). Capillary irrigation is a subsurface type of irrigation, where water is transported from the water source directly to the root zone of the plant using different capillary media such as fibrous, wicks, mat and flow system (Semananda *et al*., 2018). The advancement of this method will allow precise individual crop water characteristics and new strategies for efficient management of irrigation supply (Zainal Abidin *et al.*, 2014).

Previous research works on the effects of drip irrigation and plastic mulch on cantaloupe plants yield as reported by Seyfi and Rashidi (2007), shows that the combination of both techniques has improved the efficiency of water usage and yield in terms of weight and thickness of the fruit. Similarly, Martínez and Reca (2014) compared the efficiency of water use of surface drip irrigation to subsurface drip irrigation based on three years experiment on an olive orchard. The result shows that the subsurface drip irrigation system performs better than the surface drip system in terms of water-saving and crop yield.

Rhuanito *et al.*, (2016) proposed a control system for water stress management using circulating aquaponics system for the cantaloupe fruit quality and yield rate. Also, Wiangsamut and Makhonpas (2017) demonstrated the performance of four (4) varieties of cantaloupe fruit which have been irrigated with a hydroponic system and drip irrigation system. The findings suggested that cantaloupe plant could best be cultivated with drip irrigation system rather than the hydroponic system, due to better fruitiness, weight and thickness.

Since little work have been reported on the performance comparison of drip and fibrous capillary irrigation on cantaloupe plant, this paper presents the investigation of drip and fibrous capillary irrigation system for cantaloupe plant cultivation based on yield, quality of the harvested fruit and water use efficiency. To evaluate the performance of both irrigation methods, field experiment has been performed under different irrigation schemes in greenhouse cultivated of cantaloupe plants.

2. Literature Review

2.1. Experimental Design

The cultivation experiment on cantaloupe plants was conducted in a greenhouse environment located in Universiti Teknologi Malaysia, Johor Bahru (1.05633^o N, 103.6382^o E). A 0.15mm UV plastic was used as the rooftop while a treated 24 mesh net was used to surround and cover up the greenhouse environment, to prevent an attack from pest while providing natural ventilation.

The experiment was carried out in two different greenhouses namely (GH1 and GH2) using coco peat inside the poly bags as a growing medium as shown in Figure 1(a) and (b). Inside GH1 with one treatment is the IoT based drip irrigation system with emitters placed closed to the roots zone of the plants were installed to supply water to the coco peat inside the poly bags. While inside GH2 is the set up for IoT based fibrous capillary with three different treatments, namely adaptive controlled with a horizontal capillary fibrous capillary interface, constant float sensor controlled with a horizontal fibrous capillary interface and lastly constant float sensor controlled with a vertical fibrous capillary interface (Rahman *et al.*, 2019).

The coco peat inside the polybags was the growing medium used to minimise soil erosion, runoff and save water. The coco peat is a good growing medium with good water holding capacity as well as moderate electrical conductivity and pH which is suitable for greenhouse cultivation (Awang *et al*., 2009; Yahya *et al*., 1997).

(a) Drip irrigation monitoring system in GH1

(b) Capillary irrigation monitoring system in GH2

Figure 1 (a) and (b). Visual monitoring of cantaloupe plant cultivation via raspberry pi camera at GH1 and GH2.

The experimental cultivation of the cantaloupe plants started with the planting of the seedling as a nursery on the 1st of July 2019, after which it germinated after four days and ready for transplanting on the 14th of July 2019. Seventy-five (75) plants for drip irrigated, while six plants for capillary irrigation (two each for three treatments) were transplanted on the 1st of August 2019 into the polybag within that greenhouse that is naturally ventilated. An EC value of 1 dS/m, was maintained with AB liquid fertilizer, which was used to aid the growth for two weeks after transplant. A real-time monitoring of volumetric water content of the soil using a VH400 soil moisture sensor and estimated reference evapotranspiration via a weather station was used for optimal scheduling of both irrigation systems. The estimated reference evapotranspiration was used to determine the water loss, which is dependent on the crop coefficient at the different growth stage of the plant. The irrigation volume in terms of total water use (TWU) was measured using an IoT based flowmeter mounted on the main water supply pump of the greenhouse, which was used to compensate for the water loss was based on the actual evapotranspiration. Figure 1 (a) and (b) represent smart based drip and fibrous capillary irrigation with IoT monitoring system.

Real-time images of the cantaloupe plant are captured at every six hours with the help of the Crontab scheduling programming of the raspberry pi and its camera, during the day and uploaded to the IoT webpage where the plant performance in two greenhouses remotely was monitored (Abioye *et al.*, 2020). With the help of these monitoring, we could easily know if the plant is stressed or wilt as well as growth performance. The performance comparison was further carried out using analysis of variance (ANOVA) to test the significant differences between the four treatments. The hypothesis was formulated as follows:

The null hypothesis Ho: There is no significant difference between the four treatments group that is mathematically: ($H_O = A = B = C = D$).

The null hypothesis Ho: There is no significant difference between the four treatments group that is mathematically: ($H_O = A = B = C = D$).

The degree of freedom for the total group $= n - 1$ 1

$$= 8 - 1 = 7$$

Where n is the number of samples

Degree of freedom for the treatment group $k - 1$ 2

$$4 - 1 = 3$$

Where k is the number of treatments

The error for the degree of freedom $df(e) = d(a) - df$ 3

The grand mean Y_{ij}

The total sum of square (ss) $= \sum\left(\left(Y_{ij} - \overline{Y}\,..\right)^2\right)$ 4

Treatment sum of square (ss) $= \sum\left(n_i\left(Y_{ij} - \overline{Y}\,..\right)^2\right)$ 5

Error for ss = $Total\ ss - Treatment\ ss$ 6

Mean Square for Treatment for Table 4 $(MS_T) = \frac{SS_T}{DF_T} = 0.189$ 7

Mean Square for Error for Table 4 $(MS_E) = \frac{SS_E}{DF_E} = 0.01$ 8

F Statistics $(F_T) = \frac{MS_T}{MS_E}$ 9

3. Result and Discussion

The result of the performance evaluation is presented in Figure 2 to 5 and Tables 1 to 3. Different indices were used to determine the performance comparison of the two irrigation methods on the cultivated cantaloupe plants, which are cumulative plant height (m), measured leaf area (cm^2), cumulative water consumption (litre), water productivity index (WPI- kg/m^3), the weight of fruit (kg) and sweetness of fruit (brix).

Since the number of poly bags for the drip irrigation system in GH1 is higher than the fibrous capillary in GH2, two samples of each treatment were picked for normalization and averaged to get each of the results for treatment A, B, C and D. Some of the harvested fruits can be seen in Figure 2.

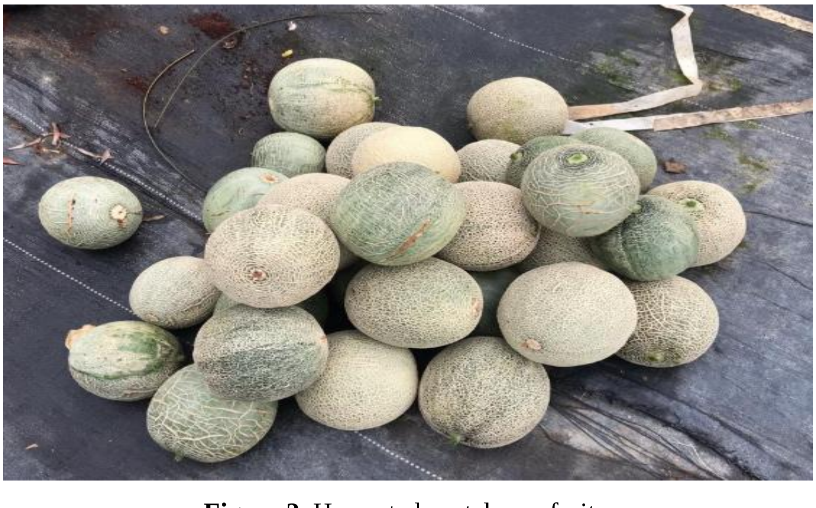


Figure 2. Harvested cantaloupe fruits.

Figure 3 illustrates a graph of cumulative water consumed during the period of cultivation of the plant, from which the drip-irrigated plant has the highest water consumed during the cultivation period. This could be due to the high rate of water loss experienced by the drip irrigation system because of evapotranspiration since water is applied to the root of the plant on the surface of the soil. From Figure 3, the drip irrigation (Treatment D) has the highest water consumption when compared to the three other treatments of fibrous capillary irrigation (Treatment A, B and C) per polybag after it was normalized.

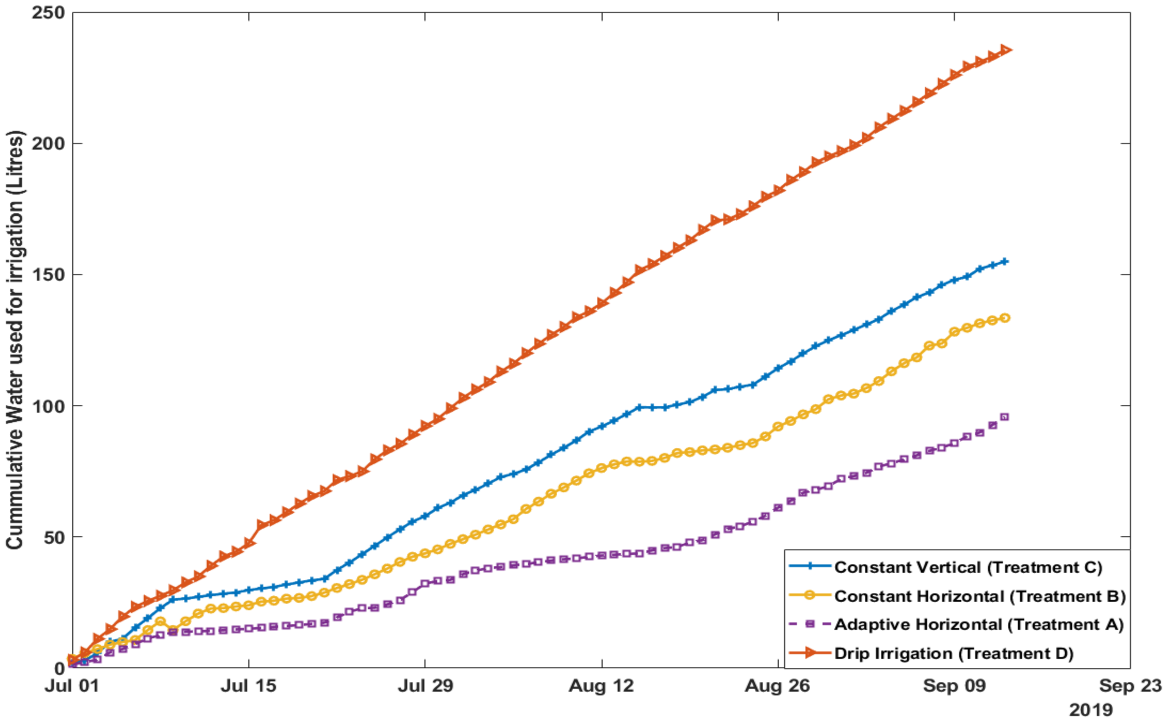


Figure 3. Graph of cumulative water consumption for the four treatments.

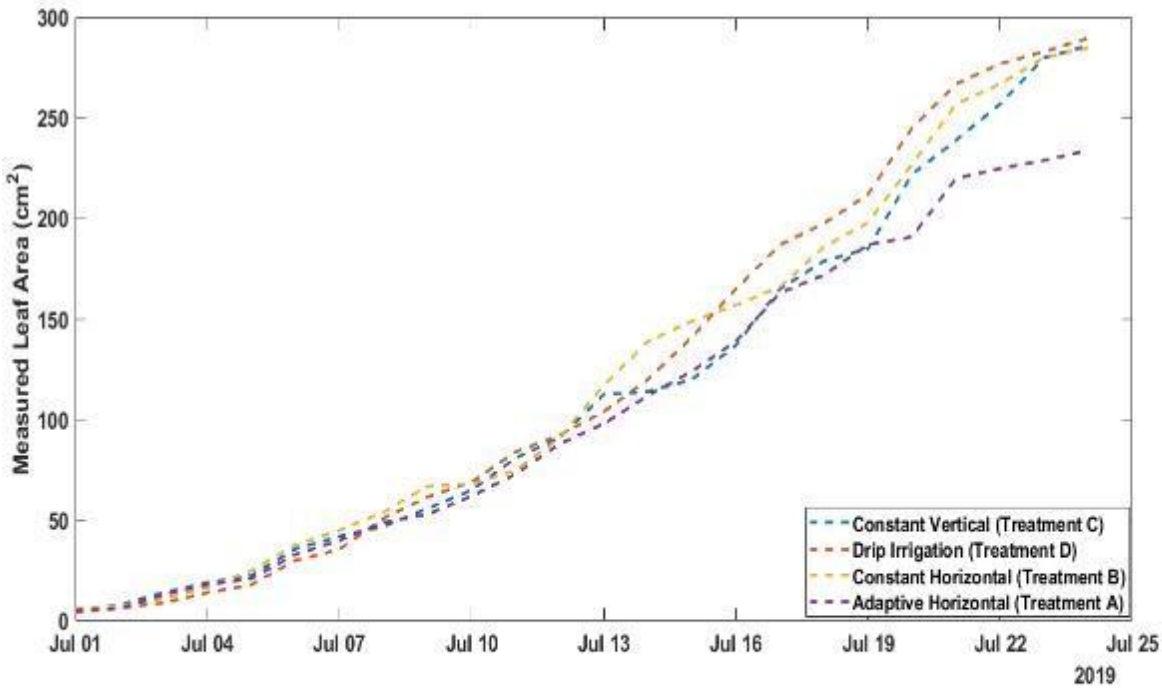


Figure 4. Graph of measured leaf area for the first three weeks after transplant for the four treatments.

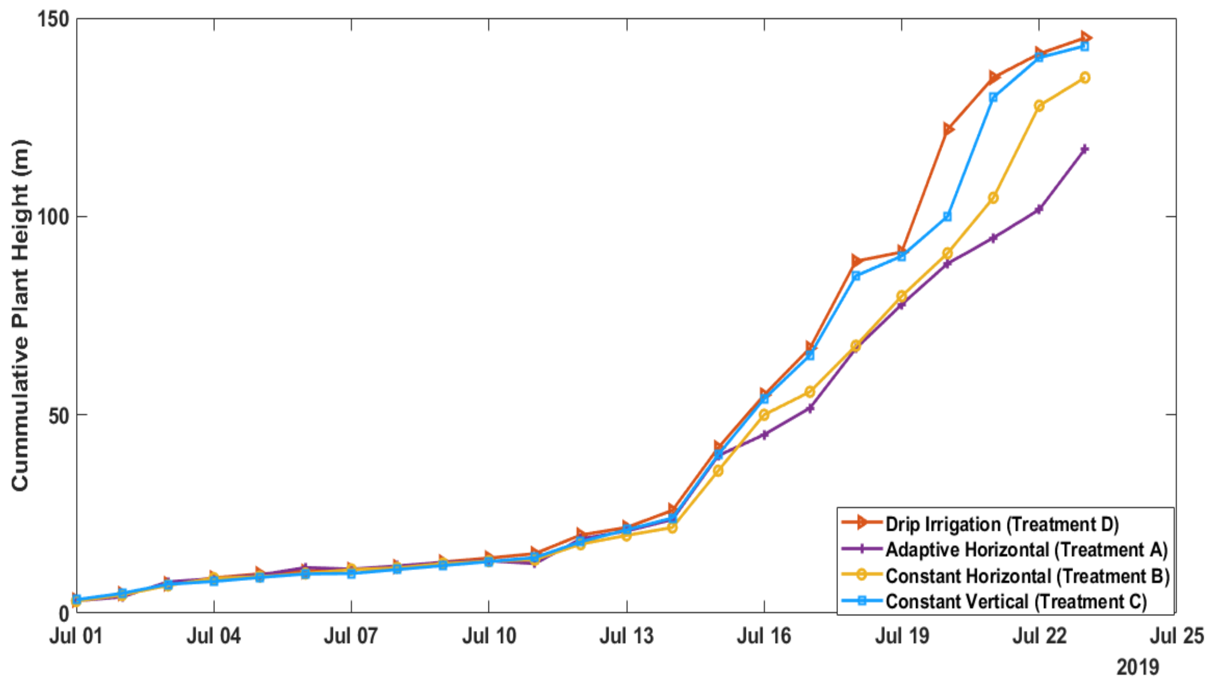


Figure 5. Graph of measured cumulative plant height for the first three weeks after transplanting for the four treatments.

Similarly, the measured plant height and leaf area of the two methods were compared with drip-irrigated cantaloupe plant having a high plant height and leave area on the average when compared with the fibrous capillary irrigated treatment as illustrated in Figure 4 and Figure 5. This is as a result of the fact that more water has been consumed by the drip irrigation system.

Table 1. Weight of harvested cantaloupe plants (kg).

Sample	**Adaptive Horizontal (Treatment A)**	**Constant Horizontal (Treatment B)**	**Constant Vertical (Treatment C)**	**Drip Irrigation (Treatment D)**
1	0.890	1.250	1.235	1.76
2	0.945	1.195	1.475	1.56
Total (Average)	0.9175	1.2225	1.355	1.66

Table 2. The sweetness of harvested cantaloupe plants (Brix).

Sample	Adaptive Horizontal (Treatment A)	Constant Horizontal (Treatment B)	Constant Vertical (Treatment C)	Drip Irrigation (Treatment D)
1	13.5	11.1	11.9	8.2
2	12.85	10.2	13.1	7.9
Total (Average)	13.175	12.5	10.65	8.05

Table 3. Water productivity index of Cantaloupe plants cultivation kg/m^3.

Sample	Adaptive Horizontal (Treatment A)	Constant Horizontal (Treatment B)	Constant Vertical (Treatment C)	Drip Irrigation (Treatment D)
1	18.5	18.79	15.9	4.85
2	19.7	17.96	19	4.85
Total (Average)	19.1	18.375	17.45	4.85

Similarly, Tables 1, 2 and 3 present the results of the weight of fruit, sweetness and water use efficiency on the harvested cantaloupe plant. According to Table 1, the drip-irrigated cantaloupe plant has a higher weight when compared to fibrous capillary irrigation treatments. While from Tables 2 and 3, the IoT based adaptive controlled fibrous capillary irrigation has water productivity index (WPI) of 19 kg/m^3 with average fruit sweetness of 13.5 Brix, while drip irrigation has WPI of 4.85 kg/m^3 and average sweetness of 8.05 degrees Brix (oBx) on the harvested fruit during cultivation of cantaloupe plants experiment. Therefore, the fibrous capillary irrigated cantaloupe plant to have better fruit quality in terms of sweetness and improved water use efficiency. This could be due to gradual water supply to the root zone of the plant through the fibrous capillary interface, based on its demand which has an effect on the sugar content of the fruit. Also, the subsurface nature of water supply to the root zone of the plant in fibrous capillary irrigation, reduce the rate of water loss due to evaporation from the soil. This could also be responsible for higher water efficiency in fibrous capillary irrigation. Tables 1, 2 and 3 was used to further analyse the statistical performance of the four treatments using Analysis of Variance (ANOVA) significant difference was established among the four treatments.

Table 4. ANOVA Table result from Table 1.

Weight of harvested Cantaloupe plant (kg)				
Source	**Degree of freedom (df)**	**Sum of Square (ss)**	**Mean Square(ms)**	**F-Statistics**
Treatment	3	0.568	0.189	14.538
Error	4	0.053	0.013	
Total	7	0.621		

Table 5. ANOVA Table result from Table 2.

The sweetness of harvested Cantaloupe plant (Brix)				
Source	**Degree of freedom (df)**	**Sum of Square (ss)**	**Mean Square(ms)**	**F-Statistics**
Treatment	3	31.54	10.51	11.587
Error	4	3.63	0.907	
Total	7	35.17		

Table 6. ANOVA Table result from Table 3.

Water Productivity Index (WPI) of Cantaloupe plant cultivation (kg/m^3)				
Source	**Degree of freedom (df)**	**Sum of Square (ss)**	**Mean Square (ms)**	**F-Statistics**
Treatment	3	271.0	91.5	107
Error	4	3.41	0.85	
Total	7	274.4		

In order to test for the significant differences between the four treatments, using $95\ \%$ confidence level, i.e. $\propto$ = 0.05, in Table 4, 5 and 6, the F value calculated is 14.538, 11.587 and 107 while the F tabulated is 6.5914. Since $F_{\propto} < F_T, ie\ \ 14.538 > 6.5914, 11.587 > 6.5914,$ and $107 > 6.5914,$ therefore we reject the null hypothesis, meaning that there are significant differences between the means of the treatments A, B, C and D in term of the average weight, sweetness and water productivity index of harvested cantaloupe plant. Therefore, the result obtained from the ANOVA analysis shows that there is significant difference among the four treatments.

4. Conclusion

An experimental investigation on the performance comparison of drip and fibrous capillary irrigation system on the cultivation of cantaloupe plant has been presented in this paper. Based on the results, the proposed irrigation methods with improved monitoring can enhance precision irrigation towards the realization of water-saving agriculture. From the performance comparison, both irrigation methods have their strength and weakness in cantaloupe plant cultivation. The result obtained from the ANOVA analysis shows that there is significant difference among the four treatments. For fibrous capillary irrigation method, the quality of fruit is found to be good with high sweetness level and higher water productivity index (WPI) compared to drip irrigation method. On the other hand, drip irrigation method produced heavier cantaloupe fruit. However, it has low water productivity index (WPI) compared to the fibrous capillary irrigation method. Therefore, it is expected that this research effort will guide farmers to adopt an effective irrigation method which complies with their cultivation objective whether to produce a good cantaloupe quality or heavier cantaloupe fruit.

Acknowledgement: The authors acknowledge the Universiti Teknologi Malaysia and the Ministry of Higher Education Malaysia (MOHE), for their partial financial support through their Prototype Research Grant Scheme (PRGS) Vote No. Q.J130000.2651.17J53.

Conflicts of Interest: The authors declare no conflict of interest in this paper.

References

Abioye, A. E., Zainal Abidin. M., Azimi Mahmud. M. S., *et al*. (2020). IoT-based monitoring and data-driven modelling of drip irrigation system for mustard leaf cultivation experiment. *Information Processing in Agriculture*, In Press, Corrected Proof. https://doi.org/10.1016/j.inpa.2020.05.004

Abioye, A. E., Zainal Abidin. M., Saiful, Azimi Mahmud, M. S., *et al*., (2020). A review on monitoring and advanced control strategies for precision irrigation. *Computers and Electronics in Agriculture*, *173*, 105441. https://doi.org/https://doi.org/10.1016/j.compag.2020.105441

Asia Society, (2019). *Asia's Next Challenge: Securing the Region's Water Future*. Retrieved on February 4th, 2020, from https://asiasociety.org/asias-next-challenge-securing-regions-water-future-0

Awang, Y., Shaharom, A. S., Mohamad, R. B., *et al*. (2009). Chemical and physical characteristics of cocopeat-based media mixtures and their effects on the growth and development of celosia cristata. *American Journal of Agricultural and Biological Science*, *4*(1), 63–71. https://doi.org/10.3844/AJAB.2009.63.71

Idham A. R. M. K., Zainal Abidin, M. S., Izran Ishak, M. H., *et al*. (2018). Analysis of Fibrous Interface Capillary Irrigation System Using HYDRUS 2D / 3D for High Water Saving Agriculture. In *MSAE Conference, Serdang, Selangor,* 1–8.

Li, Q., Sugihara, T., Kodaira, M., *et al*., (2018). Water Use Efficiency of Precision Irrigation System under Critical Water-saving Condition. In *14th International Conference on Precision Agriculture June*, Montreal, Quebec, Canada, 1−7.

Martínez, J., & Reca, J. (2014). Water use efficiency of surface drip irrigation versus an alternative subsurface drip irrigation method. *Journal of Irrigation and Drainage Engineering*, *140*(10). https://doi.org/10.1061/(ASCE)IR.1943-4774.0000745

Masde, R. M. M., & Mohd, N. R. N. (2016). Overview of Melon Industry in Malaysia. *Malaysian Agriculture Research and Development Institute, MARDI*. https://doi.org/10.1097/NOR.0b013e3181db5459

Oborkhale, L., Abioye, A. E., Egonwa, *et al*., (2015). Design and Implementation of Automatic Irrigation Control System. *IOSR Journal of Computer Engineering (IOSR-JCE), 17*(4), 99–11. https://doi.org/10.9790/0661-174299111

Rahman, M. K. I. A., Abidin, M. S. Z., Azimi, M. S., Mahmud, S. B., Ishak, M. H. I., & Emmanuel, A. A. (2019). Advancement of a smart fibrous capillary irrigation management system with an internet of things integration. *Bulletin of Electrical Engineering and Informatics*, *8*(4), 1402–1410. https://doi.org/10.11591/EEI.V8I4.1606

Rhuanito, S. F., Bailey, D., Balkaran, S., & Bernier, J. (2016). *Improving cantaloupe fruit sugar content in the UVI Commercial Aquaponic System*.

Saiful, M., Mahmud, A., Zainal Abidin, M. S, *et al*., (2020). Robotics and Automation in Agriculture: Present and Future Applications. *Application of Modelling and Simulation*, *4*, 130–140. https://doi.org/http://arqiipubl.com/ojs/index.php/AMS_Journal/article/view/130

Semananda, N., Ward, J., & Myers, B. (2018). A Semi-Systematic Review of Capillary Irrigation: The Benefits, Limitations, and Opportunities. *Horticulturae*, 4(3), 23. https://doi.org/10.3390/horticulturae4030023

Seyfi, K., & Rashidi, A. M. (2007). Effect of Drip Irrigation and Plastic Mulch on Crop Yield and Yield Components of Cantaloupe. *International Journal of Agriculture & Biology*, *8530*(9), 9–2.

Wiangsamut, B., Koolpluksee, M., & Makhonpas, C. (2017). Yield, Fruit Quality and Growth of 4 Cantaloupe Varieties Grown in Hydroponic System and Drip Irrigation Systems of Substrate and Soil Culture. *International Journal of Agricultural Technology*, *13*(7), 1381–1394.

Yahya, A., Safie, H., & Kahar, S. (1997). Properties of cocopeat-based growing media and their effects on two annual ornamentals. *Journal of Tropical Agriculture and Food Science*, *25*(2), 151–157. Retrieved from http://rac1.mardi.gov.my/jtafs/25-2/Cocopeat-based.pdf

Zainal Abidin M. S., Shibusawa, S., Ohaba, M., *et al*., (2014). Capillary flow responses in a soil – plant system for modified subsurface precision irrigation. *Precision Agriculture*, *15*, 17–30. https://doi.org/10.1007/s11119-013-9309-6

ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

HH PUBLISHER

Original Research Paper

Evaluation of Soil Stabilizer in Oil Palm Plantation Road Construction

Abd Rahim Shuib*, Mohd Khairul Fadzly Md Radzi, Aminulrashid Mohamed, Mohd Ramdhan Mohd Khalid

Malaysian Palm Oil Board (MPOB), No. 6, Persiaran Institusi, Bandar Baru Bangi, 43000 Kajang, Selangor, Malaysia.

*Corresponding author: Abd Rahim Shuib, Malaysian Palm Oil Board (MPOB), No 6, Persiaran Institusi Bandar Baru Bangi, 43000 Kajang, Selangor, Malaysia; rahim.shuib2@gmail.com.

Abstract: Plantation road construction is an important part that requires a serious planning. Any negligence in constructing and maintaining the roads will affect the infield transportation time of the harvested agricultural products as well as the process of bringing out the agricultural products to the needs. Moreover, weather conditions will make the roads impassable and create poor road surfaces which cause damage to the vehicles. Hence, without regular maintenance and resurfacing, these_roads will have limited useful lives. This paper has done the laboratory work to evaluate the unconfined compressive strength of oil palm soil by using the FJ-Adtech additive stabilisers as an enhancing medium. Lahad Datu plantation soils were mixed well with additive loadings of 14 wt. % up to 20 wt. % and being pressed at 100 kPa in compacted form sample with the size of 100 mm (height) x 50 mm (diameter). The results showed that the FJ-Ad treatment effectively improved the strength characteristics of Lahad Datu soil (4311 kPa) at 20 wt. % of loading percentage compared to the untreatment soil (1382 kPa). Field work observation also showed that the road construction surfaces treated with the stabiliser formulation showed less maintenance as 6% to 7 % cheaper compared to the conventional method. Therefore, this additive stabiliser is suitable to be used as soil treatment in the formulation for making the road surfaces more durable, less permeable and less compressed than the native soil.

Keywords: Treatment; soil stabiliser; FJ-Adtech; road construction; oil palm plantation

Received: 10th September 2020

Accepted: 14th October 2020

Available Online: 31st October 2020

Citation: Shuib AB, MdRadzi MKF, Mohamed A, *et al*. Evaluation of Soil Stabilizer in Oil Palm Plantation Road Construction. Adv Agri Food Res J 2020; 1(2): a0000122. https://doi.org/10.36877/aafrj.a0000122

1. Introduction

The Malaysian oil palm plantation area in 2019 is about 5.90 million hectares where Sabah is the second largest oil palm planted state with 1.54 million hectares (MPOB, 2020). The current standard practice in oil palm plantations is to construct 60 m of road per hectare of oil palm planted area (Phua, 2008). Thus, the state of Sabah alone needs about 300,000 km of roads in the oil palm plantations. Despite the length of these roads, minimal action has been taken to improve the road constructions. In order for an estate to have a good road network, the qualities of road constructions are major priority that needs serious considerations and plannings. It is important for a road system to be well designed, constructed and maintained for full efficiency. Improper road condition will cost the plantation to incur down time in most of the operations which then lead to inefficient in agriculture productions and affect the field activities (Asgari *et al.*, 2015; Kushwaha *et al.*, 2018).

Soils found in oil palm estates vary from peat to clay (Veloo *et al.*, 2015; Paramananthan, 2013). Estates with lateritic soils have better and more stable roads in wet season. This is different from the estates with natural clay soils because they will have compactly structured road during the dry season but adversely during the wet season. It is due to the clay soil textures where the clay particles swell when absorbing water, causing the bonding to fail and break the road surface, then inevitably form potholes. These potholes are dangerous to the vehicles carrying heavy loads (Makusa, 2012). Sandy soils are the typical type of soils in the plantation area in Lahad Datu, Sabah. Sandy soils with poor clay content are known to cause problems in regard to utilisation and management. The soils are known to have very low moisture and nutrient retention capacities where any crops grown on the soils are susceptible to moisture stress as well as multiple nutrient deficiency problems. Besides that, high surface temperatures are also the common problems where soils with a cemented sporadic horizon cause floods in wet seasons, in addition to giving moisture stress to the crops in dry seasons (Afandi *et al.*, 2001; Paramananthan, 2013).

Commonly, stabilising process on soil is performed by using bulk powder products such as acids, portal cements and fly ashes through several methods (REFs). Mechanical stabilisation is a physical technique which alters the physical nature of native soil particles either by inducing vibration or compaction, or by adding other physical properties such as barriers and nailing. Chemical stabilisation mainly depends on chemical reactions between stabiliser and soil minerals to achieve the desired effects on the final products (Firoozi *et al.*, 2017; Singh *et al.*, 2018). There is a stabiliser used for soil roads surfaces. Soil stabilisation is the modification of one or more soil properties to produce an enhanced soil substance with the desired properties of engineering. Soil stabilisation increases the strength of soil shear to give better load-bearing capability and increases soil permeability to enhance its resilience in resisting weathering cycle (Lim *et al.*, 2014).

The dried additive powder called FJ-Adtech (FJ-Ad) is a special blended and concentrated hardening agent used for mixing agent with the original port land cement (OPC). One of the advantages using the FJ-Ad is it contains constituents with a high-water content, in that would solve the shrinkage cracks on setting, as is the case with conventional cement. It has the characteristics of setting rapidly after a definite time period, hence the total time required before the final setting is brief. Therefore, there is no need to waste much time for curing, and the road may be opened to traffic immediately. Other than that, FJ-Ad has a high dry density which sturdy against freezing and thawing. In addition, it is very stable chemically and its resistance against chemicals are unyielding.

This paper discussed a project concerning a plantation road construction work at the Malaysian Palm Oil Board (MPOB) Oil Palm Plantation, at Lahad Datu Station in Sabah. The project was carried out to improve the plantation roads by applying the FJ-Adtech soil stabiliser as an enhancing medium in the involved construction of the road. Results showed that this additive soil stabiliser was suitable to be used as a treatment in the related construction processes in making the road surface more durable, as well as less permeable and less compressed than the use of native soil.

2. Materials and Methods

2.1. Preliminary work

The main compositions of this FJ-Ad additive are sodium tripolyphosphate, lignin sulphate and stearate. The treatment additive used in this project was already mixed with OPC at certain percentage formulated by MALJAPA Sdn. Bhd. The comparison of physical properties between FJ-Ad and OPC are shown in Table 1.

Table 1. Comparison of physical properties of OPC and FJ-Ad.

	Ordinary Portland Cement	**FJ-Adtech**
Specific gravity (g/cm^3)	3.15	3.04
Degree of pulverisation (%)	88 screen remainder 10	88 screen remainder 5
Relatives surface area (cm^2/g)	2.30	3.80

The initial phase of this project was to identify the optimum percentage of FJ-Adtech additive that required in-situ soil for better binding and not loosening in the presence of moisture. Initially, both native and Lahad Datu soils were mixed well with additive for 30 minutes by dry mixing method at room temperature. Table 2 lists the formulation of the composition in the samples. Additive loadings of 14 to 20 wt. % were applied for both types of soils. The mixture compositions were then poured into the test tube with the size of 100 mm (height) x 50 mm (diameter) before being pressed at 100 kPa using the hand pressing device as illustrated in Figure 1. The compacted samples were evaluated by the unconfined compressive strength (ASTM D2166) properties with at least three replication specimens to obtain an average compressive strength and standard deviation results.

Table 2. Composition of the mixture.

Type of soil	Composition mixture (wt. %)	
	soil	FJ-Ad/OPC
Lahad Datu (LDS)	86	14
	83	17
	80	20
Native (NS)	86	14
	83	17
	80	20

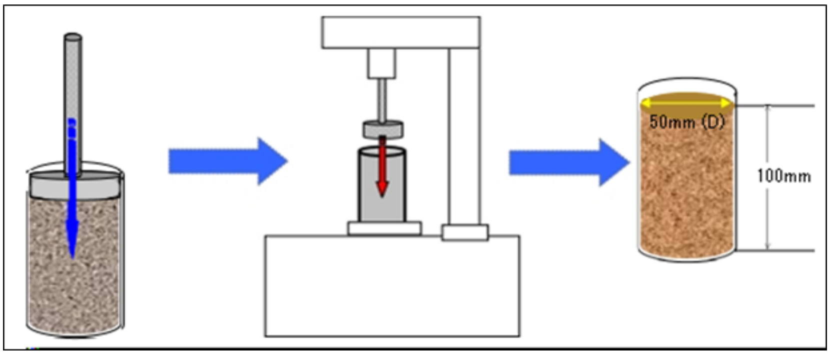


Figure 1. Compaction of treated soil using the pressing device.

2.2. Field

Figure 2 shows the flowchart of the road construction work which began by conducting the plantation site examination. The condition of the plantation sites was chosen based on the daily frequent travel by a trailer loaded with fresh fruit bunch (FFB), over 18 to 50 meters. Meanwhile, the quantity of additives composition (FJ-Ad and OPC) was determined by per/m^2 of soil condition at site. In this project, a custom-made pan mixer (Figure 3) was used for mixing of additive at construction site. The pan consisted 2.2 diameter of drum with a single blade propelled by an air-cooled diesel engine. The blade was rotating at 25 rpm with engine speed of 1 800 rpm. The pan volume of mixing is capable up to 400 kg of portland cement. Prior to that, preparation of works should be performed carefully as uneven levelling of ground would become the direct causes of unevenness in the finished surface through uneven thickness of executed layers. All vegetative remnants (like roots of trees and cobble stones) were completely removed from the surface of works, and lumps of soil were carefully smashed. The quantity of soil was reduced or added according to the thickness of works to be executed.

The next proceeding of work was to take action starting with skimming process. The soft layer of road surface was skimmed off and replaced with imported good soil from the nearby site. After that, the mixed additive composition was spread out along the road surface following the requirements per unit area. The mixing process of treatment composition with soil was done using the tractor with plough machine, an excavator and a backhoe. The mixing frequency happened at three to four times depending on the capacity of compaction machine. The materials were carefully mixed and rotovated until the colour became uniformly consistent with the controlling of water content as a precautionary step, in case it became dry. Finally, the compaction was poured out with the compaction rollers, and surface was checked for irregularity. The moisture content of the mixed soil should be close to the optimum moisture content for compaction. Since scaling was likely to develop in thin layers where unevenness was repaired by re-execution after the compaction, the mixed materials which had already been compacted was loosened up again and re-finished.

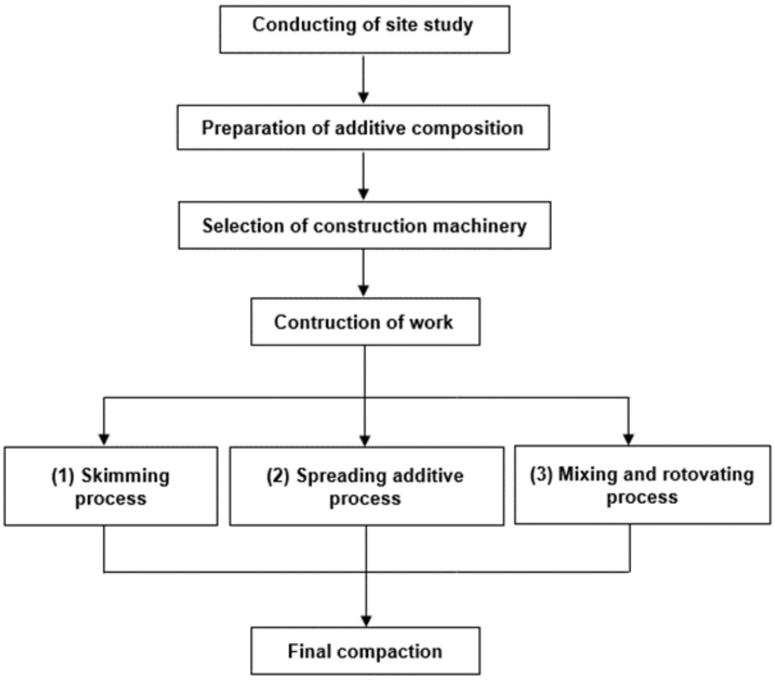


Figure 2. Flowchart for road construction process.

Figure 3. A custom-made pan mixer.

3. Results and Discussions

3.1. Unconfined Compressive Strength

Figure 4 illustrates the histogram pattern of unconfined compressive strength of Lahad Datu soil (LDS) and native soil (NS) which were treated with FJ-Adtech (FJ-Ad) at different weight percentages. The results clearly showed that the FJ-Ad treatment effectively improved the LDS strength's characteristics with the increase in weight percentage. It was obviously seen at 20 wt. %, the FJ-Ad-LDS treated samples gained the highest compressive strength of 4311 kPa as compared to the FJ-Ad-NS treated samples which was 1382 kPa.

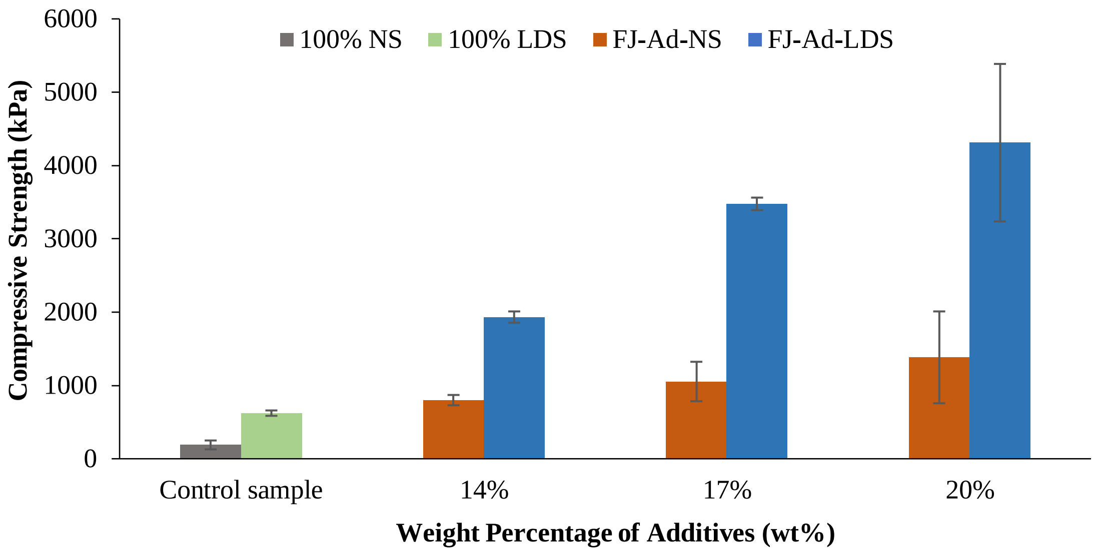


Figure 4. This Unconfined compressive strength of soil treatment samples at different weight percentage of additive materials.

3.2. Construction

3.2.1. Treatment road

Figure 5(a) and Figure 5(b) show the road with puddle forms being skimmed, filled and levelled off using good quality soil from the nearby area. The levelled road surfaces were then being ploughed by tractor with a mounted rotovator until the soils were reduced to a manageable form (Figure 5[c]). Based on the result obtained from the previous laboratory test (Figure 4), 20 wt. % FJ-Ad was applied to treat the area together with the premixed Portland cement as shown in Figure 5(d). The mixed surface was sprayed with water, and later being rotovated thoroughly again as illustrated in Figure 5(e) and Figure 5(f) respectively. Finally, a road with the durable treated surface was successfully constructed as in Figure 5(g) and Figure 5(h).

Figure 5. (a) Skimming the soft layer of road surface; (b) Importing quality soil from nearby area; (c) Rotovating the surface soil; (d) Distributing additive premix on road surface; (e) Watering the prepared surface; (f) Rotovating the prepared surface; (g) Compacting the prepared surface; (h) Completed treated road.

3.2.2. After treatment

The earlier prepared Lahad Datu Station road with stabiliser had been subjected to three monsoon seasons for the past three years. Some sections of the road were under water from one to ten days, from a few centimetres to two metres deep. The roads were found to be in very good conditions in spite of being exposed to the extreme weather. No surface damage had been observed; thus, no road repair works were made to the road sections. The rainfall intensity during the period was very high which resulted in heavy silting problems in the side drains of undulating areas. Nevertheless, the road surfaces that had been treated with the stabiliser required less maintenance work as opposed to the situation before the stabiliser application. It was also observed that the amount of dust during dry days was much lesser compared to that of untreated road surface. Figure 6 shows the yearly conditions of the road which started after it was being constructed.

Trial 1 **Trial 2**

July 2014

July 2015

July 2016

July 2017

June 2018

July 2019

Figure 6. The pictures of road condition from 2016 to 2019.

3.3. Cost Comparison

In reference to Table 3, the application costs both for road maintenance using soil stabiliser and conventional were RM 79,500 and RM 82,500 respectively. The machineries required to carry out the road maintenance operation were almost the same for both methods i.e. roller compacter and tractor with different attachments, either back pusher bucket to level the crusher run after being poured on the road and soil rotovator was used to pulverise the soil prior to applying the soil stabiliser. The only additional implementation for soil stabiliser was a custom-made giant mixer pan. The pan was used to mix portland cement and soil stabiliser which later would be distributed on the application site. In terms of the overall cost, the soil stabiliser method was 6% to 7% cheaper compared to the conventional method. The other advantage of soil stabiliser that there was no need to import outside soil to do road maintenance, but the in-situ soil surface could be improved by adding the material. The cost of crusher run in this exercise was RM 60 per tonne, but this cost will vary according to the distance of source to the application site.

Table 3. The application costs both for road maintenance using soil stabiliser and conventional.

Estimation cost for laying gravel road (conventional method) based on 1 km	
Assumption:	
Material cost for crusher run	= RM 60 per ton
Cost machinery & labour for laying	= RM 11 per ton
Density of crusher run	= 2 ton per m^3
Quantity require:	
For 1,000 m (L) x 4 m (W) x 0.15 m (T)	= 600 m^3
Density of crusher run — 600 m3 x 2 ton per m^3	= 1,200 tons
Material cost for crusher run — RM 60 per ton x 1,200 tons	= RM 72,000.00
Cost of machinery & labour — RM11 per ton x 1,200 tons	= RM 13,200.00
Hence, total cost	= RM 85,200.00
Estimation cost for road construction using stabilizer based on 1 km	
Assumption:	
Material cost for FJ-Adtech	= RM 45 per kg
Cost for cement /OPC: 1 bag = 50 kg	= RM 20 per bag
Using available soils in the estate for top layer	= 2 ton per m^3
Material cost:	
Quantity of OPC required:	
For 1,000 m (L) x 4 m (W) x 0.15 m (T)	= 600 m^3
OPC (@130kg/m3): 130 kg x 600 m3	= 78,000 kg or 1,560 bags
Hence, cost of OPC	= RM 31,200.00
FJ-Adtech (1% x 1 kg OPC): 1% x 78,000	= 780 kg
Cost of FJ-Adtech	= RM 35,100.00
Cost of machinery & labour (same as gravel road)	= RM 13,200.00
Hence, total cost	= RM 79,500.00

4. Conclusion

This study proved that the use of soil stabilisation allowed the unbound materials to be stabilised with cementation compound (cement, lime, fly ash, bitumen or their combinations) for greater strength, lower permeability and lower compressibility than the native soil. It is a cost saving for the plantation company if they opt for soil stabiliser method for road maintenance since the road constructed with stabiliser is usable in both dry and wet seasons. Furthermore, the presence of stabiliser is capable of making the road surfaces more durable when strengthening occurs progressively over time as treated soil cures. In conclusion, the in-situ soil can be treated with soil stabiliser in replacement of the use of the expensive crusher.

Acknowledgments: The authors would like to thank the Director General of MPOB for allowing this experimental study to be conducted at Lahad Datu Station, Sabah.

Conflicts of Interest: The authors declare no conflict of interest; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Reference

Afandi, A. M., Tayeb, M. D., Sapudin, S., *et al*. (2001). Performance of oil palm on coral soils. *Oil Palm Bulletin 44*, *44*, 1–18. Retrieved from http://palmoilis.mpob.gov.my/publications/OPB/opb44-afandi.pdf

Asgari, M. R., Baghebanzadeh Dezfuli, A., & Bayat, M. (2015). Experimental study on stabilization of a low plasticity clayey soil with cement/lime. *Arabian Journal of Geosciences*, *8*(3), 1439–1452. https://doi.org/10.1007/s12517-013-1173-1

Firoozi, A. A., Guney Olgun, C., Firoozi, A. A., & Baghini, M. S. (2017). Fundamentals of soil stabilization. *International Journal of Geo-Engineering*, *8*(1). doi: 10.1186/s40703-017-0064-9.

Kushwaha, S. S., Kishan, D., & Dindorkar, N. (2018). Stabilization of expansive soil using eko soil enzyme for highway embankment. *Materials Today: Proceedings*, *5*(9), 19667–19679. https://doi.org/10.1016/j.matpr.2018.06.329

Lim, S. M., Wijeyesekera, D. C., Lim, A. J. M. S., *et al.* (2014). Critical review of innovative soil road stabilization techniques. *International Journal of Engineering and Technology Research*, *3*(5), 204–211.

Makusa, G. P. (2012). *Soil Stabilization Methods and Materials in Engineering Practice*. Luleå University of Technology.

MPOB. (2020). *Production of crude palm oil*. Retrived from http://bepi.mpob.gov.my/index.php/statistics/production/135-production-2015/736-production-of-crude-oil-palm-2015.html. 1727–1740

Paramananthan, S. (2013). Managing marginal soils for sustainable growth of oil palms in the tropics. *Journal of Oil Palm and the Environment*, *4*(1), 1–16. https://doi.org/10.5366/jope.2013.1

Phua, S. K. (2008). *Oil plam cultivation — Drainaga, irrigation & infrasructures (inland and coastal)* [Lecture notes]. Intensive Diploma in Oil Palm Management Technology, Malaysian Palm Board, Ministry of Primary Industry. 316–325.

Rauch, A. F., Harmon, J. S., Katz, L. E., *et al*. (2002). Measured effects of liquid soil stabilizers on engineering properties of clay. *Transportation Research Record*, (1787), 33–41. https://doi.org/10.3141/1787-04

Singh, R., Ray, D. S., Mehrotra, A., Afaque Khan, M. (2018). A review paper on comparative study of soil stabilization with widely used admixtures like lime, cement, flyash and bitumen emulsion. *International Journal of Engineering Trends and Technology*, *58*(2), 96–99. doi: 10.14445/22315381/ijett-v58p218.

Veloo, R., Van Ranst, E., & Selliah, P. (2015). Peat characteristics and its impact on oil palm yield. *NJAS - Wageningen Journal of Life Sciences*, *72*, 33–40. https://doi.org/10.1016/j.njas.2014.11.001

ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

Original Research Article

Performance Evaluation and Viability of a Pedestrian-type Low Land Cabbage Transplanter

Mohd Fazly Mail[1]*, Hafidha Azmon[1], Mohd Shahmihaizan Mat Jusoh[1], Mohd Nur Hafiz Mat Azmin[2], Mohd Nadzim Nordin[1], Mohd Zubir Md Idris[1]

[1]Farm Mechanisation Program, Engineering Research Centre, Malaysian Agricultural Research and Development Institute (MARDI), Serdang, Selangor

[2]Technology Commercialization and Business Centre, Malaysian Agricultural Research and Development Institute (MARDI), Serdang, Selangor.

*Corresponding author: Mohd Fazly Mail, Farm Mechanisation Program, Engineering Research Centre, Malaysian Agricultural Research and Development Institute (MARDI), Serdang, Selangor: fazlym@mardi.gov.my

Abstract: This article reports on the performance and costs of owning and operating a pedestrian-type low land cabbage transplanting machine. The tests were carried out on tin-tailing soil at MARDI Kundang Research Station. They were undertaken in view of the need to mechanize low land cabbage transplanting operation due to shortage of agricultural labours. The machine performed satisfactorily when operated on planting bed with or without the existence of the plastic mulch. Cabbage seedlings required bigger holes on the planting bed which is layered with plastic mulch to avoid mortality of seedlings due to the heat absorbed by the plastic. Based on the performances test, the results showed that the field efficiency were 91.36% and 92.21% for with and without plastic mulch respectively on the planting bed. On average, 407s were recorded for the machine to transplant the seedlings along 100m planting bed. Compared with the traditional method, the transplanter gives 82-85% saving in labours that required to plant the seedlings. The calculation of break-even annual use for the implement was 33 ha/year. The implement was projected to be viable to use for 1600 h/year.

Keywords: low land cabbage; transplanter; machine performance; work rate, viability

Received: 14th September 2020

Accepted: 14th October 2020

Available Online: 26th October 2020

Citation: Mohd Fazly M, Hafidha A, Mohd Shahmihaizan MJ, *et al.* Performance evaluation and viability of a pedestrian–type low land cabbage transplanter. Adv Agri Food Res J 2020; 1(2): a0000123. https://doi.org/10.36877/aafrj. a0000123

1. Introduction

Cabbage or scientifically known as *Brassica oleracea* var. Capitata belongs to Brassicaceae family which is grown at temperate and subtropical regions (Peter & Hazra, 2015). The most extensive types of cabbages that cultivated in Malaysia are from variety of round and Chinese cabbages. The total planted area for round cabbage in Malaysia is about 3,677 ha which is equal to 83,600 mt of production while Chinese cabbages covered 552 ha area which can produce 11,912 mt fresh product per year (DOA, 2019). Pahang is the state leading producer of round cabbages accounting for 72,104 mt in 2018, followed by Sabah with 7,776 mt and Kelantan in the third place with 528 mt (DOA, 2019). All producers are located at temperate regions and highland which is ideal to cultivate the round cabbages.

Cabbages nowadays can be produced in lowland areas to cater the domestic demand and in consideration of lack of additional spaces to cultivate cabbages at highland areas (Farahzety *et al*., 2017). Production of low-land cabbages are encouraged by the government as it can be grown in large scale on the flat land with mechanisation. Low productivity of current cabbage cultivation in Malaysia is due to traditional approach in farming activities. Difficulties in operating machineries on hillside enforced to manual operations for cabbage productions. It is different from producing cabbages in low-land, whereby the ground enable mechanization which initiated by engines such as tractors and power tillers. (McNulty & Grace, 2009). Agricultural mechanizations are the key to improve consistency of plant spacing, ensuring better seedling distribution, optimizing the input usage, reducing labours in field but still able to maintain high productivity (Reid, 2011).

Cabbages can be grown by seeding directly in field or by transplanting seedlings that raised in nurseries (FAO, 2012). In Malaysia, cabbage is commonly grown from transplants and the activity is laborious, back breaking and time consuming when it is implemented manually. The conventional practice requires labours to bend the body and squat in order to punch a hole on the ground and plant seedlings by pressing down the root ball in the soil with hands (Khadatkar *et al*., 2018). The existence of plastic mulch for weed control has aggravated the difficulties to the labours to prepare a planting hole on a raised bed. Besides, traditional punching holes process on plastic mulching consumes a lot of time to ensure the plastic is fully torn and holes spacing are accurate to allow growth of the plants after seedling planting. The plant spacing is an important factor as it can influence on marketable yield, head diameter and volume of cabbage production (Znidarcic *et al*., 2007; Rahman *et al*., 2007).

The labours requirement and consistency in preparing plant spacing are the factors in cabbage productions that show the necessities for mechanizations of transplantations. Transplanters are designed based on seedling type to be used in the field. Cabbage seedlings are categorized as root-ball type, thus the transplanter machine is needed to handle seedlings with extra care to avoid any damage to the root while putting the seedlings into the raised bed. Cabbage transplanter can be found in the market in two forms; automatic and semiautomatic version. The pedestrian-type transplanter is an example of semiautomatic transplanter as it requires a labour to manually transfer the seedlings into the pot supply while automatic tranplanter can eliminate labour as it can self-pick up the seedling from the production tray into the feeder (Khadatkar *et al*., 2018; Kumar & Raheman, 2008).

MARDI has owned the *PH1-A* pedestrian-type vegetables transplanter to transplant cabbage in the raised bed plantation. This work was undertaken to evaluate the performance of the transplanter to increase the production of low land cabbage through appropriate farm mechanization.

2. Materials and Methods

2.1 Machine Description

The *PH1-A* pedestrian-type low land cabbage transplanter (Figure 1) is a lightweight (155 kg), compact and semi-automated self-propelled transplanter. The machine is suitable for root-ball type seedlings. The transplanter consists of an air-cooled 4-cycle gasoline engine, a power transmission system, hydraulic system, sensor roller, planting shoe, covering wheels, handlebar, handle assembly with several control levers, rotary pot supply system, both sided seedling racks and farm-wheels.

The working principle of the transplanter is based on manual operations that feeding the root ball seedlings from the rack into the rotary pot supply system. There are total of eight pots. One plate is located under the pots with an outlet to allow the seedlings drop into the planting shoe while it is rotating. The planting shoe assists the seedlings transplant on the planting bed in upright orientation. The planting shoe mechanism was designed to open and close the holding part after planting to ensure not to take off the seedlings or pull off the laying plastic mulch while moving forward. The covering wheels are functioning to place soil around the planted seedlings to keep in upright position. There is planting depth control lever that can be switched up to 15 levels which is equal to 5 mm different for each level. The hydraulic auto-tracking system controls the vehicle body height. Front and rear vehicle body heights are adjusted by the parallel horizontal link mechanism to keep the planting depth and position stable. The system is supported up to 10-degree inclined angle position. The transplanter has a sensor roller to detect the planting bed surface to permit planting on uneven ridges. The suitable ridge height is below 300 mm. The planting ridge width can be adjusted between 500 mm to 1070 mm. The transplanter has a plant spacing gauge between 200 mm to 500 mm.

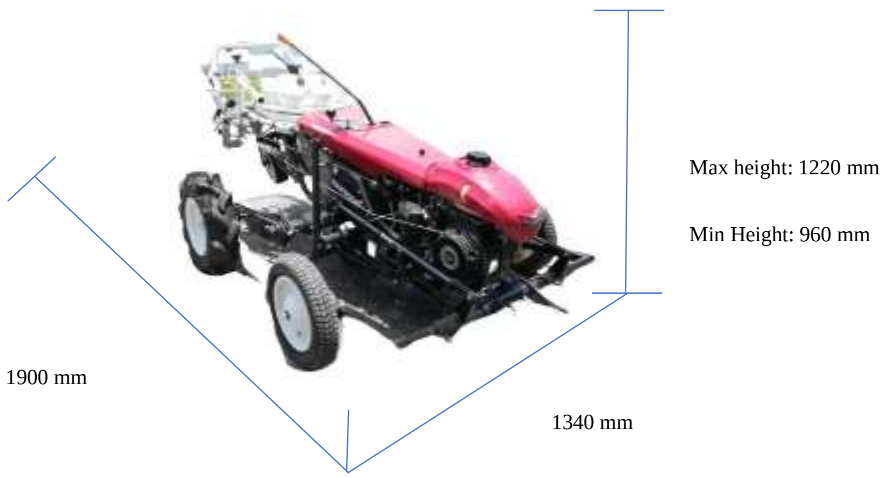


Figure 1. Overall view of the *PH1-A* pedestrian-type vegetables transplanter.

2.2 Functional Performance Test

The machine mechanical functioning of the transplanter components was observed without taking any work rate data. Observations were made on implement's ease of operation, planting depth control and space lever, gear shift, hydraulic stop lever, sensor roller, covering wheel lever, rotary cup, fuel consumption and working speeds. The observations on operational functional performance were made on the forward speeds suitable for the tin-tailing soil and were repeated several times to get the optimum speed without damaging the seedlings and for the ease of operator in handling the equipment. The completeness of the puncher mechanism that plant the seedlings on the planting bed and suitability of the root ball size to the opening mouth of the planting shoe and the turning circle diameter of the transplanter were also observed.

2.3 Field Performance Test

The lowland cabbage transplanter was functionally tested by MARDI Research Station in Kundang. The test plots were of tin-tailing soil with flat to gently rolling topography (0-3 degrees gradient). The test plots were planted with lowland cabbage variety F1 Hybrid 311 at a 0.85 m between rows and 0.5 m within rows with 0.05 m depth. The seedlings were planted in the planting bed without and with plastic mulching. The crop rows in the plot were 97–100 m long. Observations were made and data were collected while the implement was operated in the field doing the various tasks. Total time taken to plant the seedlings on the planting bed for each row over the whole plot, total time taken for stoppages due to implement breakdown or mishandling of the machine and total time taken for turning at the end of the rows were recorded.

2.4 Performance Analyses and Evaluation

The machine's theoretical and effective field capacities and field efficiency were analyzed. The test was repeated several times on the tin tailing soil type. The test was compared between the operating on planting bed without and with plastic mulching. At the end of each evaluation the wear occurring on the transplanter was observed. The theoretical field capacity was calculated without considering the time losses during operation (Equation 1).

$$TFC = W \times S \tag{1}$$

Where,

TFC = theoretical field capacity, W = the width between-row spacing (m), S = the average forward speed (m/s).

Time losses during operation such as turning at the end of rows, mishandling and repairing implement breakdown were considered to calculate the effective field capacity (Equation 2).

$$EFC = W \times S \times FE = TFC \times FE \quad (2)$$

Where,

EFC = effective field capacity which is the work rate achieved over the whole plot with considering the total time taken for the work done at the plot,

FE = the field efficiency of the implement under real conditions.

The *FE* can be calculated by dividing the effective field capacity, *EFC* and theoretical field capacity, *TFC* (Equation 3). Field efficiency is normally expressed as percentage.

$$FE = \frac{EFC}{TFC} \times 100 \quad (3)$$

2.5 Fuel Consumption

The fuel consumption was manually estimated to predict the usage of fuel used over time during the machine operation. The tank capacity of the transplanter is two litres. Full tank fuel was filled before starting the operation. After an hour of operation, the tank was refilled to estimate the fuel consumption used.

2.6 Project Viability and Feasibility

Project viability and feasibility are the main elements to be of concern before implementing or offering services to the targeted clients. Profit oriented main focus is to ensure all expenses must get return or profit. In other words, it is cost effective and viable. To achieve that purpose, a projected cash flow analysis was developed to get some indicators on its viability and feasibility.

In determining and generating the financial indicators certain assumptions need to forecast based on right study and experiences. Assumptions and data used in estimating the owning and operating cost of *PH1-A* pedestrian-type transplanter involved are shown in Table *1* below:

Table 1. Assumptions and data used in estimating the owning and operating cost of *PH1-A* pedestrian-type transplanter.

Assumptions	Value
Services Covered	17 ha/month (72ha / year)
Working Hours	8 hours/day

Assumptions	Value
Services Price	RM 800/ha
Planted Area (Cabbage) in Malaysia	3,588 ha (DOA, 2018)
Potential Market	68 ha/year (1.9% from total planted area)
Transplanter	RM 40,000 (1 unit)
Machine Life Span	10 years
Depreciation & Amortization	RM 3,600/year
Maximum Transplanter Used	1,600 hours/year
Life to Wear Out	5,000 hours

3. Results

3.1 Functional and Field Performance

The performance of the low land cabbage transplanter under test condition was generally satisfactory. This is especially for the planting function and ease of operation. The transplanter worked easily, quickly and accurately at the test plots. The sensor roller helped the transplanter run efficiently even on uneven soil. The hydraulic auto-tracking system automatically moved up and down based on the unevenness of the soil to keep the transplanter always horizontal position to ensure accurate planting. The seedlings were easily planted on the planting beds on tin-tailing soil conditions with the planting shoe mechanism. The planting shoe mechanism succeeded in opening and closing the holding part efficiently without taking off the seedlings and pulling off the laid plastic mulch. The soils were dragged by the covering wheels to cover the seedlings for stable planting after being planted. The planting depth control lever was easily used to switch up for the different of depth level. The planting depth was set at 50 mm depth as required by the agronomist. In the test, the proportion of seedlings not being in upright orientation after planting was very low, at 5% of the whole plot.

The theoretical field capacity of the transplanter was obtained by its forward travel speed was measured while transplanting a sample distance with a mean of 98.85 m in a row for both planting bed without and with plastic mulching (Figure 2), and the planted seedlings on the planting bed were counted. All unproductive tasks were not taken into considerations. Several sample readings were taken to get a representative average reading. The forward speed of the operating transplanter ranged from 0.279 m/s to 0.285 m/s for ridges without plastic mulching and 0.242 m/s to 0.260 m/s for ridges with mulch. From the data, the corresponding mean spot work rate was estimated at 0.0853 ha/h and 0.0752 for planting bed without and with plastic mulching respectively.

The effective field capacity was obtained after considering the time losses for unproductive tasks such as turning at headland, travelling from one planting row to another, unloading empty trays and taking new seedling trays. The time taken to transplant the whole plot and that for the unproductive tasks were recorded. In the test, the trial plot was 0.221 ha in size. The results obtained for theoretical field capacities and effective field capacity of the low land cabbage planting on tin-tailing soil is summarized in Table 2. The time spent on various field tasks is given in Table 3. Field efficiency level of 91.36 – 92.21% obtained in the current field test was very good. The transplanter consumed 1.5 l of gasoline fuel hourly.

Table 2. Theoretical field capacities and effective field capacity of the low land cabbage planting on tin-tailing soil at MARDI Kundang Research Station (based on 0.221 ha plot).

Planting bed condition	Forward speed (m/s)	Theoretical field capacity (ha/h)	Effective field capacity (ha/h)	Seedling planting rate (seedling/hr)
Without plastic mulching	0.279	0.0853	0.0786	2006
With plastic mulching	0.246	0.0752	0.0687	1770

Table 3. Proportion of time spent on various tasks involved in low land cabbage planting.

Task	Proportion of time spent (%)	
	Without plastic mulching	**With plastic mulching**
Planting seedlings	92.21	91.36
Turning and travelling at the headland	4.58	5.11
Unloading empty tray and taking new seedlings tray	3.20	3.58

Using the pedestrian-type vegetables transplanter, the amount of labour required for transplanting the cabbage seedlings is low. Based on the overall work rate from Table 2, only 12.72–14.56 man-h are required by the transplanter to transplant a hectare of seedlings compared with 85 man-h required by the manual method. This would represent a saving of about 82–85%. The large saving in labour should be attractive to the potential users.

(a) (b)

Figure 2. Transplanter operated on planting bed a) with and b) without plastic mulching.

3.2. Viability of Owning and Operating

Five years projected cash flow has been developed by using related assumptions. Generally, the project is viable by referring to the indicators in Table 4:

Table 4. Financial Indicators of the *PH1-A* transplanter.

Indicators	Value	Benchmarking / Guide
Net Present Value (NPV)	RM 10,998	Positive Value (bigger is better)
Internal Rate Return (IRR)	24%	> 15% (short cycle crops)
Return on Investment (ROI)	69%	> 50% very good
Pay Back Period (PBP)	1.99 years	> Shorter time is better
Benefit Cost Ratio (BCR)	1.62	> 1 ($1.00: $1.62)
Discount Rate Used / Interest	10%	Only 5–8% /year

The cost of production per hectare is RM 615 while recommended production charge is RM 800/ha with 30% profit margin gain from the services charges. Current charge on planting with conventional way is around RM 1200–1400/ha (price in 2018) which is cheaper around RM 400-600/ha and we gain more profit by using transplanter services.

The viability of owning and operating the transplanter was assessed for the case when it is used for 1,600 hour operating/year. This is equivalent to using it for about 133 hour operating/month. On the other hand, for all machineries they have their own period of life to wear out which is the maintenance needs to be implemented to make sure optimum performance of the machineries. For this transplanter, period life to wear out estimated up to 5,000 hours operation or about three years operation due to rugged design with easily replaceable parts. While the transplanter life span estimated until 10 years before not relevant to operate more according this projected cash flow. This project only needs 1.99 years pay-back period which is sufficient to gain profit from this service.

4. Discussion

The performance of the *PH1-A* pedestrian-type vegetables transplanter on tin-tailing soil was generally satisfactory. The transplanter reduced labour costs as compared with the manual method of transplanting the cabbage seedlings. As conclusion, this project is viable and feasible to be implemented supported by related indicators from projected cash flow analysis based on relevant and reliable assumptions. Furthermore, in new era of agriculture, adaptation of machineries in production become priority to ensure the consistency, quality, accuracy and productivity efficiency are controlled. Without considering the usefulness of machineries, farmers or our agriculture sector will be left behind and hard to compete with advanced agriculture related countries like Thailand, Vietnam and others. Further research needs to be conducted for evaluating the optimum usage of the transplanter with various plant spacings as this paper only report on performance of machine on single plant spacing.

Funding: This research was supported and funded by Mechanization and Automation Fund under the Ministry of Agriculture and Agro Food, Malaysia.

Acknowledgments: The authors thank MARDI Kundang Research Station and their staffs for providing the low land cabbage plots for the tests and their assistance during the field tests. We wished to specially thank our team members Mr. Noraznal Mohd Zainal, Miss Norahshekin Abdul Rahman, Mr. Zawayi Mat, Miss Siti Ashah Abdul Rahim**,** Zul Fadzli Marzuki, Mohd Khairil Izani Ishak, Ahmad Kamil Zolkafli, Mustafar Yaakob, Muhammad Akmal Mohd Salleh, Zulhazmi Abu Bakar, Joehari Abdul Rani, Mohammad Shamsul Idris, Mohd Rosli Pairan, Zainal Abidin Abu Bakar for their dedication and valuable contributions rendered during the tests conducted on the transplanter.

Conflicts of Interest: The authors declare no conflict of interest, and also the funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

Agricultural Machinery Management (2000). *ASAE Standards,* 344–349.

DOA. (2019). *Booklet Statistik Tanaman 2019 (Sub-Sektor Tanaman Makanan), Jabatan Pertanian Malaysia*. Retrived on 15 December 2019 from http://www.doa.gov.my/index/resources/aktiviti_sumber/sumber_awam/maklumat_pertanian/perangkaan_tanaman/booklet_statistik_tanaman_2019.pdf

FAO (2012). *Crop water information: Cabbage*. Retrieved on 3 March 2020, from http:// www.fao.org/nr/water/cropinfo_cabbage.html.

Farahzety, A. M., Illias, M. K., Rozlaily, Z., *et al*. (2017). Teknologi pengeluaran kubis bulat tanah rendah secara penanaman terbuka. *Prosiding Persidangan Kebangsaan Pemindahan Teknologi (CONFERTECH),* 136–143.

Kumar, G. V. P., & H. Raheman, H. (2008). Vegetable transplanters for use in developing countries-A review. *International Journal of Vegetable Science, 14*(3), 232–255

Khadatkar, A., Mathur, S. M., & Gaikwad, B. B. (2018). Automation in transplanting: A smart way of vegetable cultivation. *Current Science, 115*(10), 1884–1892

McNulty, P. B., & Grace, P. M. (2009). Agricultural Mechanization and Automation. *Encyclopedia of Life Support Systems, 1*, 1–46

Peter, K. V., & Hazra, P. (2015). *Handbook of vegetables*, Studium Press LLC.

Reid, J. F. (2011). The impact of mechanization on agriculture. *The Bridge, 41*(3), 22–29.

Rahman, M., Iqbal, M., Jilani, M. S., *et al*., (2007). Effect of different plant spacing on the production of cauliflower (*Brassica oleraceae* var. Botrytis) under the agro-climatic conditions of D.I. Khan. *Pakistan Journal of Biological Sciences.* 10(24), 4531–4534.

Znidarcic, D., Kacjan-Marsic, N., Osvald, J., *et al*., (2007). Yield and quality of early cabbage (*Brassica oleracea* L. var. capitata) in response to within-row plant spacing. *Acta agriculturae Slovenica*, 89(1), 15–23.

ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

HH PUBLISHER

Original Research Article

Development of Efficient Processing System for Young Coconut Husk

Mohd Shahmihaizan Mat Jusoh[1]*, Wan Mohd Aznan Wan Ahamad[2], Mohd Nadzim Nordin[1], Md. Akhir Hamid[3], Sentoor Kumeran Govindasamy[4], Zawayi Mat[1], Norahshekin Abdul Rahman[1]

[1]Engineering Research Centre, MARDI Headquarters, 43400, Serdang, Selangor.

[2]Director General Office. MARDI Kota Bharu, 15710 Kota Bharu, Kelantan.

[3]Director General Office. MARDI Alor Setar, 06600 Alor Setar, Kedah.

[4]Industrial Crop Research Centre, MARDI Bagan Datuk, 36300 Sungai Sumun, Perak.

*Corresponding author: Mohd Shahmihaizan bin Mat Jusoh, Engineering Research Centre, MARDI Headquarters, 43400, Serdang, Selangor; shahmi@mardi.gov.my

Abstract: A processing system for young coconut husk was developed to cater abandoned young coconut husk in the coconut industry. This was a new invention as an alternative to the current coconut husk extractor in the coconut industry. There were several machines developed; 1) chopping machine, 2) young coconut husk extractor, 3) conveyor system, and 4) rotary screener. This processing system was introduced to ensure the abandoned young coconut husk can be extracted into fiber and cocopeat. The evaluation results showed that the average machine capacity of the young coconut husk extractor was 350.79 kg/hour with the average weight ratio of unfiltered cocopeat and fiber produced at 70% and 30% respectively. The assessment of quality for fiber and cocopeat was done by using rotary screener that was equipped with 16 mesh nets. The result of cocopeat was 2.8% in the extracted fiber after extraction and filtration. Based on the analysis, cost of operation was RM 3.80/hr or equal to RM 668.70/month for the entire processing system. Total monthly income for machines owner was RM 52,923.30 and the ROI was 88.21%. The results showed that the processing system was able to process the abandoned young coconut husk into fiber and cocopeat. Performance evaluation of each machine should be carried out in the future research to identify machines efficiency and durability.

Keywords: young coconut husk; chopping machine; coconut husk extractor; conveyor system; rotary screener; fiber; cocopeat; machine capacity; cost of operation; income, ROI

Received: 14th September 2020

Accepted: 14th October 2020

Available Online: 31st October 2020

Citation: Mat Jusoh MS, Wan Ahamad WMA, Nordin MN, *et al.* Development of efficient processing system for young coconut husk. Adv Agri Food Res J 2020; 1(2): a0000124. https://doi.org/10.36877/aafrj. a0000124

1. Introduction

Coconut was grown in more than 90 countries. In Malaysia, it was the fourth important crops in terms of acreage after oil palm, rubber and paddy (Christoper, 2018). The coconut industry has significant socio-economic implications as it provides the source of revenues and employment to households. In addition, it supports a number of vibrant small and medium coconut-based processing industries and exporters.

In Malaysia, 95% of coconut growers were smallholders with an average yield of 5,966 kg coconuts/hectares in 2016. Coconut production was increased from 2016 to 2018 at 504,773 MT to 538,685 MT (Jabatan Pertanian Semenanjung Malaysia, 2018). The demand for young coconuts have begun to emerge with government initiatives, especially the Ministry of Agriculture in the 1990s through the encouragement of drinking young coconut water (Mohd Rashid *et al.*, 2016). Young coconuts can be defined as at an immature stage, contains mainly water and a little jelly-like meat instead of the hard white flesh found in mature coconuts. The young coconut which was just as a non-commercialized beverage has turned out to be a very popular beverage among community. The higher market price and high market demand have attracted farmers to grow coconut.

Based on the report by Mohd Hafizudin *et al*. (2016) showed that 46.0% of consumers preferred *Pandan* varieties and 12.3% followed by *Matag.* Another 24% did not show a tendency to young coconut variety. A total of 32.12 million young coconuts per month were estimated to fulfill the demand based on the results of the study.

The increase in demand for young coconut has contributed to the increase in residual products such as coconut husk. Based on production in 2018, as much as 44% of coconut husk is unutilized and disposed in open field (Tafsir & Mohd Hafizudin, 2018). There was no systematic disposal methods of coconut husk as they were thrown and burned openly and it can lead to pollution (Refs). The development of processing system for young coconut husk, to process the husk into value-added products such as cocopeat and fiber could overcome this pollution. This cocopeat can be sold at RM 7/bag or RM 1.40/kg while fiber can be sold at RM 1.20/kg (Mohd Zaffrie *et al.* 2018). There were several usages of cocopeat in the industry such as planting media in fertigation system while coir fiber can be processed into bed, pillow, car cushion, and dashboard.

Evaluation of the developed young coconut husk extractor and rotary screener had been carried out in previous research to identify its performance. It was able to improve the efficiency, quality and production of cocopeat and fiber. The capacity of the young coconut husk extractor was up to 514.9 kg/hour with the average weight ratio of unfiltered cocopeat and fiber produced at 65.4% and 34.6% respectively meanwhile the results of cocopeat quality evaluation have found only 5.7% fiber contained in the cocopeat mixture after extraction and filtration (Wan Mohd Aznan *et al*. 2019).

This paper explained the improvement of the system by developing all machineries involved in the processing line of young coconut husk extractions into fiber and cocopeat. The function of operation each machine was described clearly and cost of operation was explained in detail.

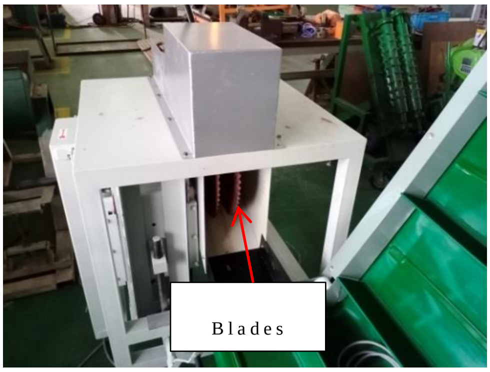
2. Materials and Methods

2.1. Machines Description and Operation

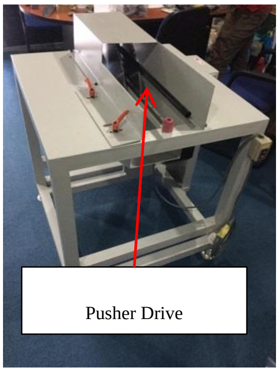
All machines were developed and fabricated at Engineering Research Center, MARDI Serdang, Selangor. The fabricated processing line of young coconut husk was placed at Engineering Research Center Workshop, MARDI Serdang.

2.1.1. Chopping machine

A chopping machine as shown in Figure 1 was developed to cut the young husk into three pieces. It was developed to make sure all materials fed into young coconut husk extractor were standard in sizes. The chopping machine comprised of a 1.5 kW single phase electric motor, belt and pulley, two 12- inch blades, and a pusher drive. The pusher drive was designed to push and lock the young coconut husk into the rotating blades to cut it into three pieces. The rotating blades were powered by the electric motor.



(a)



(b)

Figure 1. Chopping machine consist of: (**a**) Two blades; (**b**) Pusher drive.

2.1.2. Conveyor 1

A conveyor 1 as shown in Figure 2 was designed to transport the young coconut husk from the chopping machine to the young coconut husk extractor. The conveyor system was powered by a 0.75 kW electric motor and it was equipped with several partitions in the conveyor belt.

Figure 2. Conveyor 1.

2.1.3. Young coconut husk extractor

A young coconut husk extractor as shown Figure 3 was designed to extract the young coconut husk into cocopeat and fiber. It was powered by a 6.8 kW diesel engine at 3000 rpm. It consists of two main function sections which were extraction mechanism and scraper mechanism. Both mechanisms were driven by the engine via belting mechanism. The extraction mechanism comprises of spike, cylinder drum, combing devices, filtering rods and fin plate whereas the scraper mechanism was installed under the filtering rod to smoothen the extraction operation by preventing the clogging of cocopeat. The scraper mechanism had been designed to operate continuously at speed of 0.03 m/s through mechanical concepts. It was equipped with components such as speed reducer, chain and sprocket.

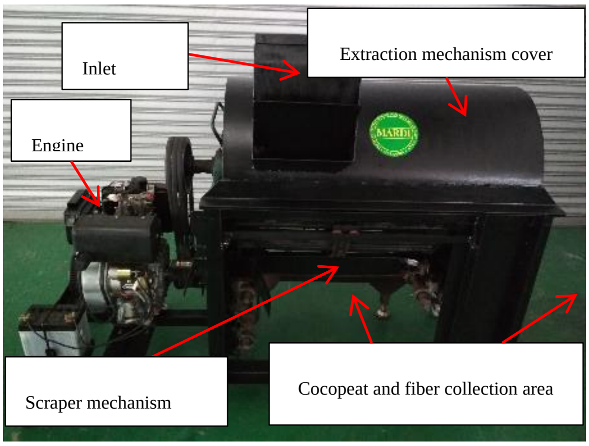


Figure 3. Young coconut husk extractor (Wan Mohd Aznan *et al.* 2019).

2.1.4. Conveyor 2

A conveyor 2 as shown in Figure 4 was designed to transport the cocopeat to the collection area. The conveyor system was powered by a 0.75 kW electric motor.

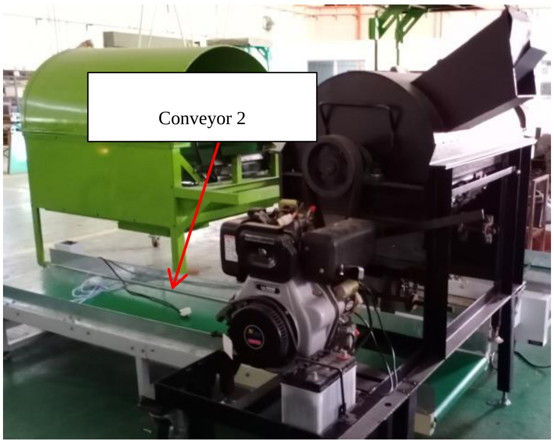


Figure 4. Conveyor 2

2.1.5. Conveyor 3

A conveyor 3 as shown in Figure 5 was designed to transport the fiber from the coconut husk extractor to the rotary screener. The conveyor system was powered by a 0.75 kW electric motor and it was equipped with several partitions in the conveyor belt.

Figure 5. Conveyor 3.

2.1.6. Rotary screener

A rotary screener as shown in Figure 6 was designed to do filtering process of fiber and cocopeat. It was powered by a 0.75 kW electric motor and equipped with a 16 mesh of a plastic net.

Figure 6. Rotary screener (Wan Mohd Aznan *et al*. 2019).

Figure 7 showed an efficient processing system for young coconut husk extractor that had been developed to produce better quality of cocopeat and fiber. It consists of chopping machine, conveyor 1, young coconut husk extractor, conveyor 2, conveyor 3 and rotary screener.

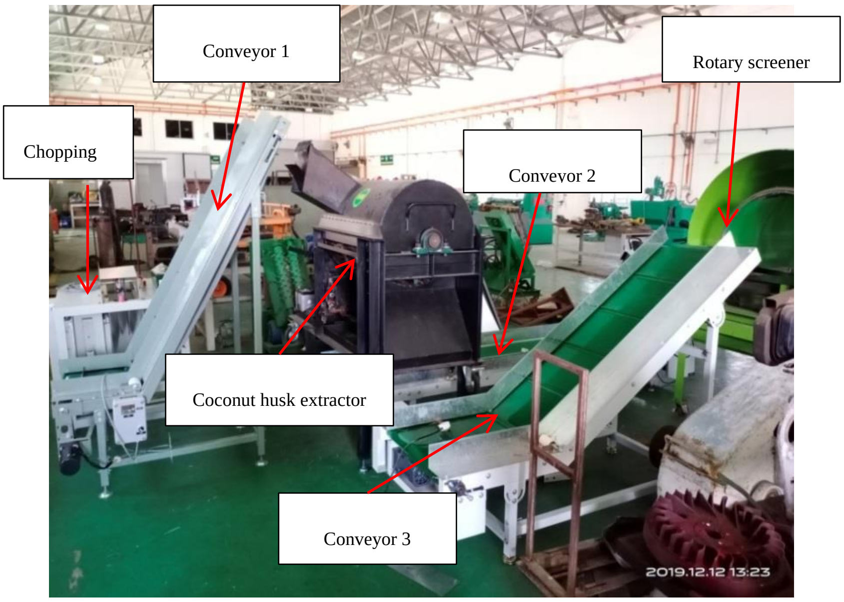


Figure 7. Efficient processing system for young coconut husk.

2.2. Sample Preparation

Performance assessment has been carried out on the machines and quality of the products produced which were cocopeat and fiber. The young coconut husk used in this machine evaluation was obtained from young coconut water stalls around Bandar Baru Bangi, Selangor. The experiment was done in MARDI Serdang, Selangor. The sample was dried up under open sunlight for a week before feeding into the extractor.

2.3. Extraction Process of Cocopeat and Fiber from Young Coconut Husk

Operation of young coconut husk processing was repeated 20 times to determine the actual processing capacity of the machine. A total of 500 kg of young coconut husk was used for the extraction process. The outputs from the extractor were discharged and collected at different outlet path. Data such as the weight of the young coconut fiber, cocopeat and fiber produced and the processing period were recorded for calculation of machine capacity and gross product ratio. The machine capacity was calculated by using the following formula:

$$Machine\ Capacity\ (\frac{kg}{h}) = \frac{Total\ Weight\ of\ Material\ (kg)}{Duration\ of\ Processing\ (h)} \quad (1)$$

Meanwhile, the gross product ratio was calculated using the following equation:

$$Percentage\ of\ gross\ cocopeat\ weight\ (\%) = \frac{Weight\ of\ gross\ cocopeat\ (kg)}{Weight\ of\ gross\ cocopeat\ and\ fiber\ (kg)} x\ 100 \quad (2)$$

$$Percentage\ of\ gross\ fiber = \frac{Weight\ of\ gross\ fiber\ (kg)}{Weight\ of\ gross\ cocopeat\ and\ fiber\ (kg)} x\ 100 \quad (3)$$

Moisture content of the young coconut husk and cocopeat also recorded as a reference. Determination of moisture content for these materials was performed by using moisture balance AND MX-50. A total of 1g sample was used for each assessment at a temperature of 105°C (Mani *et al*. 2004). Five samples for each material were used to perform this evaluation.

2.4. Quality Evaluation of Cocopeat from Young Coconut Husk

Quality evaluation of cocopeat produced via young coconut husk processing machine was performed for 5 samples to measure its product ratio. Cocopeat quality control was necessary to prevent the excessive content of fiber in the cocopeat mixture.

Total weight of filtered cocopeat and fiber were recorded for calculation of the weight ratio. Then, the cocopeat mixture that was filtered by using rotary screener was further analyzed in the laboratory by using a multi-layer shaker to determine the percentage of fiber that was still contained. The weight of fiber obtained from the analysis was recorded for computation of cocopeat and fiber ratio in ready-to-sell products. The percentage of the cocopeat and fiber is calculated using the following formula:

$$Percentage\ of\ cocopeat\ weight\ (\%) = \frac{Weight\ of\ filtered\ cocopeat\ (kg)}{Weight\ of\ filtered\ cocopeat\ and\ fiber\ (kg)} x\ 100 \quad (4)$$

$$Percentage\ of\ fiber\ weight\ (\%) = \frac{Weight\ of\ filtered\ fiber\ (kg)}{Weight\ of\ filtered\ cocopeat\ and\ fiber\ (kg)} x\ 100 \quad (5)$$

3. Results and Discussion

3.1. Machine Capacity of Young Coconut Husk Extractor

Figure 8 showed results of machine capacity analysis for the young coconut husk processing machine. In average, the young coconut extractor was able to process 350.79 kg/h of the husk.

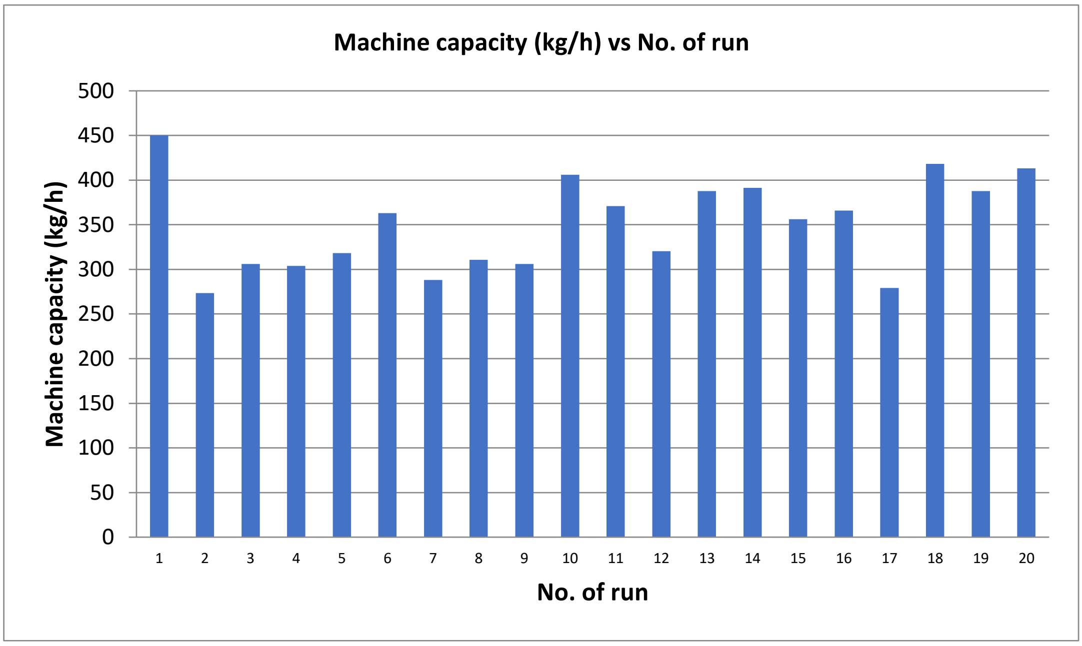


Figure 8. Machine capacity for young coconut husk extractor.

The factor that influenced this trend was young coconut husk moisture content. The moisture content of the collected young coconut husk varied from 70% to 90% due to the exposure of the material to the environment within a certain period of time before processing. Direct exposures to the sunlight and small cutting size have contributed to faster drying rates and reduced the moisture content of the husk (Onwuka & Nwachukwu, 2013).

Figure 9 showed the result of gross product ratio for fiber and cocopeat that was extracted by the machine. The average result has indicated that the extracted husk contained 146.5 kg (30%) fiber and 350.5 kg (70%) cocopeat.

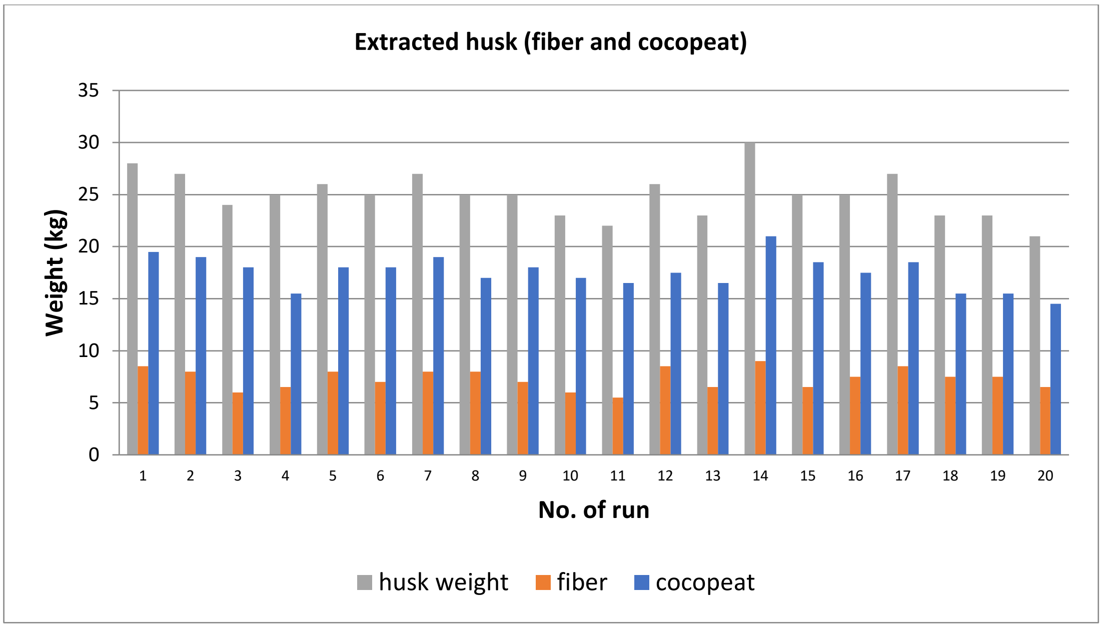


Figure 9. Result of product ratio of fiber and cocopeat after extraction process.

3.2. Percentage of cocopeat in fiber

The fiber from the extractor was filtered by using the rotary screener to extract the remaining cocopeat in the fiber. Results of the screening process are shown in Table 1. The average value of cocopeat in the fiber was 2.8% only and the picture of fiber before screening process was displayed in Figure 10.

Table 1. Results of product ratio for extracted fiber after filtered via rotary screener.

Sample	Extracted fiber weight (kg)	Weight of cocopeat in fiber (kg)	% cocopeat in fiber	% fiber
1	8.5	0.2	2.4	97.6
2	8	0.19	2.4	97.6
3	6	0.18	3.0	97.0
4	6.5	0.19	2.9	97.1
5	8	0.24	3.0	97.0
6	7	0.23	3.3	96.7
7	8	0.22	2.8	97.3
8	8	0.25	3.1	96.9
9	7	0.23	3.3	96.7
10	6	0.16	2.7	97.3
11	5.5	0.17	3.1	96.9
12	8.5	0.2	2.4	97.6
13	6.5	0.18	2.8	97.2
14	9	0.27	3.0	97.0
15	6.5	0.17	2.6	97.4
16	7.5	0.18	2.4	97.6
17	8.5	0.19	2.2	97.8

Sample	Extracted fiber weight (kg)	Weight of cocopeat in fiber (kg)	% cocopeat in fiber	% fiber
18	7.5	0.2	2.7	97.3
19	7.5	0.25	3.3	96.7
20	6.5	0.19	2.9	97.1
Average			**2.8**	**97.2**

Figure 10. Extracted fiber before screening process.

3.3. Cost of operation

The power consumption and cost of operation were calculated based on tariff provided by local supplier as shown in Table 2.

Table 2. Tariff rates for the domestic consumer.

Tariff A-Domestic Tariff	Unit	Rates (sen)
For the first 200 kWh (1- 200 kWh) per month	sen/kWh	21.8
For the next 100 kWh (201- 300 kWh) per month	sen/kWh	33.40
For the next 300 kWh (301- 600 kWh) per month	sen/kWh	51.60
For the next 300 kWh (601- 900 kWh) per month	sen/kWh	54.60
For the next kWh (901 kWh onwards) per month	sen/kWh	57.10
The minimum monthly charge is RM 3.00		

(Source: Tenaga Nasional Berhad, 2014)

Table 3 showed operation cost of the processing system for young coconut husk extractor for a month (22 days operation for 8 hours/day). The operation cost was quite cheap which was RM 668.70/month.

Table 3. Operation cost of the processing system for young coconut husk extractor.

Machine	Power, (kW)	Tariff (RM/kWjam) or SFC(diesel)	Operation (hr)	Operation cost/day	Operation cost/month
Chopping Machine	1.5	0.218	8	RM 2.62	RM 57.55
Young coconut husk extractor (diesel)	6.8	RM 2.82	8	RM 22.55	RM 496.04
Rotary screener	0.75	0.218	8	RM 1.31	RM 28.78
Conveyor 1	0.75	0.218	8	RM 1.31	RM 28.78
Conveyor 2	0.75	0.218	8	RM 1.31	RM 28.78
Conveyor 3	0.75	0.218	8	RM 1.31	RM 28.78
Total				**RM 30.40**	**RM 668.70**

3.4. Machine investment cost and profit gained

Table 4 showed a processing system for young coconut husk early cost for each machine. Total cost to set up all the machines was RM 60,000.

Table 4. Machine early cost.

Machine	Price (RM)
Chopping Machine	11,000
Conveyor 1	5000
Young coconut husk extractor	25,000
Conveyor 2	5000
Conveyor 3	5000
Rotary screener	9,000
TOTAL	**60,000**

Table 5 showed profit gain in a month by considering this processing system produce 350 kg/h of fiber and cocopeat. Material cost was RM 0.20/kg while considering wage for workers RM 0.20/kg for fiber and RM 0.30/kg for cocopeat. Total monthly income for machines owner was RM 52, 923.30.

Table 5. Nett income for machine owner.

	Fiber	Cocopeat	Monthly (RM)
Monthly sales (RM)	22,176.00	60,368.00	82,544.00
Raw material cost (kg)	61,600.00		(12,320.00)
Machines operation cost			(668.70)
Wage for workers	3,696.00	12,936.00	(16,632.00)
Nett income			**RM 52,923.30**

Return of investment (ROI) for this processing system was 88.21% which was very high and it was good to invest on these machines.

4. Conclusion

Development of young coconut husk processing machine was necessary to enhance the agro-waste to value added product and to avoid environmental pollution from the abandoned young coconut husk. This machine was capable to process 350.79 kg/h coconut husk in average which contains 70% of cocopeat and 30% of fiber. Utilization of rotary screener has improved the extraction by 2.8% cocopeat contains in the fiber.

The ROI was high and it was very good for farmers or entrepreneurs to take this technology. Therefore, processing of the young coconut husk by using these entire processing machines developed by MARDI was capable of producing quality value-added products and gain high income to farmers or entrepreneurs. For further research, the input material for the drying process can be improved instead of sunlight drying to reduce time consumption.

Supplementary Materials: The following are available online at http://www.journals.hh-publisher.com/index.php/AAFRJ//xxx/s1, Figure S1: title, Table S1: title.

Funding: This work was funded by project under the code of P-RM 413.

Acknowledgments: The authors would like to gratefully acknowledge MARDI for funding this project. The appreciation also extended to Mr. Kamil Zolkafli, Ms. Siti Ashah Abdul Rahim, Mr. Hakimi Zulkifli, and Mr. Mohd Syukri Hassan for their assistance during machine evaluation. My gratitude as well to others either directly or indirectly involved in the development of young coconut husk processing machine.

Conflicts of Interest: The authors declare no conflict of interest.

References

Christoper J. B. (2018, August 7–9). Implementation of coconut policies and initiatives: The real challenges to empower the industry. *National Coconut Conference*, Ipoh Perak.

Jabatan Pertanian Semenanjung Malaysia. (2018). Booklet statistic tanaman (sub-sektor tanaman makanan) 2018 [PDFfile]. Retrieved from http://www.doa.gov.my/index/resources/aktiviti_sumber/sumber_awam/maklumat_pertanian/perangkaan_tanaman/booklet_statistik_tanaman_2018.pdf

Mani S., Tabil L. G. & Sokhansanj S. (2004). Grinding performance and physical properties of wheat and barley straws, corn stover and switchgrass. *Biomass and Bioenergy*, *27*(4), 339–352.

Mohd Hafizudin Z., Mohd Zaffrie M. A., Nor Amna A'liah M. N., *et al*. (2016). Kajian potensi dan kecenderungan pengguna terhadap kelapa segar dan Produk Makanan Berasaskan Kelapa (PMBK) di Malaysia, Laporan Kajian Sosioekonomi 2016.

Mohd Rashid R., Nor Amna A'liah M.N., Mohd Hafizudin Z. & Mohd Dainori M.S. (2016). Potensi pembangunan industri kelapa negara dari perspektif rantaian nilai, Laporan Kajian Sosioekonomi 2016.

Mohd Zaffrie, M.A., Mohd Hafizudin Z. & Azahar H. (2018). The market potential of non-food coconut-based products in Malaysia, National Coconut Conference, 7-9 August 2018, Ipoh Perak. eISBN 978-967-936-663-1

Onwuka U.N. & Nwachukwu G. (2013). Grain size and heat source effect on the drying profile of cocoa beans. Nigerian Journal of Technology (NIJOTECH), Vol. 32. No. 3, pp. 417-423, ISSN: 1115-8443

Tafsir S. & Mohd Hafizudin Z. (2018, August 7–9). Industry outlook and consumer preference for fresh and processed coconut products. *National Coconut Conference*, Ipoh Perak.

Tenaga Nasional Berhad. (2018). *Electricity tariff schedule* [PDF file]. Retrieved from https://www.tnb.com.my/assets/files/Tariff_Rate_Final_01.Jan.2014.pdf

Wan Mohd Aznan W.A., Mohd Shahmihaizan M.J., Md Akhir H., *et al*. (2019, March 21). Evaluation of performance for young coconut husk processing machine and its product quality. *Konvensyen Kebangsaan Kejuruteraan Pertanian Dan Makanan*, Wisma Tani, Kementerian Pertanian Malaysia, Putrajaya.

ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

HH PUBLISHER

Original Research Article

Performance of a Triangular Rubber Tracked Tractor in Paddy Fields

Ahmad Mohd Taufik [1]*, Khadzir Mohd Khusairy[2], Omar Mohamad Fakhrul Zaman[3]

[1]Engineering Research Center, MARDI HQ, Serdang, Selangor, 43400, Malaysia.

[2]Engineering Research Center, MARDI Seberang Perai, Penang, 1320, Malaysia.

[3]Engineering Research Center, MARDI Seberang Perai, Penang, 06500, Malaysia.

*Corresponding author: Ahmad Mohd Taufik, Engineering Research Center, Mardi HQ, Serdang, Selangor, 43400, Malaysia; taufik@mardi.gov.my.

Abstract: Tracked tractors have been commonly used on paddy fields to overcome soft soil problem. However, triangular-shaped rubber-tracked tractors with high clearance has not been properly tested. The objective of the research was to evaluate the performance of a triangular, rubber-tracked tractor used in paddy fields. This tractor was tested in typical paddy field conditions at MARDI Seberang Perai. The prime mover was attached with a rotary tiller. The performance tests include measuring the soil bearing capacity before and after machine disturbance, machine work rate per hectare and the effective field capacity. The fuel consumption was also recorded. Results showed that the tracked tractor obtained an effective field capacity of 0.576 hr/ha with average fuel consumption of 20 liters/ha. The lightweight tractor also contributed in producing less ground effects, combined with the use of low ground contact pressure tracks, that caused minimal soil disturbance that would affect the soil hardpan layer. The tractor had enough power to move in typical paddy field condition, with no soft soil problems. The tractor was able to turn 360 degrees within a small area, which made it suitable for working in paddy fields. This prime mover has potential to be used in paddy fields.

Keywords: triangular rubber tracked tractor; low ground contact pressure; machine performance; soft soil; paddy mechanization

Received: 6th October 2020

Accepted: 6th November 2020

Available Online: 20th November 2020

Citation: Ahmad MT, Khadzir MK, & Omar MFZ. Performance of a triangular rubber tracked tractor in paddy fields. Adv Agri Food Res J 2020; 1(2): a0000132. https://doi.org/10.36877/aafrj.a0000132

1. Introduction

Tractors have been used for land preparation in the Malaysian paddy production. Land preparation is fully mechanized, be it using 2-wheel or 4-wheel tractors. Omar *et al.* (2019) reported that there are 10,000 units of tractors used in Malaysian paddy production, with 30% of it are 4-wheel tractors. From this percentage, 83% is owned by private service providers while the remaining 17% is owned by government agencies.

Although mechanization has helped increase the productivity of paddy production, it has also been blamed to cause soft soil condition. Soft soil condition is defined as a condition with high compressibility and low strength, with a hardpan layer of less than 0.3 MPa at 30 cm soil depth (Kim, 2010; Nordin *et al.*, 2014; Rendana *et al.*, 2017). Soft soil condition is caused by the extensive use of heavy field machinery which damages the soil hardpan layer (Ahmad *et al.*, 2014; Ahmad *et al.*, 2015). The soil hardpan layer is required in paddy fields to support the weight of field machinery, other than to prevent water leakage (Hemmat & Taki, 2003).

Soil hardpan layer damage is claimed to be caused by the usage of high ground contact pressure pneumatic rubber tyres (Vial *et al.*, 2020). This type of tyres has small contact area to the ground surface, and when using tractors and combine harvesters with total mass of more than 5tons, hence creating big pressure to the soil surface (Taghavifar & Mardani, 2013).

An alternative to reduce this problem is to use tracks replacing rubber pneumatic tyres. Agricultural tracks provide better traction performance and mobility, and reduces soil compaction (Fukushima *et al.*, 2019; Zhao *et al.*, 2020). There are several options of agricultural track configurations that are available such as full tracks, half-tracks and 4 half-tracks or quad-tracks. From these configurations, there are two types of track material used, which are rubber tracks or steel tracks.

A different type of tracked tractor has been recently imported into Malaysia. This uniquely designed tractor is equipped with full tracks, except that the full tracks are triangular shaped. The oscillating crawler units is claimed to have better stability on uneven ground surface (Fukushima *et al.*, 2019). This type of machine has not yet been fully tested scientifically and technically in Malaysian paddy fields, hence requires a specific experiment.

The objective of this paper is to evaluate the machine performance in terms of machine performance, slippage and soil bearing capacity.

2. Materials and Methods

2.1 Machine Description

The tractor is a fully tracked tractor with a power rating of 60 kW (80 hp) at a rated engine speed of 2400 rpm. The tractor is powered by a direct-injection, vertical, water-cooled, four-stroke turbodiesel engine. The tractor is 3.7 m long and 1.65 m wide. The tractor is equipped with a rubber track system that is driven by a drive sprocket attached at the rear end of the chassis. The rubber track is triangular shaped with 6 rollers and two idlers. Weight ballast of 120 kg was attached to the front end of the tractor. The overall weight of the tractor is 2600 kg. A rotary tiller with was attached to the tractor. The working width of the implement was 203 cm (80 in rotary tiller). The tillage depth was measured manually using a steel ruler from the soil surface to the tillage disturbance area.

Table 1. Tractor specifications.

Item	Description
Brand	Wong
Model	NF802
Power Rating kW (Hp)	60 (80) at 2400 RPM Engine Speed
Power Take-Off (PTO) speed	720RPM at 1000 RPM Engine Speed
Engine type	direct-injection, vertical, water-cooled, four-stroke turbodiesel
Implement width, cm	203
Total weight, kg	2600
Overall length, m	3.69
Overall width, m	1.65
Fuel Tank Capacity, liters	75

Figure 1. The triangular rubber tracked tractor attached with a rotary tiller.

2.2 Experimental Setup

The experiment was conducted at MARDI Seberang Perai using a paddy field area of 10 ha consisting of sandy loam soil. The type of soil and tillage depth was recorded. The test plots had no events of soft soil problem. Machine workrate per hectare was measured using a stopwatch. The effective field capacity was measured using the time consumed for real work and lost for other activitiies such as turning,loading or unloading and adjustment depending on field have been used.

Effective field capacity (ha/hr),

$$S= \frac{A}{T_P} + T_1 \quad (1)$$

where

A=Area covered (ha)

T_p= Productive time (hr)

T_l=Non-productive time (hr)

The fuel consumption was measured by filling up full tank of the tractor before tillage work. After completing a number of hectares, amount of fuel used was measured by how much fuel is refilled into the tank. The amount of fuel used in liters, divided by the number of hectares covered, gives the fuel consumption in litre per hectares (l/ha).

Slippage, or wheel slip can be defined as the ratio between the actual travel speed of the vehicle and the theoretical travel speed of its wheel. The theoretical speed of the wheel was measured by measuring the distance of the wheel when rotating for a number of ten revolutions on tarmac. This value was then compared with the actual travel speed, by measuring the distance of the wheel after rotating ten revolutions on paddy soil.

Soil conditions were evaluated by the soil penetration or soil compaction. Readings of soil compaction were taken before and after the passage of the tractor, at the beginning, halfway, and at the end of the test area, with 3 replicates for each sampling area. Two types of soil compaction data were taken, which were soil compaction after passage of tractors' tracks and no disturbance which acted as the control data. The soil strength was measured up to 80 cm depth using a soil cone penetrometer (Penetrologger, Eijkelkamp, The Netherlands) with a base area of 323 mm^2 (ASABE, 2009). Tracks soil disturbance data was taken. No disturbance data was also taken as control. The machine sinkage was also measured. The results from the soil compaction were analyzed using ANOVA (SAS, 2015).

3. Results and Discussions

3.1. Machine Performance

Table 1 shows the results obtained from the experiment. The tillage depth was roughly 40cm using the full working width of the implement, 203 cm. The measured effective field capacity using this tractor was 0.576 hour/hectares, which is considered fast if compared to most rear half-tracked tractors that are commonly used. The use of a wide rotary tiller showed effectiveness of the tillage work. The fuel consumption is average, using 20 liters for one hectare of land. This is mainly caused by the machine operated by MARDI operators and the soil condition of the experimental plot. Better fuel consumption is expected, done by a skilled and experienced operator with better soil conditions, at a range of 10–15 liters per hectare in typical paddy field conditions.

Table 2. The summary results for machine performance.

Performance Evaluation	Results
Tillage depth (cm)	40
Working width (cm)	203
Effective field capacity (hr/ha)	0.576
Fuel consumption (l/ha)	20

3.2 Slippage

Slippage is important in assessing the tractive efficiency and optimal settings of a prime mover. Slippage is used as an indicator to determine the correct tractor weight ballast and operating speed, which can result in not only efficient performance, but also fuel efficient. The slippage of between 3–5% is targeted. It was observed that the slippage on farm roads is 4.25%. In paddy fields, without the implement, the slippage is still within the targeted range, 4.15%. However, when fixed on the rotary tiller, the slippage dropped to 2.39%. Although not within the targeted range, the quality of tillage is excellent. The operation was smooth and easy to handle by the operator. During operation, there were times when the front end of the tractor was tilted upwards. Although this does not affect the performance of the tillage, but it might cause visibility and handling problems to the operator. This can be solved by installing enough ballast when more draught force is required.

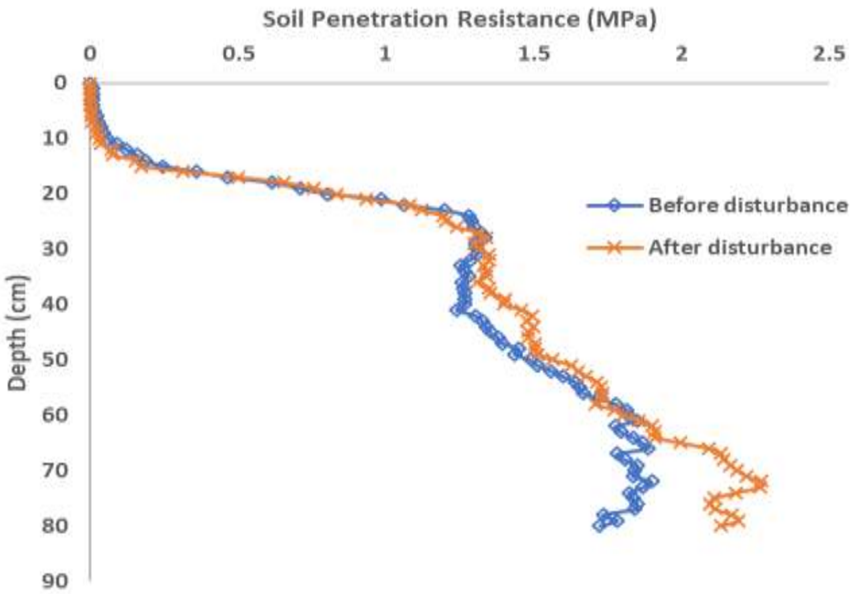
Table 3. The summary for slippage.

Condition	Slippage,% (Standard Deviation)
Farm Road	4.25 (1.5)
Paddy field (without rotary tiller)	2.39 (2.3)
Paddy field (with rotary tiller)	4.15 (2.5)

3.3 Soil Bearing Capacity

The soil effects after tractor disturbance was not significant (t = 0.30, p = 0.763). This showed that the low ground contact pressure of the tracked tractor has minimal effect on typical paddy fields. Although the working depth of the machine is 40 cm, the graph shows that there is no significant damage to the soil strength at 0–40 cm. This tractor will be useful for fields that are currently without any soft soil condition, as results here show no significant effects.

Figure 2. Soil penetration resistance of machine before and after disturbance.



4. Conclusions

The tracked tractor was tested in typical tillage conditions on paddy fields. The tracked tractor showed impressive results, obtaining an effective field capacity of 0.576 hr/ha with average fuel consumption of 20 liters/ha. Feedbacks from tractor operator were positive, although the tractor requires some training to operate, due to the use of tracks instead of wheels. Maneuverability of the tractor was excellent, able to turn 360 degrees within a small area, which makes it perfect for paddy field cultivation. The tractor had enough power to move in typical paddy field condition, with no soft soil problems. The low weight of the tractor also contributes in producing less ground effects, combining with the use of low ground contact pressure tracks. This prime mover has potential to be used in paddy fields.

Author Contributions: Investigation, M.K. Khadzir, M.T. Ahmad; resources, M.K. Khadzir; writing—original draft preparation, writing—review and editing, M.T. Ahmad, M.K. Khadzir, M.F.Z. Omar.;

Acknowledgments: The researchers would like to express gratitude to Wong Engineering Sdn Bhd for providing one unit of NF802 for the duration of the experiment. The researchers would also like to thank the Engineering Research Center staffs from MARDI Seberang Perai for their assistance throughout the experiment.

Conflicts of Interest: The authors declare no conflict of interest.

References

Ahmad, M. T., Khadzir, M. K., Mohamed Isa, F., *et al*. (2014). Preliminary trial of a quad-steel tracked tractor on paddy field. *Proceedings of National Conference on Agricultural and Food Mechanization*, 130–133.

Ahmad M. T., Khadzir M. K., Md Isa M. F., *et al*. (2015). Performance of a Quad-Steel Tracked Tractor on Paddy Field. *Proceedings of Malaysian Soil Science Conference. Malaysian Soil Science Society (MSSS).*

ASABE. (2009). *Soil Cone Penetrometer*. In ASABE Standards.

Fukushima, T., Katagiri, H., Mitsuoka, M., *et al*. (2019). Proposal of a measurement method for the tension of crawlers' rubber tracks by using their inner structure. *Engineering in Agriculture, Environment and Food*. https://doi.org/10.1016/j.eaef.2019.12.010

Hemmat A., & Taki O. (2003). Comparison of compaction and puddling as pre-planting soil preparation for mechanized rice transplanting in very gravelly Calcisols in central Iran. *Soil and Tillage Research,* 70(1), 65–72.

Kim, H. B. (2010). *Problematic soils in search for solution*. *UPM Press*. UPM Press. https://doi.org/10.1201/9781315380643-9

Nordin M. N., Hamid A. A., Sharu E. H., *et al*. (2014). Kaedah penggantian tanah untuk meningkatkan kekuatan struktur tanah di kawasan tanah jerlus. *Jurnal Teknologi*, *70*(6), 45–47. https://doi.org/10.11113/jt.v70.3536

Omar S. C., Shaharudin A., & Tumin S. A. (2019). The Status of the Paddy and Rice Industry in Malaysia. In Khazanah Research Institute. Kuala Lumpur.

Rendana M., Idris W. M. R., Rahman Z. A., *et al*. (2017). Effect of hasil tani organic compound product (HTOC) on the recovery of soft soil in rice field Mada Alor Senibong, Kedah, Malaysia. *Asian Journal of Environment, History and Heritage*, *1*(2), 13–20.

Taghavifar H., & Mardani A. (2013). Potential of functional image processing technique for the measurements of contact area and contact pressure of a radial ply tire in a soil bin testing facility. *Measurement: Journal of the International Measurement Confederation,* *46*(10), 4038–4044. https://doi.org/10.1016/j.measurement.2013.07.019

Vial L. K., Molesworth A., & Lefroy R. D. B. (2020). Balancing rice and non-rice crops: Managing the risks from soil constraints in Mainland Southeast Asian rice systems. *Field Crops Research*, 246, 1–17. https://doi.org/10.1016/j.fcr.2019.107677

Zhao Z., Mu X., & Du F. (2020). Constitutive model research for rubber-cord composites used in rubber track. *Materials Today Communications*, 23, 1–7. https://doi.org/10.1016/j.mtcomm.2020.100937

ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

Original Research Article

Design and Development of Double Rotor Drum Shredding Machine for Managing Pineapple Residue in Peat Soil

Adli Fikri Ahmad Sayuti[1], Rohazrin Abdul Rani[2]

[1]Engineering Research Centre, Malaysia Agriculture Research and Development Institute, Serdang, 43000 Selangor, Malaysia, adlifikri@mardi.gov.my

[2]Engineering Research Centre, Malaysia Agriculture Research and Development Institute, Serdang, 43000 Selangor, Malaysia, rohazrin@mardi.gov.my

*Corresponding author: Adli Fikri Ahmad Sayuti, Engineering Research Centre, Malaysia Agriculture Research and Development Institute, Serdang, 43000 Selangor, Malaysia; adlifikri@mardi.gov.my

Abstract: In Malaysia, Pineapple is a one of tropical crop that contributes in generating Malaysian economy. Pineapple is mostly planted on mineral and peat soils, where each has different practices and approaches. In peat soil condition, nowadays farmers normally manage the pineapple residues by using a chemical to kill and fire to burn before it been replanting. This is common practice to remove the pineapple residues. With this method soil fertility can be affected and open burning will be polluting the environment, as the government nowadays recommending toward green approach. For pineapple farm in mineral soil, MARDI has come out with a machine to shred and plough pineapple plant residues back into the soil which are practiced for mineral soil. The machine is adopt a rotovator concept. Unfortunately, the machine had the unsatisfied result because the plants were not chopped into small pieces but only separated into a few large parts. In the 11th Malaysian plan (RMK-11), the development of a new concept and prototype with a double rotor drum, design type blade, special blade arrangement and speed gave a promising result in a way to manage the residues of pineapple plants easily without chemical or fire. The purpose of the paper is to discuss the design and development of the machined for management of pineapple plant residues on peat soil, including the functionality test. Special arrangement of the blade and type of blade is a focus part that been consider before it been attach to the double rotor drum. The machine capable working rate is 0.28 ha/hr and the machine efficiency is 92 %. Maximum machined operation is 7–8 hours per day. As a result the machine chop smooth with fine and easy manage disposal pineapple residue.

Keywords: shredding machine; pineapple residue; prototype; pineapples crops

Received: 6th October 2020

Accepted: 7th November 2020

Available Online: 24th November 2020

Citation: Adli Fikri AS & Rohazrin AR. Design and development of double rotor drum shredding machine for managing pineapple residue in peat soil. Adv Agri Food Res J 2020; 1(2): a0000133. https://doi.org/10.36877/aafrj.a0000133

1. Introduction

Pineapple is one of the tropical fruits that has a bright future in supporting the Malaysian export market economy. Currently, 95 % of the domestic canned pineapple production is the exported market while the rest is for domestic market. Fresh pineapple contributes only 30 % of the export market and 70 % for domestic market (MPIB, 2012). In Malaysia, pineapple is generally grown on two main areas, peat and mineral soil, each of which has different practices and approaches. The management of pineapple residues which mainly consist of the leaves and stems is always a matter of environmental concern. In common practice, pineapple residues are managed by using of a chemical to kill and fire for burning (Ahmed *et al.*, 2003). This is not a green approach, because frequently use of chemical can affect the soil fertility and open burning will pollute the environment (Liu *et al.*, 2013). In the 9th Malaysian plan (RMK-9), MARDI has come out with a machine to shred and plough pineapple plant residues for mineral soil as shown in Figure 1 below. This machine was design to be operating in mineral soil. The depth soil penetration is 12" (30 cm) The machine has adopted a motivator concept. Unfortunately, the machine had the unsatisfied result because the plants were not chopped into small pieces but only separated in a few large parts. In the 11th Malaysian plan (RMK-11), the development of a new concept and prototype with a double rotor drum, design type blade, special blade arrangement give a promising result in a way to manage the residues of pineapple plants easily without chemical and fire to burn. For peat soil condition, the machine have maximum of 2" (5.08 cm) for depth soil penetration because if the blade dig more depth it might disturb the hardpan surface. The purpose of the paper is to discuss the design and development of the machined for management of pineapple plant residues on peat soil, including the functionality test.

Figure 1. Existing machine pineapple mulched.

2. Materials and Methods

2.1. Machine Design

Main focus of the study was is to be operate the machine in the peat soil area. Which means that the design of the machine must have the appropriate amount of weight that allowed it to be carried out under the conditions of the peat soil. The machine was designed for a small power tractor with a minimum power of 38 HP and mounted implement with high PTO driven. The general specification is 980 mm in length, 1480 mm in width and 400 mm in height as shown in Figure 2 and Table 1. The machine was driven by a PTO 1:1 ratio gearbox connected to a long shaft and been attached using triple pulley and belting. There are many types of rotovator blades available in market. Those are C shape, L shape and J shape. This machine was designed with two rotors drum and fixed with a swinging L shape of blade as shown in Figure 3 and the blade composition is shown in Figure 4. The blades are arranged in helical form with 4 blade L-shape fully covered side by side between the rotors. L-shaped blades are better compared to C or J type blades in trashy conditions as they are more effective in killing and they do not pulverize the soil as much shown in Figure 5. The complete prototype is shown in Figure 6.

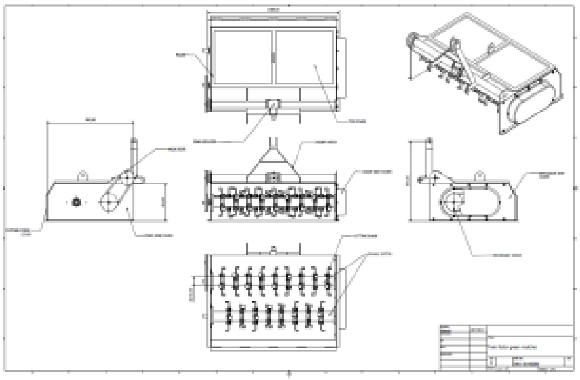


Figure 2. Technical drawing of the machine.

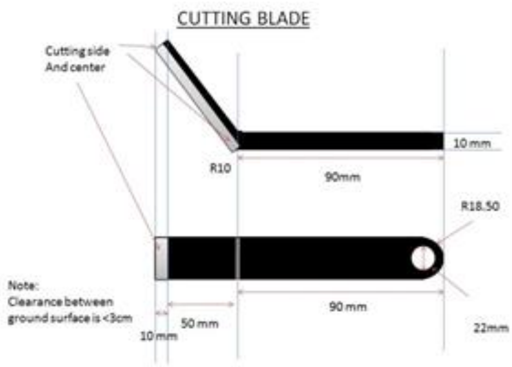


Figure 3. Design of the cutting blade.

Table 1. Technical design specification.

Parameter	Value
Length	980cm
Width	1480cm
Height	400cm
Weight	200kg
Working rate	0.25 ha/hr
Minimum tractor power	38hp
Power	PTO Driven

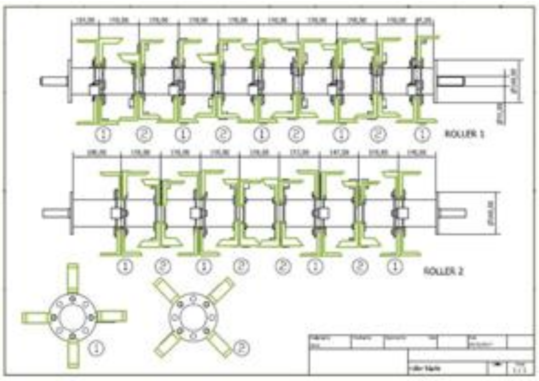


Figure 4. Blade arrangement.

Figure 5. Composition of blades at the drum in actual view.

Figure 6. Prototype double rotor shredding machine.

2.2. Fabrication

The prototype machine was fabricated by the local fabricator according to given technical drawing. Some of the components were changed due to the availability in a local market. The machine has been developed in small scale sizes which are to be operated in a peat soil condition. The designed of the machine is basically normal like existing rotovator except for the 2 rotor drums and the arrangement of the blades were arranged in special composition. The special feature of this blade arrangement is that it covers every row of crops throughout in straight line. Each row of crop passed will be exposed to the blades of this machine allowing no crop to be left behind from being hit by the blade.

2.3. Test and evaluation

The machine prototype was tested and evaluated for the functionality mounted by Kubota 38 hp high clearance tractor at pineapple testing plot station MARDI Pontian, Johor shown in Figure 7. Using 2 different speed rate of 1.1 km/hr and 1.3 km/hr with 3nd gears low and high and the speed of the PTO is 540 rpm driven for same gear. Fixed 2000 rpm tractor speed in the same gear, distance of 12 m × 16 m with 8 replicates and total area of 0.0192 hectares show in Figure 8 and time had been taken and recorded for analysis.The main aim is to ensure that plant residues are produced as fine material using 2 different gears but the same PTO speed.

Figure 7. Test and evaluation of the prototype.

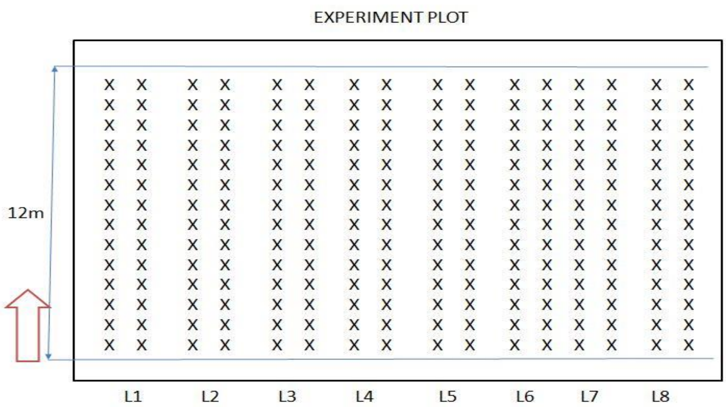


Figure 8. Experiment plot.

3. Results

The first prototype of the shredding machine was successfully fabricated in 8 weeks of fabrication works. The machine was then tested and evaluated for functionality.

3.1. Machine Capacity and Machine Efficiency

Table 2 shows the results obtained from the experiment. The speed of 1.1 km/hr and 1.3 km/hr were used in this experiment was approximately using maximum PTO speed of 540 rpm to shred the crop. Using 38 hp tractor speed of 2000 rpm speed of tractor in 2 gear low and 3 gear low, the average time taken was 28 seconds and 36 seconds for 12 m distance. Table 2 show that after the machine was tested and data was analyzed. It has been shown that the working rate is 0.28 ha/hr. Therefore, the result is fine and easy disposal pineapple plant residues without using chemical and fire to burn that can polluting the environment.

Table 2. The summary of results performance evaluation for new design prototype and existing machine.

Performance Evaluation	New prototype	
Sub-Plot (12m X 16m)	L1, L2, L3, L4	L5, L6, L7, L8
Tractor speed (Km/hr)	1.1 km/hr	1.3 km/hr
Machine capacity (hr/perday)	7-8	7-8
Field work rate (ha/hr)	0.25	0.28
Power take off (PTO)(Rpm)	540(Max)	540(Max)
Machine efficiency (%)	89%	92%
Tractor speed (Gear&Rpm)	2 Low (2000rpm)	3 Low (2000rpm)

4. Discussion

The machined efficiency depends on the speed of the PTO to chop the crop into small pieces show in Figure 9. The speed of the tractor must also be in slow motion because the crop is in different sizes. If the speed of the tractor is fast, the crop will pass through without chopping the crop. This prototype seem to have higher force impact in chopping the crop because it have two drum, special blade arrangement and very sharp blade compare to the existing machine which were like normal rotovator. The result for existing machine was unsatisfied because the plants were not chopped into small pieces but only separated into a few large parts shown in Figure 10. Table 3 show the performance evaluation for both machine in different soil condition. This machine is using the same concept and purpose as rotovator machine which are to use to plough by series of blade that cut, pulverizes mixer and level the soil before replanting. Using rotovator concept added with double rotor drum full with special arrangement of bladed seem easily chop the pineapple crop easily based on actual view.

Table 3. The summary of results performance evaluation for new design prototype and existing machine.

Performance Evaluation	Result	
Machine	**New prototype (Peat soil)**	**Existing machine (Mineral soil)**
Machine capacity (hr/perday)	7–8	7–8
Field work rate (ha/hr)	0.27	0.108
Machine efficiency (%)	92	43
Power take off (PTO)(Rpm)	540(Max)	540(Max)
Tractor speed (Gear&Rpm)	2 Low (2000 rpm)	2 Low (2500 rpm)

Figure 9. Fine and fibrous material pineapple residues pineapple residues management.

Figure 10. Chopped into small pieces but only separated into a few large parts.

5. Conclusions

According based on functionality observation, second gear low and third gear low speed of the tractor and 2000 rpm with maximum PTO driven has resulted in fine and easy disposal pineapple plant residues. Re-rotor after a week using normal rotavator machine or this prototype can be done before the replanting show in Figure 9. As conclusion, by using this machine, it will reduce negative impact of environment and also prevent the use of chemical and open burns. This machine has a great potential to solve pineapple residue and is widely implemented. It has been designed and fabricated locally, making it easier to adapt to Malaysia's environment and conditions.

Figure 9. The pineapple residue rotting after 1 week and it been shred once more time before replanted.

Author Contributions: The researchers would like to thank to co-authors: Md Akhir Hamid, Mohd Taufik, Ahmad, Sarif Hashim, Ramlan Ismail, M. Humaizi Md Jamin, Norahshekin A.R, Noor Al- Anuar. M and Norhafizi Mansor also the staffs of MARDI Serdang and MARDI Pontian, Johorfor their assistance.

Funding: This research was fund under development fund RMK-11 by MARDI, Serdang, Selangor, Malaysia.

Acknowledgments: In this segment, you may acknowledge any support that is not addressed by the author's contribution or funding sections.

Conflicts of Interest: The authors declare no conflict of interest.

References

Ahmed, O. H., Husni, M. H. A., Awang Nor, A. G. *et al*. (2002). The removal and burning of pineapple reside in pineapple cultivation on tropical peat: An Economic viability comparison. *Pertanika Journal of Tropical Agriculture Science, 25*(1), 47–51.

Lembaga Perindustrian Nanas Malaysia (MPIB). (2012). Retrieved from http://www.mpib.gov.my/lembaga-perindustrian-nanas-malaysia/

Liu, C. H., Liu, Y., Fan, C. *et al.* (2013). The effects of composted pineapple residue return on soil properties and the growth and yield of pineapple. *Journal of Soil Science and Plant Nutrition, 13*(2), 433–444.

ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

Original Research Article

Impacts of Fertigation Via Surface and Subsurface Drip Irrigation on Growth Rate of Rockmelon

Wan Fazilah Fazlil Ilahi [1*], Nik Norasma Che'Ya[1],Muhamad Faris Abdillah Razali .[1], Nur Hidayu Abu Hassan [1]

[1]Department of Agriculture Technology, Faculty of Agriculture, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia.

*Corresponding author: Fazilah W. F. F., Department of Agriculture Technology, Faculty of Agriculture, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia; wanfazilah@upm.edu.my

Abstract: Fertigation is one of the most important application of irrigation that are being used in commercial farming. This aplication help farmers to timely supply the water through drip irrigation coupled with accurate amout of water, rate of fertilizer application, and at the same time improving the nutrient uptake and water use efficiency (WUE) by the plant. The water supply through surface and subsurface drip irrigation systems are the most efficient irrigation practice compared to others.Water supply from subsurface drip irrigation system is directly into the root zone, while for surface drip irrigation, water is supplied above the root zone. However, the use of surface drip irrigation system can cause the irrigation water easily evaporate to environment and reduce the WUE by plant. Rockmelon (*cucumis melo*) was selected as plant material in this study. Rockmelon is one of the plant that contain sweet and juicy along with other nutritional value. It also has commercial interest in a number of countries, including Europe, United States, Mediterranean and Asia. The objectives of the study were to observe the different growth rate of rockmelon between surface and subsurface drip irrigation as well as to observe the efficiency of irrigation. This study was conducted under the rain shelter at *Unit Fertigasi Projek Keusahawanan Ladang 10*, Universiti Putra Malaysia (UPM). There were two treatments of irrigation tested, surface and subsurface drip irrigations. Data collection include leaf diameter, leaf length and fruit circumferences. The effect of irrigation on growth performance of rockmelon were observed during week one and week six and was analyzed with Statistically Analysis System (SAS). The result of this study showed that, the growth for surface drip irrigation is higher compared to subsurface drip irrigation and both treatments achieved 25% of irrigation application efficiency.

Keywords: rockmelon; fertigation; surface irrigation; subsurface irrigation; cocopeat

Received: 6th October 2020

Accepted: 6th November 2020

Available Online: 20th November 2020

Citation: Fazilah WFF, Norasma CYN., Abdillah RMF, *et al*. Impacts of fertigation via surface and subsurface drip irrigation on growth rate of rockmelon. *Adv Agri Food Res J* 2020; 1(2): a0000134. https://doi.org/10.36877/aafrj.a0000134

1. Introduction

Irrigation is one of the vital aspects in crop production, for example most of the crop species heavily rely on water as source of food for nutrients uptake, food production and transpiration. However, in many countries with sacred and limited water resources, providing water to crop is one of the major issues and globally are aiming to get the highest water usage and application. Water use efficiency must be improved for the better safeguard of food security because of the enormous contribution of the increasing crop production. Moreover, fertilizer has been used in every region of the world and the application has been enhanced by the farmers all over the world (Wu *et al.*, 2019).

Over the years, with the improvement and enhancement in technology, fertigation has increasingly developed and used by the farmers. Increasing water rivalry between rural, industrial and urban consumers makes it necessary to continually improve irrigation in commercial agriculture and effective management techniques can help to improve efficiency of plant water by scheduling correctly and applying fertilization water (Çolak *et al.*, 2018). Therefore, maximum fertigation efficiency requires knowledge of crop nutrient requirements, soil nutrient supply and injection technology of fertilizers, irrigation schedule, crop and soil monitoring techniques. Fertilization by drip irrigation can reduce overall fertilizer application levels if properly managed and reduce the adverse environmental impact of production (Sidhu *et al.*, 2019).

Drip irrigation is one of the methods that has been used in fertigation and can be applied as surface and subsurface irrigation systems. The fertilizer and irrigation water are distributed through the system to increase the efficiency of fertilizer use to raise crops. Furthermore, it can increase nutrient uptake and plant water while reducing nutrient leaching. In addition, different method such as surface drip irrigation and subsurface drip irrigation, can contribute to varying the effect on water and nutrient distribution. Wu *et al.* (2019) reported that the subsurface shifted the root density to a deeper depth and had increased annual yield compared to surface drip irrigation.

Melon is normally irrigated by methods of furrow or drip. Similar yields could be achieved with both methods in soils with considerably high water holding capacity and under complete irrigation, but irrigation water requirements decrease and water usage output increases with drip irrigation and using drip irrigation can increase fruit size and marketable yield, as well as early harvesting in sandy soils (Şengül *et al.*, 2014). The use of techniques such as drip irrigation and fertigation through subsurface method with mulching may contribute to the water and nutrient productivity in melon production due to reduction of the accumulation of water and fertilizer salts in the soil surface. This technique allows good water and nutrition application to the melon crop, minimizing the effects of atmospheric evaporative demand, improving the quality and melon yield, better water and nutrients spatial distribution in the roots also reducing the environmental impact by excessive fertilization (Monteiro *et al.*, 2014). The study conducted by Monteiro *et al.* (2014) found that between surface and 0.40 m drip irrigation, the crop with 0.40 m underground drip resulted in better water productivity in sandy loam and clay planted in rows. This was due to the application of water next to the roots and thus reduced loss due to evaporation. There is a need for further studies to decide about the feasibility of using fertigation with surface or subsurface irrigation for individual melon planted in polybags with soilless media as this method is widely practiced in Malaysia. Therefore, the objectives of the study were to observe the different growth rate of rockmelon and efficiency between surface and subsurface drip irrigations for soilless media in polybags.

2. Materials and Methods

2.1. Experimental Design and Field Management

The study was conducted at *Unit Fertigasi Projek keusahawanan Ladang 10*, UPM under rain shelter. A total of 6 rain shelters were used in this study. The study was designed in randomised complete block design (RCBD) with six replications. Each of the replication contain two treatments and labelled as TI for surface drip irrigation system and T2 as subsurface drip irrigation system. Each of the treatment contain four samples in each replication and the total of the samples were 48 (Figure 1).

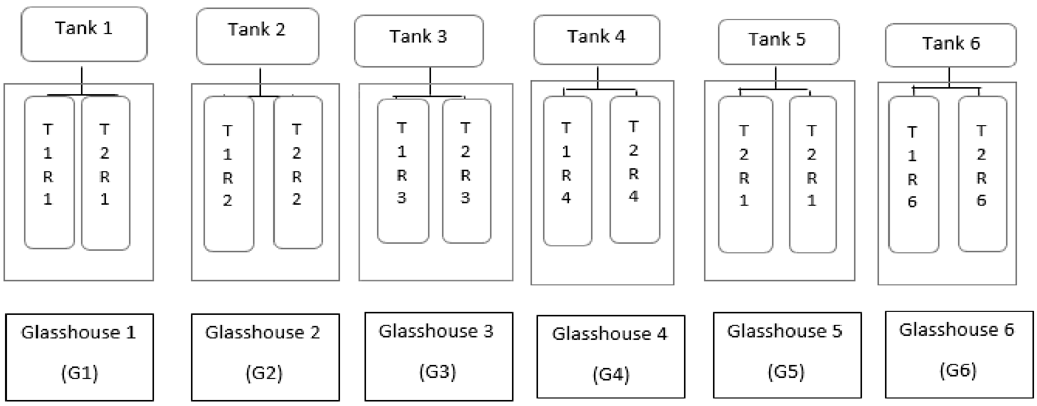


Figure 1. Arrangement of experimental design of rockmelon in the rain shelter.

For treatment 1, surface drip irrigation system was used as the irrigation method for the plants. Water was distributed through the point source drip emitters in form of water droplets. For this treatment, the pipeline and the drippers were located on the surface of growing medium. In treatment 2, the rockmelon was irrigated through sub surface drip irrigation system. Point source drip emitter of 2 l/hr was used as water distributor for the plant. The pipeline and drip emitters were placed inside the growing medium for this treatment. The pipeline was buried in the soil at 5 cm depth from the surface. Each polybag will be irrigated 3 times per day and receive 200 ml of fertigation water for each irrigation.

2.2. Sample Preparation

In this study, rockmelon was chosen as an experimental plant and all plants were planted in polybag with cocopeat as growing medium. As much as 48 rockmelon plants were planted in the polybag in this experiment. The fertigation system used the formulation of fertilizers A and B to provide nutrient to the plants to enhance the growth of rockmelon.

Rockmelon is an annual crop with 60–75 days of growth cycle after transplanting and commonly grown in glasshouse or under rain shelter. In this study the variety of rockmelon used was Melon F-1 Hybrid by SAKATA. The seed was sowed in tray seedlings using peat moss as the medium for seed sowing. Upon preparation for transplanting, 48 polybags were prepared using cocopeat as planting medium.

Before sowing the seeds in the seedling tray, the rockmelon seeds were soaked in the water first for 2–3 hours. The reason why the seed must be soaked in water is to soften the seed coat and remove the chemical around the seed. Later seeds were sow in the seedlings tray for 12–14 days. Peat moss was used as the medium for seed sowing. After sowing, the seed must be covered with black plastic or placed in covered place to avoid the water to easily evaporate until the shoot grow. The seeds were watered 3 times per day according to weather condition.

Due to transplanting, cocopeat was used as the growing medium. Cocopeat must be wet before transplanting. The rockmelon seedling aged 12–14 days were transplanted from seedling tray into the growing medium in the polybag.

2.3. Irrigation Efficiency

Irrigation system application efficiency is the amount of water stored in the root zone that is available to meet crop transpiration needs in relation to the amount of irrigation water applied to the field. The system is important to identify the achievement level of existing system applied so that further improvements can be made. Application efficiency is a performance that express how well an irrigation perform when is operated to deliver specific amount of water. Irrigation application efficiency formula can be expressed in equation (1):

$$\mathbf{Ea} = \frac{\mathbf{WS}}{\mathbf{WD}} \text{ X } 100 \tag{1}$$

Where,
Ea = irrigation application efficiency
Ws= water stored by irrigation
Wd= water delivered to the area being irrigated

2.4. Data Collection

The growth of rockmelon plant in each treatment is based on two irrigation methods which were surface and subsurface drip irrigations method. Data was collected during first week after transplanting until week six. The initial plan for data collection was until week 10 (until harvest), however due to pest and disease outbreak occurred at week 6 most of the trees were affected and had to be removed. Meanwhile, the ripe rockmelon fruits were harvested.

The effect of growth rate on the two treatments were measured by taking the leaf length, leaf diameter and fruit circumferences using the measuring tape. The leaf length was measured from the end of leaf vein to the tip of leaf and leaf diameter was measured from side to side of the leaf. Four leaves were chosen randomly from a tree for measurements purposes. The fruit diameter was measured by taken the circumference of the fruit as soon as the trees started fruiting and the reading were recorded as weekly basis until week 6. Fruit weight after harvest was not measured in this study as the rockmelon was only planted until 6 weeks due to the disease outbreak.

2.5. Data analysis

The effect of each treatment on the growth parameter: leaf length, leaf diameter and fruit diameter were analysed using Statistical Analysis Software (SAS). Analysis of Variance (ANOVA) was performed to find the significant effect of different irrigation methods to leaf diameter, leaf length and fruit circumference. Mean comparison using Least Significant Differences (LSD) test at $p < 0.05$ was employed for mean comparison. Differences were considered significant when the p value was < 0.05.

3. Results and Discussion

3.1. Leaf Diameter, Leaf Length, Fruit Circumferences

Table 1 shows the result on plant growth for leaf diameter, leaf length and fruit circumferences of rockmelon from week 1 until week 6 after transplanting. During week 1 there was no significant difference for leaf diameter between T1 and T2. During week 6, result showed significant difference between treatments for leaf diameter. T1 which is surface drip irrigation show higher mean value compared to T2, subsurface drip irrigation. In addition, from other parameters which were leaf length and fruit circumferences, the result showed no significant differences between each treatment in week 1 and week 6.

The usage of cocopeat as growing medium was the reason for the insignificant results as cocopeat was at maximum water holding capacity for each treatment T1 and T2 during measurements. Cocopeat is known for its high water holding capacity which can retain water in the fibrous materials at longer period. Thus, readily available water for plant uptake is available at all time especially when irrigation water is replenishing every day. Therefore, for both treatments, there were no significant difference in plant growth parameter due to high water holding capacity of cocopeat. However, based on leaf diameter, it can be concluded that T1 had better growth parameter suggesting that surface drip irrigation is a better method compared to subsurface drip irrigation.

It was found that the growth of rockmelon for surface drip irrigation is higher compared to subsurface drip irrigation. This is due to water was efficiently distributed from the drip to the plant which results in better growth since plants received enough water intake that were used for vegetative growth. However, due to the disease and pest outbreaks, the yield of rockmelon was not able to be collected.

Table 1. Leaf diameter, leaf length and fruit circumference in treatment T1: surface drip irrigation and T2: subsurface drip irrigation, data are means value (n = 48).

Days after transplanting (week)	Treatment	Leaf diameter (cm)	Leaf length (cm)	Fruit circumference (cm)
Week 1	T1	5.342a	4.496a	15.002a
	T2	5.300a	4.703a	16.665a
Week 6	T1	22.467a	14.496a	32.133a
	T2	20.933b	15.119a	30.827a

Values in each column with same letter did not differ significant at $p < 0.05$ according to LSD.

3.2. Irrigation Application Efficiency

The irrigation application efficiency for all treatments in the six rain shelters gave the same value of 25%. The calculation of the irrigation application efficiency was done to show the efficiency of the irrigation between two treatments. This study show that both of the treatments achieved 25% of irrigation application efficiency resulting in no difference between the treatments. In general, the overall efficiency should be around 45% for good irrigation application. This experiment was done using the pre-installed set up from *the Unit Fertigasi Projek keusahawanan Ladang 10*, UPM provider, thus maintenance interference were limited. The poor water application efficiency may be due to the leakage from the drippers and lateral pipes occurred. However, despite the low efficiency, the usage of cocopeat had increased water availability in the medium as cocopeat can retain water longer in the pores (Ilahi & Ahmad, 2017).

4. Conclusions

From this study, comparison of the rockmelon growth performance from the two treatments, surface drip irrigation (T1) and subsurface drip irrigation (T2) was done. For surface drip irrigation treatment, water was irrigated on the surface of the medium, while for subsurface drip irrigation treatment, drippers were buried 5 cm depth in the medium and water was dripped at the root zone. The outcome of this study shown that the effect of the treatments had significant difference for leaf diameter. However, for leaf length and fruit circumference there were no significant difference between treatments. Based on the result, it can be concluded that surface drip irrigation gave better result compared to subsurface drip irrigation due to the planting cultivation in polybags with cocopeat growing medium.

It can be concluded that, the medium used for planting is the main factor that effected the irrigation and the growth of the rockmelon. Cocopeat was used as planting medium in this study. Cocopeat is commonly used as planting medium due to its ability to hold water in pores at higher rates and longer period (Ilahi & Ahmad, 2017; Yahya *et al.*, 2009). Thus, when the water is discharge from the drippers into the medium, water is still available in the cocopeat and it show no different between treatments.

Supplementary Materials: The following are available online at http://www.journals.hh-publisher.com/index.php/AAFRJ//xxx/s1, Figure S1: title, Table S1: title.

Author Contributions: Conceptualization, W.F.F. and N.N.C.; methodology, W.F.F. and M.F.A.; software, X.X.; formal analysis, W.F.F. and M.F.A.; writing—original draft, W.F.F. and M.F.A.; writing—review and editing, W.F.F. and N.A.H.

Funding: The fees was supported by Long Term Research University Grant (LRGS) of Universiti Putra Malaysia, Serdang, Selangor, Malaysia.

Acknowledgments: The researchers would like to thank LRGS Faculty of Agriculture, staffs of Taman Pertanian Universiti and Department of Agriculture Technology, Faculty of Agriculture UPM for their assistance.

Conflicts of Interest: The authors declare no conflict of interest, and also the funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

Çolak Y. B., Yazar A., Gönen E., *et al*. (2018). Yield and quality response of surface and subsurface drip-irrigated eggplant and comparison of net returns. *Agricultural Water Management, 206*, 165–175.

Ilahi W. F. F., & Ahmad D. (2017). A study on the physical and hydraulic characteristics of cocopeat perlite mixture as a growing media in containerized plant production. *Sains Malays, 46*(6), 975–980.

Monteiro R. O. C., Coelho R. D., & Monteiro P.F.C. (2014). Water and nutrient productivity in melon crop by fertigation under subsurface drip irrigation and mulching in contrasting soils. *Ciência Rural, 44*(1), 25–30.

Şengül N., Çavuşoğlu O. Y. N. H. Ş., & Doğan E. (2014). Yield and fruit quality response of drip-irrigated melon to the duration of irrigation season. *Journal of Soil Water*.

Sidhu H., Jat M., Singh Y., *et al*. (2019). Sub-surface drip fertigation with conservation agriculture in a rice-wheat system: A breakthrough for addressing water and nitrogen use efficiency. *Agricultural Water Management*, 216, 273–283.

Wu D., Xu X., Chen Y., *et al*. (2019). Effect of different drip fertigation methods on maize yield, nutrient and water productivity in two-soils in Northeast China. *Agricultural Water Management,* 213, 200–211.

Yahya A., Shaharom A. S., Mohamad R., *et al*. (2009). Chemical and physical characteristics of cocopeat-based media mixtures and their effects on the growth and development of *Celosia cristata*. *American Journal of Agricultural and Biological Sciences, 4*(1), 63–71.

ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

Original Research Article

Effect of Light Emitting Diode (LED) Spectra on Plant Growth

Nur Syahirah Talib[1], Diyana Jamaludin[1*], Nur Sakinah Abdul Malek [1]

[1]Department of Biological and Agricultural Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

*Corresponding author: Diyana Jamaludin, Department of Biological and Agricultural Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia; diyana_upm@upm.edu.my.

Abstract: The effect of lights generated by red, blue and white light emitting diodes (LED) on growth and development of lettuce were investigated and compared with lettuce without supplemental lighting. A vertical multi-tier hydroponic system was used to grow lettuce. Each tier consisted of 60 heads of lettuce with different LED colour and one tier without LED was used as control. The following measurements on plant physiology were taken: number, length and chlorophyll content of leaves, height and weight of plants. Based on number of leaves, red LED shows the highest number of leaves compared to lettuce under blue, white and control treatment. The similar trend also can be found in the lengths of leaves which shows the highest length produce under red LED. Red LED also produce highest weight of lettuce by 28 % as compared to white LED. White LED improved lettuce growth development in the height by 13 % and amount of chlorophyll content. Lettuce grown under blue LED shows lowest growth and development compared to lettuce grown under red and white LEDs based on parameters above, and lettuce without LED were died within 2 weeks. This result indicated that the red LED was the most effective spectra in growth response of lettuce plants. This study also demonstrates the effectiveness of LED in improving lettuce growth on vertical multi-tier hydroponic system.

Keywords: light emitting diodes; growth; vertical; chlorophyll content; lettuce

Received: 6th October 2020

Accepted: 7th November 2020

Available Online: 24th November 2020

Citation: Talib NS, Jamaludin D & Abdul Malek, NS. Effect of light emitting diode (LED) spectra on plant growth. Adv Agri Food Res J 2020; 1(2): a0000135. https://doi.org/10.36877/aafrj.a0000135

1. Introduction

It is estimated that 53 % of the world's population live in the urban area (Moreno-Monroy *et al.*, 2020) and the numbers keep increasing in which will lead to continuous demand of food source in urban area. In order to support higher demand of fresh food in urban area, some growers initiate to use limited area and space in the urban for agriculture activities. Urban agriculture is defined by the FAO as the growing of plants and the raising of animals within and around cities. Due to limited area and space available in urban, most of the structure design of crop production use the vertical, multi-tier with hydroponic system. However, one of the issues faced by the vertical farming system is the limited light exposure due to shading effect from the vertical tier itself. Light is known as the primary environmental factor for plant growth and development. Therefore, supplemental lighting was introduced to support crop growth and production in closed and shaded environment. Light Emitting Diode (LED) represent a promising technology as a grow lamps compared to conventional lighting using high pressure sodium (HPS) and fluorescent lamps. Some of the advantages of LEDs are the possibility to optimize lighting spectra to specific wavelength need by crop (Olle & Virsile, 2013), energy saving in converting electrical energy to photon energy (Mitchell, 2012), minimal heat emission and longer lifetime (Bourget, 2008).

Table 1 shows the general wavelength effect to plant physiology. The photosynthetic active radiation (PAR) wavelength is the light use by plant for photosynthesis between 400–760 nm encompass the blue (425–490 nm), red (625–700 nm) and far red (700–740 nm) light. Red light is usually the basal component which sufficient for plant growth and photosynthesis (Olle & Virsile, 2013). It was also found that increasing the red LED intensity from 660 to 690 nm helps increase lettuce biomass (Goins *et al.*, 1997). Blue LED is responsible for vegetative growth, and was reported to enhanced ß carotene in Kale plants (Lefsrund *et al.*, 2008) and increased anthocyanin concentration in lettuce (Stutte *et al.*, 2009). White LED was found to be more conductive to human eyes (Han *et al.*, 2017) and designed to mimic natural light by providing plants a balanced spectrum of red, blue and green. In this study, effect of different light treatment on the lettuce growth; number, length and height of leaves, chlorophyll content, and weight of plants were measured.

Table 1. Wavelength effect on plant physiology.

Wavelength (nm)		**Effect on Plant Growth**
UV (Ultraviolet)	280	Significantly reduce quantum yield and rate of photosynthesis
	315–400	Promotes pigmentation, thickens plants leaves and may be used to prevent harmful insects.
Visible Spectrum	440–470	Chlorophyll absorption peaks at 439 nm and 469 nm. The blue spectrum is the most efficiently absorbed spectrum, promoting mainly vegetative growth.
	510	Quantum absorption in the green spectrum. Little absorption is the yellow spectrum
	610	No chlorophyll benefit. Efficiently absorbed by algae phycoerythrin and phycocyanin receptprs.
	640–660	Chlorophyll absorption peaks at 642 nm and 667 nm. 660 nm is the most vital wavelength for flowering. Speeds up seed germination and flower/ bed onset.
	740	Increase the rate of photosynthesis
Infrared	1000–1400	No plant activity detected at this wavelength. Heat generated.

(Source: www.urbanvine.com)

2. Materials and Methods

2.1. System Design

The multi-tier hydroponic structure has 5 tiers with 162 cm height and 120 cm width. Each tier had 2 units of rectangular tray which were connected with a small PVC pipe. Each rectangular tray consisted of 30 holes for plants which made up to 60 plants were grown on each treatment or tier (Figure 1). A fertigation tank with size of 59 cm × 43 cm × 37 cm was used as fertigation reservoir that pump in water with fertilizer into the hydroponic unit. Lettuce (*Lactuca Sativa*) seeds were sown inside a germination tray, watered and covered until seeds were germinated within 8–12 days. These seedlings were then transplanted to the peat disc (PD 24 mm) as growing medium which made from coconut fibre that has faster water absorption and retention. Lettuce were then harvest after 30 days after transplant.

(a) **(b)**

Figure 1. The vertical multi-tier hydroponic system; (**a**) initial project setup, **(b)** lettuce growth in the end of project.

2.2. Light Treatment

Four lighting LED treatments were compared; control unit with no supplemental lighting (on the top tier), white LED, blue LED (with ratio of 5 blue and 1 red LED) and red LED (with ratio of 5 red and 1 blue LED). Two set of LEDs were installed in each tier with the distance of 25 cm between LED and the top of hydroponic tray. The light intensity from each LED are similar with 100 $\mu mol/m^2/s$ from a 15 W power consumption. A timer was used to switch on the lighting system for 8 hours per day from 08:00 to 14:00.

2.3. Data Collection and Analysis

The data collection was taken on lettuce growth performance based on number and length of leaves, height and weight of plants and also amount of chlorophyll content. The number of leaves was counted manually once a week. The length of leaves was measured from apex to petiole and the height was measured from apex of leaves to top of peat disk using a ruler. Amount of chlorophyll content on the leaves was measured by using chlorophyll meter (Konica-Minolta SPAD 502 Plus) (Figure 2a). It was a non-invasive measurement; by clamped the meter over lettuce leaves and received an indexed chlorophyll content reading (-9.9 to 199.9) in less than 2 seconds. Average reading was taken from 3 different points. Weight of lettuce was measured using a digital weighing scale after harvest (Figure 2b). The significance different between means were analysed using one-way analysis of variance (ANOVA) as well as Tukey's multiple-comparison analysis. The significant level was set at $p \leq 0.05$.

(a) **(b)**

Figure 2. (**a**) Measuring the amount of chlorophyll content on the leaves by using SPAD 502 Plus Chlorophyll Meter, **(b)** Measuring lettuce weight after harvest on digital weighing scale.

3. Results

3.1. Effect of different LEDs Treatment n Lettuce Number of Leaves

In the first initial week, the highest number of leaves is on red LED and the lowest is under control treatment. It shows that lettuce with supplemental lighting produce almost 5 times more leaves than lettuce without supplemental lighting. In week 2 dan 3, lettuce under supplemental lighting continue to produce greater amount of leaves while lettuce without supplemental lighting started to shows senescence (Figure 3). Lettuce under red LED shows highest number in week 4 while lettuce under control treatment were completely died by week 4. One-way ANOVA shows that there are significant differences ($p \leq 0.001$) between different colours of LED to number of lettuce leaves. Tukey HSD further analysis shows that the significance is between control treatment and lettuce under LED. There is no significant different between blue, red and white LED to number of lettuce leaves produced.

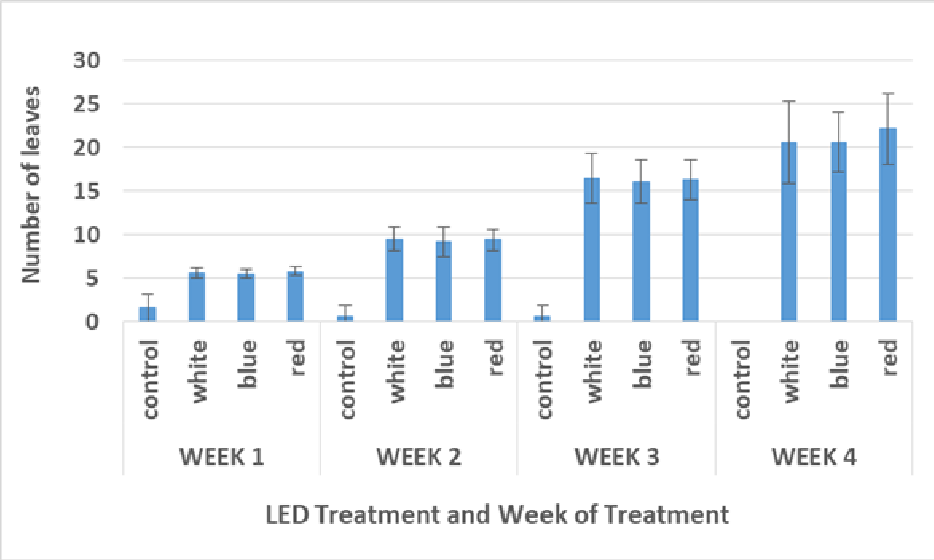


Figure 3. Number of leaves in each week under different LED treatments.

3.2. Effect of Different LEDs Treatment on Lettuce Length of Leaves

White LED shows highest leaves length for week 1 and week 2 (4.12 cm and 8.15 cm respectively) with significant difference with blue LED (2.17cm) and control treatment (0.51 cm). However, during harvest at week 4, the highest leaves length was lettuce under red LED with average of 13.96 cm compared to blue LED (11.03 cm) and white LED (12.51 cm) (Figure 4). Based on Tukey HSD analysis, it shows that the length of leaves under red LED is significantly different with other treatment.

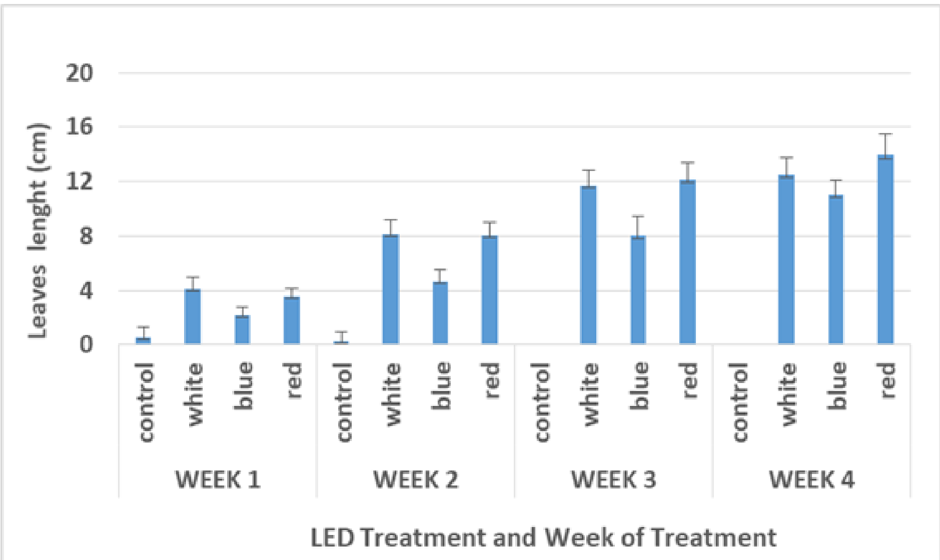


Figure 4. Length of leaves in each week under different LED treatments.

3.3. Effect of Different LEDs Treatment on Lettuce Height

Figure 5 shows lettuce height in week 3 and 4 under different LED treatment. It shows that lettuce under white LED had highest plants in week 3 (13.83 cm) and week 4 (17.06 cm) compared to lettuce under red and blue. ANOVA and Tukey HSD analysis also shows that there is significant difference of lettuce height between white, blue and red LED. White LED improved lettuce height by 13 % compared to red LED. Lettuce under blue LED had the lowest height while there is no data for lettuce under control treatment as lettuce were completely died by week 3.

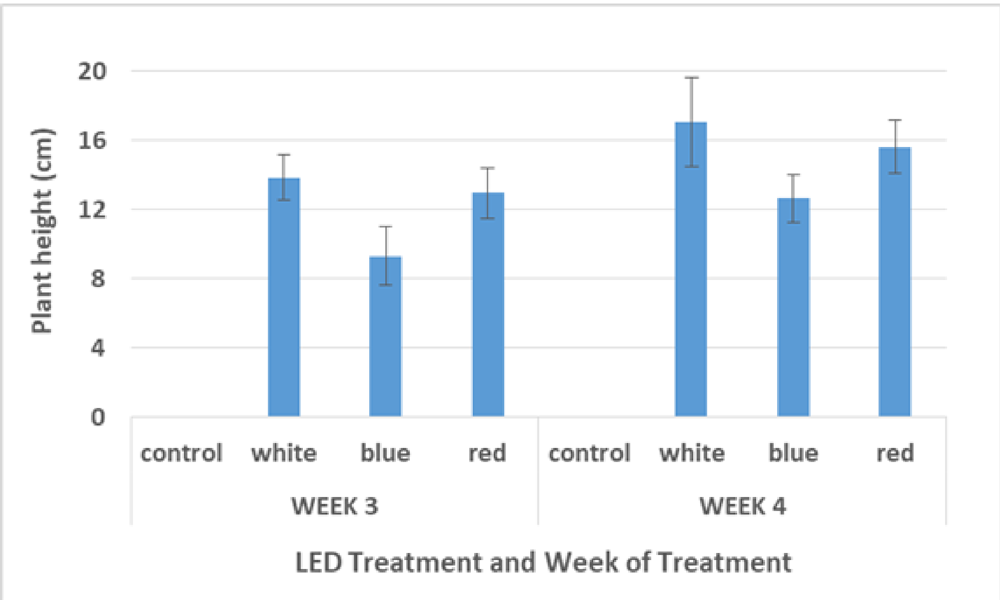


Figure 5. Height of lettuce plant in week 3 and 4 under different LED treatments.

3.4. Effect of Different LEDs Treatment on Lettuce Chlorophyll Content

Figure 6 shows the SPAD index of chlorophyll content from the SPAD Meter. Chlorophyll content in lettuce leaves during week 4 was found highest under white LED (173.57) followed by blue LED (43) and red LED (32.66).

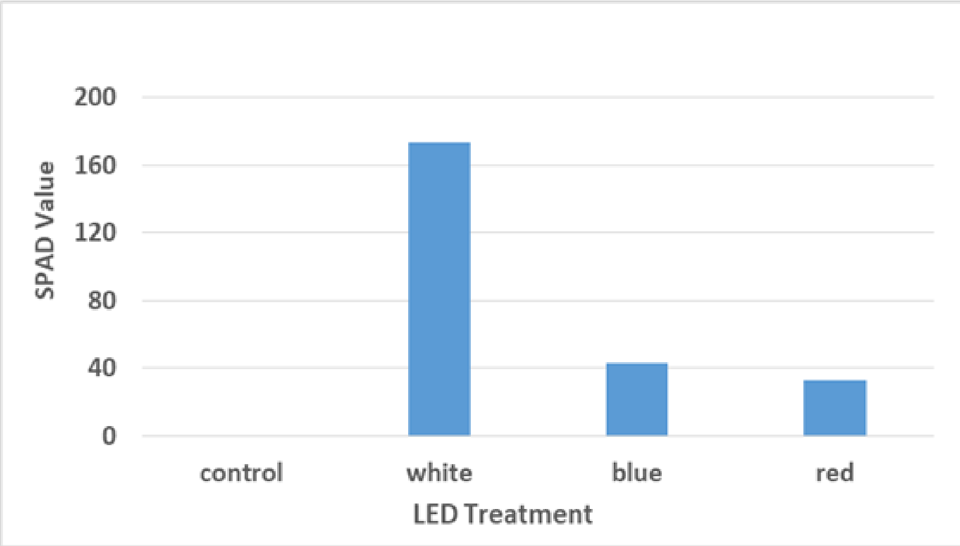


Figure 6. Amount of chlorophyll content in week 4 under different LED treatment.

3.5. Effect of Different LEDs Treatment on Lettuce Weight

Figure 7 shows that lettuce under red LED produce highest weight during harvest (22.63 g) followed by white LED (18.09 g) and blue LED (14.29 g). This conclude that red LED increased mass production of lettuce by 28 % additional in weight compared to lettuce weight under white LED. There is significant difference in lettuce weight produced under red LED with white and blue LED.

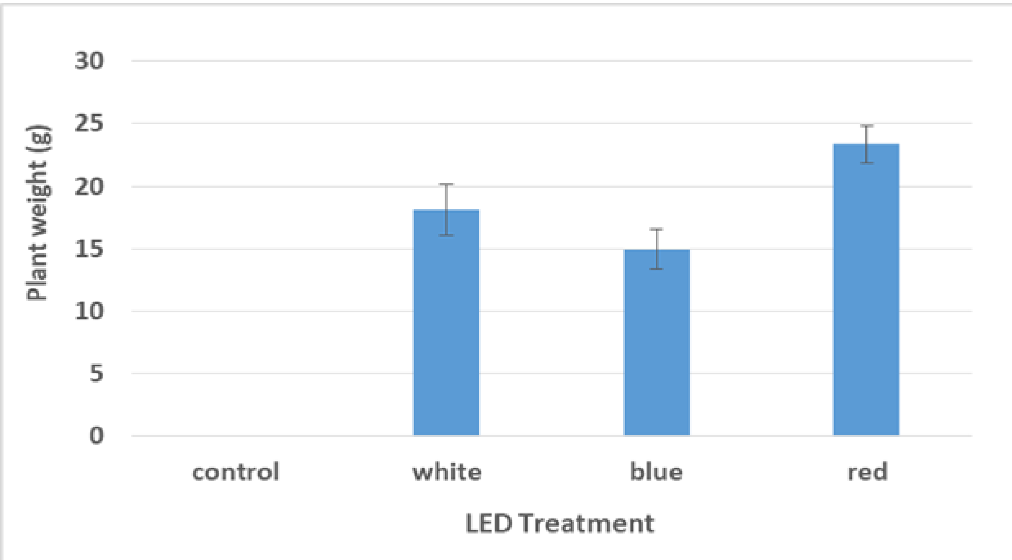


Figure 7. Lettuce weight during harvest under different LED treatment.

4. Discussions

The research shows that LED supplemental lighting improved lettuce growth physiology for a vertical multi-tier hydroponic system. Red LED (ratio of 5 Red: 1 Blue) produced highest number of leaves and length. This results support by research finding of Miyashita *et al.* (1997) which shows that plants under red LEDs increased in shoot length compared to plants under white LED. Studies by Yanagi *et al.* (1996) also showed that lettuce plants grown under red LEDs alone had more leaves and longer stems compared to plants grown under blue LEDs only. Increased red light application resulted in higher leaf area and stem length, while increased in blue light application resulted in significant inhabitation of stem extension and thickening of leaf (Lu *et al.,* 2012).

Lettuce height was found to be highest under white LED, while blue LED produced the lowest lettuce height. Nanya *et al.* (2012) also found that tomato plant under blue LED decreased in stem elongation growth but promote flowering. White LED also produce highest chlorophyll content in leaves compared to red and blue LED. Since white LED have the full spectrum of wavelength, this may contribute to the high chlorophyll content in the leaves. Research by Choi *et al.* (2015) showed that strawberries grown under white LED have higher level of chlorophyll and higher fruits production.

Since lettuce was sold based on its's weight, this parameter is important to figure out which LED give the highest production in weight basis. It shows that red LED has significantly increased the lettuce weight by 28 % compared to blue LED. The highest value is also due to lettuce under red LED has highest number of leaves that contribute to the total weight produced.

It is interesting to understand the light intensity profile of these LED and find the best distance between the LED and crops to gain the optimum light intensity while avoiding heat stress from the light.

5. Conclusions

This result indicated that the red LED was the most effective in growth response of lettuce plants. This study also demonstrates the effectiveness of LED supplemental lighting in improving lettuce growth on vertical multi-tier hydroponic system. Although the mechanisms of changes in phytochemicals under different supplemental LED are not well known, the results demonstrated that supplemental LED could be strategically used to enhance growth of lettuce grown under red LED.

Author Contributions: Nur Syahirah Talib: Methodology, Investigation, Data Curation, Formal analysis, Writing — original draft. Diyana Jamaludin: Conceptualization, Resources, Review and Editing, Supervision. Nur Sakinah Abdul Malek: Formal analysis, Writing.

Funding: The authors gratefully acknowledge the financial support from Universiti Putra Malaysia with grant under UPM Grant Scheme (Project Code: GP-IPM/2018/9606700).

Acknowledgments: The authors would like to acknowledge Assistant Engineer Mr. Muhammad Azlan Othman and Mr. Tajul Urus Osman.

Conflicts of Interest: Declare conflicts of interest or state "The authors declare no conflict of interest."

References

Bourget, C.M. (2008). An introduction to light-emitting diodes. *HortScience, 43*, 1944–1946.

Choi, H. G., Moon, B. Y., & Kang, N. J. (2015). Effects of LED light on the production of strawberry during cultivation in a plastic greenhouse and in a growth chamber. *Scientia Horticulturae, 189*, 22–31.

Goins, G.D., Yorio, N.C., Sanwo, M.M., *et al.* (1997). Photomorphogenesis, photosynthesis and seed yield of wheat plants grown under red light-emitting diodes (LEDs) with and without supplemental blue lighting. *Journal of Experimental Botany, 48*, 1407–1413.

Han, T., Vaganov, V. A., Cao, S., *et al.* (2017). Improving "color rendering" of LED lighting for the growth of lettuce. *Scientific Reports, 7*, 1–7.

Lefsrund, M. G., Kopsell, D.A., & Sams, C.E. (2008). Irradiance from distinct wavelength light-emitting diodes affect secondary metabolites in kale. *HortScience, 43*, 2243–2244.

Lu, N., Maruo, T., Johkan, M., *et al.* (2012). Effects of supplemental lighting within the canopy at different developing stages on tomato yield and quality of single-truss tomato plants grown at high density. *Environmental Control in Biology, 50*(1), 1–11.

Mitchell, C.A. (2012). Plant lighting in controlled environments for space and earth applications. *Acta Horticulturae, 956*, 23–36.

Miyashita, Y., Kimura, T., Kitaya, Y., *et al.* (1997). Effects of red light on the growth and morphology of potato plantlets in vitro using light emitting diodes (LEDs) as a light source for micropropagation. *Acta Horticulturae, 418*, 169–173.

Moreno-Monroy, A. I., Schiavina, M., & Veneri, P. (2020). Metropolitan areas in the world. Delineation and population trends. *Journal of Urban Economics,* 103242.

Nanya, K., Ishigami, Y., Hikosaka, S., *et al*. (2012). Effects of blue and red light on stem elongation and flowering of tomato seedlings. *Acta Horticuturae, 956*, 261–266. https://doi.org/10.17660/ActaHortic.2012.956.29

Olle, M., & Viršile, A. (2013). The effects of light-emitting diode lighting on greenhouse plant growth and quality. *Agricultural and Food Science, 22*(2), 223–234. https://doi.org/10.23986/afsci.7897

Stutte, G. W., Edney, S. & Skerritt, T. (2009). Photoregulation of bioprotectant content of red leaf lettuce with light-emitting diodes. *HortScience, 44*, 79–82.

Yanagi, T., Okamoto, K. & Takita, S. (1996). Effects of blue, red, and blue/red lights of two different PPF levels on growth and mor-phogenesis of lettuce plants. *Acta Horticulturae, 440*, 117–122.

11 core guidelines to know before buying grow lights. (2020, September 2). Retrieved from https://www.urbanvine.co/blog/11-core-guidelines-urban-farmers-must-know-before-buying-grow-lights.

ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

HH PUBLISHER

Original Research Article

Transfer of Technology (Tot) Skills Factors Contributing to Work Performance Among Extension Agents in Malaysian Cocoa Board, Peninsular Malaysia

Athirah Rajuddin[1], Nur Bahiah Mohamed Haris[1*], Jasmin Arif Shah[1]

[1]Department of Agriculture Technology, Faculty of Agriculture, Universiti Putra Malaysia (UPM), 43400 Serdang, Selangor, Malaysia

*Corresponding author: Nur Bahiah Mohamed Haris, Department of Agriculture Technology, Faculty of Agriculture, Universiti Putra Malaysia (UPM), 43400 Serdang, Selangor, Malaysia; nurbahiah@upm.edu.my

Abstract: The main function of agricultural extensionists is to facilitate learning and disseminate new knowledge and technologies through non-formal educational settings. This will lead to improved agricultural productivity and increase farmers' income. In the lens of the cocoa production scenario in Malaysia, it used to be a popular crop as this sector became the third-largest producer in the world since the 1980s, however that has changed over the years. Despite the reduced size of land use and the dropping production of cocoa over the past decades, exports of cocoa beans and cocoa products are growing steadily each year. Thus, with the overwhelming demand for Malaysian chocolate products from other regions, cocoa production should be boosted and not overlooked. Transfer of Technology (ToT) can be seen as the main catalyst that can improve farmers' performance through extension agent capabilities, this study will determine the factors of ToT skills that contribute to the work performance of extension agents in the Malaysian Cocoa Board (MCB). A total of 353 productive cocoa farmers were employed in this study to evaluate the work performance of extension agents using a structured questionnaire. The data was analysed using descriptive and regression analyses. The results indicated that all the ToT skills (technical skill, technology delivery skill, and evaluation skill) are significant ($p < 0.05$) towards the work performance of extension agents. The R^2 value of 0.520 implies that the three contributors explain about 52% of the variance in the work performance in this study. Hence, this shows the importance of ToT skills in improving the work performance of extension agents, particularly in the MCB and cocoa industry in Malaysia.

Keywords: transfer of technology (ToT); extension agents; work performance; cocoa productivity and production

Received: 6th October 2020

Accepted: 6th November 2020

Available Online: 24th November 2020

Citation: Rajuddin A, Mohamed Haris NB, Arif Shah J. Transfer of technology (ToT) skills factors contributing to work performance among extension agents in Malaysian Cocoa Board, Peninsular Malaysia. *Adv Agri Food Res J* 2020; 1(2): a0000136. https://doi.org/10.36877/aafrj.a0000136

1. Introduction

In the 1950s, cocoa or its scientific name *Theobroma cocoa L.* was introduced in Malaysia. It became Malaysia's third-largest commodity crop and dominated agricultural exports. Malaysia also is well known for producing high-quality chocolate products among other countries. Presently, local cocoa production capacity has reduced drastically to the extent that it can't sustain the grinding sector, and this has resulted in an imbalance between the upstream and downstream sectors (Ramle, 2012). Based on data from the Malaysian Cocoa Board (MCB), the cocoa growing area has shrunk from 400,000 ha in 1990 to an estimated 15,000 ha in 2018, largely due to competition for land use with other high-yielding crops and diseases. The production also has reduced drastically each year and this is reflected in the cocoa grinding production. In fact, data from the Department of Statistics Malaysia (DOSM) in 2019 has shown that cocoa production declined by 20% in 2018 compared to the previous year. This might due to reduce in land use size or poor management in cocoa production.

According to the Malaysian Cocoa Board (MCB), the biggest participants and involvement in cocoa farming come from smallholders which make up 95% of the entire production while the estate sector constitutes 5% of the cultivated area. This emphasises the huge contribution of smallholders in Malaysia's commodity specifically in cocoa production and how they depend on extension agents in transferring technology and assisting in production.

As the extension agents play an important role between government agencies and smallholder farmers in providing information and convincing them to adopt relevant technology. Agricultural extension service develops the specified skills for farmers to adapt to the new technology to suit their level of literacy, knowledge and skills in disseminated technology. However, the farmers are responsible for technology acceptance and also the appliance of technology in the right way; without a good relationship between extension agents and farmers, the technology transferred won't meet expectations (Motolani *et al.*, 2017).

Grosse (1996) explained that the Transfer of Technology (ToT) is the process of transferring technology from the places or research groups of its origination to extensive distribution among more people and places. Technology transfer is a learning process; in terms of the concept and experiences of extension agents and farmer-related expertise, resources and services. Technology transfer requires both informal and formal education between extension agents in delivering the technology and the farmers as receivers.

Thus, because of the reliance of smallholder farmers on the ToT from the extension agents, this study aims to determine the ToT skills factors (in terms of technical skill, technology delivery skill and technology evaluation skill) that contributes to the work performance of extension agents. The specific objectives are as follows:

1. To determine the level of ToT skills and work performance,
2. To determine the relationship between ToT skills with work performance, and
3. To determine the strongest independent variables (ToT skills) that contribute to work performance.

The use of the Iceberg Model (Spencer & Spencer, 1993) in this research has strengthened the components of the ToT skills in extension agents; namely technical skill, technology delivery skill and technology evaluation skill. The Iceberg Model is composed of two elements: visible (including knowledge and skills), and hidden (including motives, traits, self-concepts). This study involved the first part, which is the knowledge and skills of extension agents in ToT. Knowledge refers to the information or ideas in improving cocoa production, while skills are the ability to perform a certain task in managing cocoa production.

Technical skills are the skills and information required to carry out in different roles. This might be related to agriculture, engineering, statistical or scientific research. Pezeshki-Raad and Aghai (2002) claimed that on the technical side, extension agents require expertise that ranges from efficient and conventional agronomic methods to the marketing of agricultural products. Motolani *et al.* (2017) described the technical skills as being linked to the work performance of extension agents and at the same time, become a strong indicator of work performance of extension agents.

Also, the ability to deliver technology differs in terms of how technology is to be disseminated; with the quality of delivering technology to recipients. The expertise of technology transfer requires extension agents to deliver extension services, including program planning, implementation, facilitation, group involvement and management. Wasihun *et al.* (2014) and Maoba (2016) indicated that the extension service would provide a clear delivery mechanism that will improve farmers' participation and relationship in the extension programme.

Whereas the evaluation is defined by order and preparation to evaluate a completed or continuing program, project or strategy, its design, operation and outcomes. Warner (2014) claimed that evaluation training is required to help extension agents properly align with the research base and the findings. Therefore, the evaluation skills are the ability of extension agents to collect and interpret data to evaluate which goals have been achieved. By evaluating the success of an extension agent against the expertise of technology delivery, they can be more inspired to increase their skills and therefore enhance their job performance.

Hence, this study implied these three important skills namely: technical skills, technology delivery skills and technology evaluation skills as the element of ToT skills that might promote the working performance of extension agent particularly in the MCB in Peninsular Malaysia.

2. Materials and Methods

The study was conducted in Peninsular Malaysia. The target population of this study consisted of all productive cocoa farmers who have been exposed to the extension activities facilitated by the extension agents of the MCB in the Peninsular states for a minimum of five years and at least two training sessions. This study employed a stratified random sampling method that covers all three regions that involve in smallholders farmers in MCB in Peninsular Malaysia. The list of productive cocoa farmers in each region was obtained from the MCB, where the sample was divided into three regions: Northern, Eastern and Southern regions. The Northern region consisted of 218 productive cocoa farmers (in Hilir Perak), Eastern region had 133 productive cocoa farmers (in Machang) and Southern region with 210 productive cocoa farmers (in Jengka). The total number of productive cocoa farmers in these three regions was 561. A total of 376 productive cocoa farmers were selected based on Krejcie and Morgan (1970) table, which determined the actual sample size of this study.

2.1 Research Design

This study is a descriptive correlation which combines descriptive and correlational studies. ToT skills consist of three components, which are technology skill, technology delivering skill, and technology evaluation skill, that serve as the independent variables, whereas work performance becomes the dependent variable.

2.2 Instrument and Measurement

The survey (in the form of the structured questionnaire) was used as the instrument to collect data from the respondents. The questionnaire was adapted from by Sail (2010) and Motolani *et al*. (2017) that contained three parts. The first part of the questionnaire gathered respondents' demographic profiles. The second part looked into the ToT skills, while the last part of the questionnaire measured the work performance of extension agents. A six-point Likert-scale option (1=strongly disagree, to 6=strongly agree) was used to measure the respondents' perceptions towards the given statements in the questionnaire. The following information is further details of the designed instrument:

Section A: The first section of the questionnaire is designed to collect data on the personal demographic and farm profile of the respondents. The demographic part contains six items including age, gender, race, monthly income and level of education. Four items are in the crop information which includes year started to plant cocoa, cultivated land acreage and source of information on cocoa technology.

Section B: This section measures the ToT skills with three components: (i) Technical Skill contains nine statement items measuring the level of ToT using the technical skill on technologies of cocoa plant pruning, fertilizer application, pest and disease control and processing of cocoa beans, (ii) Technology Delivery Skill contains nine statement items on the level of delivery of cocoa technology skill in teaching of theory, methods and practical ways of pruning, grafting, fertilizing, controlling pests and diseases and processing of cocoa beans, and (iii) Technology Evaluation Skill contains nine statement items on the level of evaluating farmer's understanding of cocoa technology on pruning, fertilization, controlling pests and diseases and processing of cocoa beans.

Section C: This part of the questionnaire measures work performance. The questions cover the communication of extension agents with farmers; success in presenting cocoa crop technology, ability to encourage farmers to practice cocoa crop technology, ability to reduce cocoa crop problems, ability to resolve problems regarding cocoa production, and ability to cooperate and successfully assist farmers in adopting new technologies.

2.3 Data Analysis

Descriptive, correlation and multiple regression analyses were used to analyse the data through SPSS ver.24 software. A descriptive analysis of respondents' profiles was finalised using mean, frequency and percentage values. ToT and work performance level were described by using the range level (low, moderate and high) based on mean, frequency and percentage values. Pearson's correlation coefficients were used to analyse the correlations of ToT with work performance. Multiple regression analysis was completed to prove the ToT factors that contributed the most to the work performance of extension agents in this study.

3. Results

3.1 Demographic Profiles of Respondents

The results of respondents' demographic characteristics are shown in Table 1. The majority of the farmers were male with 88.4% and followed by female (11.6%). In terms of age, the data shows that most of the sample were aged more than 50 years old, followed by 22.1% of respondents distributed in the group of ages 40–49 years old. Only 0.3% of respondents were below 19 years of age. The majority of the farmers in this research were Malay (47.9%), followed by Orang Asli (39.3%), Chinese (15.6%) and Indian (0.3%).

Table 1. Respondents' demographics.

Items	Peninsular Malaysia	
	Freq	**%**
Gender		
Male	312	88.4
Female	41	11.6
Age		
≤19	1	0.3
20–29	6	1.7
30–39	34	9.6
40–49	78	22.1
≥ 50	234	66.3
Race		
Malay	169	47.9
Chinese	55	15.6
Indian	1	3
Orang Asli	128	36.3

There was a huge difference between the types of work of the respondents. Only 15.3% were involved in cocoa farming on a full-time basis, while the majority (84.7%) were on a part-time basis. For education, it can be observed from the sample that most of the cocoa farmers had only completed primary schooling (81.0%), followed by 17.6% who completed secondary schooling. Besides, only 0.8%, 0.3% and 0.3% had education at Certificate, Diploma and Bachelor or Degree levels respectively (as depicted in Table 2).

Table 2. Frequency distribution of respondents' work type and education.

Items	Peninsular Malaysia	
	Frequency	**%**
Types of Work		
Full-time	54	15.3
Part-time	299	84.7
Level of Education		
Complete Primary School	286	81.0
Complete Secondary School	62	17.6
Certificate	3	0.8
Diploma	1	0.3
Bachelor/Degree	1	0.3

3.2 Level of Transfer of Technology (ToT) and Work Performance of Extension Agents

The results in Table 3 present the levels of ToT in low, moderate and high. The table shows that all the variables are at a high level (with a range of 4.34 to 6.00), and the Technical Skill is at the highest level with a mean of 4.56 (*SD* = 0.63), followed by Technology Delivery

Skill with mean 4.51 (*SD* = 0.63) and Technology Evaluation Skill with mean 4.49 (*SD* = 0.65).

Table 3. Level of transfer of technology (ToT) skills in extension agents (*n* = 353).

ToT Skills	Mean	Std Dev (*SD*)
Technical Skill	4.56	0.63
Technology Delivery Skill	4.51	0.63
Technology Evaluation Skill	4.49	0.65

The descriptive analysis of technical skill in Table 4 reveals that 75.6% shows a high level, followed by 21.8% at moderate and only 2.5% at a low level. This shows that extension agents have high technical skills in transferring the technology of cocoa farming activities to the farmers. The results of the delivery skills show that a majority (72.8%) rate the agents at a high level, while 24.9% of the cocoa farmers indicate that the extension agents have moderate skill in delivering technology. Only 2.3% claim a low level. In contrast, the ability to evaluate technology shows that 73.1% of respondents rate the agents at a high level based on their perceptions, while 24.6% indicate as moderate and 2.3% rated them as having low evaluation skills.

Table 4. Level of transfer of technology (ToT) skills in extension agents (*n* = 353).

ToT Skills	Level	Frequency (%)	Percentage (%)
Technical Skill	Low (1.00–2.669)	9	2.5
	Moderate (2.67–4.339)	77	21.8
	High (4.34–6.00)	267	75.6
Technology Delivery Skill	Low (1.00–2.669)	8	2.3
	Moderate (2.67–4.339)	88	24.9
	High (4.34–6.00)	257	72.8
Technology Evaluation Skill	Low (1.00–2.669)	8	2.3
	Moderate (2.67–4.339)	87	24.6
	High (4.34–6.00)	258	73.1

In terms of extension agents' work performance, the majority of cocoa farmers claimed that their extension agents' performance was high (75.6%), whereas 21.5% rated them moderately and 2.8% with low performance (refer to Table 5).

Table 5. Level of work performance of extension agents.

	Level	F	%	M	SD
Work Performance (WP)	Low (1.00–2.669)	10	2.8	4.50	0.64
	Moderate (2.67–4.339)	76	21.5		
	High (4.34–6.00)	267	75.6		

3.3 Relationship of Transfer of Technology with Work Performances

To determine the relationships between ToT skills and work performance, the results in Table 6 reveals that all the ToT skills correlate significantly at the level of 0.01%. Based on Guildford Rule of Thumb (1973), these findings show a moderate and positive relationship of ToT skills with the work performance of extension agents.

Table 6. Relationship between ToT skills with work performance.

		X1	X2	X3	Y
X1	Technical Skill	1	.760**	.719**	.677**
X2	Technology delivery skill		1	.633**	.651**
X3	Technology evaluation skill			1	.636**
Y	Work performance				.636**

**. Correlation is significant at the level of $p < 0.01$

3.4 ToT skills factors contributing to work performance of extension agents

The third objective of the study was to determine the ToT skills that contributed the most to the work performance. From the findings in Table 7, all variables were significant towards the work performance of extension agents. Technical skills indicated the highest contribution towards work performance (with Beta Coefficient 0.276). The Adj.R^2 value of 0.520 implies that the three contributors explain about 52% of the variance in the work performance, while there are 48% of unknown factors which were not considered in this study.

Table 7. Multiple regression analysis for work performance in Peninsular Malaysia.

Model	Unstandardized Coefficients		Standardized Coefficients	*t*	Sig.
	B	Std. Error	Beta		
Y (Constant)	0.863	0.187		4.607	.000
X_1 Technical skill	0.280	0.064	0.276	4.357	.000

X_2 Technology delivery skill	0.272	0.059	0.270	4.593	.000
X_3 Technology evaluation skill	0.254	0.054	0.259	4.701	.000

4. Conclusions

Based on the findings and discussion provided, cocoa extension agents in Peninsular Malaysia have a high competency level in transferring the technology. However, delivery skills indicate a slightly lower percentage rather than other skills. It reflected that farmers might claim that the extension agents possibly less confident in delivering the technology, and this should not be overlooked. Whereas, all three variables of technical skill, technology delivery skill and technology evaluating skill showed positive and moderate relationships towards work performance. This shows a good indicator that the extension agent in MCB is competent in transferring the technology and ToT skills are important to improve the quality of extension agents' work.

Technical skill had the highest Beta value, which demonstrated that it contributed the most to the work performance of MCB extension agents in the Peninsular. Therefore, the study has shown that farmers and extension agents have successfully performed the extension role. The function of ToT reflects the work performance of extension agent achievement to increase the smallholder potential and empowers them to increase cocoa production. The three components of ToT are influential as they have a positive correlation to the work performance of cocoa extension agents. The study's outcomes serve as input for the MCB to improve the extension service in training cocoa farmers. Also, the knowledge and skill can help improve cocoa farmers to increase their productivity by using the right techniques and skills of the technology in their farms. This study offers knowledge about the recent skills of extension agents in the MCB that can be used to identify the factors that influence the work performance of extension agents.

The ToT skills must be highlighted as the main component to improve farmers' productivity and cocoa production in Malaysia through extension agent performance. Therefore, the extension agents might consider themselves as competent if they were aligned with the latest technologies, they can deliver technology to farmers and as well as evaluate their performance regularly. Farmers should benefit from extension agents capabilities who have excelled in all ToT skills so that they can apply to their farm and increase their production and income.

Funding: This research was supported by Long Term Research University Grant (LRGS) of Universiti Putra Malaysia (UPM) Serdang, Selangor, Malaysia**.**

Acknowledgments: The researchers would like to thank the staff at the Felda Mill in Trolak, Perak for their assistance, and also Dr. Salim Hasan for supportive encouragement to finish this research.

Conflicts of Interest: The authors declare no conflict of interest, and also the funders had no role in the design of the study; in the collection, analyses or interpretation of data; in the writing of the manuscript or in the decision to publish the results.

References:

Grosse (1996). International technology transfer in services. *Journal of International Business Studies, 27,* 781–800.

Guildford, J. P. (1973). *Fundamental Statistics in Psychology and Education* (5th ed.). New York: McGraw-Hill.

Krejcie R. & Morgan, D. W. (1970). Determining sample size for research activities. *Educational and Psychological Measurement, 30,* 607–610.

Maoba, S. (2016). Farmers' perception of agricultural extension service delivery in Germiston Region, Gauteng Province, South Africa. *South African Journal of Agricultural Extension, 44*(2), 167–173.

Motolani, M. M., Hassan, S., Oluwatoyin, O., *et al.* (2017). ToT and HRD competencies and its relationship to extension agents' performance among cocoa smallholders. *IOSR Journal of Agriculture and Veterinary Science, 10*(12), 14–21.

Pezeshki-Raad, G. & Aghai, H. (2002). An assessment of contact farmers' educational activities in Iran (A national study). *Proceedings of the 18th AIAEE Annual Conference*, Durban, South Africa.

Ramle, K. (2012). Contribution of group dynamics factors to technology adoption among Malaysia cocoa clusters, PhD Dissertation. *Universiti Putra Malaysia, Selangor, Malaysia (Unpublished).*

Sail, R. M. (2010). Human resources development and transfer of technologies and their relationship to extension agents' job performance. *Akademika 79, 79*(10),127–137.

Spencer, L. & Spencer, S. (1993). *Competence at Work: Model for Superior Performance*. New York: John Wiley & Sons.

Warner. (2014). Enhancing the capacity to create behavior change: extension key leaders' opinions about social marketing and evaluation. *Journal of Agricultural Education*, *55*(4), 176–190.

Wasihun B. N., Kwarteng, J. A., & Okorley, E. L. (2014). Farmers' perception of their level of participation in extension in Ethiopia: Policy Implications. *Journal of Agricultural Extension and Rural Development, 6*(2), 80–86.

ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

Original Research Article

Mechanical Properties and Antioxidant Activity of Sweet Potato Starch Film Incorporated with Lemongrass Oil

Roseliza Kadir Basha[1]*, Nor Faezah Abuhan[1], Siti Hajar Othman[1], Noor Zafira Noor Hasnan[1], Rashidah Sukor[2], Nazatul Shima Azmi[1,3], Nor Amaiza, Mohd Amin[1], Zanariah Mohd Dom[1]

[1]Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

[2]Department of Food Technology, Faculty of Food Science and Technology, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

[3]Department of Mechanical Engineering Technology, Faculty of Engineering Technology, University Tun Hussein Onn Malaysia, 84600, Pagoh, Johor, Malaysia

*Corresponding author: Roseliza Kadir Basha, Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia; roseliza@upm.edu.my

Abstract: This study was carried out to investigate the mechanical properties and antioxidant activity of starch based film containing essential oil. Active antioxidant films have been prepared with sweet potato starch by incorporating lemongrass oil. Sorbitol with different concentration levels (10–50% w/w dry starch basis) has been used as a plasticiser. The process begins with the extraction of sweet potato starch into powder, followed by the process of gelatinisation of starch, mixing the solution with plasticiser and incorporation of lemongrass oil before casting. Analysis on the mechanical properties using a universal testing machine and antioxidant activity using 2, 2-diphenyl -1-picrylhydrazyl (DPPH) assay were carried out. The film with thickness of 0.1±0.01 mm showed tensile strength (TS) and elongation at break at (EAB) 69.22–307.16 MPa and 5.39–57.72% respectively. The increasing concentration of lemongrass oil resulted in a significant increase in EAB but reduction in TS. The antioxidant activity of the lemongrass oil in starch-based film was 29–43% and increased with the increase of lemongrass oil concentration. Thus, the incorporation of essential oil in the starch based film was found to be directly affected by the mechanical properties and the antioxidant activity related to the stability, shelf life and application of the film on the packaging area.

Keywords: active packaging; sweet potato starch film; antioxidant activity

Received: 6th October 2020

Accepted: 6th November 2020

Available Online: 24th November 2020

Citation: Kadir Basha R, Abuhan NF, Othman SH, *et al*. Mechanical properties and antioxidant activity of sweet potato starch film incorporated with lemongrass oil. *Adv Agri Food Res J* 2020; 1(2): a0000137. https://doi.org/10.36877/aafrj.a0000137

1. Introduction

Starch a renewable source, appears to be the best raw material of biodegradable polymer with low cost and abundantly available (Gonzáles *et al.*, 2016). Starch from different sources has been studied as a potential film-forming agent, including from potato, barley, wheat, tapioca and rice. According to Jimenez *et al.* (2012), starch is known to be completely biodegradable in soil and water, making it has great advantage from an environmental point of view.

Despite the advantages of the starch-based films, they also possess many disadvantages like brittle nature, poor mechanical properties and water solubility. Hence, to overcome this, plasticiser needed to be blend in together with the starch constituents during film making. Plasticiser is a low molecular weight of non-volatile substance and addition into film reduces the internal hydrogen bonding between polymer chains while increasing molecular volume, resulting in an improvement of film flexibility (Mali *et al.*, 2006). The plasticisers commonly used in starch-based films is glycerol and sorbitol in which it avoids film cracking during handling and storage (Shaw *et al.*, 2002; Gontard *et al.*, 2003; Chillo *et al.*, 2008; Müller *et al.*, 2008; Liu *et al.*, 2011; Yan *et al.*, 2012; Azmi *et al.*, 2019). Plasticiser also decreases the glass transition temperature of the film due to weakened strength of macromolecular interactions (Gaudin *et al.*, 1999; Sanyang *et al.*, 2015; Nor *et al.*, 2017).

Besides that, the greatest hurdle of the food industry is the limited shelf life of products, as a consequence of oxidation reactions such as degradation, enzymatic browning and oxidative rancidity (Soliva-Fortuny *et al.*, 2003). Many studies have been carried out on the effect of incorporating antioxidant on the functional properties of different biopolymers and coatings. It can enhance the functional properties of the biopolymer and increase the shelf-life of food production (Al-Hashimi, 2020). Antioxidant agents from natural resources, such as essential oils (Bonilla *et al.*, 2013; Perdones *et al.*, 2014) and plant extracts (Li *et al.*, 2014) have been widely studied to replace the synthetic agents that commonly being used. In this study, lemongrass oil was incorporated into the starch-based films. According to Burt (2004), the essential oils from plants or spices are rich sources of biologically active compounds such as terpenoids and phenolic acids. The incorporation of antioxidant can prevent food oxidation that can derive in the development of off-flavors, color and flavor changes, and also nutritional losses of the food components (Supardan *et al.*, 2016). In direct food applications, a high concentration of essential oils is generally needed to achieve effective antioxidant activity but the concentrations may exceed organoleptically acceptable levels (Viuda-Martos *et al.*, 2008). However, the addition of antioxidant in packaging materials provides advantages compared to direct addition to food, such as the lower amount of active substances required, activity focused on the product surface, controlled release to the food matrix, and elimination of additional steps on production process needed for antioxidant addition (Bolumar *et al.*, 2011).

Hence, this study focused on the preparation and characterisation of mechanical properties and antioxidant activity of starch-based films from sweet potato with the addition of lemongrass oil as an antioxidant.

2. Materials and Methods

2.1 Materials

The fresh sweet potato was obtained from the wet market at Seri Serdang, Selangor. Lemongrass oil antioxidant was supplied from R & M chemicals (Ever Gainful Enterprise Sdn. Bhd., Malaysia). Sorbitol and 2-2-diphenyl-1-pircyl hydrazyl (DPPH) were purchased from Sigma-Aldrich (Sigma Aldrich (M) Sdn. Bhd., Malaysia).

2.2 Sweet Potato Starch Preparation

Figure 1 shows the flow of starch preparation and extraction from sweet potato flesh. The fresh sweet potato was grated and blended with distilled water and filtered using filter cloth. The sediment was taken out from the filtrate called starch. The starch was rinsed three with water, and the water was decanted each time. Then, the wet starch was dried in the oven at temperature of 40°C for 24 hours.

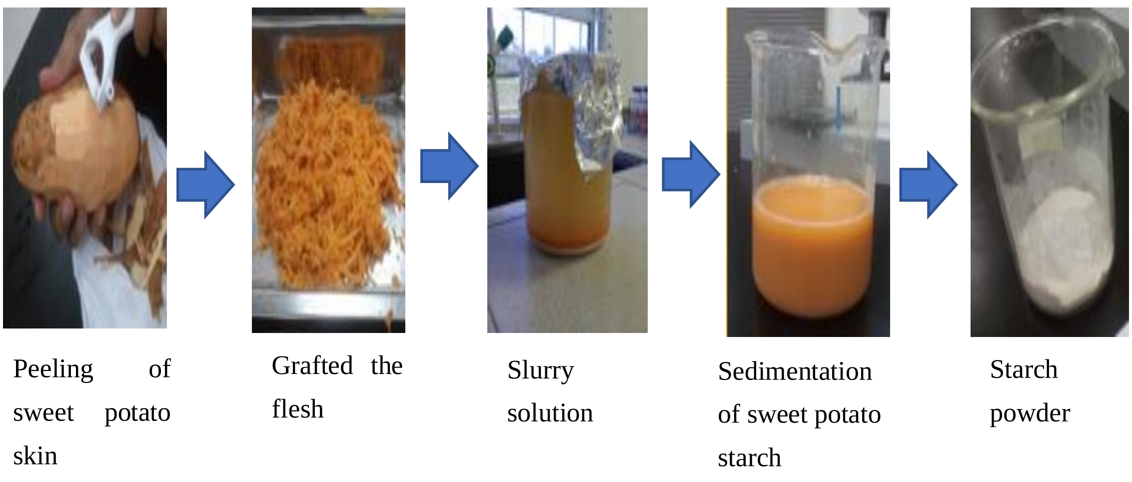
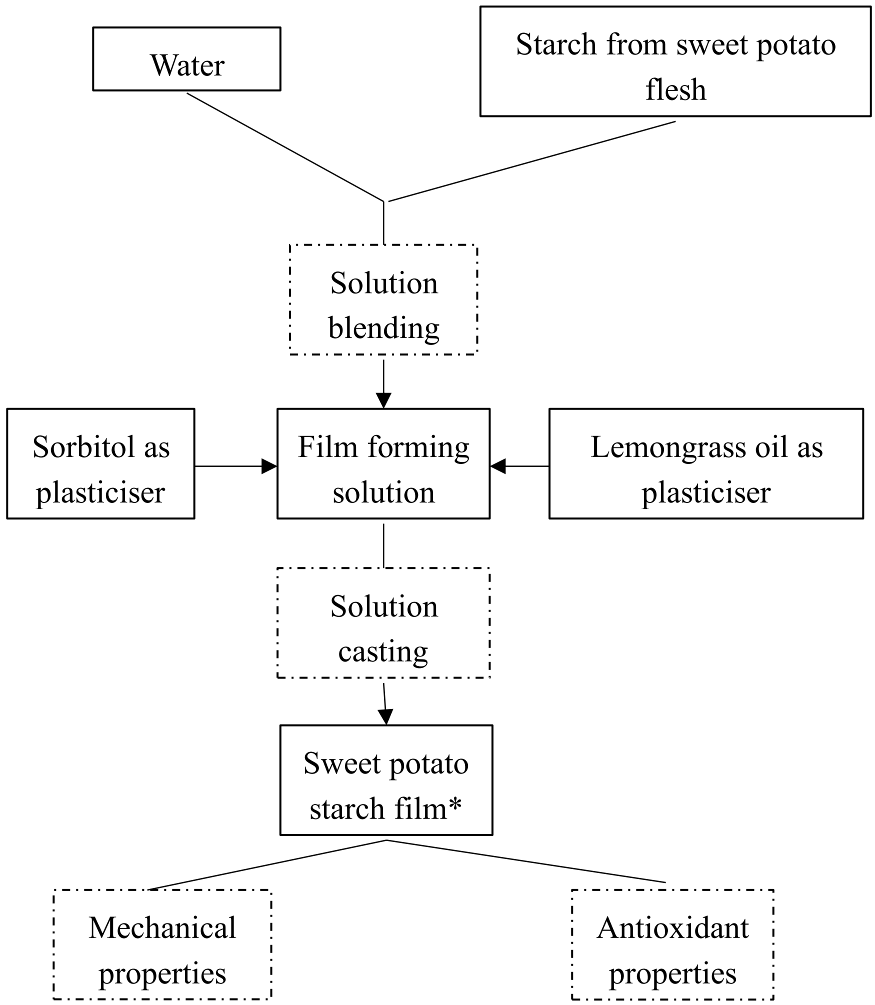


Figure 1. Extraction of starch powder from sweet potato flesh.

2.3 Film Formation

Figure 2 showed the preparation process of sweet potato starch film. The films were prepared by using solution casting method (González *et al.*, 2016). Sweet potato starch films with different concentrations of sorbitol (10–50% w/w dry starch basis) were prepared and analysed. Then, a combination of 40% sorbitol was chosen to prepare films containing lemongrass oil at different concentrations.



*more than one formulation

Figure 2. Film preparation flow chart.

2.4 Mechanical Test

The mechanical properties were analysed using Universal Testing Machine (Instron Model 5566, United State) with a load cell of 10kN. Force (N) and deformation (mm) were recorded with a cross-sectional test speed at 50 mm/min and initial gauge length, 50 mm (Shen *et al.*, 2010). Film sample strips were cuts in a rectangular shape with a size 13 mm x 64 mm. The thickness of the film was measured using a digital vernier caliper at six arbitrary points of the film.

2.5 Antioxidant Activity Test

The antioxidant activity of lemongrass oil at different concentrations and film with or without lemongrass oil were analysed using the 2, 2-diphenyl -1-picrylhydrazyl (DPPH) assay (Gulluce *et al.*, 2007). Each sample of 25 mg was dissolved in 3 ml of distilled water, and then a 2.8 ml of film extract solution was mixed with 0.2 ml of 1 mm methanolic solution of DPPH. The mixture was incubated for 30 minutes in a dark environment at ambient temperature. After that, the absorbance was measured at 517 mm using the UV spectrophotometer.

3. Results and Discussions

3.1 Characteristics of The Sweet Potato Starch Film

3.1.1 Sweet potato starch film containing sorbitol

On a dry basis, sweet potato is rich in starch content approximately 58−76% (Chen *et al.,* 2003). The main constituent of the sweet potato starch is 18% of linear amylose and 82% of branched amylopectin. The mean diameter of each starch granule is 25 µm. Figures 3 and 4 show plasticized starch film (0.1±0.01 mm thickness) with and without the lemongrass oil respectively. The lemongrass oil concentrations added were ranging from 0−1.5 wt. % from the total solution. As the concentrations of the lemongrass oil increased, the dried films were easier to be peeled off from the trays. This is due to the more essentials oil droplets suspensions distributed on the surface of the film matrix as it were unstable in the emulsion system. Moreover, the essential oil with low density tend to be separated and localise on the upper surface of the film and forming the bi-layer film (Tongnuanchan *et al.,* 2014). However, the texture of the film is not smooth due to agglomeration of the lemongrass oil in a certain part of the film layer. In addition, as high concentration of lemongrass oil was added, an unacceptably strong aroma was released by the film due to citral constituent which is the strong lemon-like odour of the oil.

Figure 3. Plasticized starch-based film without lemongrass oil.

Figure 4. Plasticized starch-based film with lemongrass oil.

3.2 Mechanical Analysis

3.2.1 Sweet potato starch film with different sorbitol concentration

The results showed in the Table 1 that 69.22−307.16 MPa and 5.39–57.72% of tensile strength (TS) and elongation at break (EAB) respectively. Gaudin *et al.* (1999) reported that, sorbitol plasticiser may be strongly bound with starch under low sorbitol contents (below 27% (w/w of solids), thereby decreasing the mobility parts of the starch in wheat starch films exerting antiplasticisation effect, whereby the films were rigid and brittle. The results showed that by increasing the plasticiser concentration the TS of the film decreased. In contrast, by increasing the plasticiser concentration, the elasticity properties increased. This is due to the characteristic of the plasticiser that decreases the intermolecular bonds between the amylose, amylopectin and amylose-amylopectin of the starch matrix and thus substitutes them with the hydrogen bonds newly formed between the plasticiser and starch.

Table 1. Tensile strength (TS) and elongation at break (EAB) of the film incorporated with different sorbitol concentration.

Sorbitol concentration (%)	TS (Mpa)	EAB (%)
10	307.16	5.39
20	261.18	7.28
30	270.57	7.81
40	69.22	57.72
50	82.33	54.94

The mechanical properties of the sweet potato starch film plasticised with 40 wt. % sorbitol, incorporated with lemongrass oil were assessed by measuring their tensile strength and elongation at break for different concentration of lemongrass oil (0%, 0.5%, 1% and 1.5% [v/v]). The results show TS of the film exhibit a decreasing trend as the concentration of the lemongrass oil increased. This indicates that the TS became weaker when lemongrass oil was incorporated into the film structure. The tensile strength of the film with 0 wt. % to 1.5 wt. % of lemongrass oil decreased from 69.2 MPa to 5.4 MPa. This phenomenon can be primarily explained by the increase of the weaker polymer-oil interactions, development of heterogeneous film structure and discontinuities in the polymer network in the higher concentration of lemongrass oil (Shojaee-Aliabadi *et al.*, 2013). On the other hand, from the result, it showed that the incorporation of lemongrass oil had increased the percent of elongation in the range of 57.7% to 71.8%. The results obtained were consistent with the study carried out by Zivanovic *et al.* (2005) that found increasing in the elongation at break for the chitosan films incorporated with the essential oil. This phenomenon of the increasing trend in elongation at break when incorporating the essential oil into the film may be attributed to the complex structures formed between the lipids and starch polymers which reduce the cohesion of the starch network forces subsequently decreasing the film resistant to breakage (Jimenez *et al.*, 2013).

3.3 Antioxidant Activity

Sweet potatoes are rich in antioxidants such as phenolic acids, anthocyanins, tocopherol and β-Carotene (Woolfe, 1993). Results showed that sweet potato starch film without lemongrass oil obtained 9.35% scavenging-activity on the DPPH assay. It has been found that the orange-fleshed sweet potato varieties are related to higher β-Carotene that exerts antioxidant functions in lipid phases by quenching the free radicals (Sies & Stahl, 1995).

The antioxidant activities of sweet potato starch film with lemongrass oil were increased with increasing of lemongrass oil concentration. The free radical scavenging activity of the lemongrass oils mainly contributed by the flavonoids (Cheel *et al.*, 2005). Therefore, higher antioxidant activity was achieved by having higher concentration of lemongrass oil being exposed to the DPPH test solution. This result was in agreement with the result obtained from the study carried out by Miksusanti *et al.* (2013), the incorporation of ginger essential oil into starch edible film had yielded an increase in antioxidant activity, in which for concentration 0.5 wt. %, 1.0 wt. % and 1.5 wt. %, the antioxidant activity were 5.7%, 11.8% and 15.2% respectively.

The scavenging activity of the DPPH assay was compared between the lemongrass oil and the sweet potato starch film with lemongrass oil for the concentration of 0.5%, 1% and 1.5%. Figure 5 represents that the scavenging activity of the DPPH for the standard lemongrass oil increases with the concentration which is 88.9%, 91.9% and 93.6% respectively. Based on Møller *et al.* (1999), the anti-oxidative effectiveness in natural sources was reported to be mostly due to the phenolic compounds and the high amount of the phenolic content will lead to higher anti-oxidative efficiency.

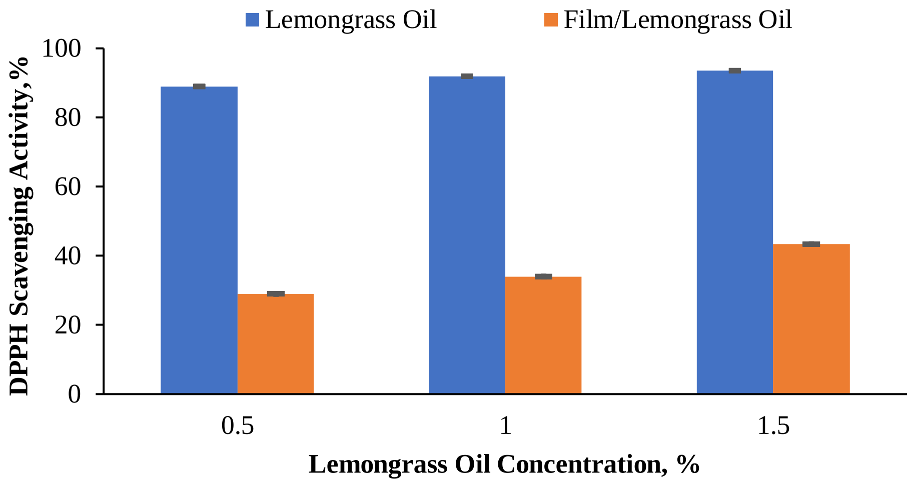


Figure 5: DPPH radical scavenging activity of SPS film with lemongrass oil and lemongrass oil from R & M Chemicals.

The results also showed that the percentage of scavenging activity of lemongrass oil when being incorporated into the film was reduced when compared to the standard oil. Comparing the percentage of scavenging activity between 0.5% standard oil, and 0.5% being incorporated into the film, the percentage were 88.9% and 29%, respectively. Overall, 60% reduction of the antioxidant activity of the lemongrass oil was observed when incorporated in the film. Similar activities can be seen for the concentration of 1% and 1.5% in which the antioxidant activity of film decreasing 58% and 50%, respectively than the standard lemongrass oil. Based on the study by Bonilla *et al.* (2013) on the starch-chitosan film incorporated with Basil essential oil, the compound lose their antioxidant capacity during film formation, probably due to the volatilisation during film drying.

4. Conclusion

Sweet potato starch can be used as a material for film formation when plasticised by sorbitol. The increasing concentrations of lemongrass oil provide a significant increase in elongation at break but reduction in tensile strength. Sweet potato starch film shows about 9.35% of antioxidant activity. The antioxidant activity was increased with the increasing of lemongrass oil concentration in starch-based film.

Acknowledgments: The authors acknowledge Universiti Putra Malaysia for providing financial support for the research project (GP/2017/9547500) and (GP/2017/9574000).

Conflicts of Interest: The authors declare no conflict of interest, and also the funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

Al-Hashimi A.G., Ammar, A.B., Lakhmanan G., *et al.* (2020). Development of a millet starch edible film containing clove essential oil. *Foods*, 9(184), 1–14.

Azmi, N. S. Kadir Basha, R., Othman, S. H., *et al.* (2019). Characterisation of antioxidant tapioca starch/polyaniline composites film prepared using solution casting method. *Food Research*, *3*(4), 317–324.

Bolumar, T., Andersen, M.L., & Orlien, V., (2011). Antioxidant active packaging for chicken meat processed by high pressure treatment. *Journal of Food Chemistry*, *129*, 1406–1412

Bonilla, J., Talon, E., Atares, L., *et al*. (2013). Effect of the incorporation of antioxidants on physicochemical and antioxidant properties of wheat starch-chitosan films. *Journal of Food Engineering, 118*(3), 271–278.

Burt, S. (2004). Essential oil: Their antibacterial properties and potential applications in foods–A review. *Journal of Food Microbiology*, *94*(3), 223–253.

Cheel, J., Theoduloz, C., Rodriguez, *et al*. (2005). Free radical scavenger and antioxidants from lemongrass (*Cymbopogon cintratus* (DC.) Stapf.). *Journal of Agricultural and Food Chemistry, 53*, 2511–2517.

Chen, Z., (2003). Physicochemical properties of sweet potato starch and their application in noodles (PhD's thesis, Wageningen University, Netherlands).

Chillo, S., Flores, S., Mastromatteo, *et al*. (2008). Influence of glycerol and chitosan on tapioca starch based edible film properties. *Journal of Food Engineering, 88*(2), 159–168.

Gaudin, S., Lourdin, D., Le Botlan, D., *et al*. (1999). Plasticisation and mobility in starch–sorbitol films. *Journal of Cereal Science, 29*, 273–284.

Gontard, N., Guilbert, S., & Cuq, J. L. (1993). Water and glycerol as plasticisers affect mechanical and water vapor barrier properties of an edible wheat gluten film. *Journal of Food Science, 58*(1), 206–211.

González, P., Medina, C., Famá, L., *et al.* (2016). Biodegradable and non-retro gradable ecofilms based on starch–glycerol with citric acid as crosslinking agent. *Carbohydrate Polymers, 138*, 66–74.

Gulluce. M., Sahin. F., Sokmen. M., *et al*. (2007). Antimicrobial and antioxidant properties of the essential oils and methanol extract from *Mentha longifolia* L. ssp. *Longifolia. Journal of Food Chemistry, 103*, 1449–1456.

Jimenez A., Fabra M.J., Talens P., *et al*. (2012). Edible and Biodegradable starch films: A review. *Food Bioprocess Technology*, 5, 2058–2076.

Jimenez, A., Fabra, M. J., Talens, P., *et al*. (2013). Phase transitions in starch based films containing fatty acids. Effect on water sorption and mechanical behavior. *Food Hydrocolloids, 30*, 408–418.

Li, J.H., Miao, J., Wu, J.L., *et al*. (2014). Preparation and characterisation of active gelatin-based films incorporated with natural antioxidants. *Food Hydrocolloids, 37*, 166–173.

Liu, H., Chaudhary, D., Yusa, S.I., *et al*. (2011). Glycerol/starch/Na+-montmorillonite nanocomposites: A XRD, FTIR, DSC and1H NMR study. *Carbohydrate Polymers, 83*(4), 1591–1597.

Mali S., Groddmann M.V.E., Garcia M.A., *et al.* (2006). Effects of controlled storage on thermal, mechanical and harrier properties of plasticised films from different starch sources. *Journal of Food Engineering, 75*, 453–460.

Miksusanti, Herlina & Masril K. I., (2013). Antibacterial and antioxidant of Uwi (*Discorea Alata*) starch edible film incorporated with ginger essential oil. *International Journal of Bioscience, Biochemistry and Bioinformatic*, *3*(4), 354–356.

Møller, J. K.S., Medsen. H. L., Aaltonen, T. *et al*. (1999). Dittany (*Origanum dictamnus*) as a source of water-extractable antioxidants. *Food Chemistry, 64*(2), 215–219.

Müller, C.M.O., Yamashita, F. & Laurindo, J.B. (2008). Evaluation of the effects of glycerol and sorbitol concentration and water activity on the water barrier properties of cassava starch films through a solubility approach. *Carbohydrate Polymers, 72*(1), 82–87.

Nor, M. H. M., Nazmi, N. N. M., & Sarbon, N. M. (2017). Effects of plasticiser concentrations on functional properties of chicken skin gelatin films. *International Food Research Journal*, *24*(5), 1910–1918.

Perdones, Á., Vargas, M., Atares, L., *et al*. (2014). Physical, antioxidant and antimicrobial properties of chitosan-cinnamon leaf oil films as affected by oleic acid. *Food Hydrocolloid*, *36*, 256–264.

Sanyang, M. L., Sapuan, S. M., Jawaid, *et al*. (2015). Effect of plasticiser type and concentration on tensile, thermal and barrier properties of biodegradable films based on sugar palm (*Arenga pinnata*) starch. *Polymers*, *7*(6), 1106–1124.

Shaw, N. B., Monahan, F. J., O'Riordan, *et al*. (2002). Physical properties of WPI films plasticized with glycerol, xylitol, or sorbitol. *Journal of Food Science*, *67*(1), 164–167.

Shen, J., Lu, G. & Ruan, D. (2010). Compressive behaviour of closed-cell aluminium foams at high strain rates. *Composite Part B: Engineering*, *41*(8),678–685.

Shojaee-Aliabadi, S., Hosseini, H., & Mohammadifar, M.A., (2013). Characterisation of antioxidant-antimicrobial K-carrageenan films containing *Satureja hortensis* essential oil. *Journal of Biology Macromolecule*, *52*, 116–124

Sies, H. & Stahl. W. (1995). Vitamin E and C, beta-carotene and other carotenoids as antioxidants. *The American Journal of Clinical Nutrition*, *62*(6), 1315–1321.

Soliva-Fortuny, R. C., & Martin-Belloso, O. (2003). New advances in extending the shelf-life of fresh-cut fruits: A review. *Trends in Food Science & Technology*, *14*(9), 341–353.

Supardan, M.D., Annisa, Y.,Arpi, N., *et al.*(2016). Cassava starch edible film incorporated with lemongrass oil: Characteristic and application. *Advanced Science Engineering Information Technology*, *6*(2), 216–220.

Tongnuanchan, P., Benjakul, S., & Prodpran, T. (2014). Structural, morphological and thermal behaviour characterisation of fish gelatin film incorporated with basil and citronella oils as affected by surfactants. *Food Hydrocolloids*, *41*, 33–43.

Viuda-Martos M., Ruiz-Navajas Y., Ferna´ndez-Lo´pez J., *et al*. (2008). Antibacterial activity of different essential oils obtained from spices widely used in Mediterranean diet. *International Food Science and Technology*, *43*, 526–531.

Woolfe, J. (1993). Sweet potato: An untapped food resource. Cambridge: Cambridge University Press.

Yan, Q., Hou, H., Guo, P. *et al*. (2012). Effects of extrusion and glycerol content on properties of oxidized and acetylated corn starch-based films. *Carbohydrate Polymers*, *87*(1), 707–712.

Zivanovic, S., Chi, S., & Draughon, A. F. (2005). Antimicrobial activity of chitosan films enriched with essential oils. *Journal of Food Science*, *70*(1), 45–51.

ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

Original Research Article

Banana Powder Production via Foam Mat Drying

Siti Amirah Razali[1], Mohd Zuhair Mohd Nor[1,2]*, Mohd Shamsul Anuar[1], Rosnah Shamsudin[1,2], Wan Anwar Fahmi Wan Mohamad[3]

[1]Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia, ctmiera95.r@gmail.com, mshamsul@upm.edu.my, rosnahs@upm.edu.my

[2]Laboratory of Halal Science Research, Halal Products Research Institute, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

[3]School of Food Industry, Faculty of Bioresources and Food Industry, University Sultan Zainal Abidin, 21300, Terengganu, Malaysia, fahmimohamad@unisza.edu.my

*Corresponding author: Mohd Zuhair Mohd Nor, Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia; zuhair@upm.edu.my

Abstract: Banana puree is one of the main commercial banana products available in the market worldwide. However, like other purees, banana puree deteriorates quite rapidly and gets a chilling injury when refrigerated. Therefore, this study focused on the dehydration of banana puree using a foam mat drying (FMD) technique to prolong its shelf life. It involved whipping the banana puree to form foams with the help of whey protein concentrate (WPC) and carboxymethyl cellulose (CMC) as the foaming agent and foam stabilizer, respectively. The study evaluated the effect of different foaming agent percentages (5, 7.5, 10, 12.5 and 15%) and drying temperatures (50, 60, 70 and 80°C) on the production of the foam mat dried banana powder. Besides that, the drying curves of banana puree using FMD and oven drying methods were compared. The banana powders produced were also analyzed in terms of the foam density, moisture content, solubility, color (browning index) and flowability (caking strength). Based on the findings, the FMD technique has proven to produce a good quality banana powder better than the control sample especially at a higher foaming agent concentration (15%) and drying temperature (80°C). By using the FMD technique, the banana puree has the capacity to be dried three times faster compared to the conventional oven drying method to form a more stable banana powder.

Keywords: banana; drying; foam mat drying; fruit powder; fruit puree

Received: 27th October 2020

Accepted: 27th November 2020

Available Online: 16th December 2020

Citation: Razali, S. A., Mohd Nor, M. Z., Anuar, M. S., *et al*. (2020). Banana production via foam mat drying. *Adv Agri Food Res J* 2020; 1(2): a0000142. https://doi.org/10.36877/aafrj.a0000142

1. Introduction

Banana (*Musa acuminate*), one the most popular fruit around the world, offers a quick boost of vitality and is a good source of vitamins C, B6, and potassium (Sampath Kumar *et al.*, 2012). Although most of the banana fruits are consumed fresh, this fruit can also be processed for different food applications such as snacks, desserts and beverages. Banana puree, as one of the main products of the banana, is the basis used in many bakeries, confectionery and beverages produce including ice cream, cakes, biscuits, yoghurt, smoothies and sorbet. Unfortunately, banana puree has a short shelf-life, since it can easily be oxidized and spoil to microbial activities. In order to overcome this shortcoming, drying of the banana puree is an alternative to extend its shelf-life.

The dehydration or drying process takes place when water vapor is taken away from its surface into the surrounding space, resulting in a dried material with an extended shelf life and reduced water activity of food products. During drying, the moisture content of the sample can be brought down to a low level to avoid microbial spoilage and undesirable enzymatic reactions (Vasudevan *et al.*, 2020). Through the dehydration process, the banana puree can be dried and further converted into powder form.

The banana powder has the potential to be commercialized in the market, since it is more convenient compared to the fresh puree in terms of long shelf-life, reduced volume or weight, simpler storage and handling and can be easily reconstituted for usage in varieties of banana-based products. However, some difficulties in producing the powder are expected, mainly due to the high sugar content and the stickiness characteristic of the banana puree. Without suitable processing approaches, the drying for the puree will take a long time and the produced powder may turn to be very hygroscopic and easily agglomerate. This will cause a caking problem, especially during the handling and storage of the bulk powder.

In order to solve this issue, suitable processing approaches to produce the banana powder should be considered, especially during the drying process. One of the emerging dehydration process technique, suitable for heat-sensitive, high sugar content and viscous foods, is the foam mat drying (FMD) technique. The FMD technique involves the transformation of products from a liquid state to a stable foam, followed by air drying (Affandi *et al.*, 2017). The formation of the foam structure in this technique requires the existence of a foaming agent, mostly protein-based substances and a foam stabilizer, mostly polysaccharide-based substances. This technique can be used for large scale production of fruit powders because of its suitability for all types of fruit puree, rapid drying at a lower temperature, retention of nutritional quality, easy reconstitution and cost-effective for producing easily reconstitute fruit powders (Brar *et al*., 2020; Sangamithra *et al.*, 2015). By considering these advantages, the foam mat drying (FMD) technique has the potential to be applied to produce the banana powder. However, more explorations are needed to refine the process. Hence, the aim of this study is to determine the effect of foaming agent percentage and drying temperature on the quality attributes of the banana powder produced via foam mat drying (FMD) technique.

2. Materials and Methods

2.1 Sample Preparation

Banana of the Cavendish variety was bought from convenience stores (Sri Serdang, Selangor, Malaysia). The bananas were peeled and blanched by placing them in boiling water for 1 min to inactivate the polyphenoloxidase, which triggers the generation of dark pigment (Yap *et al.*, 2017). The blanched banana was then mashed to produce banana puree and was considered as the raw ingredient in the foam mat drying procedure.

2.2 Foam Mat Drying (FMD) Technique

Foam mat drying (FMD) procedure consist of the mixture of (1) banana puree; (2) whey protein isolate (WPI) as the foaming agent (80% protein content); (3) carboxymethyl cellulose (CMC) as the foam stabilizer; and (4) distilled water. The ingredients were weighed based on the modified formula from Abbasi and Azizpour (2016) are shown in Table 1.

Table 1. The formulation for foam mat drying of banana puree.

Ingredients	Formula	
Banana puree	100 g	
Foaming agent (WPI)	5–15%	Based on the
Foam stabilizer (CMC)	8%	weight of the
Water	85%	banana puree

WPI, CMC and distilled water were whipped using a kitchen mixer (ELB-ESMB9925SS, Elba, Malaysia) at a maximum speed of 1150 rpm for 50 minutes prior to the addition of the banana puree. Mixing was continued for another five minutes at the same speed. The foamed mixture as illustrated in Figure 1(a) was removed from the mixer and further analyzed for foam density determination.

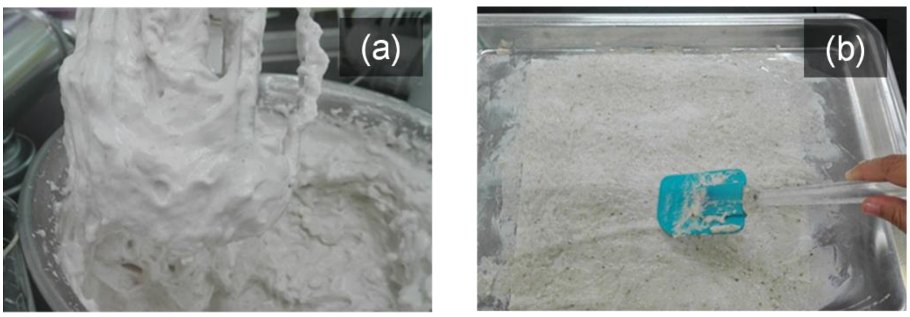


Figure 1. The foamed banana puree mixture: (**a**) after the wiping process, (**b**) during spreading on a tray.

The foam mixture produced was then spread uniformly with a thickness of 3.0 ± 0.02 mm on a metal tray, which the base has been covered with parchment baking paper as illustrated in Figure 1(b). The banana mat layer was placed in the hot air oven (UN55, Memmert, Germany) for the drying process. Once the drying process was completed, the dried mat was removed from the metal tray and grounded by a mixer grinder (MX-AC210SW, Panasonic, Japan) prior to sieve by a 100 µm screen mesh. The produced banana powder was stored in an air-tight container at room temperature and was used for the subsequent analyses for the evaluation of the powder quality.

2.3 Experimental Procedures

This study was performed in 3 phases. Phase 1 was an observation on the effect of foaming agent percentage of 5, 7.5, 10, 12.5 and 15% in the formulation of the foam mixture, on the quality of the foam and powder produced. For this phase, the drying process was fixed at 80°C for 7 hours. The investigation in the study was further extended in Phase 2 to investigate the impact of drying temperature at 50, 60, 70 and 80°C on the attributes of the produced FMD banana powder. The drying process was performed for seven hours and the formulation of the mixture was fixed using a 10% foaming agent. In phase 3, a comparison was done on the drying curve between FMD and conventional oven drying technique by observing the free moisture (X) removal until it reaches equilibrium.

2.4 Analyses

2.4.1 Determination of foam density

The foam density was determined according to Bag *et al.* (2011), where 50 ml of the foam was poured into a 50 ml graduated cylinder at room temperature. The samples were weighed, and foam density was calculated according to Equation 1.

$$\text{Foam density} = \frac{\boldsymbol{weight\ of\ foam\ (g)}}{\boldsymbol{volume\ of\ foam\ (cm^3)}} \quad (1)$$

2.4.2 Determination of moisture content

The moisture content of the banana powder was determined by using a moisture analyzer (MX-50, A&D Weighing, Japan).

2.4.3 Determination of solubility

The solubility of the banana powder was determined by using a dissolution tester (D-63512, Pharma Test, Germany). Banana powder of 2.5 g was placed in a vessel filled with

250 ml distilled water inside a temperature-controlled water bath. The dissolution tester was operated at 250 rpm and at 45°C, where the time (in min) for the powder to dissolve was recorded.

2.4.4 Determination of color

The color properties of the banana powder were determined using a portable spectrophotometer (CR-10, Konica Minolta, Japan). The calibration of the device was performed using a white and black calibration plate prior to the analysis. The color properties were recorded in terms of lightness (L*), redness (a*) and yellowness (b*) values, in order to measure the browning index (BI), based on Equation 2 (Nasser *et al.*, 2017);

$$\boldsymbol{BI} = \frac{[\mathbf{100}\ (\boldsymbol{x} - \mathbf{0.31})]}{\mathbf{0.17}} \tag{2}$$

where *x* was calculated based on Equation 3;

$$\boldsymbol{x} = \frac{\boldsymbol{a}^{*} + \mathbf{1.75}\ \boldsymbol{x}\ \boldsymbol{L}^{*}}{(\mathbf{5.645} \times \boldsymbol{L}^{*} + \boldsymbol{a}^{*} - \mathbf{3.012} \times \boldsymbol{b}^{*})} \tag{3}$$

2.4.5 Determination of flowability

The flowability of powders can be measured by using a powder flowability analyzer probe (TTC, USA) attached to a texture analyzer (TA.XTPlus, Stable Micro Systems, UK). The flowability of the powder was determined by running a caking test. All samples were fixed at 70 mL volume for each experiment. The blade travels down and upwards through the powder column at a nominal speed of 50 mm.s^{-1}.

2.4.6 Determination of drying curve

The drying curve of the samples was determined according to the free moisture, *X* of the sample as the function of drying time. The free moisture, *X* of the sample was calculated based on Equation 4.

$$\boldsymbol{X} = \boldsymbol{X_t} - \boldsymbol{X}^{*} \tag{4}$$

where X_t was the moisture content at a time (t) was calculated using (Equation 5) and X^* was equilibrium moisture content (kg equilibrium moisture kg dry solid^{-1}):

$$\boldsymbol{X_t} = \frac{\boldsymbol{W} - \boldsymbol{W_s}}{\boldsymbol{W_s}} \tag{5}$$

where W is the weight of the wet solid in (kg) and W_S is the weight of dry solid in (kg).

3. Results and Discussion

3.1 Effect of Different Percentages of Foaming Agent

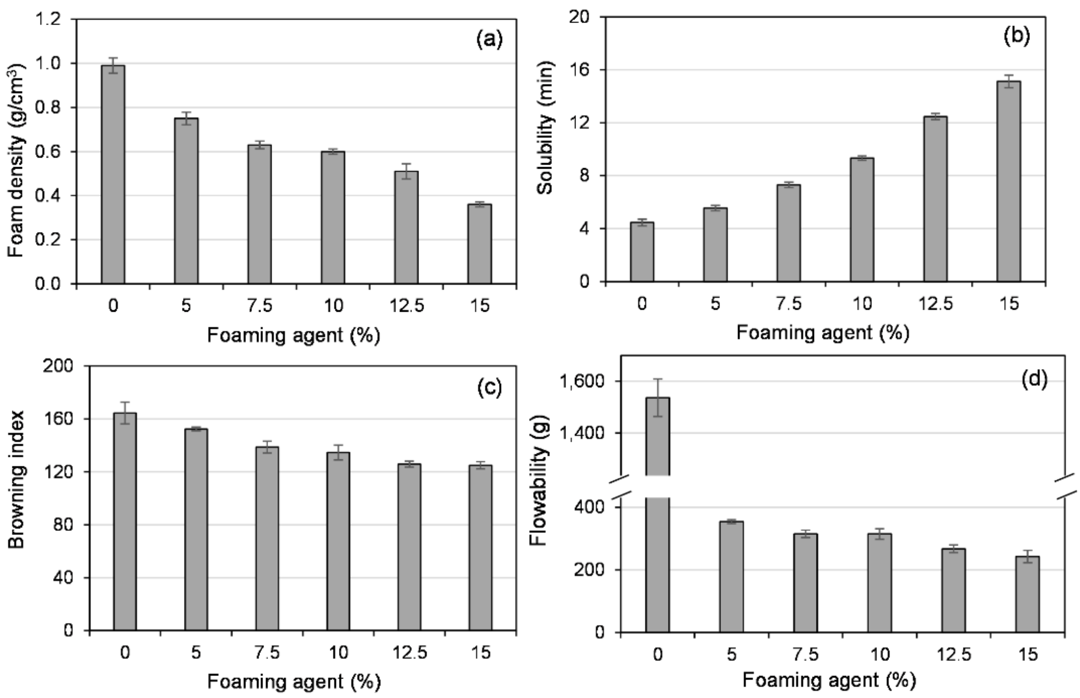


Figure 2. Effect of different percentage of the foaming agent on: (**a**) foam density; (**b**) solubility; (**c**) browning index; and (**d**) flowability of the samples

Different percentages of the foaming agent (WPC) i.e. 5, 7.5, 10, 12.5% were being added to the banana puree to observe their effects on the produced samples. Figure 2(a) shows the effect of different percentages of the foaming agent on the resulted foam density. The density of the foam decreases significantly with the increment of the WPC concentration. A 63% reduction has been achieved at 15% foaming agent compared to the control sample, (at 0% foaming agent). This clear trend is due to the reduction of the interfacial tension at the air or liquid interface with the increment of WPC concentration and subsequently reduces the surface tension of the foam structure (Dachmann *et al.*, 2018). Hence, more entrance of air into the foam structure is expected and subsequently resulting the density to reduce (Affandi *et al.*, 2017). Lower foam density of the mat will facilitatefacilitates better moisture removal during the drying process.

The solubility duration of the banana powder produced at different percentages of foaming agent is displayed in Figure 2(b). The time to solubilize the powders increased significantly with the rise of the concentration of WPC, in which powder with 15% WPC required 3-fold longer time to solubilize compared to the control powder. Hence, t high WPC content in the FMD powder resulted to the powder with a low solubility rate. This has been affected by the change in the microstructure of the FMD mixture due to its reduction of hygroscopic behavior (Cano-Chauca *et al.*, 2005). Hygroscopic is the property of absorbing the water and is mostly low if the powder is in an amorphous state (Cano-Chauca *et al.*, 2005). It is expected that higher WPC in the formula increases the amorphous behavior of the produced banana powder, thus reducing the hygroscopic character and the solubility rate of the powder. Besides, the solubility rate might be also due to the pore structure of the powders. FMD samples have been reported to have high porosity and stretched pore shape with skeletal-like structure compared to a compact and less porous structure of a non-foamy sample (Sangamithra *et al.*, 2015).

Figure 2(c) exhibits the browning index (BI) of the banana powder at different percentages of foaming agent and a control sample. As shown in the figure, the effect of WPC on the browning index exhibited a decreasing trend. The structure of WPC is made of protein, so by increasing the amount of WPC in the formula, the amino acids existing in its chemical composition reduces the sugar in the system, which lead to a lesser browning effect during the drying process (Wilson *et al.*, 2014). Besides, the existence of CMC in the FMD powders is believed to affect the lower BI value compared to the control sample. The CMC, which acts as a foam stabilizer, has a hydrophilic structure that can contribute to the reduction of humidity of the mixture and subsequently affect the Maillard-reaction during the drying process (Abbasi & Azizpour, 2016).

The flowability of the banana powder, characterized by its loose particulate solids, treated with different percentages of foaming agent and a control sample is displayed in Figure 2(d). The flowability of the banana powder was determined based on its caking strength of the powders using a texture analyzer. Caking strength is a measurement to evaluate the potential of the particular powder to form cake based on the force required to cut through the cake formed after the compaction, which would determine the strength of the cake (Shah *et al.*, 2008). The greater the strength, the higher the tendency of the powder to form hard cake, which is not easy to disperse. Thus, the tendency of the powder to be involved in caking is high. Based on the result obtained in Figure 2(d), the control-powder has a significantly stronger caking strength than any of the FMD powders. It can be proven that the caking strength of the banana powder is decreasing as the concentration of WPC increased. This finding has proven that the existence of the foaming agent and its concentration level have a significant effect on lowering the caking problem of the banana powder resulted from reduction of hygroscopicity of the powder (Seeranguravar *et al.*, 2017). The hygroscopicity characteristic produces a sticky powder. The stickiness can lead to the rise of the cohesiveness, powder-caking and increase the adhesion to the surface of the powder. Thus, low hygroscopicity behavior leads to a decrease in the caking strength and an increase in the flowability.

Based on the findings in this study, higher foaming agent concentration led to a better foam density and powder's solubility, browning index and flowability, however, other factors such as the cost of the raw materials and protein allergenicity effect should also be evaluated for a more feasible banana powder production.

3.2 Effect of Different Drying Temperatures

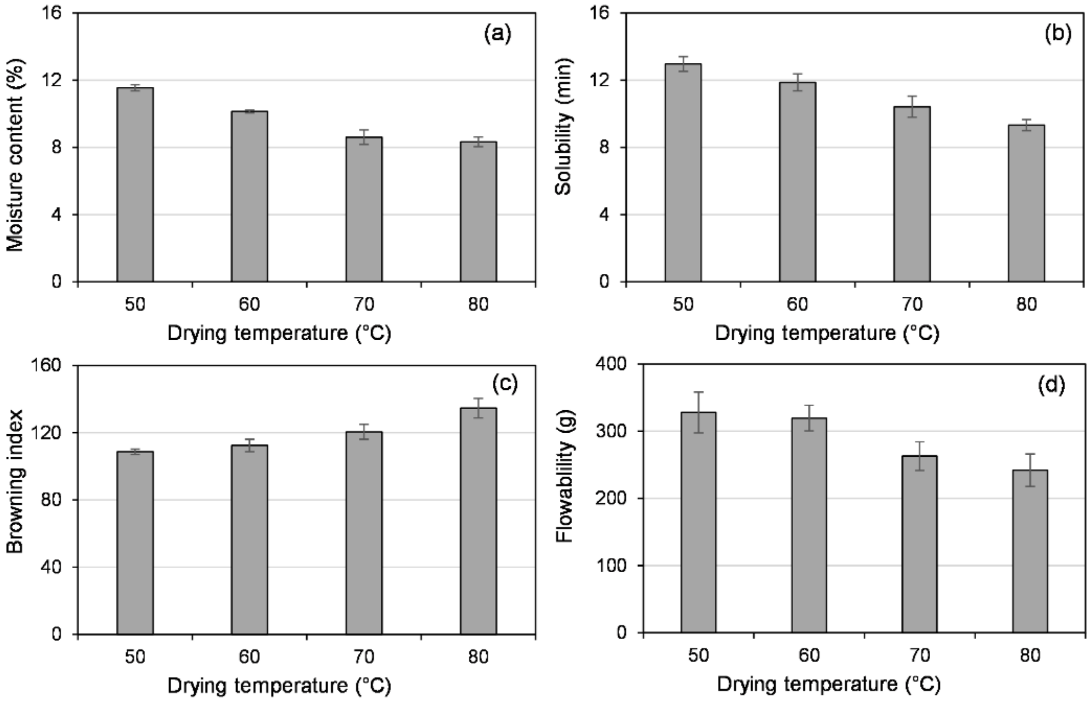


Figure 3. Effect of different drying temperatures on: (**a**) moisture content; (**b**) solubility; (**c**) browning index; and (**d**) flowability of the produced powders

For the purpose of further exploration in this research, this study has chosen a 10% foaming agent in the formulation to proceed with the determination of the effect of different drying temperatures of the FMD technique. The drying temperature was varied at 50, 60, 70 and 80ºC and the characteristics of the FMD powder produced were evaluated.

Figure 3(a) shows the effect of different drying temperatures on the moisture content of the produced powder at a fixed drying time of six hours. As expected, the lowest drying temperature of 50ºC produced powder with the highest moisture content, 27% higher compared to the sample dried at 80°C. Higher drying temperatures have resulted to more moisture removal within the sample. This is because the higher amount of heat generated in the oven creates a relatively larger vapor pressure difference between the internal and the surface of the sample, which leads to more rapid moisture removal, hence, forming a sample with lesser moisture content.

Based on Figure 3(b), the powder produced at higher drying temperature required lesser time to dissolve in water. This might be related to the reduction of moisture content in the sample as shown in Figure 3(a). The lower the moisture content in the samples, the powder became less sticky and has lesser contact with water (Franco *et al.,* 2016). Besides, the reduction of the solubility time might also be due to the increment of denatured protein in the powder at the higher drying temperature, since the foaming agent used in this study was categorized as protein. Meanwhile, Figure 3(c) exhibits the browning index (BI) of the banana powder at different drying temperatures. An increment of the drying temperature leads to a higher browning index. The BI value for powder dried at 80°C was 134.61 compared to the BI of 108.67 of the powder dried at 50°C. This trend is due to the Maillard-reaction that was accelerated at a higher drying temperature because the heat both increases the rate of chemical reactions and increase the evaporation of water in the samples. Nevertheless, the BI value for the sample dried at 80°C is still low compared to the control sample with 164.43 BI value, as per illustrated in Figure 2 (c).

The flowability of the banana powders dried at different temperatures is shown in Figure 3(d). The finding shows a decreasing trend of the flowability of the powder as the drying temperature increases. The flowability of the powder is related to the caking behavior as what has been discussed in the previous section and can be associated with the moisture content in the sample. Higher moisture content in the banana powder would lead to higher caking strength. This can be proven by similar trends in Figure 3(d) with Figure 3(a) that shows the decrement of the moisture content of the powder as the drying temperature increases. Low moisture content leads to a lower tendency for the powder to form crystalline bond caking. The crystalline bonds are formed between particles when the material is soluble and high on the water source.

Based on Figure 3(a) to (d), it is clear that at a higher drying temperature, the powder being produced has good attributes in terms of moisture content, solubility rate and flowability, although a slight increment of the browning index occurred. However, the operating cost and drying duration may still need to be considered further to choose the best drying temperature for the foam mat drying technique of banana powder.

3.3 Drying curve of FMD and conventional oven drying method

A comparison of the drying curve between the FMD-treated and control samples has been performed as exhibited in Figure 4. The FMD treated-sample was prepared with 10% of WPC, while the control sample was the untreated banana puree dried using the conventional oven drying method. Both samples were dried at 80ºC. The moisture removal of both samples was observed at a certain time interval (every 1 hour) based on the weight loss of each sample until they reach constant weight.

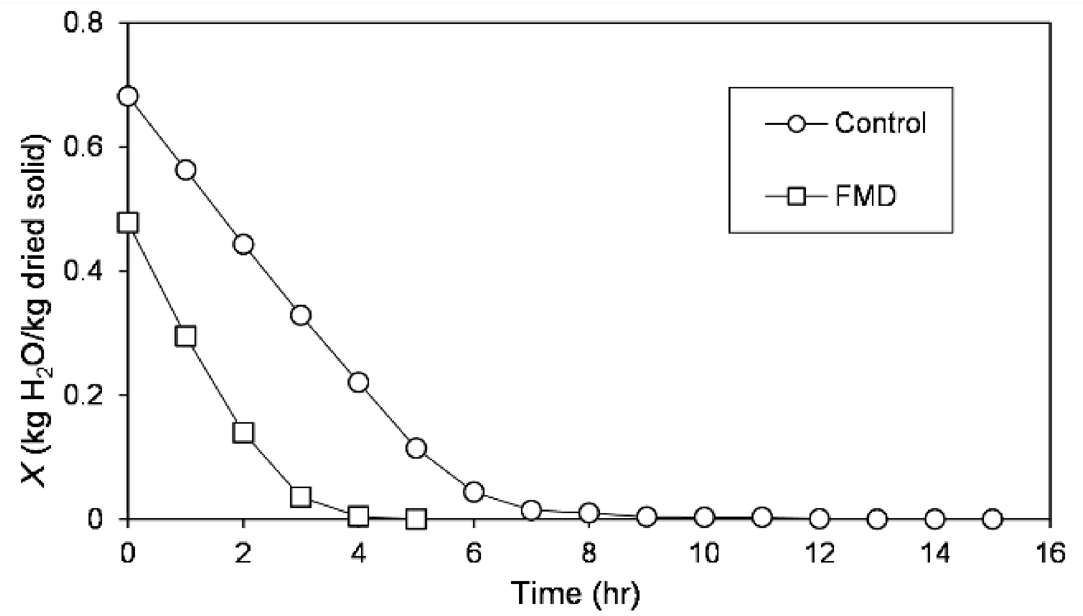


Figure 4. Drying curve of free moisture, X against drying time for FMD and control samples at 80°C

As shown in Figure 4, the addition of foaming agent has reduced the initial free moisture of the FMD sample compared to the control sample. The FMD treated sample exhibited a steep drying curve indicating massive loss of free moisture during the first three hours before it approached the zero-equilibrium value after five hours. The control sample exhibits a gradual decline of free moisture loss in six hours before approaching equilibrium after 15 hours. These findings further support the FMD concept where better moisture removal is expected from a porous structure of the FMD treated-sample during the drying process. The moisture removal from the control sample, which was a plain banana puree, required a longer time to achieve since the sample was denser and stickier. In comparison, the drying process of the FMD treated-sample required a drying time of three times shorter than the control sample, proving that the FMD technique can accelerate the drying time compared to the conventional method.

4. Conclusion

In this study, the banana puree has been successfully converted into powder by using the foam mat drying (FMD) technique. The density of the puree foam decreased significantly with the increase in the foaming agent concentration. High foaming agent percentage (15% WPC) and drying temperature (80°C) produced powder that has better attributes in terms of moisture content, solubility rate, browning index, and flowability. However, other factors including the cost of the raw materials and operation as well end product's protein allergenicity effect should also be considered before the optimal processing approaches can be decided. By using the FMD technique, the drying time of the banana puree to form banana powder can be reduced up to three times compared to the conventional oven drying method.

Author Contributions: Conceptualization, M.Z.M. Nor and S.A. Razali.; formal analysis,S.A. Razali; writing—original draft preparation, S.A. Razali and M.Z.M. Nor; writing—review and editing, M.S. Anuar, R. Shamsudi and, W.A.F. Wan Mohamad.

Funding: This research was financially supported by Universiti Putra Malaysia, Serdang, Selangor, Malaysia

Acknowledgments: Authors are thankful to the laboratory technicians, Department of Processing and Food Engineering, Faculty of Engineering, for their considerable help to complete this research successfully.

Conflicts of Interest: The authors declare no conflict of interest, and also the funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

Abbasi, E. & Azizpour, M. (2016). Evaluation of physicochemical properties of foam mat dried sour cherry powder. *LWT - Food Science and Technology*, *68,* 105–110.

Affandi, N., Zzaman, W., Yang, T. A., *et al.* (2017). Production of Nigella sativa beverage powder under foam mat drying using egg albumen as a foaming agent. *Beverages*, *3*(1), 1–15.

Bag, S. K., Srivastav, P. P. & Mishra, H. N. (2011). Optimization of process parameters for foaming of bael (*Aegle marmelos* l.) fruit pulp. *Food and Bioprocess Technology*, *4*(8), 1450–1458.

Brar, A. S., Kaur, P., Kaur, G., *et al.* (2020). Optimization of process parameters for foam-mat drying of peaches. *International Journal of Fruit Science*, 1–24.

Cano-Chauca, M., Stringheta, P. C., Ramos, A. M., *et al.* (2005). Effect of the carriers on the microstructure of mango powder obtained by spray drying and its functional characterization. *Innovative Food Science and Emerging Technologies*, *6*(4), 420–428.

Dachmann, E., Hengst, C., Ozcelik, M., *et al.* (2018). Impact of hydrocolloids and homogenization treatment on the foaming properties of raspberry fruit puree. *Food and Bioprocess Technology*, *11*(12), 2253–2264.

Franco, T. S., Perussello, C. A., Ellendersen, L. N., *et al.* (2016). Effects of foam mat drying on physicochemical and microstructural properties of yacon juice powder. *LWT - Food Science and Technology*, *66*, 503–513.

Nasser, S., Moreau, A., Jeantet, R., *et al.* (2017). Influence of storage conditions on the functional properties of micellar casein powder. *Food and Bioproducts Processing*, *106*, 181–192.

Sampath Kumar, K. P., Debjit B., Duraivel, S., *et al.* (2012). Traditional and medicinal uses of banana. *Journal of Pharmacognosy and Phytochemistry*, *1*(3), 51–63.

Sangamithra, A., Sivakumar, V., Kannan, K., *et al.* (2015). Foam-mat drying of muskmelon. *International Journal of Food Engineering*, *11*(1), 127–137.

Seerangurayar, T., Manickavasagan, A., Al-Ismaili, A. M., *et al.* (2017). Effect of carrier agents on flowability and microstructural properties of foam-mat freeze dried date powder. *Journal of Food Engineering*, *215*, 33–43.

Shah, R. B., Tawakkul, M. A. & Khan, M. A. (2008). Comparative evaluation of flow for pharmaceutical powders and granules. *AAPS PharmSciTech*, *9*(1), 250–258.

Vasudevan, N., Sulaiman, R., Chong, G. H., *et al.* (2020). Development of foam mat dried soursop powder using arabic gum and fish gelatin as foaming agent. *Food Research*, *4*(Suppl. 1), 237–243.

Wilson, R. A., Kadam, D. M., Chadha, S., *et al.* (2014). Evaluation of physical and chemical properties of foam-mat dried mango (*Mangifera Indica*) powder during storage. *Journal of Food Processing and Preservation*, *38*(4), 1866–1874.

Yap, M., Fernando, W. M. A. D. B., Brennan, C. S., *et al.* (2017). The effects of banana ripeness on quality indices for puree production. *LWT - Food Science and Technology*, *80*, 10–18.

ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

Original Research Article

Optimization of Design and Operational Parameters of a Soil-Dispensing Machine for Preparing Seedling Tray

Hafidha Azmon[1]*, Mohd Fazly Mail[1], Mohd Shukry Hassan Basri[2], Norahshekin Abdul Rahman[1], Siti Ashah Ab Rahim[1]

[1]Farm Mechanization Program, Engineering Research Centre, Malaysian Agricultural Research and Development Institute (MARDI), Serdang Selangor, fazlym@mardi.gov.my

[2]Smart and Precision Farming Program, Engineering Research Centre, Malaysian Agricultural Research and Development Institute (MARDI), Serdang Selangor, shukry@mardi.gov.my

*Corresponding author: Hafidha Azmon, Farm Mechanization Program, Engineering Research Centre, Malaysian Agricultural Research and Development Institute (MARDI), Serdang Selangor, Malaysia; hafidha.mardi@1govuc.gov.my

Abstract: The conventional method of soil filling into nursery trays before seeding is known to be the most inexpensive approach prior to planting vegetables. However, this activity is very labourious and time-consuming if the operation is meant for high volume seeding. This study is done to develop soil-dispensing machine, evaluate its performance and to compare with traditional practice of soil filling into the nursery tray. The optimization of each parameter is also evaluated to obtain the exact volume of soil to fill the nursery tray to the fullest. A low-cost soil dispensing machine is developed in MARDI and it is using locally materials available in the market. The structure of the machine is fabricated using mild-steel and stainless-steel at the less cost. The machine consists of a conveyor, nursery tray holder, soil dispenser, scrapper, soil compactor, wiper motors, gears, microcontroller and sensors. There are three factors with two levels involve in this test; hopper angle, conveyor speed and auger speed. The hopper angles are evaluated at 45° and 65° while conveyor speeds are tested at 19 cm/s and 21 cm/s. The minimum and maximum speed of auger selected is 3.5 cm/s and 4.5 cm/s, respectively. Manual filling of soil into seedling tray was compared with filling soil using semi-automatic operated soil-dispenser. The results indicated that the model is significant with *p*-value <0.0001. Conveyor speed, auger speed and hopper angle were significant on the volume of soil dispensed with both speeds shows a *p*-value <0.0001, while hopper angle shows *p*-value equal to 0.00112. The combination of both speeds greatly affected the response with *p*-value <0.0001. There is no interaction between each speed and the hopper angle. From the optimization analysis, the operating conveyor speed, auger speed and angle of hopper should be set at 19.0 cm/s, 4.5 cm/s and 65° to discharge 2912 cm^3 soil. In order to dispense 1190 cm^3 of soil, conveyor speed, auger speed and hopper angle should be set at 21 cm/s, 4.3 cm/s and 50°. The result indicated that the machine can complete the seeding and soil filling process within 1 min per tray, while manual process took five minutes to complete the whole seeding process.

Keywords: nursery tray; soil dispenser; soil compactor; seed dispenser

Received: 27th October 2020

Accepted: 27th November 2020

Available Online: 4th December 2020

Citation: Azmon H, Mail MF, Basri MSH, *et al.* (2020). Optimization of design and operational parameters of a soil-dispensing machine for seedling tray. *Adv Agri Food Res J 2020*; 1(2): a0000143. https://doi.org/10.36877/aafrj. a0000143

1. Introduction

Vegetables are rich in vitamins and comparatively cheaper source of food. They provide all the important nutrients such as proteins, fats, starch, minerals and vitamin. Thus, their daily consumption is necessary for a balanced diet. Nowadays, increasing awareness in Malaysia citizen on healthy lifestyle has boost the demand for vegetable in Malaysia. Malaysia has produced 1.06 million tons of vegetables in 2018 which is 5.6% higher than a year before (DOA, 2019). Pahang is the biggest vegetable producing state in Malaysia with 18,296 ha grown area followed by Johor with 17,171 ha (DOA, 2019). The statistic shows that vegetable production is projected to increase annually by 1.6% due to the increment of 2.1% demand for vegetables from the citizens starting of the year 2016 (DOA, 2016). Despite the increment on vegetable production, Malaysia still needs to import 1.49 million tons of vegetables to cater an inadequate demand in the country (DOA, 2019). Food production in Malaysia is still beyond the quantity required by Malaysian citizen. This is supported by the report from Ministry of International Trade and Industry that the demand for food is projected to increase more than 70% in 2050 due to the increment of the population in the city (MITI, 2015).

The Malaysian government has synthesized a strategic planning to increase vegetable production in the country. Instead of expanding agricultural land, vertical farming concept and urban farming are introduced to the urban communities in order to increase food production (DOA, 2016). Urban farming has been accepted in Malaysian and this activity is expected to increase food security among communities. Producing vegetables for the vertical farming requires seedling preparation in the nursery tray before it can be transferred to the pot.

Planting vegetable involves a few steps before it can be harvested. There are two methods of seeding; direct seeding and transplanting in the nursery tray. Direct seeding is a method of sowing seed in the field, while transplanting requires seed to be sown in the nursery tray. In nursery practice, germinated plant in the tray will be transferred into the field a few weeks after seeding. Sowing seed in the tray can solve the problem of seed wastage, especially when using an expensive hybrid seed compared to direct seeding (Space & Balmer, 1977). Plants germinated in tray experience uniform crop development, efficient use of space and poses low risk of transplant injury due to the tray preserves healthy root form (Luna *et al.*, 2009). The main reason for the extra step of using nursery tray is to limit the amount of space initially required for germinating seeds. A lot of seedlings can be produced in a very small space using this method. It allows the farmer to select the strongest and most vigorous seedlings for use in transplants. Apart from all advantages of transplanting, seeding in the nursery tray requires extra work compared to the direct sowing. The farmer has to manually fill in the nursery tray with soil to prepare a medium for the seedling.

For transplanting activity, soil preparation in the nursery tray is the earliest process in planting vegetable. It is also one of the important stages, as it prepares the room for the seed to grow. Conventional activity on preparing media in nursery tray is the most inexpensive approach, but it is a labourious and time-consuming operation for high volume seeding (Pandiyaraj *et al.*, 2017; Muthamil *et al.*, 2015). It is largely operated by hand in Malaysia and contribute to higher number of workers and consume longer time compared to an operation conducted by a machine.

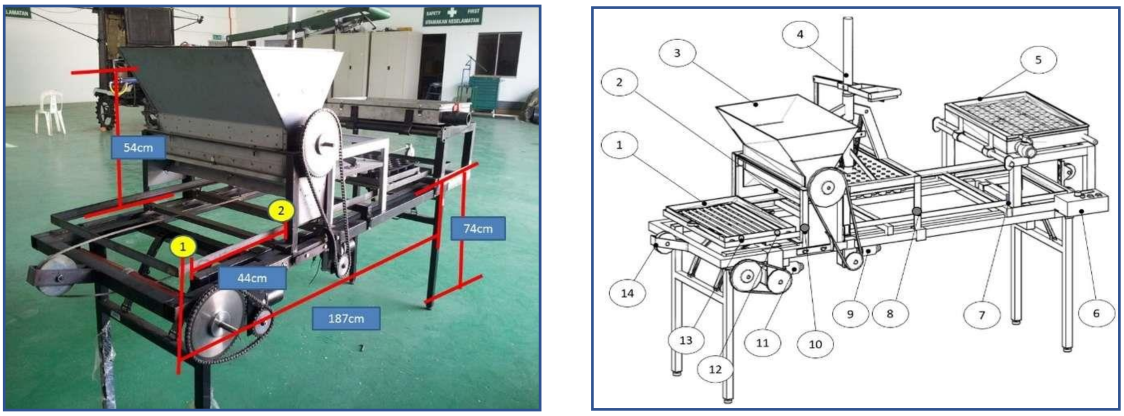
Manual soil-filling into the nursery tray is back breaking (Yeoh, 1988). This activity is not a good ergonomic practice for the human's body posture. In order to solve the problem that occurs in conventional seedlings production, soil-dispensing machine is developed with the local material available in the country to reduce the cost of the machine. A soil dispenser is developed to assists the farmer in sowing seed and to reduce the time to prepare the seedlings. A seed dispenser namely Tray Seeder which has been developed in MARDI is attached to this machine to complete the sowing process. The seed-dispenser is used to sow vegetables seeds into the nursery tray (Hafidha *et al.*, 2020). The objective of this research is to evaluate the performance of the soil dispensing machine and to compare with traditional practice of soil filling into the nursery tray. The optimization of each parameter is also evaluated to obtain the exact volume of soil to filling the nursery tray. The effect of different hopper angle, speed of conveyor and auger to the volume of soil dispensed into the nursery tray using this machine are evaluated.

2. Materials and Methods

The machine performance assessment were conducted at Engineering Research Centre, in MARDI Serdang, Selangor. The machine used in this experiment was designed for releasing soil and seeds into a nursery tray. The test was conducted using peat moss from Holland. This research includes modification of the machine, testing, evaluation and analysis upon determination of the optimum parameters of the machine to achieve the target volume of soil dispensed into the nursery tray.

2.1 Prototype of Soil-Dispensing Machine

A soil-dispensing machine, as shown in Figure 1, consists of a conveyor, nursery tray holder, soil dispenser, scrapper, soil compactor, wiper motors, gears, microcontroller and sensors made up of different parts as per listed in Table 1. It was developed using locally materials available in the market. The structure of the machine was fabricated using mild steel and stainless steel at the less cost. Motors are used to move the conveyor and rotate the auger attached to the hopper. The main part of the soil-dispenser is a hopper which is a container used to store peat moss or soil (Prajakta *et al.*, 2015). It is tapered downward to allow the soil to be dispensed with the help of an auger. The auger is actuated by a motor and controlled by a microcontroller.



(**a**) (**b**)

Figure 1. Soil dispensing machine: (**a**) Photographic view; (**b**) Isometric view.

Table 1. Parts of soil dispensing machine.

No	Part
1	Conveyor
2	Nursery tray holder
3	Scrapper
4	Soil dispenser / hopper
5	Soil compactor
6	Seed dispenser
7	Microcontroller / main switch /push button PB3
8	Limit switch (S1)
9	Distance sensor 2 (S2)
10	Auger’s motor
11	Distance sensor 1 (S1)
12	Conveyor’s motor
13	Magnet 1 (M1)
14	Magnet 2 (M2)
15	Limit switch (S2)

The operation of the system is summarized in the flowchart in Figure 2. The operation began with putting the nursery tray on the nursery tray holder. There are two magnets attached to the tray holder for the distance sensors to detect the tray existence. The machine started by pushing the start button and the motor begin to actuate the conveyor. The conveyor moving forward to the soil-dispenser bringing the nursery tray to pass under the hopper. When the holder reached the dispenser, the auger motor started and allowing the soil to discharge from the hopper. The auger stops discharging soil when the holder passing the dispenser and move towards the soil-compactor. The conveyor stops when the distance sensor detected the arrival of the nursery tray, which has been positioned under the soil-compactor. The compactor compresses the soil in the nursery tray, making the depth of the current soil become more compact or about ¾ depth of nursery tray. This process is done manually by the operator. The conveyor starts moving, when the compactor is back to its original position. The nursery tray continues moving towards the seed-dispenser. The tray stops next to the seed-dispenser and the seed sowing begin to operate. The seeding process is done manually by the operator. Operator bring the plate attached with seeds facing to the nursery tray and switch-off the vacuum pressure to release the seed into the nursery tray.

After seeding completed, the operator needs to push the button and the conveyor motor rotates counterclockwise, bringing the tray holder back towards its original position. The nursery tray passes under the compactor and move towards the soil-dispenser. When the tray-holder reached the hopper, auger motor starts operating and soil discharges from the hopper into the nursery tray. The volume of soil discharged from the hopper is an amount needed to cover the seed on the compacted soil. The auger motor stopped discharging the soil, when the tray passed the hopper. The tray finally returned to its original position.

The soil-dispenser conducts two jobs as the machine operated. Firstly, the soil dispenser is used to fill soil into empty nursery tray. The full volume of soil is then being compressed by the compactor. Secondly, after seeds has been sowed on the compacted soil, the dispenser fills the nursery tray with soil to cover the seed. The scraper is used to flatten soil on top of the nursery tray. The conveyor is used to move the nursery tray from original position to soil dispenser and return to its original position. The soil dispensing machine was semi-automated and controlled by an Arduino microcontroller.

2.2 Microcontroller and Sensors

Arduino is chosen as a microcontroller for this prototype machine because it is reliable and cheap for prototype testing purposes (Daniel & Peter, 2012). Arduino is preferable over the other microcontrollers because it is simple to code and it can be run in an open source platform (Parmenter *et al.*, 2014). The controller is suitable for many types of sensor's integration (Louis, 2018). Distance sensors and limit switches are used on this machine to allow the operation of motors.

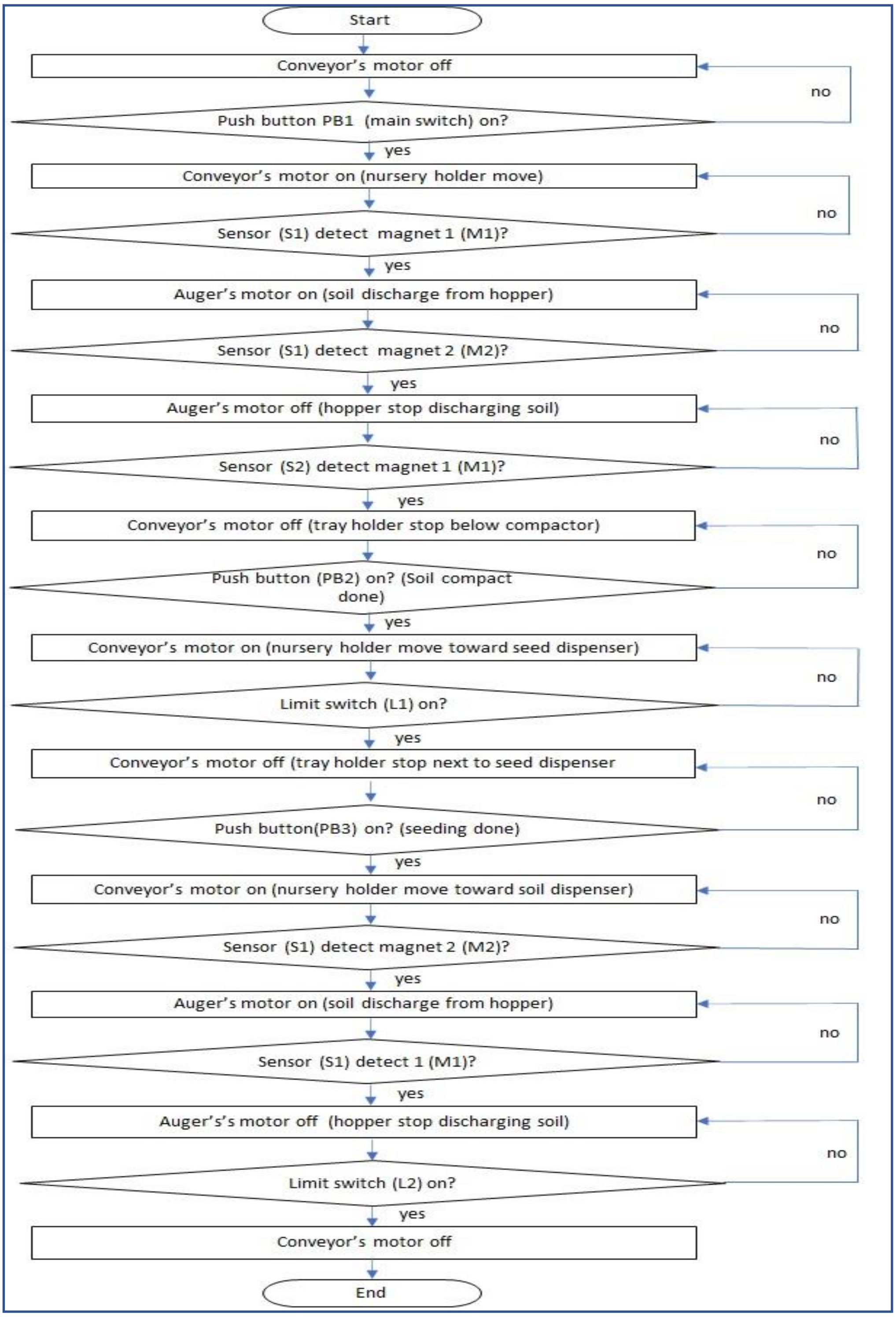


Figure 2. Flowchart of machine operation.

2.3 Test Procedure

2.3.1 Determination of properties of the nursery tray

Three samples of nursery tray were selected from various types available in the market. The dimension of the hole and the size of the nursery tray were measured. The shape of a nursery tray hole is similar to the frustum of a cone, where the top portion of the cone has been cut off forming a lower base and an upper base that is circular and parallel. The volume of total holes on nursery tray is measured to calculate the volume of soil needs to dispensed. The volume of each hole was calculated using Equation 1 (Szirtes & Rosza, 2007):

$$\text{Volume of frustum of a cone (cm}^3\text{)} = \frac{\pi\left(\text{Diameter}_{\text{big}}{}^2(\text{cm}^2)+\text{Diameter}_{\text{small}}{}^2(\text{cm}^2)+\text{Diameter}_{\text{big}}(\text{cm})\times\text{Diameter}_{\text{small}}(\text{cm})\right)}{12} \quad (1)$$

2.3.2 Determination of the soil volume by varying hopper angle, speeds for conveyor motor and auger motor

The speed of agricultural and food processing machinery often affects its performance (Jarimopas & Rattanadat, 2007). The exact speed of the auger and the conveyor is important in order to discharge an accurate volume of soil. Therefore, it is essential to determine the best conveyor speed and rotating auger, which is actuated by motors. Each motor consists of two pieces of spur gears. The gears are used to increase rotational speed of the conveyor and the auger. The transmission power is conveyed by a roller chain. A good soil dispensing machine will be perceived by the farmer as a “perfection”, when the soil dispensed into the whole nursery tray’s cells can be filled to the fullest volume, without any spillage and wastage. The combination of two speeds results in an accurate timing for the nursery tray to reach at the position below the seed dispenser and the period of auger needed to dispense an exact volume of soil.

Arduino has its own motor driver. Thus, the speed of the motor is measured in 8-bit unit. The motor was controlled from the microchip and the speed can be changed by altering the algorithm. The 8-bit represents value 0 to 255, which 0 is the minimum speed and 255 is the maximum speed motor. The motor shall operate at the selected speed, between 0 to 255, when the input number is entered on Serial Monitor and processed via Arduino algorithm. The combination of two motor’s speed in this experiment was monitored and the volume of soil dispensed from the hopper was measured. The value of 0 to 255 is referred to Pulse Width Modulation or known as PWM, where the output 0 is equal to 0% of duty cycle and 255 is equal to 100% of duty cycle. The speed of 3.5 cm/s and 4.5 cm/s were tested for auger capacity, while 19 cm/s and 21 cm/s were tested for conveyor capacity.

Figure 3 shows the orientation of angle of the hopper. The angle (θ) is an important parameter affecting soil dispensing performance. Thus, θ, is the angle between two perpendicular walls of the hopper. The machine has been developed with 45° and 65° angle of hopper. These angles were chosen based on manual fabricating of hopper in the fabrication workshop. Testing has been done with these two designs of hopper and the volume of soil dispensed from the hopper is observed at the end of the operation.

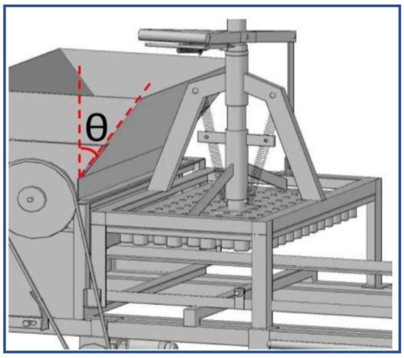


Figure 3. Hopper angle, θ.

2.3.3 Design optimization of the soil dispensing machine

The optimum value for hopper angle, speed of conveyor and speed of auger were determined based on the result obtained earlier from the experiment. Three factors of two levels variance were selected in this experiment as shown in Table 2. The statistical analysis was performed by Design Expert software at significant of 95% level of confidence for variance ($p \leq 0.05$).

The optimum values were determined twice. Firstly, optimum volume of soil dispensed is determined, when soil completely filled up the empty holes of nursery tray to the maximum, which is before soil is compacted. Secondly, the optimum volume of soil dispensed is needed to cover the whole seeds in the nursery tray, which occurs after soil is compacted.

Table 2. Factors and 2 level of variance in the experiment.

Factor	Unit	Low level	High level
Conveyor speed	cm/s	19	21
Auger speed	cm/s	3.5	4.5
Hopper angle	degree	45	65

3. Results and discussions

3.1 Properties of the Nursery Tray

Table 3 shows the volume of total holes calculated by using Equation 1. All types of nursery tray tested can be used with the soil-dispensing machine, since the dimension of the tray is suitable for design of the machine. However, the 104-type of nursery tray, composed of 104 holes, is widely used to germinate leafy vegetable due to its suitability volume of hole for root to grow. The target volume for soil to dispense from the hopper to fill the capacity of the nursery tray is 2873 cm^3.

Table 3. Parameter of nursery tray.

Tray types (No of holes)	Volume of all holes, V (cm^3)
51	4870.856
84	3745.905
104	2873.099

After the soil compacting step, the total volume of soil in the nursery reduces to 1693 cm^3. The soil compactor compressed the height of the soil in the nursery tray from 4.0 cm to 3.2 cm and the diameter of top soil in the nursery tray from3.7 cm to 1.8 cm. The volume of soil needed to cover the seeds on top of the whole soils was 1180 cm^3. This volume is calculated using formula of Equation 1.

3.2 Determination of the Soil Volume by Varying Hopper Angle, Speeds for Conveyor Motor and Auger Motor

Table 4 shows an experimental design and volume of soil dispensed from the hoper into the nursery tray. Result of the analysis of variance is shown in Table 5. From the statistical analysis, the model is significant with *p*-value <0.0001. Conveyor speed and auger speed were significant on the volume of soil dispensed from the hopper with a *p*-value <0.0001. Hopper angle shows significant effect on the response with *p*-value of 0.00112. The combination of both speeds greatly affected the response with *p*-value <0.0001. Therefore, there is no interaction between the hopper angle, conveyor speed and auger speed.

Table 4. Volume of soil dispense from hopper.

Standard	Run	A: Conveyor speed	B: Auger speed	C: Hopper angle	Volume
1	6	19	3.5	45	2236
2	1	19	3.5	45	2278
3	24	19	3.5	45	2317
4	23	21	3.5	45	1976
5	11	21	3.5	45	1807
6	16	21	3.5	45	1943
7	17	19	4.5	45	2964

Standard	Run	A: Conveyor speed	B: Auger speed	C: Hopper angle	Volume
8	22	19	4.5	45	2903
9	10	19	4.5	45	2877
10	18	21	4.5	45	1031
11	2	21	4.5	45	1076
12	7	21	4.5	45	998
13	5	19	3.5	65	2369
14	15	19	3.5	65	2412
15	9	19	3.5	65	2343
16	3	21	3.5	65	1998
17	13	21	3.5	65	2016
18	12	21	3.5	65	2061
19	4	19	4.5	65	2986
20	14	19	4.5	65	3007
21	19	19	4.5	65	3096
22	21	21	4.5	65	1003
23	20	21	4.5	65	1032
24	8	21	4.5	65	1079

Table 5. Analysis of variance table.

Source		Sum of squares	DF	Mean Square	F Value	Prob > F
Model		1.179E=007	4	2.947E+006	1040.73	< 0.0001
	A	7.898E+006	1	7.898E+006	2788.93	< 0.0001
	B	1.210E+005	1	1.210E+005	42.72	< 0.0001
	C	41334.00	1	41334.00	14.60	0.00112
	AB	3.729E+006	1	3.729E+006	1316.67	< 0.0001
Residual		53808.00	19	2832.00		
Lack of Fit		13125.33	3	4375.11	1.72	0.2029
Pure Error		40682.67	16	2542.67		
Cor Total		1.184E+007	23			
Std. Dev.	53.22			*R*-Squared	0.9955	
Mean	2075.33			Adj *R*-Squared	0.9945	
C.V	2.56			Pred *R*-Squared	0.9928	
Press	85854.32			Adeq Precision	83.107	

Equation 2 indicates the final equation in terms of actual parameters that can be used to predict the soil volume.

$$\text{Volume(cm}^3\text{)} = 1418.56293+3.87109\mathbf{A}+11.05204\mathbf{B} +4.15000\mathbf{C}-0.080442\mathbf{AB} \quad (2)$$

Figure 4 shows the interaction graph of auger and conveyor speed.

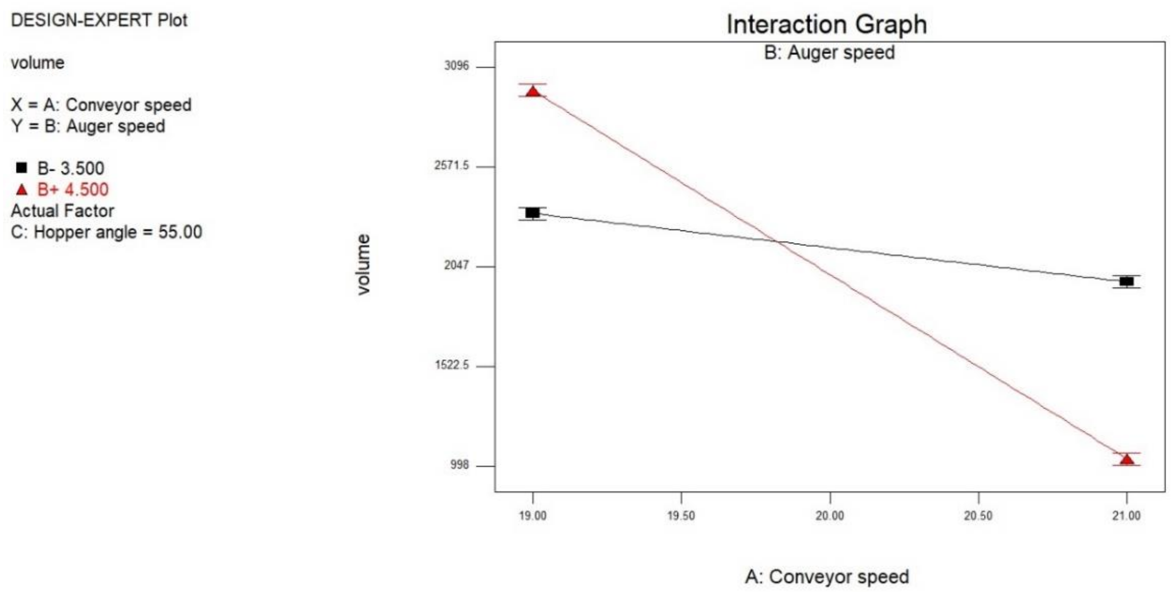


Figure 4. Interaction graph of auger and conveyor speed.

3.3 Design Optimization of the Soil Dispensing Machine

In order to achieve the target volume of soil to be dispensed by the hopper for the empty nursery tray, which is 2873 cm^3, the operating conveyor speed, auger speed and angle of hopper should be set at 19.01 cm/s, 4.30 cm/s and 64.92°, respectively. The numerical optimization of the parameters with the response of desirability is shown as 3D surface graph in Figure 5. Machine modification is required to achieve the target of the output volume thus, the nearest solution of optimized parameter to set up the machine is 19.10 cm/s, 4.5 cm/s and 65° for the conveyor speed, auger speed and angle of hopper, respectively. These tested parameters produced an output of 2912 cm^3.

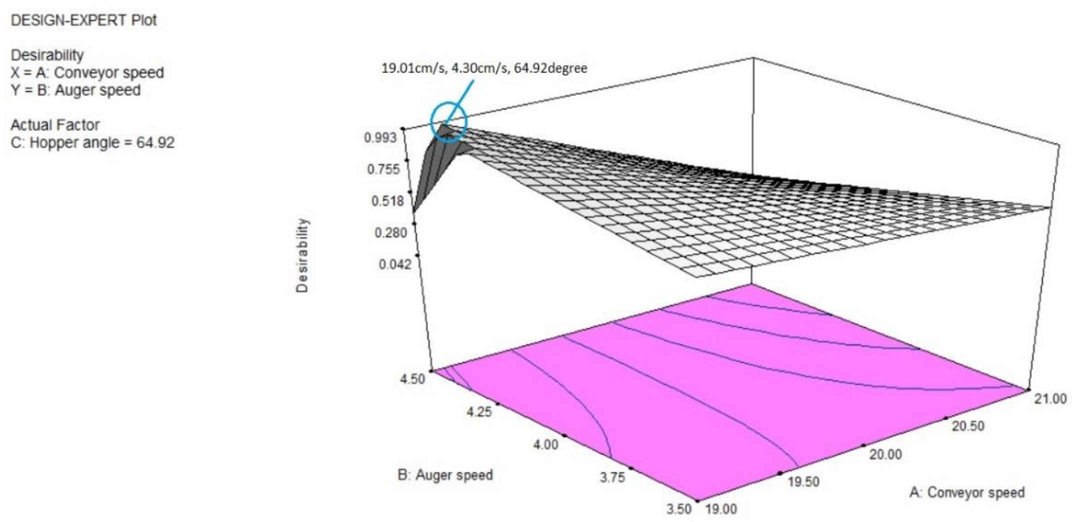


Figure 5. Surface graph shows the numerical optimization of the parameters for volume 2873cm^3.

For the second times of soil dispensing operation, the volume of 1180 cm^3 is required to cover the whole seeds in the nursery tray. The optimal value of the operating conveyor speed, auger speed and angle of hopper should be set at 20.96 cm/s, 4.37 cm/s and 51.77°, respectively, to achieve the volume of 1180 cm^3 discharged soil. Figure 6 shows the surface graph of the numerical optimization for target volume of 1180 cm^3. the nearest solution of optimized parameter to set up the machine is 21.0 cm/s, 4.3 cm/s and 50° for the conveyor speed, auger speed and angle of hopper respectively. These tested parameters shall then produce an output of 1190 cm^3.

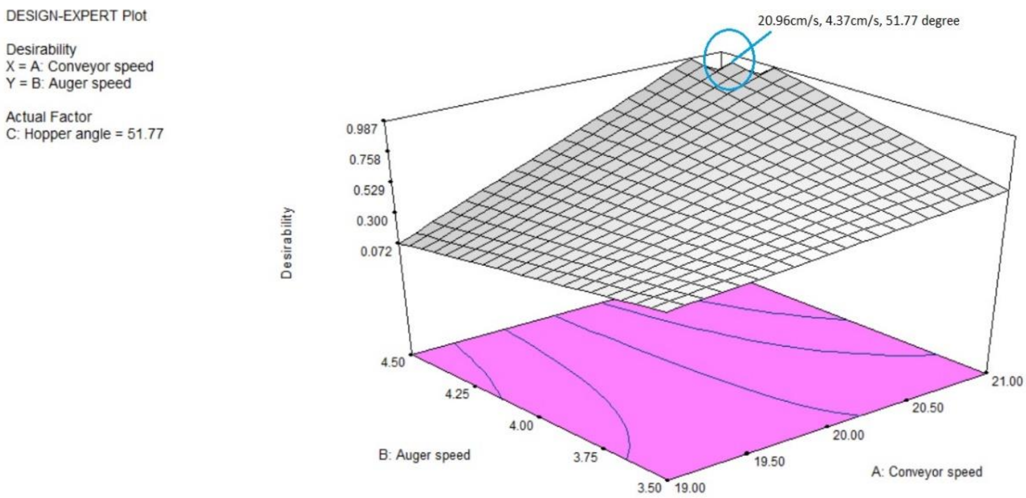


Figure 6. Surface graph shows the numerical optimization of the parameters for volume 1180 cm^3.

From the optimization analysis, it can be concluded that to discharge 2912 cm^3 of soil to fill the empty nursery tray requires lower conveyor speed, higher auger speed and hopper angle compared to discharge 1190 cm^3 to cover the seed on the compacted soil. Reducing the conveyor speed allows longer time for the soil to discharge into the nursery tray, while increasing the auger speed allows, more volume of soil to discharge from the hopper. The angle of hopper also contributes to the volume of soil discharge. Thus, the bigger the angle, the highest the volume of soil could be dispensed.

3.4 Performance of the Soil Dispensing Machine

The performance of the machine is faster than manual activity on soil filling into the nursery tray. The continuous operation test indicated that the machine could achieve soil filling of nursery tray at an average time of 30 seconds and results in a complete process on seeding in one minute. Manual filling of the soil into the nursery tray took about three minutes to complete the cells and the whole seeding process took more than five minutes to complete the nursery tray.

The optimized soil-dispensing machine has alleviated the time consumption problem and trouble in filling soil and sowing small seeds into the continuous semi-automatic seeding system. The machine can provide high productivity and lower operating and labour cost compared to manual sowing operation.

4. Conclusions

The results clearly indicate that conveyor speed, auger speed and hopper angle can highly impact the volume of soil discharged from the soil-dispenser. The model is significant with *p*-value of <0.0001. Conveyor speed, auger speed and hopper angle were significant on the volume of soil dispensed with both speeds shows a *p*-value of <0.0001, while hopper angle shows *p*-value equal to 0.00112. The combination of both speeds greatly affected the response with *p*-value <0.0001. There is no interaction between each speed and the hopper angle.

From optimization analysis, the operating conveyor speed, auger speed and angle of hopper should be set at 19.0 cm/s, 4.5 cm/s and 65° to discharge 2912 cm^3 soil. In order to cover seed of the compacted soil, 1190 cm^3 soil is required, thus parameters should be set at 21 cm/s, 4.3 cm/s and 50° with respect to conveyor speed, auger speed and hopper angle. The result shows that the machine can completely fill the nursery tray with soil and seed within one min per tray compared to manual process that took five min to complete the whole seeding process.

Conflicts of Interest: The authors declare no conflict of interest, and also the funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

Daniel, K. F., & Peter, J. G. (2012). Open-source hardware is a low-cost alternative for scientific instrumentation and research. *Modern Instrumentation*, *1*, 8–20.

DOA. (2016). *Pelan strategik jabatan pertanian 2016–2020.* Retrieved on January 10, 2020 from http://www.doa.gov.my/index/resources/aktiviti_sumber/sumber_awam/penerbitan/pelan_strategik_doa_ 2016_2020.pdf

DOA. (2019). *Booklet statistik tanaman 2019 (sub-sektor tanaman makanan), Jabatan Pertanian Malaysia*. Retrived on December 15, 2019 from http://www.doa.gov.my/index/resources/aktiviti_sumber/sumber_awam/maklumat_pertanian/perangkaan_tanaman/booklet_statistik_tanaman_2019.pdf

Hafidha, A., Mohd Fazly, M., Mohd Taufik, A., *et al*. (2020). Performance evaluation of a seed dispenser for sowing seed into nursery tray. *ASM Science Journal, 13*(4), *27*–35.

Jarimopas, B., & Rattanadat, N. (2007). Development of a young coconut fruit trimming machine. *Journal of Food Engineering, 79*(3), 752–757. doi: https://doi.org/10.1016/j.jfoodeng.2006.01.082

Louis, L. (2018). Working principle of arduino and using it as a tool for study and research. *International Journal of Control, Automation, Communication and Systems, 1*(2), 21–29. doi: https://doi.org/10.5121/ijcacs.2016.1203

Luna, T., Dumroese, W. K., & Kasten, R. (2009). *Seed Germination and Sowing Options; Nursery Manual for Native Plants: A Guide for Tribal Nurseries: Nursery management*. Agriculture Handbook, U.S. Department of Agriculture. 1, 133–151

Muthamil, M. C. K., Thankamani, S. J. K., Annamalai, *et al*. (2015). Design and development of power-operated continuous-run potting machine for seedling-nursery. *Indian Journal of Agricultural Sciences, 85*(6), 817–820.

MITI (2015). *Laporan Kementerian Perdagangan Antarabangsa dan Industri (MITI).* Retrived on December 15, 2019 from http://www.miti.gov.my/miti/resources/MITI_Report_2015- 5.pdf

Pandiyaraj, P., Kumar, Y. R., Vijayakumar, S., *et al*. (2017). Modern nursery raising systems in vegetables. *International Journal of Agriculture Sciences, 9*(52), 4889–4892

Parmenter, J., Jensen, A. N., & Chiu, S. (2014). Smart irrigation controller. *Electro/information technology (EIT), 2014 IEEE International Conference*, 394–398. doi: https://doi.org/10.1109/EIT.2014.6871796

Prajakta, H., Nimish J., Pranav K., Amol, M.K. (2015). Automatic weighing and packaging machine. *International Research Journal of Engineering and Technology, 6*(5), 2129–2138. doi: https://doi.org/10.1016/j.isatra.2013.05.006

Space, J. C., & Balmer, W. E. (1977). *Minimum cost calculation for container planting.* USDA Forest Service. South Eastern Area State and Private Forestry. Retrieved on March 12, 2020 from https://www.fs.fed.us/psw/publications/documents/psw_gtr200/psw_gtr200guide.pdf

Szirtes, T., & Rozsa, P. (2007). *Forms of Dimensionless Relations*: *Applied Dimensional Analysis and Modeling,* Chapter 13 (2nd ed.). Elsevier Inc., 377

Yeoh, K. C. (1988). Mechanical transplanting of vegetable. *Teknologi Sayur-Sayuran, 4*, 33–38.

ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

Original Research Article

Fertiliser Concentration Detection by Means of Hydroponic Root Zone Cooling System on Roof Top Garden for *Lactuca sativa* Cultivation

Ahmad Syafik Suraidi Sulaiman[1], Ahmad Safuan Bujang[.1,] Seri Aishah Hassim[1], Muhammad Shahiran Affief Azman[1]

[1]Smart and Precision Agriculture Programme, Engineering Research Centre, MARDI Headquarters Serdang, 43400 Selangor, Malaysia

*Corresponding author: Ahmad Syafik Suraidi Bin Sulaiman. Smart and Precision Agriculture Programme, Engineering Research Centre, MARDI Headquarters Serdang, 43400 Selangor, Malaysia; syafik@mardi.gov.my

Abstract: Nutrient film technique (NFT) is a hydroponic technique, whereby a very shallow stream of water containing all the dissolved nutrients required for plant growth is re-circulated past the bare roots of plants in a watertight gully, also known as channels. Problems commonly associated with NFT hydroponic system such as water temperature, can easily increase under direct sunlight in the tropics region, especially in the roof top garden, that can affect the quality of fertiliser used to cultivate the crop. Therefore, a study to develop a cooling system for NFT hydroponic technique is significant to control the water-dissolved nutrient temperatures suitable for crop growth. This paper highlights the studies conducted on fertiliser concentration distribution in the NFT hydroponics root zone cooling (HRZC) system for *Lactuca sativa* cultivation on roof top garden under the influence of water temperature, air temperature, relative humidity and ambient carbon dioxide. The fertiliser concentration distribution is determined by taking the electric conductivity (EC) reading of the fertiliser flowing along the NFT channels within three targeted points (left, middle, right) atfour different height levels of the cultivation beneath the roof top garden. The EC readings of the fertiliser remained steady, except for the tank along the levels from left, middle and right locations ranging from 1.64–1.66 µS. The water temperature, air temperature, relative humidity and ambient carbon dioxide fluctuated along these three points ranging from 20.50–22.80°C, 31.39–32.23°C, 67.06–68.65%, and 459.39–472.13 ppm, respectively. It was found that under the influence of those environment parameters and NFT root zone cooling system with different level and height, the fertiliser concentration distribution from point to point of data taken is not significantly different along the NFT channels. This finding is significant that integration of NFT root zone cooling system is an alternative to *Lactuca sativa* cultivation on roof top garden, despite the affecting surrounding temperature that may affect the quality and quantity of fertiliser and crops cultivation. This technique can be extended for the cultivation of other hydroponic vegetables, rice and flowers and promote the culture of roof top farming in the society to avoid the highly polluted soil on the ground environment that may bioaccumulate into the plant system that may ended up as a health threat to fellow consumers.

Keywords: fertiliser concentration; NFT hydroponic; root zone cooling; roof top garden; environmental parameters

Received: 27th October 2020

Accepted: 27th November 2020

Available Online: 11th December 2020

Citation: Sulaiman ASS, Bujang AS, Hashim SA, *et al*. Fertiliser concentration detection by means of hydroponic root zone cooling system on roof top garden for *Lactuca sativa* cultivation. Adv Agri Food Res J 2020; 1(2): a0000144. https://doi.org/10.36877/aafrj.a0000144

1. Introduction

Malaysia Agriculture Research and Development Institute (MARDI) has developed several cooling techniques in the greenhouse to increase the production of the temperate crop in the lowland. Research has been done to explore the alternative technology of cooling such as root zone cooling system, misting fan, evaporative pad and ventilation fan which can reduce the production cost (Ahmad Syafik *et al.*, 2010). This root zone cooling system can be adapted to the hydroponics cultivation method, which enables the water-dissolved nutrient temperature to be controlled. It was reported that the effect of root zone temperature is greater on root growth especially in the early stage of crop development (Mohammud *et al.*, 2012).

Extreme root zone temperature manipulation can cause excessive vegetative growth, flower abscission and poor fruit set. Thus, it is important to consider the crop requirements before planning for cooling technique (Mat Sharif, 2006). In this study, the hydroponic root zone cooling (HRZC) system was developed to cultivate high-value vegetables in tropics and to determine the effects of HRZC on crops growth and yields. Among the many varieties of high-value vegetables in Malaysia, Lettuce, scientifically named as *Lactuca sativa* varieties has been chosen as a selected vegetable in this study due to its affordable price in Malaysian markets, which is between RM 6/kg and RM 8/kg. Moreover, *Lactuca sativa* also known and popular because it can be grown easily with the hydroponics system besides having simple maintenance procedure.

The hydroponic root zone cooling system includes the chiller, cooling water pump, and hydroponic growing container. Among these devices, the chiller consumes most power of the HRZC system. The consumed energy is related to the loading of the system and it is necessary to determine the precise minimum power of the chiller to be used in order to reduce the production cost. There were several literatures discussing how to optimise the chiller loading, Braun *et al.* (1989) proposed the equal loading distribution (ELD) method. This method was established under the same operating characteristic of the chiller. Due to the different operating characteristic of the chiller, Braun *et al.* suggested that the power consumption of the chiller was correlated with load of air conditioner, cooling water return temperatureand chiller water supply temperature. The fertiliser concentration (EC) distribution studies on the NFT hydroponics root zone cooling (HRZC) system for *Lactuca sativa* cultivation on roof top garden proven to be highly influenced by water temperature, air temperature, relative humidity (RH) and ambient carbon dioxide (CO_2) was investigated.

The objective of the study is to evaluate the HRZC system performance in distributing and controlling water-dissolved nutrient temperatures to meet crop-root requirement needs.

2. Materials and Methods

2.1 Hydroponics Root Zone Cooling System Development

The study was conducted at Engineering Research Centre, Malaysian Agricultural Research and Development Institute (MARDI) in Serdang, Selangor, Malaysia with latitude N 2° 59’ 51.4392”, longitude E 101° 41’ 26.2284” and 37.8 m above sea level (Diyana, 2009). HRZC was developed by the integration of 1 HP chiller system that can control the water-dissolved nutrient temperature inside the NFT channels (Figure 1). The water-dissolved nutrient was chilled till 10°C and flowed using a 0.5 HP water pump to the NFT channels, which was 10 m long and vertically arranged at 4 m long each level at the wall of the roof top garden structure. The water-dissolved nutrient temperature inside the 10 m length of the NFT channels at different heights levels was controlled between 15–25°C using a pipe valve and water with velocities between 5–10 m^3/s. The chiller was switched on for 12 hours from 7.00 a.m. in the morning till 7.00 p.m. in the evening.

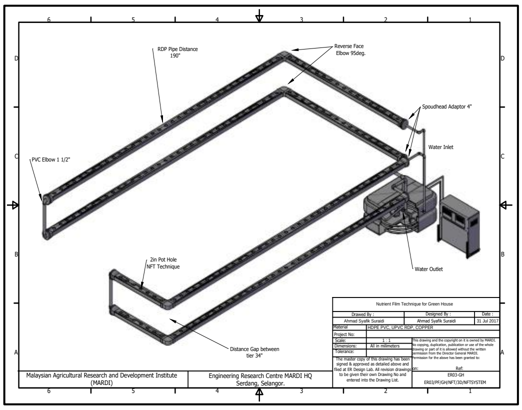


Figure 1. Systems schematic drawing.

2.2 Lactuca sativa Cultivations

Lactuca sativa was planted in a Nutrient Film Technique (NFT) hydroponics channels of 0.2 m wide, 0.1 m thick and 10 m long at each four levels that were vertically arranged on the wall of the roof top garden structure. The water level inside the growing NFT channel was 0.8 m deep, which can be reached by the crop roots. The crop spacing was 0.1 m, and for 10 m long of growing NFT channel that can accommodate near 300 crops. *Lactuca sativa* was transplanted under the roof top garden after three weeks of seeding and germination in the nursery. The crops were transplanted and grow inside the structure for three weeks before being harvested.

2.3 Data Collection

The readings of water-dissolved nutrient EC and temperature for 10 points i.e. from H1.1 to H1.10 along the NFT channels at different heights of cultivation under the roof top garden were collected for four weeks between 8.00 a.m. and 5.00 p.m. in order to determine the fertiliser concentration distribution along the growing NFT channels. The ambient temperature, relative humidity (RH) and carbon dioxide reading was also collected at the same interval and time to study the correlation between the ambient parameters and fertiliser concentration distribution temperature long the NFT channels under the roof top garden cultivation.

3. Results and Discussions

3.1 Effect of Level on the Environmental Parameters

Table 1 shows the EC, fertiliser temperature (T_{water}) and environmental parameters (T_{air}, RH, CO_2) subjected to three-point locations for four levels of *Lactuca sativa* cultivation at different height beneath the roof top garden. The EC readings were not significantly different from point to point along the growing NFT channels with different height of crop cultivation except for the water tank, ranging from 1.64–1.66 µS. The water temperature fluctuated along the levels for left, middle and right locations ranging from 20.50–22.80°C, respectively. The air temperature fluctuated along the levels for left, middle and right locations ranging from 31.39–32.23°C, respectively. The RH fluctuated along the levels for left, middle and right locations ranging from 67.11–71.06%. On the other hand, the carbon dioxide fluctuated along the levels for left, middle and right locations ranging from 459.39–472.13 ppm, respectively. In this case, all parameters (EC, water temperature, air temperature, RH and CO_2) were not significantly different with the level and point location.

Table 1. Environmental parameters subjected with three point locations at different levels for reticulation system.

Level	Parameter	Point location		
		Left	Middle	Right
A1	EC	1.65±0.01[a]	1.65±0.01[a]	1.64±0.01[a]
	T_{water}	20.66±0.99[a]	20.83±1.05[a]	20.50±1.04[a]
	T_{air}	31.85±0.74[a]	31.79±0.67[a]	31.50±0.76[a]
	RH	69.47±2.41[a]	68.83±2.24[a]	70.03±2.33[a]
	CO_2	468.13±4.40[a]	458.00±3.31[a]	460.00±3.53[a]
A2	EC	1.66±0.01[a]	1.66±0.01[a]	1.65±0.01[a]
	T_{water}	20.83±1.00[a]	20.94±1.02[a]	21.31±1.01[a]
	T_{air}	32.18±0.74[a]	31.99±0.66[a]	31.96±0.75[a]
	RH	67.11±2.40[a]	68.89±2.19[a]	69.16±2.21[a]
	CO_2	464.25±3.82[a]	468.38±3.55[a]	468.63±3.73[a]
B1	EC	1.65±0.01[a]	1.65±0.01[a]	1.66±0.01[a]
	T_{water}	20.98±1.00[a]	21.08±0.95[a]	21.64±0.94[a]

Level	Parameter	Point location		
		Left	Middle	Right
	T_{air}	31.71±0.75[a]	31.76±0.66[a]	31.46±0.75[a]
	RH	69.43±2.43[a]	69.96±2.15[a]	70.63±2.29[a]
	CO_2	465.25±3.56[a]	462.50±3.44[a]	459.38±4.02[a]
B2	EC	1.65±0.01[a]	1.66±0.01[a]	1.65±0.01[a]
	T_{water}	21.41±0.91[a]	21.48±0.87[a]	21.35±0.87[a]
	T_{air}	32.19±0.74[a]	31.91±0.66[a]	31.83±0.75[a]
	RH	68.16±2.38[a]	68.98±2.15[a]	69.24±2.34[a]
	CO_2	464.88±2.95[a]	470.63±3.81[a]	466.50±3.59[a]
C1	EC	1.65±0.01[a]	1.65±0.01[a]	1.65±0.01[a]
	T_{water}	21.80±1.05[b]	21.88±1.03[b]	21.78±1.03[b]
	T_{air}	31.60±1.11[a]	31.63±0.96[a]	31.45±0.96[a]
	RH	69.48±3.84[a]	70.04±3.31[a]	71.06±3.13[a]
	CO_2	464.50±3.48[a]	465.63±4.47[a]	465.38±5.47[a]
C2	EC	1.65±0.01[a]	1.65±0.01[a]	1.65±0.01[a]
	T_{water}	21.60±1.03[b]	21.86±0.99[b]	22.44±1.00[b]
	T_{air}	32.20±1.09[a]	31.91±0.96[a]	31.63±0.97[a]
	RH	67.24±3.75[a]	69.18±3.39[a]	69.09±3.20[a]
	CO_2	462.25±3.17[a]	469.13±0.81[a]	466.63±5.44[a]
D1	EC	1.65±0.01[a]	1.65±0.01[a]	1.65±0.01[a]
	T_{water}	21.95±0.91[a]	22.51±0.87[a]	22.61±0.87[a]
	T_{air}	31.43±0.74[a]	31.52±0.66[a]	31.39±0.75[a]
	RH	68.88±2.38[a]	70.15±2.15[a]	70.61±2.34[a]
	CO_2	464.00±2.95[a]	472.13±3.81[a]	462.25±3.59[a]
D2	EC	1.65±0.01[a]	1.66±0.01[a]	1.65±0.01[a]
	T_{water}	22.80±1.05[b]	22.68±1.03[b]	22.58±1.03[b]
	T_{air}	32.23±1.11[a]	32.19±0.96[a]	31.60±0.96[a]
	RH	67.36±3.84[a]	68.13±3.31[a]	68.91±3.13[a]
	CO_2	463.63±3.48[a]	466.75±4.47[a]	466.50±5.47[a]
Tank	EC	1.53±0.03[a]	1.53±0.03[a]	1.53±0.03[a]
	T_{water}	22.45±0.85[b]	22.45±0.85[b]	22.45±0.85[b]

* Abbreviation of variables were EC: EC, T_{water}: water temperature, T_{air}: air temperature, RH: relative humidity, CO_2: carbon dioxide. Different letters within the same column indicate statistical difference by the Tukey's test, $P < 0.05$ for nine levels.

Furthermore, Chen *et al.* (2016) reported the growth of Boston lettuce and coral lettuce for germination with the nutrient solution circulating between the planting beds and storage tank with a pump in order to maintain the uniformity of the nutrient intake. An efficient hydroponic system governed by environmental factors that affected the crop growth, which was light intensity, EC, pH, temperature, humidity, CO_2 and others. (Amado *et al.*, 2016; Shamshiri *et al.*, 2018). In previous work, Hasegawa *et al.* (2014) reported the changes in CO_2 and temperature in relation to the growth of the plant samples. It was observed that plants cultivated at low temperature showed high photosynthesis rates compared to the plants cultivated at high temperature. Therefore, it can be noted that temperature was vital in the plant growth and yield. Tamura *et al.* (2018) studied the phytochemical accumulation and yield of leaf lettuce in conjunction with various growth factors including temperature, EC and light intensity, in order to determine the efficiency of hydroponic system. From the findings, the ambient temperature at the roof top garden at all three points are within accepted value for *Lactuca sativa* cultivation, once the NFT channel is equipped with Hydroponic Root Zone Cooling system.

3.2 Effect of Time on the Environmental Parameters

Table 2 shows the environmental parameters subjected with three point locations at different time for the growing NFT channel. The fertiliser EC readings were not significantly different along the growing NFT channel for left, middle and right locations ranging from 1.58–1.67 µS. But the fertilizer EC readings are significantly different for morning and afternoon. The optimal fertiliser EC decreased as temperature increased. The water temperature almost maintained the same throughout the recorded time for left, middle and right locations ranging from 18.79–24.73°C. On the contrary, the air temperature slightly decreased along the time for left, middle and right locations ranging from 24.82–25.94°C. The RH increased significantly along the time for left, middle and right locations ranging from 53.06–58.16%. The carbon dioxide slightly increased in the morning and fluctuated in the afternoon throughout the time for left, middle and right locations ranging from 361.60–381.45 ppm, respectively. It can be noted that all parameters can be influenced with the time as the temperature surrounding NFT channel differs as they are correlated to one another.

Table 2. Environmental parameters subjected with three point locations at different time for reticulation system.

Time	**Parameter**	**Point location**		
		Left	**Middle**	**Right**
Morning	EC	1.58±0.01[b]	1.59±0.01[b]	1.59±0.01[b]
	T_{water}	18.79±0.55[b]	18.92±0.53[b]	19.09±0.54[b]
	T_{air}	25.14±0.41[a]	25.14±0.37[a]	24.82±0.43[a]
	RH	57.06±1.46[a]	57.57±1.32[a]	58.16±1.47[a]
	CO_2	379.48±1.55[a]	380.38±1.94[a]	381.45±2.38[a]
Afternoon	EC	1.67±0.01[a]	1.67±0.01[a]	1.67±0.01[a]
	T_{water}	24.60±0.51[a]	24.71±0.51[a]	24.73±0.51[a]
	T_{air}	25.94±0.52[a]	25.81±0.46[a]	25.75±0.50[a]
	RH	52.37±1.58[a]	53.06±1.43[a]	53.58±1.39[a]
	CO_2	363.90±2.51[b]	366.25±2.04[b]	361.60±1.39[b]

* Abbreviation of variables were EC: EC, T_{water}: water temperature, T_{air}: air temperature, RH: relative humidity, CO_2: carbon dioxide. Different letters within the same column indicate statistical difference by the Tukey's test, $P < 0.05$ at two different time periods.

3.3 Pearson Correlation Between EC, Temperature of Fertiliser Distribution and Environment Parameters

The Pearson correlation between EC, temperature of fertiliser distribution and environmental parameters *in the*NFT channel at the roof top garden is presented in Table 3. The results demonstrated there was a strong correlationship between environmental parameters and fertiliser concentration parameters. Based on the result, the CO_2 was highly correlated to the air temperature (r = 0.953). Among the environmental parameters values, the highest correlation was recorded between air temperature and water temperature (r = 0.965). These observations showed the discrepancy in all environmental parameters that exhibited the importance of these parameters in affecting the quality of the fertiliser concentration for *Lactuca sativa* cultivation under the roof top garden structure, which was directly exposed with the fluctuated weather or ambient.

Table 3. Pearson correlation coefficients between environmental factors and fertilizer concentration parameters for growing NFT channel under roof top garden.

	EC	**Twater**	**Tair**	**RH**
T_{water}	0.205			
T_{air}	0.200	**0.965***		
RH	0.347*	-0.195	0.817*	
CO_2	0.470*	-0.159	**0.953***	0.944*

Abbreviation of variables were EC: EC, T_{water}: water temperature, T_{air}: air temperature, RH: relative humidity, CO_2: carbon dioxide. * The means are significant at $P < 0.05$.

The findings from this research such as Electrical Conductivity from fertilisers present in the NFT channel, temperature of fertilizer distribution and environmental parameters namely, water temperature, air temperature, relative humidity and carbon dioxide are strongly correlated which have proven the validity of the result and accuracy with the previous literatures in the parameters required for crop quality and growth in hydroponic technique, especially at the roof top garden. In a research conducted by Baek *et al.* (2016), temperature and air flow stagnation were important for the plant cultivation in order to determine the crop quality and growth in a hydroponic system. Tamura *et al.* (2018) suggested that the growth and quality of vegetables cultivated using the hydroponic technique was influenced by the temperature, humidity, light source and fertiliser. Moreover, Lee *et al.* (2019) reported the growth of crisp-head lettuce by comparing the type of cultivar, temperature and light intensity. It was revealed that the growth of crisp-head lettuce was significantly influenced by temperature in low light intensity condition for all type of cultivars. In a similar study, Lee *et al.* (2013) investigated the productivity and quality of lettuce under artificial plant factory, indicating that low temperature conditions were applied to avoid tip-burn due to reduction of photosynthetic rates.

4. Conclusion

From the study, it was found that the fertiliser concentration distribution for growing NFT channels under the roof top garden for *Lactuca sativa* cultivations are not significantly different from different point of data taken either horizontally or vertically. The fertiliser EC and temperature reading were significantly different from time to time, which can be seen during the data taken in the morning and in the afternoon. The environmental parameters such as ambient temperature, RH and CO_2 have a significant correlation on EC and temperatures of fertilizer distribution under the roof top garden. Thus, this study provides a range of information, which could be required for the evaluation of NFT root zone cooling system for crop cultivation under the roof top garden.

Funding: This research was supported by RM11 Development project under Ministry of Agriculture, Malaysia (MOA).

Acknowledgments: The researchers would like to thank the staffs of Engineering Research Centre MARDI for their assistance.

Conflicts of Interest: The authors declare no conflict of interest, and also the funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

Ahmad Syafik, S.S., Mohd Faisal, H., & Mohd Hafiz, H. (2010). *Effect of growth media cooling using chilled water system for tomato growth to the temperature and humidity under controlled environment structures in lowland.* In Malaysia Science and Technology Conference. Petaling Jaya, Selangor, Malaysia.

Amado, T. M., Valenzuela, I. C., & Orillo, J. W. F. (2016). Horticulture of lettuce (*Lactuvasativa* L.) using red and blue LED with pulse lighting treatment and temperature control in snap hydroponics setup. *Jurnal Teknologi*, *78*, 67–71.

Baek, M. S., Kwon, S. Y., & Lim, J. H. (2016). Improvement of the crop growth rate in plant factory by promoting air flow inside the cultivation. *International Journal of Smart Home*, *10*(2), 63–74.

Chen, W. T., Yeh, Y. H. F., Liu, T. Y., *et al*. (2016). An automated and continuous plant weight measurement system for plant factory. *Frontiers in Plant Science*, *7*, 1–9.

Hasegawa, Y., Yamanaka, G., Ando, K., *et al*. (2014). Ambient temperature effects on evaluation of plant physiological activity using plant bioelectric potential. *Sensors and Materials*, *26*(7), 461–470.

J.E Braun, S.A. Klein, J.W Mitcell, *et al*. (1989). Application of optimal control to chilled water systems without storage. *ASHRAE transaction*, *95*(1), 663–675.

Lee, J. G., Choi, C. S., Jang, Y. A., *et al*. (2013). Effects of air temperature and air flow rate control on the tipburn occurrence of leaf lettuce in a closed-type plant factory system. *Horticulture Environment and Biotechnology*, *54*(4), 303–310.

Lee, R. J., Bhandari, S. R., Lee, G., *et al*. (2019). Optimisation of temperature and light, and cultivar selection for the production of high-quality head lettuce in a closed-type plant factory. *Horticulture Environment and Biotechnology*, *60*(2), 207–216.

Mat Sharif, I. (2006). Design and development of fully controlled environment greenhouse for the production of selected temperate crops in lowland tropics. *In International Symposium on Greenhouse, Environmental Controls and In-*

house Mechanisation for Crop Production in Tropics and Sub-tropics. Cameron Highlands: Acta Horticulturae (ISHS), 710, 127–134.

Mohammud, C.H., Illias, M.K., Zaulia, O., *et al*. (2012). Effect of Rhizosphere cooling on tomato crop performance under controlled environment structure. *In Malaysia International Conference on Trend Bioprocess Engineering (MICOTRIBE)*, 1–8.

Shamshiri, R. R., Kalantari, F., Ting, K. C., *et al*. (2018). Advances in greenhouse automation and controlled environment agriculture: A transition to plant factories and urban agriculture. *International Journal of Agricultural and Biological Engineering, 11*(1), 1–22.

Tamura, Y., Mori, T., Nakabayashi, R., *et al* (2018). Metabolomic evaluation of the quality of leaf lettuce grown in practical plant factory to capture metabolite signature. *Frontiers in Plant Science, 9*, 1–11.

ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

Original Research Article

Utilization of Sweet Potato in Development of Boba

Anis Syafikah Mohd Yusof[1], Zanariah Mohd Dom[1]*, Rosnah Shamsudin[1].

[1]Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

*Corresponding author: Zanariah Mohd Dom, Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia; nana@upm.edu.my

Abstract: Commercial substance in a drink, known as boba or bubble tea, is extensively consumed by all generations from children to the elders and various societies. Boba, which are known as tapioca pearls are originally made up of tapioca starch and then served with milk tea. This sweet potato pearl has lower calories than tapioca, which can give benefits to the consumer since it has a lot of nutritional value such as high β-carotene, rich in vitamin C, high value of dietary fiber, antioxidants level and protein content. Therefore, in this research, sweet potato flours were prepared in three varieties to make boba pearls, where: (1) sweet potato flour was substituted with 50% sweet potato flour and 50% tapioca flour, (2) 100% sweet potato flour added with fish gelatin; (3) 100% sweet potato flour added with bovine gelatins. These substitutions affected the physicochemical properties of the mixture such as pH and textural properties chewiness and chewing energy. According to the result, boba containing fish gelatin showed lower chewing energy with 217.678±3.8 g of chewiness and 4136.833±39.1 g.%, therefore suitable for all level of generations. Through this finding, boba lovers are able to consume boba safely without any possible choking incidences and indigestion as claimed by other critics of boba consumption.

Keywords: boba; sweet potato; tapioca pearls; beverages

Received: 11th November 2020

Accepted: 12 December 2020

Available Online: 21st December 2020

Citation: Mohd Yusof AS, Mohd Dom Z, Shamsudin R. Utilization of sweet potato in development of boba. Adv Agri Food Res J 2020; 1(2): a0000149. https://doi.org/10.36877/aafrj.a0000149

1. Introduction

Boba, known as tapioca balls or tapioca pearls are originally discovered from Taiwan in the early 1980s and gained by removing starch from tapioca. But lately, there has been an ascent in the trend, where people from all generations feel the “addiction” and “pleasure” when chewing a soft texture pearl shape of boba in their mouth. Commonly, bobas will be served with milk tea which known as Bubble Milk Tea (BMT). BMT become one of young generations favorite drinks as abundant franchises with different brands were opened all over Malaysia.

Sweet potato (*Ipomoea batatas*) is perennial shrubs that originate in the tropics of ideal continent of America, which is planted in sandy soils or soil that contain high absorption of water (Mohd Zahari *et al*., 2014). Sweet potato has the characteristics, which large in size, starchy, originally sweet-tasting and tuberous root where their shoots or young leaves usually can be eaten as greens (Williams & Ammerman, 1968). Sweet potatoes were normally found in orange fleshed color that playing important roles in human health.

Sweet potato is important crop for developing countries by their growing period where this sweet potato required a short period of growing which usually in 90–120 days (Mohd Hanim *et. al*., 2014). Besides being one of the basic foods in certain country such as Soloman Islands, this sweet potato plays a very important roles in human diets, where they consist of high nutritional value. These nutritional qualities are mostly required and meeting nutritional need by humans such as carbohydrate, fiber, vitamin A and C and high protein contents (Mais & Brennan, 2008).

According to Mohd Hanim *et al*. (2014), in Malaysia, according to the tubers crop popular ranks, sweet potato is the second most popular next to tapioca and has been developed on a small scale since 17th century. It is usually being used as one of basic ingredients in producing snacks and commonly well known in traditional confectionery such as *onde-onde*, *bingka* and *keria*. Maleki (2001) stated that this sweet potato can be used as supplementary food for infants and can be compared to other cereal baby foods that usually contain wheat that may cause hypoallergenic effect to babies. This statement is supported by Sarmin *et al*. (2016) that added sweet potato as free-gluten content that contributes to allergic and digestion problems to the babies.

Sweet potato contains high nutritional value that can give many benefits to human being. Higher dietary fiber content of sweet potato as reported by Mohd Hanim *et al.* (2014), whereby consuming it can give huge impact on eaten food by reducing the rate of glucose breakdown and absorption. Besides, this huge impact helps to ensure the glucose level in body maintaining a normal blood sugar level and helps to facilitate a steady breakdown of carbohydrates (Brennan & Samyue, 2004).

Moreover, according to a study conducted by Aprianita *et al.* (2009), they found that sweet potato is suitable to be used in food products that require continuous thermal processing such as food for children and the elderly. This may due to the presence of high protein content that prolonged the starch swelling process and increase in velocity. Continuous thermal processing products are defined as products that undergo a process with combination of temperature and time required to eliminate a desired number of microorganisms from a food product continuously. For example, baby food products required continuous heating process to ensure microorganisms in food is killed and food products safe to be consumed.

In practicing a healthy lifestyle, the ingredients used to make boba, which is from tapioca can be replaced by using sweet potato. 60 grams of sweet potatoes can be converted into approximately 54 calories, which is lower than the calories in tapioca. Besides, the fiber content in sweet potato is insoluble that promotes insulin regulating the amount of sugar in blood of diabetes patients Another important benefits of utilizing sweet potato has moderate value of glycemic index, which is 54 that lies in medium GI, compared to tapioca that has value of 85, which falls into high GI value (Ebere *et al.*, 2017). This would benefit those existing patients and dieting patients to refrain from consuming food with lower glycemic index value and lower calories.

This study is aimed to develop a formulation of boba by using sweet potato and to investigate and compare the textural properties and sensory analysis of boba from mixture of sweet potato flour, tapioca flour and gelling agent.

2. Materials and Methods

2.1 Raw Materials

The sweet potato flour (Azuri, Malaysia) was purchased from a bakery shop located at Subang Jaya, while tapioca flour (Cap Kapal ABC, Malaysia) was bought from nearby supermarket. Fish and bovine gelatins were obtained from supplier (Phywon System Ingredient Sdn. Bhd., Malaysia).

2.2 Preparation of Boba

The sweet potato flour was mixed formulated with tapioca flour and gelatin, which function as gelling agent. The formulations of the mixture are shown in Table 1. There were three important steps in boba preparation.

Firstly, sweet potato flour, tapioca flour and gelatin powder were weighted into a bowl into three different flour mixture percentages. Then, 50 mL of filtered water was boiled inside a small size pot until it reached boiling point, 100^{o}C. Next, pour 13.2 mL of boiled water slowly, while stirring continuously by using a spoon until they started to stick together. Then, each flour-mixture was kneaded using hands to produce a thick dough.

The thick dough was rolled and cut into five mm long batons. The batons were rolled between palms to make a round shape bobas.

Finally, 200 mL of filtered water was boiled again in a medium size pot. The raw boba were placed slowly into the pot as the water boiled vigorously. The boba were stirred continuously until they were completely tender. The boba werecooked around 15 min to ensure the boba were fully cooked. Then, the cooked boba were strained by using a scoop and poured into a plate to let them cool off. The cooled boba pearls were then kept inside an airtight container and stored at room temperature until further process took place.

Table 1. Formulation of boba.

Sample	Formulation of boba mixture	Mass of sweet potato flour (SPF) (g)	Mass of tapioca flour (g)	Mass of fish gelatin (g)	Mass of bovine gelatin (g)
A	50 % SPF*	10.0	10.0	0.0	0.0
B	100 % SPF*	20.0	0.0	0.0	1.0
C	100 % SPF*	20.0	0.0	1.0	0.0
D	Commercial boba				

*SPF: sweet potato flour

2.3 Determination of pH Value

Determination of pH value was following the method by Ashogbon (2012). Each of different formulation ratio with total weight of five g was filled into a beaker and mixed with 20 mL of distilled water. The resulting suspension was stirred for five min and left to settle for ten min. The pH of the supernatant was measured by using a calibrated digital pH meter (PB-10, Sartorius, Germany) in triplicates, to reduce reading error.

2.4 Determination of Textural Properties

The textural properties were determined by using Exponent Software that was installed in a texture analyser (TA-XT plus, Stable Micro System Ltd, United Kingdom). Data such as chewiness, stiffness and chewing energy were determined by the installed software. The probe used to determine all the properties as mentioned above was SMS/Chen-Hoseney Dough Stickiness RiData. Each produced boba pearl was placed under the texture analyser to measure the listed properties, which are chewiness and chewing energy. For each test, five bobas with the same weight were chosen to be tested in triplicates.

2.5 Determination of Water Holding Capacity (WHC)

One g sample was added with 5 mL of distilled water and vortexed for one min to ensure the sample and water were mixed homogenously. Next, the mixtures were centrifuged for 10 min at 3000 g at room temperature in a centrifuge (Universal 320, Hettich Zentrifugen, Germany). The supernatant was then decanted carefully and the mass left in the tube was measured using the electronic balance. The water holding capacity was calculated using the formula below:

$$\text{Water holding capacity (WHC)} = \frac{(W_2 - W_1)}{W_0} \quad (1)$$

where W_0 is the weight of the sample; W_1 is the sum of weight of centrifuge tube and sample; W_2 is the sum of weight of centrifuge tube and sediments.

2.6 Sensory Analysis

Sensory analysis with 9-hedonic points analysis type was done for all the samples A, B and C prepared in the lab and sample D was bought from an online store. The analysis was conducted by the participation of ten un-trained panelists who were randomly selected among students at Faculty of Engineering, University Putra Malaysia. This analysis was carried out to analyze consumer's acceptability on several criteria such as appearance, texture, taste and chewiness. The analysis additionally asked the panelists on which test they like the most, why they like the chosen test and finally, will they consider to change their preferences to the sample they have chosen.

3. Results and Discussions

3.1 pH Value

Table 2. The pH value of formulation boba

Sample	pH
A	5.50 ± 0.025
B	5.71 ± 0.023
C	5.41 ± 0.005

Based on Table 2, the pH of three different formulations of sweet potato flours ranged from 5.41–5.71 were categorized as low acidic. Besides, this range of pH value is accepted as the common pH value of sweet potato flour is 5.6 pH as reported by Adeleke and Odedeji

(2010). Sample B was the lowest acidic as the present of bovine gelatin, which its pH value is categorized as alkaline as it undergoes alkaline hydrolysis. Sweet potato generally contains 37% of ascorbic acid as stated by the United States Department of Agriculture (USDA, 2012), therefore this might be the reason why sweet potato flours are slightly acidic. Adeleke and Odedeji (2010) stated that acidic products tend to have a longer shelf life as the food spoilage bacteria do not grow in acidic condition. This statement then is proven by Smith and Stratton (2007) claimed that a pH of 4.6 or lower, will not support the growth of Clostridium botulinum in food preservation that extends shelf- life of product to longer duration.

3.2 Chewiness and Energy Needed to Chew

Chewiness is the energy required to chew a solid food until it is ready for swallowing. Figure 1 and Figure 2 show the graph of chewiness, g and graph of energy needed to chew, g. % of four samples, which A represents 50% SPF and 50% tapioca flour, B represents 100% SPF with added of bovine gelatin, C represents 100% SPF with added of fish gelatin and D represents commercialized boba. Commercialized boba were compared to the formulated boba in three readings.

Sample C that was formulated using 100% SPF and added with fish gelatin shows the best result, where the chewiness value was 217.678±3.803 that give the lowest value compare to others result, hence it required the least energy to chew, 4136.833±39.08382. Samples A and B with chewiness value of 254.287±5.483 and 240.43±7.114, respectively, have almost same range of energy needed to chew, which lies between 4400–4600 g.%. Despite of the observed differences, samples A, B and C were better compared to sample D based on the tested parameters

According to Figure 2, the energy needed to chew for sample B and C, which combination of sweet potato and gelatin (i.e. bovine or fish gelatin), exhibited significant difference. The energy needed to chew for sample C was lower with value of 4100–4200 g.% compared to sample B, which required 4400–4600 g.%. Despite of adding the gelling agent to both samples (i.e. samples B and C), sample C with the addition of fish gelatin consume less chewing energy due to lower melting point than bovine gelatin. Lower melting point affects the energy to chew as when the gelatin exposed to heat, the gelatin started to spread makes the gelatin thinner and easily to mix homogenously with the flour.

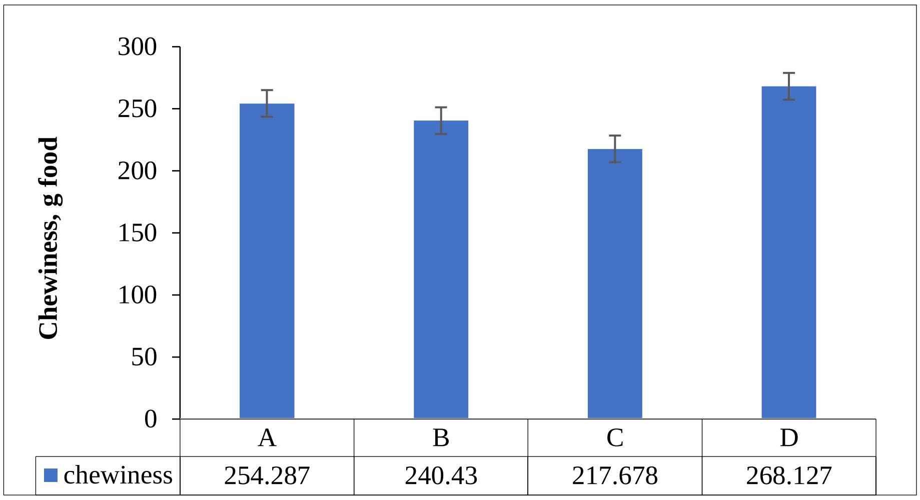


Figure 1. Chewiness of the sample.

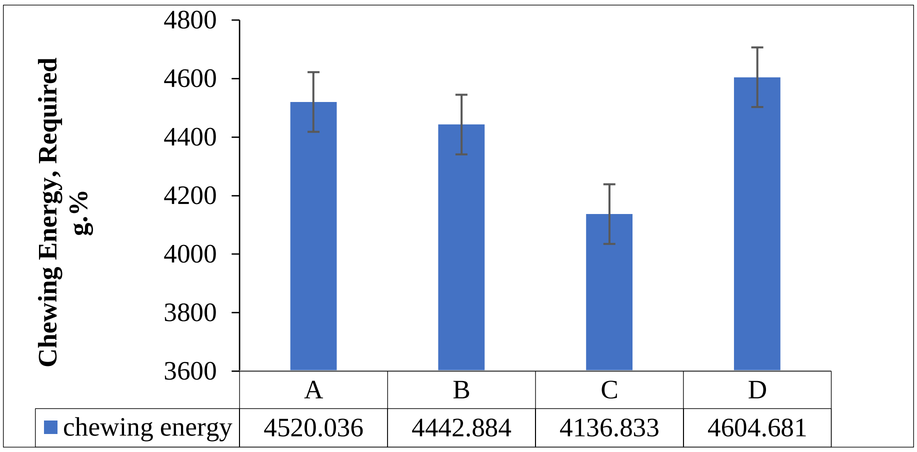


Figure 2. Energy needed to chew.

3.3 Water Holding Capacity (WHC)

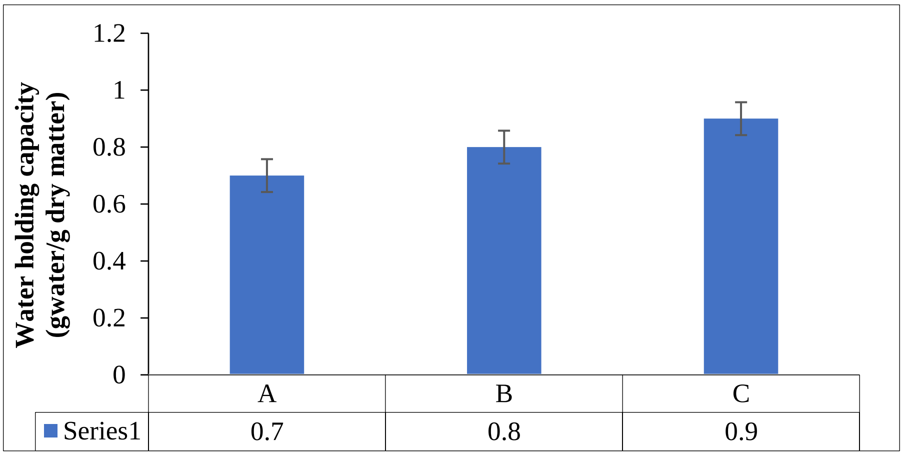


Figure 3. Water holding capacity (WHC) of different sample.

Figure 3 describes the water holding capacity of different samples at the same temperature, which in room temperature. The highest WHC was sample C with 0.9 g water/g dry matter, while sample A has the least water holding capacity, which is 0.7 g water/g dry matter.

According to International Starch Trading from Denmark, sweet potato contains higher amount of starch compared to tapioca. Therefore, contain higher amount of starch indicates higher amount of amylose and amylopectin content. Compared to tapioca, sweet potato has a little bit higher amount of amylose, which is 20%, while tapioca has 17% of amylose content. According to Liu (2005), starch gelatinization process started when the starch granules were exposed to heat in the presence of water that cause the molecular order to collapse within the starch producing irreversible changes. When the temperature of a suspension of starch granules in excess of water increases to the gelatinization temperature, the starch granule lost its bi-refringence and crystallinity, with concurrent swelling. This change is irreversible and called as gelatinization. The total gelatinization usually occurs over a temperature range (10–15°C).

3.4 Sensory Analysis

Table 3. Sensory evaluation of different formulation of boba.

Sample Labelled	Question based on appearance	Question based on taste	Question based on chewiness	Question on sample like the most
A	4.2	4.1	4.3	4.5
B	4.1	4.0	3.5	4.0
C	4.3	4.3	4.9	4.9
D	4.5	4.6	3.9	4.6

Table 3 shows the result of sensory evaluation obtained from 50 un-trained panelists. The results were measured using 5-point Linkert scale representing each question. The panelists were mostly in early adulthood categorized as boba lovers.

From the results obtained for questions based on "appearance" and "taste", sample D placed as the highest rank, while sample B ranked the lowest. The result may due to the way of brown sugar being coated to the boba. Since sample D was bought from online store, the raw boba received have already been coated and dried well with brown sugar resulted to nice taste and attractive appearance with glossy look. The taste of boba was influenced by the amount of brown sugar that is caramelized during cooking. Most of the panelists chose sample D due to high amount of brown sugar used, while sample B is made with lower amount of brown sugar for health purpose and to satisfy the needs of the elderly and babies.

For questions based on "chewiness" and "the sample they like the most", sample C hits the highest rank with 4.9 out of 5. Compared to sample D in term of chewiness, sample C is more accepted due to the present of gelling agent, which is fish gelatin. According to the result obtained, despite being loyal consumers of sample D, they chose sample C it is easier to chew and takes less energy to chew than other samples. In regards to the safety of consumers and its digestibility, the less chewy is the boba pearl, therefore, the higher chance of it to be ingested safely through the mouth until it reaches the guts. Therefore, sample C has been chosen as the best boba formulation that can be mass produced commercially to be marketed domestically and globally, as a health and comfort drink suitable for all ages (9-month baby to 75+ years old adult).

4. Conclusion

The result from this study signifies that the best formulation of mixture of sweet potato flour added with fish gelatin resulted to lower energy in chewing, therefore it is suitable for the youngest (age with partial teeth development) to the eldest generation in the society. The pH value of all samples tested in this study was low acidic, which can be one of benefits in longer shelf-life as bacteria that can spoil food is not able to grow in acidic condition. Sample C, which was made with formulation of sweet potato added with fish gelatin was ranked the highest, which were being preferred the most by all participated sensory panelists. Moreover, sweet potato has moderate value of glycemic index, which is 54 that lies in medium GI, compared to tapioca that has value of 85, which falls into high GI values (Ebere *et al.,* 2017). In the nutshell, this research has proven that sweet potato boba has many benefits than tapioca boba and can be safely consumed by all generations.

Acknowledgments: Authors are thankful to the laboratory technicians, Department of Processing and Food Engineering, Faculty of Engineering, for their considerable help to complete this research successfully.

Funding: This research was financially supported by Universiti Putra Malaysia, Serdang, Selangor, Malaysia. Project number GP-IPB/2018/9660301

Conflicts of Interest: The authors declare no conflict of interest, and also the funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

Aprianita, A., Purwandari, U., Watson, B., *et al*. (2009). Physico-chemical properties of flours and starches from selected commercial tubers available in Australia. *International Food Research Journal, 16*(4), 507–520.

Adeleke, R. O., & Odedeji, J. O. (2010). Functional properties of wheat and sweet potato flour blends. *Pakistan Journal of Nutrition, 9*(6), 535–538.

Ashogbon, A., & Akintayo, E. (2012). Morphological, functional and pasting properties of starches separated from rice cultivars grown in Nigeria. *International Food Research Journal, 19*(2), 665–671

Brennan, C., & Samyue, E. (2004). Evaluation of starch degradation and textural characteristics of dietary fiber enriched biscuits. *International Journal of Food Properties, 7*(3), 647–657.

Ebere, R.A., Imungi, J.K. & Kimani, V.N. (2017). Glycemic Indices of Cassava and Sweet Potatoes Consumed in Western Kenya. Food Science and Quality Management. ISSN 2224-6088 (Paper) ISSN 2225-0557 (Online). Vol.63, 2017

Liu, Q. (2005). Understanding starches and their role in foods. In S. W. Cui (Ed.), *Food Carbohydrates* (pp 309–355). United State of America: CRC Press.

Mais, A., & Brennan, C. S. (2008). Characterisation of flour, starch and fibre obtained from sweet potato (kumara) tubers, and their utilisation in biscuit production. *International Journal of Food Science and Technology, 43*(2), 373–379.

Maleki, S. J. (2001). The big eight food allergens. *Dietitian's Edge*, *57*, 60.

Mohd Hanim, A. B., Chin, N. L. & Yusof, Y. A. (2014). Physico-chemical and flowability characteristics of a new variety of Malaysian sweet potato, VitAto flour. *International Food Research Journal, 21*(5), 2099–2107.

Mohd Zahari, N. I., Ahmad, S. M. & Hassan, H. (2014). Penghasilan tepung pracampuran hasilan bakeri berasaskan ubi keledek VitAto (Development of premix flour for VitAto sweet potato based bakery products). 6, 9–16

Sarmin, S., Anvarali, M. N., Umar, N. A., *et al.* (2016). Complementary baby food from local sweet potato (VitAto). *Buletin Teknologi MARDI*, 9, 73–78

Smith, D. A., & Stratton, J. E. (2007). *Food preservation, safety and shelf life extension. Food processing entrepreneurs series.* University of Nebraska-Lincoln Extension. Retrieved from http://ianrpubs.unl.edu/live/g181 6/build/g1816.pdf.

United States Department of Agriculture (USDA) (2012). Household USDA food fact sheet. Retrieved from http://www.fns.usda.gov/sites/default/files/HHFSSWEET%20POTATOESFRESHDec%202012.pdf.

Williams, J. L., & Ammerman, G. R. (1968). Canning of stored sweet potatoes. *Mississippi Farm Research*, *31*(6).

ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

HH PUBLISHER

Original Research Article

Sweet Potato Peel Flour Applications in The Textural Quality of Waffle Ice Cream Cone and Other Food Products

Zanariah Mohd Dom[1]*, Nurul Atikah Mohd Zulkeple Amin[1], Roseliza Kadir Basha[1]

[1]Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

*Corresponding author: Zanariah Mat Dom, Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia; nana@upm.edu.my

Abstract: Sweet potatoes are nutritious vegetables commonly grown in Malaysia. However, its beneficial skins are mostly peeled and thrown away. The sweet potato peel has a slightly bitter taste with its good nutritional food value in producing healthy food products. In this study, sweet potato peel flour (SPPF) is added to the existing wheat flour in the formulation of ice cream waffle cones. The amount of wheat flour added in the mixture depends on the SPPF amount added. Preliminary study on the content of protein, moisture, crude fiber, protein, carbohydrate and fat were conducted and determined. Then, the SPPF was added based on the formulation of 5%, 10% and 15% addition to the wheat flour at 95%, 90% and 85%, respectively, in a batter mix formulation for the making of ice cream waffle cones. The control was made out of 100% wheat flour, in order to compare with the newly formulated ice cream waffle cones batter mixture. Substitution of SPPF has impacted the quality of waffle ice cream cone in regards to its physicochemical properties such as colour, odour, tensile strength and textural properties. As the results, waffle cones of SPPF had lower value of L*, a* and b*, which turned darker than a controlled sample. The 5% formulation of sweet potato peel flour (SPPF) resulted to the highest crispiness of the waffle cones. Tensile strength of fiber materials in sweet potato peels flour became stable and balanced with the cone structure. Overall SPPF formulated waffle cones have passed the physical analysis and food applications' requirements. As the SPPF have high value in water holding capacity, it can contribute to other food applications.

Keywords: sweet potato; sweet potato peel flour; waffle; sweet potato peel waffle cones; food application

Received: 11th November 2020

Accepted: 12th December 2020

Available Online: 30th December 2020

Citation: Mohd Dom Z, Mohd Zulkeple Amin NA, Kadir Basha R. Sweet potato peel flour applications in the textural quality of waffle ice cream cone and other food products. Adv Agri Food Res J 2020; 1(2): a0000150. https://doi.org/10.36877/aafrj.a0000150

1. Introduction

Sweet potato (*Ipomoea batatas*) is a dicotyledonous plant that belongs to morning-glory family, Convolvulaceae. It is widely grown throughout the tropics and warm temperature regions of the world. It is very valuable because of its short growing period for 90 days to 120 days, which is important crop for the developing countries (Mohd Hanim *et al*., 2014). Sweet potato is high in nutritional value including fiber, carbohydrate, vitamin C, vitamin A (β-carotene) and protein, which are healthy nutrients needed by the human body.

In Malaysia, sweet potato ranks the second popular tuber crops next to cassava (Mohd Hanim *et al*., 2014). There are a few varieties of sweet potato available in Malaysia including *Batang Merah, Senduduk Kulit Putih, Senduduk Kulit Merah, Mahsuri* and VitAto (Mohamad Zahari *et al.,* 2014). VitAto is an orange-flesh sweet potato and the latest sweet potato variety cultivated by the Malaysia Agricultural Research and Development Institute (MARDI) in June 2017. Research conducted by MARDI found out that the VitAto sweet potato is suitable to plant on the ground bris in the country. Most of the ground bris area involved the large-scale plantation in Kelantan and Terengganu (Hashim *et al.*, 2019).

Back then, the sweet potato is very synonym to the Malay community as the main ingredients in making traditional *kuih-muih* such as *cek mek molek, onde-onde, bingka* and *keria.* But people today are less interested on Malay traditional desserts, since they are more interested on bakery products such as biscuits, muffins and cakes. To keep the value of sweet potato in the market, more initiatives should be considered in other optimal and potential usage of sweet potato apart from making local traditional desserts.

In producing sweet potato-based food products, the sweet potato peels are being peeled off and become a disposable waste especially for the stall and restaurant operators. The sweet potato peels are being disposed as municipal solid waste, which could increase the amount of rubbish to the environment. The global amount of sweet potato waste in 2011 accounted for about 7% of the entire crop (FAO, 2016). As the sweet potato peels also contain good health nutrition, it is useless if we do not use it wisely as it has the potential to be processed as a new health product. Converting sweet potato peel into flour is an alternative way to diversify the new product from the sweet potato peel and reduce the amount of sweet potato peel waste to be disposed by the stall and restaurant operators. This contributes greatly to increase the revenue of the farmers and increase the growth of Malaysian economy.

Sweet potato peels are edible and has good source of nutritious value, which is high in carbohydrate, protein and fiber that give various beneficial effects to human health such as the main source of energy and reducing diabetes. Sweet potato peel flour (SPPF) has been applied in the food industry as a substitution of wheat flour used in waffle ice cream cone making, since the sweet potato peel flour itself has dietary fiber, which are very suitable for diabetes and cancer patients as well as those individuals who are in a special diet in controlling obesity, high cholesterol level and body weight management. (Ware, 2019)

This study been carried out due to large amount of sweet potato peel waste found in the environment. As mentioned above, in 2011 there was about 7% of sweet potato peel ended up as municipal solid waste. As we know, sweet potato peel contains nutritious value that is good for health. Therefore, in this study the sweet potato peels were being used as one of the ingredients in the waffle ice cream cone making in the form of sweet potato peel flour to reduce sweet potato peel waste production where annually there were 95% of by-products from vegetables are discarded during preparation and processing. (Marconato *et al*., 2020).

2. Materials and Methods

2.1 Materials

The sweet potato peels for making the sweet potato peel flour were collected from the stall operator in Sri Serdang, Selangor. Basic ingredients for waffle ice cream cone preparation (wheat flour, sugar, salt, egg, essence vanilla and evaporated milk) were purchased from a local supermarket.

Regarding to this study, the sweet potato peel flour has been added to the wheat flour at different formulations for the making of waffle cones. The sweet potato peel flour being prepared by drying and grinding process of sweet potato peel.

2.2 Preparation of Sweet Potato Peel Flour

The sweet potatoes were washed and separated into flesh and peel. To reduce the enzymatic browning, the peels were dipped into the 0.03% sodium metabisulphite solution for 30 minutes, drained and dried in an oven (Memmert Oven, at 65^{o}C for 6 hours). The dried peels were grounded by using the Pensonic Blender (PB-802) (Power = 250 Watt, Voltage = 220–240 V), then it passed through 125 µm sieve to extract sweet potato peel flour. Remaining of sweet potato peel flour was stored in an airtight plastic packs in room temperature for further analysis.

2.3 Water Holding and Oil Holding Capacity (WHC and OHC)

The method of determination of water and oil holding capacity is by centrifugation process was adapted from (Hussain & Choudhry, 2014). One gram of sweet potato peel flour was balanced and placed into each centrifuge tubes. Then, 10 ml of distilled water added into each centrifuge tubes. Then it was vortex for 30 minutes for uniform mixing. After standing at room temperature for 30 minutes, the samples were centrifuged for 25 min at 3000 xg. The sediments weighed after complete removal of the supernatant. The determination of oil holding capacity, 0.5 g samples homogenized with the canola oil (5 ml) in the centrifuge tubes and proceeded further as described to determine the value of water holding capacity. All the sample done triplicate to get an average result. The WHC and OHC being calculated as below:

$$\text{WHC or OHC (\%)} = \frac{(W_2 - W_1)}{W_0} \times 100 \qquad (1)$$

where W_0 is the weight of the sample, W_1 is the weight of the centrifuge tube plus sample and W_2 is the weight of the centrifuge tube plus sediments.

2.4 Waffle Ice Cream Cone Preparation

Formulations for the waffle cone is shown in Table 1. This formulation was synthesized from sorghum ice cream cone formulation (Kigozi *et al.*, 2014). The basic waffle ice cream cone formula consisted of 100 g of wheat flour, 90 ml of evaporated milk, 2 g of salt, 70 g of sugar, 3 ml essence vanilla and 2 eggs. Three other waffle ice cream cone samples were prepared with the formulation of: (1) 5% SPPF:95% wheat flour; (2) 10% SPPF:90% wheat flour; and (3) 15% SPPF:85% wheat flour. The ready batter of control, 5% SPPF, 10% SPPF and 15% SPPF were placed to rest for a few minutes before baking. The batter for each formulation was poured on the waffle cone maker pan for 3.5 minutes at 150^{o}C. Each waffle was immediately folded into sharp cones after it has been removed from the pan. The cone shape waffle was properly stored in the vacuum plastics and placed in the container to prevent the texture of waffle cone from becoming less crispy due to the exposure to the air for further analysis.

Table 1. Formulation of waffle ice cream cone samples.

Ingredients (g)	**Formulation of waffle ice cream cones**			
	Control	**5% SPPF**	**10% SPPF**	**15% SPPF**
Wheat flour	100	95	90	85
Egg	2	2	2	2
Sugar	70	70	70	70
Salt	2	2	2	2

Ingredients (g)	Formulation of waffle ice cream cones			
	Control	**5% SPPF**	**10% SPPF**	**15% SPPF**
Evaporated milk	90	90	90	90
Essence vanilla	3	3	3	3
Sweet potato peel flour (SPPF)	0	5	10	15

2.5 Waffle Ice Cream Cone Texture Analysis

Texture parameters of waffle cone were measured by TPA test using texture analyser (TA.XTplus Texture Analyzer, Stable Micro Systems, U.K) to measure the force required to cause breakage towards the waffle cone. The result of the textural profile generates for Exponent software. The probe used was the ice cream support rig (A/ICC). Measurements were carried out for the cone shape of waffle. Instrument settings were pulled to break mode: test speed 2 mm/s. Four texture parameters were determined: hardness, brittleness, toughness and crispiness. Three replicates of waffle cone from each formulation using sweet potato peel flour were determined.

3. Results and Discussions

3.1 Proximate Analysis of Sweet Potato Peel Flour (SPPF)

Table 2. Proximate analysis of flour.

Parameter	**Orange-fleshed Sweet potato peel flour (%)**	**Purple-fleshed Sweet potato peel flour (%) (Marconato *et al.*, 2020)**	**Banana peel flour (%)** (Zaleqha, 2019)
Protein	13.8	5.53	6.5
Fat	13.5	1.03	13.0
Ash	17.87	5.26	7.0
Crude fiber	3.99	12.76	16.6
Moisture content	8.56	4.32	8.9
Carbohydrate	47.38	71.09	71.0

The result of proximate analysis (Table 2) among three types of peel flours, namely, orange-fleshed SPPF, purple-fleshed SPPF and banana peel flour shows that the orange-fleshed sweet potato peel flour contained the highest amount of protein at 13.8%, compared to purple-fleshed sweet potato peel flour at 5.53% and the banana peel flour at 6.5%. Protein content is beneficial for the human body in helping to prevent the colon cancer, treating diabetes and help in controlling the weight of the body (Ware, 2019).

However, this orange-fleshed sweet potato peel flour contains higher fat and ash content. Eating food with high amount of fat and ash is not healthy. Reducing the ash intake in the diet can help to minimize the urinary tract problems in the body. Besides, the sweet potato peel flour (SPPF) also contains crude fiber which is beneficial in treating and preventing the coronary heart disease and also some type of cancers. For both orange-fleshed sweet potato peel flour and banana peel flour, they consisted of high level in moisture content. Moisture content is very important in maintaining the shelf life of the products. The orange-fleshed sweet potato peel flour has the lowest carbohydrate content compared to the other types of peel-based flour. Low carbohydrate food is suitable for people who is on diet for different types of diseases and body weight management.

3.2 Water and Oil Holding Capacity

The moisture content of the flour must be less than 7% to make sure the flour to have a long shelf life and safe to be keep at room temperature (Ahmed *et al.,* 2010). The water holding capacity for the sweet potato peel flour was 329.97%, while for oil holding capacity was 295.94%. From the result obtained from this study, the sweet potato peel flour retained water higher than the oil. The retention of sweet potato peel flour to oil correlated with the composition of protein with water and reaction of protein with other substances.

High water holding capacity flour is suitable for making viscous food products and also the meat-based products. The purple-fleshed sweet potato peel flour was used in making the hamburger (Marconato *et al*., 2020). Besides, the orange-peel sweet potato powder also used in the making of beef burger, which is the meat-based products (Mahmoud *et al.*, 2017).

3.3 L, a* and b* Colour of Waffle Ice Cream Cone*

Sweet potato peel waffle cones produced in this study were different from the commercial waffle ice cream cone in the industry today. The waffle folded into cone shape using cone shape fold. The waffle should be thin to make sure the texture produced was crispy and easier to be folded into a perfect cone shape. The control waffle cones produced were yellowish in colour, while the newly formulated waffle cones using different percentages of SPPF shows darker intensity of colour as the percentage of SPPF added increased to 15% making the appearance more attractive.

Figure 1. Control waffle cone.

Figure 2. 5% SPPF waffle cone.

Figure 3. 10% SPPF waffle cone.

Figure 4. 15% SPPF waffle cone.

Colour is one of the most important factors and analysis in determining consumer acceptance of the respective food products. Colour characteristics of the waffle ice cream cone shown in Table 3. Based on the result obtained, it indicated that the colour of the control waffle ice cream cone had higher L* value than waffle cone with substitution of sweet potato peel flour. The higher is the L* value the lighter is the colour of the waffle cone, hence, it is highly correlated to Figure 1 indicating the colour of the waffle as yellow. The waffle ice cream cone with sweet potato peel flour appeared duller in colour compared to the control waffle ice cream cone. Dull in colour might be caused by dark in colour of the sweet potato peel flour. As the percentage of added SPPF increased, the lightness value declined, with 15% SPPF waffle cone was the darkest with the lowest L* value (23.30 ± 0.70), less red with the lowest a* value (9.03 ± 0.60) and more yellow in color with the highest b* value (31.77 ± 3.07). The combination of colour characteristics of waffle ice cream cone resulted to either lightness or darker colour of the cones.

Table 3. Colour characteristics of waffle ice cream cone.

Sample	L*	a*	b*
Control waffle cone	27.57 ± 0.15	11.40 ± 0.60	29.80 ± 6.33
5% SPPF waffle cone	27.37 ± 2.15	16.97 ± 9.39	22.27 ± 8.37
10% SPPF waffle cone	24.07 ± 0.59	11.27 ± 0.74	29.60 ± 6.46
15% SPPF waffle cone	23.30 ± 0.70	9.03 ± 0.60	31.77 ± 3.07

L* indicates lightness, a* is the red/green coordinate, and b* is the yellow/blue coordinate.

3.4. Texture Analysis of Waffle Cone

Texture properties of the waffle cone is one of the important considerations in the making of waffle cone for the ice cream (Kigozi *et al.*, 2016). The texture quality of the waffle is done in a cone shape (Huang *et al.*, 1989). The texture characteristics of control waffle cone and with substitution of sweet potato peel flour were compared in Table 4. The parameters of waffle cone texture are focused on its hardness, brittleness, toughness and crispiness. From the result below, addition of sweet potato peel flour to the existing wheat flour ingredient at different formulation, 5%, 10% and 15%, which resulted to higher value of hardness of the waffle cone compared to the controlled waffle cone, which only used the wheat flour. The substitution of 10% of sweet potato peel flour out of wheat flour amount into the formulation resulted the highest hardness of waffle cone (930.43±674.99), followed by 5% SPPF waffle cone (761.27±224.25) and 15% SPPF cone (588.01±261.97). The less gelatinization occur in the batter resulted in the hardness of waffle cone texture (Kigozi *et al.*, 2014). The four different batter formulations resulted to brittleness of the waffle ice cream cone within the same range, however, the lowest brittleness value was the 15% SPPF waffle cone followed by 10% SPPF cone. For the toughness result of the waffle cone, the substitution of sweet potato peel flour gave the higher value of toughness (i.e. 5% SPPF as the toughest followed by 10% SPPF and finally 15% SPPF waffle cones) compared to the controlled one. High in toughness value as per indicated by the value of 5% and 10% SPPF formulation in the waffle cone making, promotes safer handling, shipping and distribution of the cones as it can withstand with the certain value of pressure act on it. The value of crispiness of waffle cone obtained the highest result for the substitution of 5% SPPF in the batter formulation and the least crispy of 10% SPPF waffle cone. 5% sweet potato peel flour substitution of existing amount of wheat flour yielded ice cream waffle cone high in crispiness and brittleness. The properties might be due to the high composition of fiber in the sweet potato peel flour. High fiber content increase the texture of the waffle cone to become crispy, which then effect to the texture of the waffle cone.

Table 4. Texture characteristics of waffle cone.

Sample	Hardness	Brittleness	Toughness	Crispiness
Control waffle cone	341.17 ± 89.87	3.75 ± 0.69	366.60 ± 63.30	21.67 ± 5.86
5% SPPF waffle cone	761.27 ± 224.25	3.92 ± 1.81	856.46 ± 565.79	20.33 ± 2.52
10% SPPF waffle cone	930.43 ± 674.99	3.57 ± 0.99	855.26 ± 962.03	13.00 ± 9.17
15% SPPF waffle cone	588.01 ± 261.97	3.51 ± 1.65	506.59 ± 157.11	15.67 ± 10.02

Further increasing the amount of sweet potato peel flour to be substituted to the wheat flour resulted in less crispiness of the waffle cone. This is due to the high water holding of the sweet potato peel flour, which can reached up to 329.97%. The sweet potato peel flour retains the moisture of the batter, therefore when it was being cooked, the texture of the waffle was a bit moist and not crispy.

In the context of texture properties, 5% SPPF waffle cone has yielded the best properties of second hardest, first in brittleness, the toughest and the crispiest compared to control waffle cone and other formulated SPPF waffle cones. Hence, 5% SPPF waffle cone was the best and top in textural quality among the formulated waffle cones to be commercially produced in the factory and retain its shape during making, handling, shipping and distribution. For it to have the least water holding capacity among the newly formulated cones, makes it to have longer shelf-life as it remains dry after production and less likely to be infected by fungal growth.

Table 5. Texture characteristics of waffle cone using banana peel flour.

Sample	Crispiness
Control waffle cone	18.67
5% waffle cone	14.80
10% waffle cone	17.67
20% waffle cone	24.33

Comparing the result of ice cream waffle cone from the banana peel flour, the 20% substitution of banana peel flour to replace a small percentage of wheat flour yielded the most crispiest waffle cone (Zanariah *et al.*, 2019). This is due to the lower water holding capacity of banana peel flour, which was below than 5 g/g (Bakar *et al.*, 2018).

As the substitution of sweet potato peel flour have lower influence in the ice cream waffle cone making, it can be used for other applications due to its high water holding capacity. Substance with high water holding capacity can be applied as the water binding agent in meat processed food such as nuggets, sausages, meatballs, fish balls, beef and chicken patties and hamburgers. Besides, it also suitable in the making of bakery products as it could retain the moisture and improve its texture to make the end product more moist and fluffy. The application of sweet potato peel flour can be the same as corn flour as the corn flour is high in water holding capacity (Shad *et al.*, 2013). It can be the binding agent for the food such as puddings which contain high moisture. These high water holding capacity also could be the thickener for the soups, stews and sauces.

Although the functional benefits of corn flour and sweet potato peel flour are similar, but both have different value of glycemic index. The corn flour has the glycemic index at 70 compared to sweet potato peel which have the value of 19. Food substance high in glycemic index value is not good for health as the food will be digested and absorbed into the bloodstream quickly and this cause large and rapid changes in the blood sugar levels. However, those with low glycemic index value such as sweet potato, should be applied in the food dietary intake for diabetic, obesity and cancer patients.

4. Conclusion

Based on the study, it is possible to produce waffle ice cream cone with the substitution of small percentage of wheat flour with at least 5% of sweet potato peel flour. In general, the addition of sweet potato peel flour to the existing wheat flour formulation has resulted to darker waffle ice cream proven with reduction in lightness value (L*) cone, but still suitable in the making of waffle ice cream cone. Formulation of waffle cone batter using sweet potato peel flour had darker colour compared to the control waffle ice cream cone, which appeared bright yellowish colour. For textural properties, the waffle ice cream cone made from 10% and 15% sweet potato peel flour became less crispier than waffle ice cream cone made from 100% of wheat flour, but an exception for 5% SPPF waffle cones which are similar to the crispiness of control waffle cone. This is due high water holding capacity of sweet potato peel flour. Other than that, the sweet potato peel flour can be used for other food applications such as sweet potato puree making for baby food and other usage in food preparation, bakery products, beverages mixed with coffee or chocolate, making pudding, act as thickener or emulsifying agent to the soups and sauces and also suitable in making meat-based products.

Acknowledgments: Authors are thankful to the laboratory technicians, Department of Processing and Food Engineering, Faculty of Engineering, for their considerable help to complete this research successfully.

Funding: This research was financially supported by Universiti Putra Malaysia, Serdang, Selangor, Malaysia.

Conflicts of Interest: The authors declare no conflict of interest, and also the funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

Ahmed, M., Akter, M. S., & Eun, J. B. (2010). Peeling, drying temperatures, and sulphite-treatment affect physicochemical properties and nutritional quality of sweet potato flour. *Food Chemistry*, *121*(1), 112–118. https://doi.org/10.1016/j.foodchem.2009.12.015

Bakar, S. K. S. A., Ahmad, N., & Jailani, F. (2018). chemical and functional properties of local banana peel flour. *Journal of Food and Nutrition Research*, *6*(8), 492–496.

Food and Agricultural Organization (FAO). (2016). Retrieved from: http://faostat3. fao.org/home

Hashim, I., Syariffuddeen, A., Adnan, M., *et al*. (2019). Pembangunan sistem pengendalian dan pengawetan ubi keledek VitAto. *Buletin Teknologi MARDI*, *15*, 49–64.

Huang, V. T., Luebbers, S. T., Lindamood, J. B., *et al*. (1989). Ice cream cone baking: 2. Textural characteristics of rolled sugar cones. *Food Hydrocolloids*, *3*(1), 41–55. https://doi.org/10.1016/S0268-005X (89)80032-3.

Kigozi, J., Banadda, N., Byaruhanga, Y., *et al*. (2014). Optimization of texture in sorghum ice cream cone production using sensory analysis. *The Open Food Science Journal*, *8*, 18–21. https://doi.org/10.2174/1874256401408010018

Kigozi, J., Banadda, N., Byaruhanga, Y., *et al*. (2016). Sorghum ice cream cone texture; correlations between instrumental and sensory analysis. *Journal of Advances in Food Science and Technology*, *3*(3), 134–145.

Mahmoud, M. H., Abou-Arab, A. A., & Abu-Salem, F. M. (2017). Quality characteristics of beef burger as influenced by different levels of orange peel powder. *American Journal of Food Technology*, *12*(4), 262–270. https://doi.org/10.3923/ajft.2017.262.270

Marconato, A. M., Hartmann, G. L., Santos, M. M. R., *et al*. (2020). Sweet potato peel flour in hamburger: Effect on physicochemical, technological and sensorial characteristics. *Brazilian Journal of Food Technology*, *23*, 1–9. https://doi.org/10.1590/1981-6723.11519

Mohamad Zahari, N. I, Ahmad, S. M., & Hassan, H. (2014). Penghasilan tepung pracampuran hasilan bakeri berasaskan ubi keledek VitAto (Development of premix flour for VitAto sweet potato based bakery products). *Buletin Teknologi MARDI, 6*, 9–16.

Mohd Hanim, A. B., Chin, N. L., & Yusof, Y. A. (2014). Physico-chemical and flowability characteristics of a new variety of Malaysian sweet potato, VitAto flour. *International Food Research Journal*, *21*(5), 2099–2107.

Shad, M. A., Nawaz, H., Noor, M., *et al*. (2013). Functional properties of maize flour and its blends with wheat flour: optimization of preparation conditions by response surface methodology. *Pakistan Journal of Botany*, *45*(6), 2027–2035. https://doi.org/10.13140/2.1.4326.9760

Ware, M. (2019). *What's to know about sweet potatoes?*. Retrieved from: Medical News Today https://www.medicalnewstoday.com/articles/281438

Zanariah, M. D., Nur Zaleqha, M. H., & Lisnurjannah, M. (2019, March 21). *Utilization of banana peel flour as fibre ingredient in the waffle cones*. Konvensyen Kebangsaan Kejuruteraan Pertanian dan Makanan 2019, Wisma Tani, Kementerian Pertanian Malaysia, Putrajaya.

ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

HH PUBLISHER

Original Research Article

Conceptual Development of Automated Harvester for Tall Oil Palm Tree

Mohd Hudzari Razali[1]*, Muhammad Aliuddin Bakar[1], Muhammad Syukri Mohd Sabir[1]

[1]Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA, Jasin Campus, 77300, Melaka, Malaysia.

*Corresponding author: Mohd Hudzari Razali, Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA, Jasin Campus, 77300, Melaka, Malaysia; hudzari @uitm.edu.my

Abstract: Innovation and invention in field mechanization for oil palm sector has created a variety of advancement in technology. The change in oil palm operation to mechanization will overcome the problem of labour shortage occurrence in oil palm sector. The problem occurs in harvesting tall oil palm is the height of oil palm that causes difficulty to cut the fresh fruit bunch by using manual labour. Moreover, the use of automated harvester also will make the harvesting operation easier without the requirement of skilled labour and ensuring labour safety. The automated harvester has advantages and disadvantages that need to be improved in meeting the oil palm requirement. This study overviews the mechanization that are used in harvesting tall oil palm. This research project has resulted in the development of high technology mechanization based on previously developed machine for harvesting fresh fruit bunches (FFB) at 10 meter and above of oil palm age tress. However, the previous developed machines cannot be accepted in the current and widely practiced Industrial revolution 4.0 (IR4.0). Mechanization approach makes harvesting tall oil palm a reality to overcome the problem that normally occur in oil palm sector due to height of oil palm.

Keywords: Dimension; harvesting; labour shortage; mechanization; tall oil palm

Received: 11th November 2020

Accepted: 12th December 2020

Available Online: 20th December 2020

Citation: Razali MH, Bakar, MA, & Mohd Sabri, MS. Conceptual development of automated harvester for tall oil palm tree. Adv Agri Food Res J 2020; 1(2): a0000151. https://doi.org/10.36877/aafrj.a0000151

1. Introduction

Malaysia is the one of the world's largest producers and exporters of oil palm after Indonesia. According to Kamil *et al*. (2017), palm oil in Malaysia is mostly exported to other countries such as India, China, European Union, Pakistan, Egypt and Bangladesh. In 2015, 25.37 tonnes of oil palm products were exported Malaysia to other countries (MPOB, 2016). Milling is a crucial process to extract the crude palm oil from the fruit mesocarp. It also involves the initial detachment of the individual fruit from its bunch. The milling process starts with the bunch reception, and continues with sterilization, threshing, digestion, pressing, clarification and purification. Initially, the FFB including the loose fruits are fed into the sterilizer cages through the hopper. Good management in oil palm plantation, such as in detecting unhealthy plants, fertilization plan, processing plan and irrigation management, is very important as Malaysia is the largest producer (Carolita *et al*., 2015). Therefore, harvesting and collection of oil palm requires a skill to cut the fresh fruit bunch from bunch stalk and for 3D perception of this job, dangerous, dirty and difficult that resulted in minimal involvement of the locals and increased avenues for foreign workers to work in plantation sector (Ismail, 2013). The characteristic of oil palm usually can grow up to 15 m high depends on the varieties or species of the oil palm. The height may cause harvesting problem and difficulties in manual harvesting requiring labor intensity and skillful labor. This situation has also affected the supply of palm oil in the domestic as well as world markets (Ismail, 2013).

There are around 60% of the total work operation in harvesting fresh fruit bunches (FFB) and 50% of total workers in the production cost (Sowat *et al*., 2018). The harvesting of tall oil palm tends to be difficult due to height of oil palm trees and the space of frond within fruit bunches that cannot be seen by the harvesters beneath and far from the focus point level of the eyes. Furthermore, for tall palms (greater than 2.5 metres height), a sickle attached to a long pole is used. The sharpness, shape and profile of the sickle contribute to the effectiveness of the cutting operations through pulling the sickle downwards. Energy for cutting comes mainly from the harvester testing on his endurance and it can be reduced by the tool sharpness and self-skill such as lifting, and handling the long pole, and cutting the fronds as well as fruit bunches. Hence, this would result in low productivity of the skillful labor and harvesting can be up to 2:00 pm in the evening (Jelani, 1997; Jelani *et al*., 2008). Sharence *et al*. (2018) stated that to alleviate issues surrounding the human workforce such as labor shortage and injuries, the proposed climbing robots can be deployed to replace these workers. In addition, climbing robots are smaller than harvesting machines and therefore they are not plagued by problems associated with operating huge machinery in the farm.

The study on harvesting cutter used in the mechanical harvesting was conducted at the Malaysian Palm Oil Board (MPOB). Oil palm industry Malaysia was entrusted serve by MPOB and become one of the most premier government agencies under the Ministry of Plantation Industries and Commodities The roles of MPOB are to promote and develop policies, objective and priorities that are created by national government as well as to make sure the oil palm industry is well managed and controlled by the national government. The effective service and international focus in oil palm industry that have more than 20 years was responsible by MPOB to provide best services in oil palm industry (Palm Oil World, 2019).

Based on the main geometric concept of common normal between two lines, Denavit and Hartenberg (1995) introduced a conventional technique for selecting joints of reference in robotics application that used homogeneous transformation and represented minimally as product of four basic transformations. Denavit and Hartenberg (D-H) representation has become the standard way of representing robots and modeling their motions (Denavit and Hartenberg, 1995). The method begins with a systematic approach in assigning and labeling an orthonormal (x, y, z) coordinate system to each robot joint. It is then possible to relate one joint to the next and ultimately to assemble a complete representation of a robot's geometry. D-H convention was mainly implemented in robot manipulators, which consist of an open kinematic chain in which each joint contains one DOF with either revolute or prismatic joint. The transformation was described by the following four parameters known as D-H parameters, which are a is length, α is twist, d is twist and θ is angle.

Bouketir (1999) has developed a vision-based interface for a three degree of freedom (DOF) agricultural robot that involved the D-H approach. Experiments were carried out for the robot to grab the target, which was a red fruit bunches with the help of vision (Charge Couple Device camera) and back to the home position. While Razali (2003) has developed the system able to retrieve real time dynamic video scene and from there the three coordinate axes of object target and generated using mouse click action. The coordinates were calculated using triangulation principle based on the video scene of two different locations of cameras. These 3-axis coordinates were measured from the Cartesian robot coordinate that was taken as reference point to calculate a mathematical model for robot simulation and kinematics. The workspace in the simulation software was calibrated to be the same with real robot workspace.

2. Materials and Methods

2.1 Location of Study Area

The study and data collection were conducted on harvesting cutter available at Malaysian Palm Oil Board (MPOB), Bangi.

This study utilized a descriptive analysis approach. The data has been collected, summarized and compared in the simplest way. Qualitative method was used for the case study in measurement, simple calculation and dimension method.

2.2 Parameters of Mechanization

The dimension of the object is required to make a topological measurement size of the object in covering the properties and coordinate to specify the point of the object. There are two types of dimensions such as rectangle in two-dimensional or cube in three-dimensional. The dimension of an object also called as “dimensionality”, was required to study and use in calculation because it provides the parametrization for the conceptual or visual complexity (Eric, 2017).

The comparison of several types of tractors or harvesters used in harvesting tall oil palm based on operated mechanization were conducted in this study: (1) track, (2) wheel, (3) half-track. The advantages and disadvantages were evaluated on which mechanization brings more benefit when operated in the field. The findings from comparison and evaluation of mechanization will be used for future benefits. Economic analysis was conducted by calculating the cost mechanization usage in harvesting oil palm. It included the following factors: (1) machine price; (2) economic life; (3) productivity; (4) total cost; (5) effective field capacity.

3. Results and Discussions

3.1 Parameter of Machines

Figure 1 shows the dimension of half-track mechanization from the side view of the dimension: (a) driver seat, (b) hydraulic power steering, (c) hydraulic oil tank, (d) bucket, (e) stabilizer, (f) hydraulic telescopic boom, (g) vertical telescopic boom, (h) claw cutter; (i) grapple. The important parts use for harvesting process are the hydraulic telescopic boom, claw cutter, grapple and bucket. The function of hydraulic telescopic boom is used to extend the boom to achieve suitable length to cut the FFB. Claw cutter is used to cut the FFB from the stalk and to cut the frond of the oil palm. The grapple is used to hold the oil palm fruit bunch after the cutting process and transfer of FFB to the bucket. The use of grapple is important to avoid the damage of FFB due to fall from the high elevation to the ground and to preserve the quality of the FFB. The bucket is used as a storage of FFB throughout harvesting and collecting of FFB. The track system in the movement of machine signifies the difference from this half-track mechanization to track and wheel type.

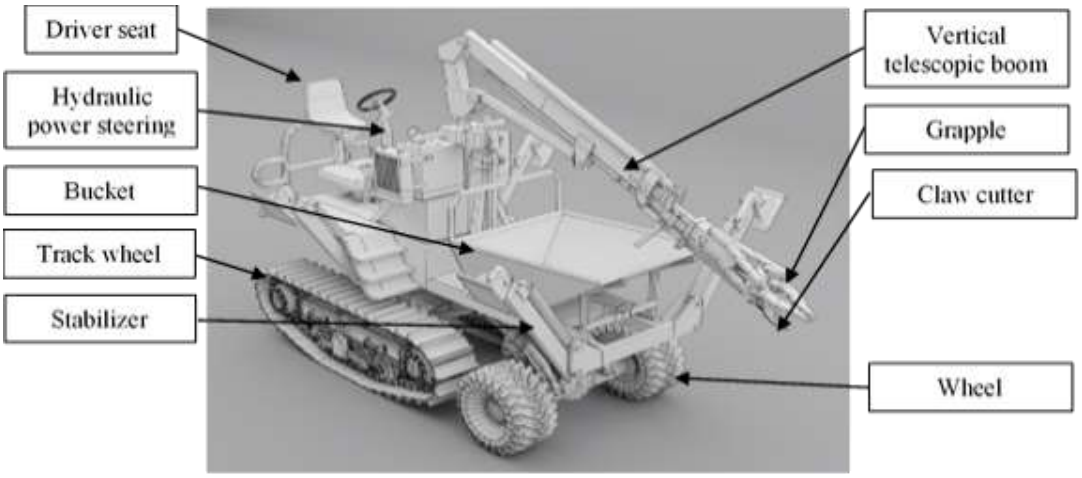


Figure 1. Side view dimension for half-track mechanization.

3.2 Motion Study for Harvesting Activities

Table 1 shows that the track type mechanization carried out the longest time to carry out harvesting activities in 112 sec from reaching the bunch, cutting, reacting and bringing FBB to bin and moving the machine to the next oil palm tree and resume its cutting activities. The wheel type contributed to moderate time taken to carry out complete cycle of harvesting activities in 103 sec. The half-track type shows the least time taken to carry out harvesting activities in 98 sec. This shows that the track type has poor performance in harvesting oil palm that need higher time to complete one cycle. Half-track type shows the best performance in harvesting process among the mechanization available in MPOB.

Table 1. Average time taken to carry out harvesting activities.

Movement/activity	Average time taken for track type (sec)	Average time taken wheel type (sec)	Average time taken half-track type (sec)
Telescopic boom extends until reaching the bunch	12	8	8
Cutting process	34	35	34
Telescopic booms react and bringing FFB to bin	28	26	26
Machine move to the next palm and resume its cutting activities	38	34	30
Total	112	103	98

Table 2 shows that track type mechanization resulted to slow speed of movement of machine to the field with the maximum average speed of 10 km/h and 3 km/h to complete one cycle of harvesting process before resuming to the next. Wheel type exhibited moderate speed of movement of machine to the field at 15 km/h maximum speed and 5 km/h to complete one cycle of harvesting process. The half-track type the best performance by ranking as the highest speed of movement of machine to the field. This shows that track type has the poorest performance in speed of movement mechanization because of the type of movement that used is track system. Average speed of mechanization moving from one palm tree to another affected the productivity of the mechanization when used in the field. However, the wheel type shows better performance than track type, which moved to the field with speed higher than track type. Integration of track type and wheel type mechanization would bring more efficiency in speed travel when used in the field in the form of half-track type. Speed of movement is important to make sure the mechanization is suitable with the topography of the oil palm field interacting with the mode of movement used that impacted the productivity of operation.

Table 2. Speed of movement of machine to the field.

Movement/activity	Average speed for track type (km/h)	Average speed wheel type (km/h)	Average speed half-track type (km/h)
Maximum speed	10	15	20
Minimum speed	5	10	15
Machine move to the next palm and resume its cutting activities	3	5	8–10

3.3 Economic Analysis of Mechanization Types Used in FBB Harvesting

Table 3. Economic analysis of mechanization types used in FFB harvesting.

Particular	Track type system	Wheel type system	Half-track system
Machine price	RM 140 000	RM 160 000	RM 180 00
Economic life	6 years	6 years	6 years
Productivity	250 FFB / 6 tonnes days	300 FFB / 8 tonnes days	350 FFB / 10 tonnes days
Labour cost	(RM 0.24 x 250 FFB) = RM 60 days	(RM 0.24 x 300 FFB) = RM 72 days	(RM 0.24 x 350 FFB) = RM 84 days
Working days	25	25	25
Fuel consumption	(18 l/day x RM 1.80) = RM 32.40	(15 l/day x RM 1.80) = RM 27.00	(17 l/day x RM 1.80) = RM 30.60
Lubricants (15% from fuel cost)	RM 4.86	RM 4.05	RM 4.59
Repair and maintenance cost	RM 60	RM 60	RM 60
Total cost	RM 277.26	RM 231.05	RM 255.19

Table 3 shows that the track type mechanization totaled up to the highest cost of harvesting. The wheel type has lowest total cost of harvesting activities and followed by half-track type shows high total cost of harvesting, but lower than track type. This shows that track type has higher total cost because the price of machine is higher because of track system usage. The wheel type has moderate total cost because of wheel system usage and will gain higher productivity based on FFB output. However, in meeting the objective of the study in solving the labour shortage and increase in productivity, half-track system shows the best productivity of 350 FFB/10 tonnes collected in 25 given days. With the half-track system, there shall be no more issues on labour shortage and low productivity in oil palm harvesting and collection.

3.4 D-H Parameters Representation of Harvester

The transformation between two successive joints was written by substituting the D-H parameters from Table 4 into the *A* matrix. The θ and d were the joint variables for revolute joints and prismatic joints, respectively with $C1$ as $\cos\theta 1$ and $S1$ as $\sin\theta 1$ designation.

Table 4. D-H parameters representation of harvester.

Joint	θ (Link angle)	*D* (Link Offset)	*a* (Link Joint)	α(Link Twist)
1(*z*0-*z*1)	$\theta 1$	0	0	90
2(*z*1-*z*2)	0	$d2$	$a1$	90
3(*z*2-*z*3)	$\theta 3$	0	$a2$	90
4(*z*3-*z*4)	$\theta 4$	0	0	0
5(*z*4-*z*5)	0	$d5$	0	0

Figure 7 show the image and schematic diagram of the harvester manipulator used to cut and harvest the oil palm FFB that currently located at MOPB, Bangi Lama, Selangor. Helena and Wan Ishak (2010) mentioned that the harvester has five DOF, where the first joint 1 was between link 0 (the fixed base) and link 1($z0 - z1$), joint 2($z1 - z2$) between link1 and 2, and so on.

Figure 2. Image and schematic diagram of the harvester manipulator for tall oil palm tress.

Wan Ishak *et al*. (2011) mentioned that present work of agricultural robotic studies in Universiti Putra Malaysia could be considered as initial research in developing of an intelligent robot eye for agriculture harvester robot. By using the concept of non- contact measurement like video-grammetry to detect the object and measure it in 3D coordinate, the development of the robot eye was explored (Razali, 2003). For further research, the robot eye must use the RGB camera, which will be automatically recognizing the mature object by pattern or by color or wave character manipulation without human intervention by clicking the target image. By using the concept of non-contact measurement like video-grammetry for the measurement and detection of coordinate of the target object, the developments of the "robot eye" were explored in agriculture sector. Camera vision recognizes the fruit maturity through forced learning concept. This concept means that the matured fruit to be harvested will be attached at placement on harvester arm if it is done manually. However, camera vision applied the current value of hue digital image of oil palm outdoor and on the field. The programmed system compares the hue value between this trained or dummy output, which can be represented as the benchmark for the input of targeted maturity fruit in reality. In outdoor condition, the vision system will be influenced by illumination changes by sunlight, temperature of environment and humidity on surface target color itself. After the vision system recognized the matured fruit, the system controller proceeds and performed the kinematic calculation for transforming the movement harvester arm automatically through auto pilot concept that had been done by Jayaselan and Wan Ismail (2010). The user shall be assisted by the arm harvester during initial fruit recognition, then when the fruit is recognized through the vision system, then this auto pilot activation took place for machine operation until the harvester automated with gripping and cutting process. This pilot operation includes loading process of fruit into the bin. SCADA system and Arduino components were integrated into the automation part. ERDAS software of GIS were used to retract the information of targeted for mapping process system. The concept of this integration system between D-H conversions, videogrammetry, and outdoor vision recognition were required for development of tall oil palm trees harvester.

4. Conclusion

There is no mechanization for harvesting has been applied on the field, except the use of motorized cutter for oil palm trees less than five meters height. However, other sectors in the oil palm industry have utilized mechanization in the processing of the output of oil palm production. Various technologies have been developed by MPOB as well as its contribution to the industry from oil palm harvesting to production of the FFB until the end process to the mill. The importance of producing machine to suit the terrains on Malaysian land is the major limitation for designer to develop appropriate design to overcome the problem that normally occur in oil palm sector due to mechanization usage. Strategic plan is crucial to choose the suitable mechanization with the good specification of mechanization, well-planned dimension or design to fulfil the requirements for mechanization to promote easy access and user-friendly to reduce labour shortage and encourage more skilled workers to be involved in the well paid 3D job (i.e. dangerous, dirty and difficult) of the oil palm sector The employed workers or labours are required to undergo training to learn the mechanism of the mechanization type and handling the machine safely and efficiently during harvesting and collection of FFB.

Acknowledgments: The researchers would like to thank the staffs of Malaysia Palm Oil Board, Bangi, Selangor for their assistance.

Funding: This research was supported internally by Faculty of Plantation and Agrotechnology, UiTM, Melaka, Malaysia

Conflicts of Interest: The authors declare no conflict of interest, and also the funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

Bouketir, O. (1999). Design and development of a vision system interface for three degree of freedom agricultural robot. *Master Thesis, Universiti of Putra Malaysia.*

Carolita, I., Sitorus, J., Manalu, J., *et al.* (2015). Growth profile analysis of oil palm by using spot 6 the case of north sumatra. *International Journal of Remote Sensing and Earth Sciences, 12*(1), 21–26.

Denavit, J., & Hartenberg, R. S. (1995). A kinematic notation for lower-pair mechanisms based on matrices. *Journal of Applied Mechanics,* (23): 215 – 221.

Eric, W. (2017, March 13). *Dimension*. Retrieved from Wolfarm Mathworld. http://mathworld.wolfram.com/Dimension.html

Helena, A, J, J., & Wan Ismail, W. I. (2010). Kinematics analysis for five DOF fresh fruit bunch harvester. *International Journal of Agricultural and Biological Engineering, 3*(3), 1–7.

Ismail, A. (2013). The effect of labour shortage in the supply and demand of palm oil in Malaysia. *Oil Palm Industry Economic Journal*, *13*(2), 15–26.

Jelani, A, R. (1997). *Design and development of an oil palm fresh fruit bunch cutting device* [Master Thesis]. University of Putra Malaysia.

Jelani, A, R., Hitam, A., Jamak, J., Noor, M., *et al.* (2008). Cantas ™ — A Tool for the efficient harvesting of oil palm fresh fruit bunches. *Journal of Oil Palm Research*, (20): 548–558.

Kamil, N. N., Balu, N., Ismail, N., *et al*. (2017). An analysis of malaysian palm oil exports to selected TPPA member countries. *Oil Palm Industry Economic Journal*, *17*(2), 34–43.

Malaysian Palm Oil Board (2016, February 23). *Overview of the Malaysian oil palm industry 2015*. Retrieved from: http://bepi.mpob.gov.my/images/overview/Overview_of_Industry_2015.pdf.

Palm Oil World. (2019). *About the Malaysian Palm Oil Board*. Retrieved on April 22, 2019, from http://www.palmoilworld.org/about_mpob.html

Razali, M. H. (2003). Videogrammetry technique for arm positioning of bio-production robot. *Master Thesis, Universiti Putra Malaysia.*

Sowat, S. N., Wan Ismail, W. I., Mahadi, M. R., *et al.* (2018). Trend in The Development of Oil Palm Fruit Harvesting Technologies in Malaysia. *Jurnal Teknologi (Sciences & Engineering)*, *80*(2), 83–91.

Wan Ishak, W. I., Hudzari, R. M., Nasir, S. M., *et al.* (2011). Videogrammetry application for stereo vision bio-production harvester. *Trends in Applied Sciences Research*, 6(5), 495–506.

ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

Original Research Article

Design and Development of an Indoor Testing Facility for Downwash and Spray Distribution Evaluations of Agricultural UAV

Siti Amni Ismail[1]*, Azmi Yahya[1], Ahmad Suhaizi Mat Su[2], Norhayu Asib[3], Anas Mohd Mustafah[1]

[1]Department of Biological and Agricultural Engineering, Universiti Putra Malaysia, Serdang, 43400, Malaysia, azmiy@upm.edu.my, anas_mustafah@upm.edu.my.

[2]Department of Agriculture Technology, Universiti Putra Malaysia, Serdang, 43400, Malaysia, asuhaizi@upm.edu.my.

[3]Department of Plant Protection, Universiti Putra Malaysia, Serdang, 43400, Malaysia, norhayuasib@upm.edu.my.

*Corresponding author: Siti Amni Ismail, Department of Biological and Agricultural Engineering, Universiti Putra Malaysia, Serdang, 43400, Malaysia; sitiamni@gmail.com

Abstract: The usage of UAV as a pesticide application technology is becoming a common practice in Southeast Asia, with a substantial proportion of agricultural areas currently being treated using this method. To date, more than 169 different UAV designs and configurations have been developed to meet such demand. Each UAV design and configuration have its own unique aerodynamic effects that may have an impact on the resulted spray droplet characteristics and distributions. Therefore, it is crucial to determine both the downwash airflow and spray patterns, and also the effective spraying application parameters for the UAV. This research outlines the development of an indoor test facility and its standardised test procedure for evaluating the downwash airflow and spraying performance of any UAV model used in agricultural applications. The test facility was designed to imitate the UAV in the actual field spraying operation. The developed test facility is 23 m long and has been designed to mount the UAV at up to 100 kg, at three spray heights (1.5 m, 2.5 m and 3.5 m) and operating at a maximum travel speed of 10 m/s. The 6x6 m sampling platform structure for pressure sensors and water-sensitive paper was built under the rail support structure to measure and collect data for the spraying distributions and downwash pressure profiles. With an indoor UAV test facility, recurring experiments based on the same standard protocols could be made available, prospecting improved UAV spraying efficiency and proper recommendations on UAV flying requirements to achieve an efficient agricultural chemical spraying operation.

Keywords: aerial spraying; unmanned aerial vehicle; agricultural chemical spraying; test rig; downwash air flow profile; spray distribution.

Received: 18th November 2020

Accepted: 18th December 2020

Available Online: 25th December 2020

Citation: Ismail SA, Yahya A, Mat Su AS, *et al.* Design and development of an indoor testing facility for downwash and spray distribution evaluations of agricultural UAV. Adv Agri Food Res J 2020; 1(2): a0000157. https://doi.org/10.36877/aafrj.a0000157

1. Introduction

Unmanned Aerial Vehicle (UAV) is a technology that has revolutionized modern agriculture and is expected to become one of the technologies of the future (Huang *et al.*, 2013). UAV has been involved in a wide range of agricultural production tasks, such as: (i) acquiring data from a variety of sensors for soil nutrients and crop health status; (ii) as a mechanical applicator for broadcasting seeds, spreading granular fertilizers, and spraying of herbicide and pesticide chemicals (Puig *et al.*, 2018). In China alone, almost 95% of Chinese agricultural aviation technology have been used in aerial plant protection operations, while the other 5% have been used in the acquisition of agricultural information (He *et al.,* 2017).

UAV as a pesticide application technology has become a common practice in Southeast Asia, with a very significant proportion of agricultural areas currently being treated using this method. In China, due to the high demand, there are more than 200 UAV manufacturers that produce more than 169 different UAV designs and configurations for pesticide application (He *et al.,* 2017). With the advantages of the UAV, it is expected to increase field capacity (ha/hr), replace human labor, reduce health problems due to pesticide exposure, high site-specific accuracy and also good for vector control in areas that are hardly accessible by man (Faiçal *et al.*, 2017; Huang *et al.*, 2009; Mievel *et al.,* 2016; Morley *et al.*, 2016). Past research by Giles and Billing (2014) indicated that, depending on the applied spraying method, flight pattern, and spray width, field capacities were able to reach between 2.0 and 4.5 ha/h, while the application rate was between 14.0 and 39.0 L/ha.

In general, although the utilization of UAV has many advantages and most likely solved many problems in the field, more attention should be paid specifically to the use of UAV in spraying operation. Basically, the UAV needs to meet the prime objective of pesticide application where the spray droplets must be uniformly distributed on the target surface with minimal losses due to drift, run-off or evaporation. However, based on the previous studies, Wang *et al.* (2017) that analyzed the performance of four UAVs typically used for pesticide operations in China stated that the pesticide applications of UAV were on a low precision and unsatisfactory. The deposition pattern and liquid spraying distribution were found to be not uniform both in lateral and longitudinal directions. Similar results were reported by Qin *et al.* (2016) in paddy cultivation and Zhang *et al.* (2016) in citrus growing. The size of droplets produced and the deposition of droplets during spraying is influenced by few factors namely environmental conditions (i.e. wind speed, humidity), spray chemical, leaf properties, and the whole spray system (i.e. spray nozzle, operating pressure) used or set during the operation (Hofman & Solseng, 2017; Pscheidt, 2012). During spraying application using UAV, the produced spray droplets produced were found to be affected by the rotor airflow (downwash) which severely affecting the pesticide deposition pattern on the crops and at the same time giving high pesticide waste due its enormous all direction drifts (He *et al.*, 2017; Wang *et al.*, 2017; Zhang *et al.*, 2017).

A few researchers have analysed downwash airflow patterns due to the important role of downwash airflow in defining the distribution of droplets on crop canopy. Based on previous studies, the downwash airflow of a multi-copter was analyzed using computational and experimental studies. Computational Fluids Dynamics (CFD) has become a robust tool in agriculture. A research by Yang *et al.* (2018) has established the efficient three-dimensional downwash numerical model based on compressible Reynolds-averaged Navier-Stokes (RANS) equations with the RNG k-ε turbulence model of SLK-5 UAV, while hovering at 3 kg load condition. Zheng *et al.* (2018) also simulated the downwash field of six-rotors UAV at varying heights.

Experimental studies were also conducted to determine the downwash airflow. Although the development of the testing facility is considered limited and expensive, it is found to be the most accurate method in any fields. Cong *et al.* (2018) designed wind speed detection equipment using a pitot tube speed sensor based on a wind pressure signal to obtain better UAV wind parameters near the ground, which effectively detect the rotor wind speed data of the UAV and has a significant advantage of reducing interference. Chen *et al.* (2017) used the Wind Speed Sensor Network measurement system (WSSN) that used the impeller type of wind speed sensor that was arranged in one line and perpendicular to the flight path. Wu *et al.* (2019) determined the downwash airflow based on the strain effect principle. A total of 27 strain gauges were arranged in three levels under the hovering UAV at a location of 2.6 m above the ground and a blade rotation of 2500±10 revolutions per minute (RPM). Feng *et al.* (2018) has also designed a facility with built-in blades and measured the downwash at hovering state with a blade speed of 2500 RPM using anemometers.

From the information provided by the experimental studies mentioned above, the concern is whether the downwash pressure profile and spray deposition of droplets obtained are presenting the behavior of the UAV during the spraying operation. It needs the understanding that the downwash flow field pattern is dynamically changed as the payload and the flight speed changes (due to the changes in the rotation of the blade). It is also worth noting that the downwash flow field also cannot be common standard to all spraying UAV due to their unique configuration (Teske *et al.*, 2018). Therefore, this research is aimed to design and develop an indoor testing facility that imitates the UAV during spraying and at the same time, able to measure the downwash of the UAV and the deposition of droplets sprayed. By having this facility, the correlation between the downwash flow profile and deposition of droplets could be analyzed and this result may lead to determining the optimum spraying operating procedure for the UAV.

2. Design of Indoor UAV Testing Facility

2.1 Description

Indoor UAV testing facility was designed primarily: (i) to evaluate the downwash airflow profile of the UAV using pressure transducers; and (ii) to quantify the spraying deposition using water-sensitive papers (spray width, droplet size (µm), number of droplets per area and spray deposit volume (µ l/cm^2) (Figure 1). The facility was located indoor to fully control the traveling operation of the tested UAV and overcome the environmental disturbances that may affect UAV spray deposition during operation. The overall length and height of the testing facility were approximately 23 m and 4.5 m, respectively. The schematic diagram of the facility is as shown in Figure 1.

The testing facility has two main sections. The first section consists of a rail support structure and its driving unit (Figure 2(a) and 2(b)). The railing beam and its two-end column supports were built from a 305 mm × 102 mm × 33 kg/m mild steel I beam. Attached to the beam is the moving carriage that was used to carry the tested UAV with a maximum weight limit of 100 kg. This moving carriage could be adjusted at three levels of height from the ground: namely 1.5 m, 2.5 m, and 3.5 m (Figure 2(c) and 2(d)). The forward speed of the moving carriage can be regulated up to a maximum of 10 m/s. This could be done by setting the required speed at the control console of the main driving unit. The height and speed of the carriage shall be set accordingly prior to the evaluation test. A mounting frame structure was built for securing the UAV to the moving carriage on the rail support structure (Figure 2(e) and (f)).

The second section is a sampling platform structure with total sampling area of 6 m x 6 m and its adjustable height chain level units at the sides. This entire sampling area can be manual set from the two height chain level units up to a maximum height of 3 m at 500 m intervals (Figure 2 (a) and 2(g)). This sampling area has a total of 49 measurement point fixtures that can be manually set to form a 0.5 m × 0.5 m or 1 m × 1 m grid coordinates in accordance to the required spray boom size of the tested UAV. Depending on the mode of conducted test, a pressure sensor or a water-sensitive paper was located at each sampling point on the grid coordinate of the sampling platform structure (Figure 2(h)).

The complete testing facility was equipped with the relevant sensor types to measure and record: (i) ambient air temperature, humidity and atmospheric pressure; (ii) spray downwash pressure at the respective 49 pressure transducer measurement points within the sampling area; (iii) the traveling speed of moving carriage with the test UAV using inductive proximity sensors which were located at fixed distance intervals on the railing beam. All these sensors were interfaced to a dedicated data acquisition system that was specially designed and developed for this test facility.

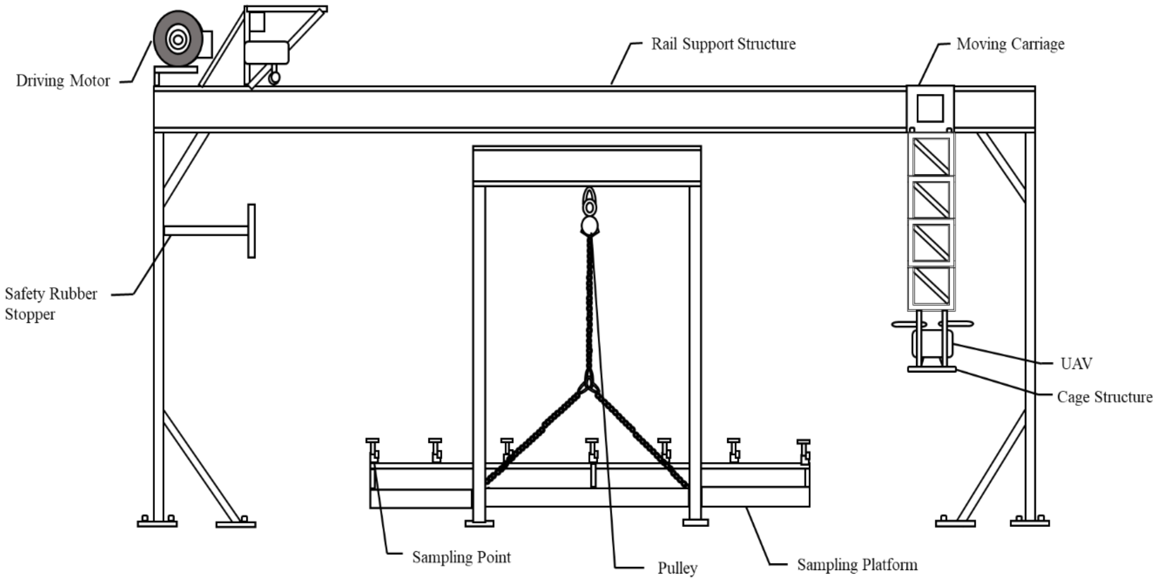


Figure 1. Schematic diagram of UAV testing facility.

Figure 2. UAV testing facility main components: (a) rail support structure and sampling platform; (b) main driving unit; (c) moving carriage at the highest level; (d) moving carriage at the lowest level; (e) mounting frame structure for UAV; (f) UAV on the moving carriage at 3.5 m from the ground; (g) sampling platform at the highest level (3 m from the ground); (h) close-up of sampling points at grid of 1 m × 1 m.

2.2 Operating Procedure

A standard operating procedure has been formulated to operate this UAV testing facility in order to facilitate for a consistent reliable and repeatable test run. The involved procedure to set up the test UAV on the rail structure and the sampling platform have been summarized in the flowchart shown in Figure 3 (a) and (b). Each of the procedure is further discussed in the respective section below.

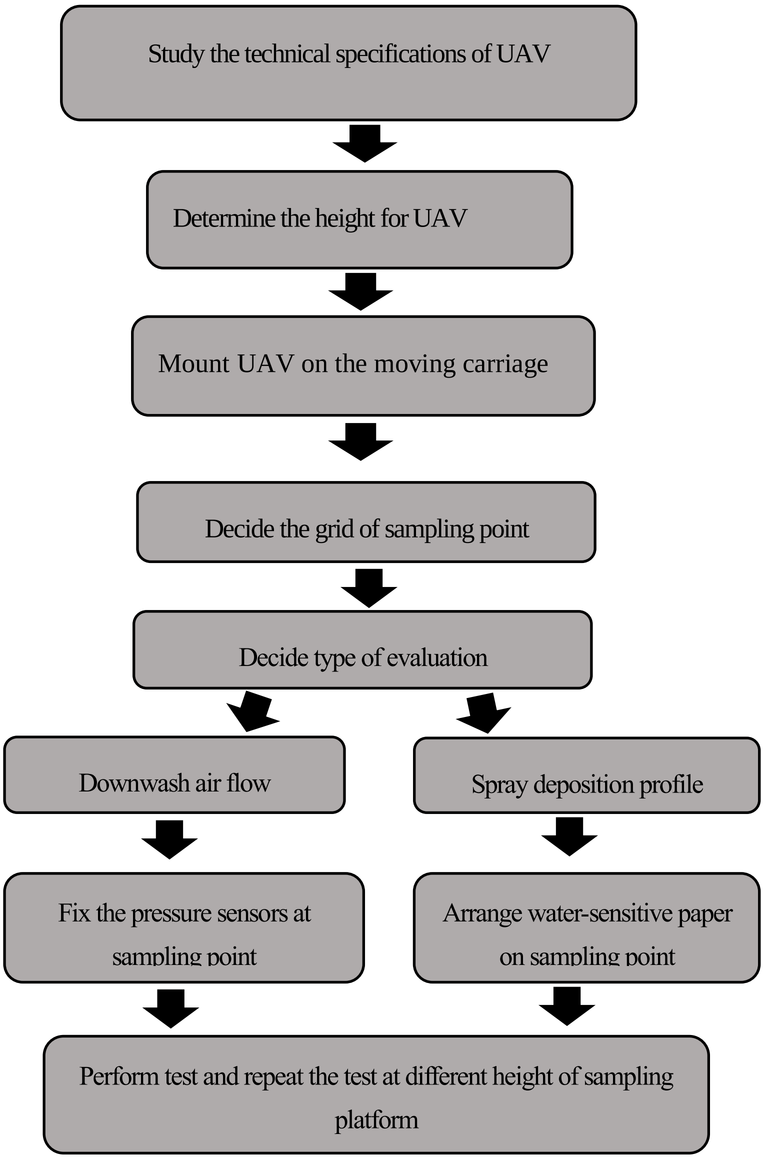


Figure 3(a). Operating procedure for UAV set-up on rail structure.

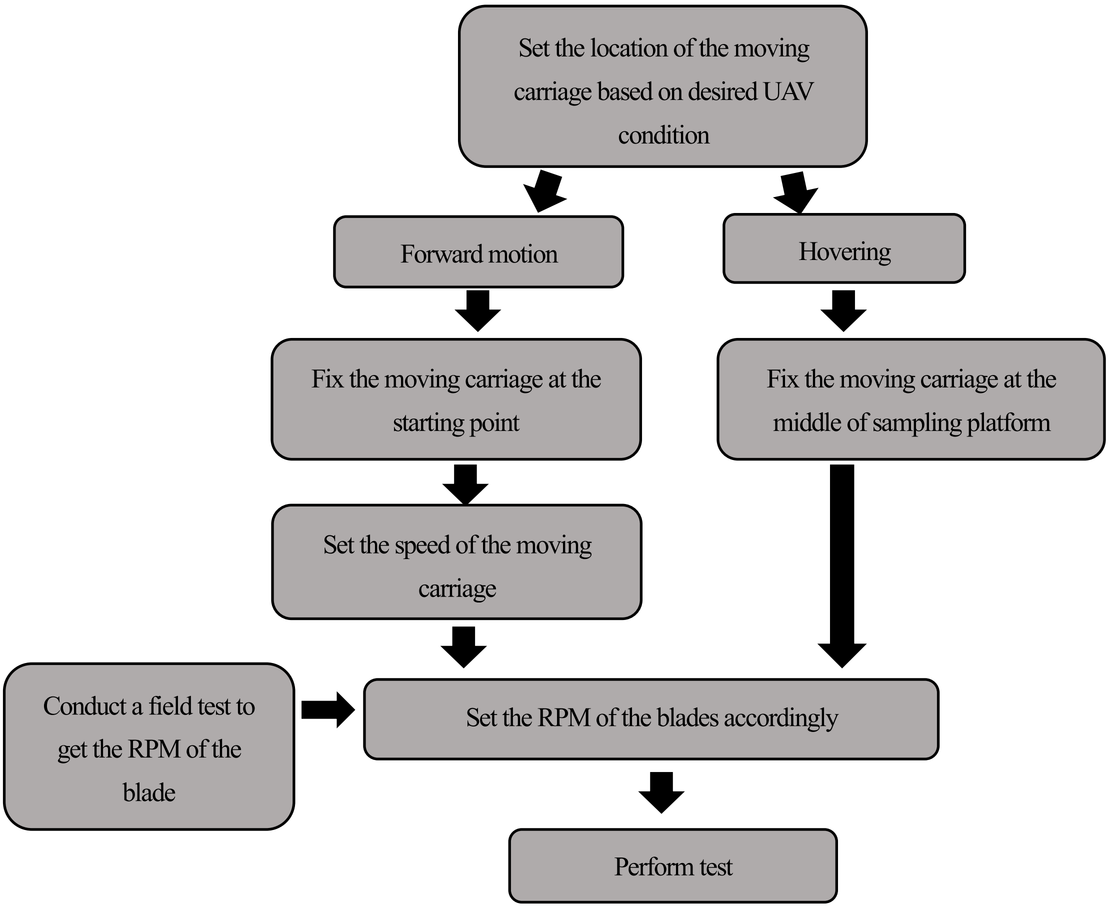


Figure 3(b). Operating procedure for sampling platform set-up.

2.2.1 Selection of UAV

The UAV that is commonly used for aerial chemical spraying in wetland rice cultivation in Malaysia was selected for this research (Figure 4). The technical specifications of the UAV are as shown in Table 1.

Figure 4. Picture of actual UAV.

Table 1. Technical specifications of UAV.

Model	Year manufactured	Number of propellers	Type of propeller	Type of brushless motor	Power Source	Max. payload	Gross UAV weight
Advansia A1	2015	6 (Hexa UAV)	T2255 - Carbon fibre straight	JMR 6215 – KV 170	Poly Lithium Battery x 2 (16000 mAh)	10L	25 kg (maximum with payload) 15 kg (without payload)

2.2.2 Setting the height, speed and location of moving carriage

The height and speed of the moving carriage of the rail support structure need to be set before executing the spraying evaluation on the tested UAV. Depending on the intended height and speed parameters, the chosen height of the moving carriage should be either 1.5 m, 2.5 m, and 3.5 m from the ground, while moving at a maximum speed of 10 m/s. The moving carriage had to be located in the middle of the sampling area for the spraying evaluation under hovering condition. For evaluation of spraying under moving condition, the moving carriage with the mounted UAV was set to move from the starting point location until the end point of the railing beam.

2.2.3 Setting the revolution per minute (RPM) of the blades

In order to obtain the downwash data of the UAV using the facility, the numbers of blade's turns in one minute or known as revolution per minute (RPM) must be set similar to the RPM of the blades during spraying. A field test was carried out beforehand to obtain the RPM data of each blade of the UAV. In this field test, the RPM of each blade on the UAV was recorded, while flying the UAV at the different pay load and flying speed. After the field test, these recorded RPMs would be accessed from the UAV flight controller console using the interface software. These RPM data would be used as a reference when setting up the RPM of the individual blades during the evaluation test using the UAV testing facility.

2.2.4 Deciding the area of the sampling point

The sampling point area had to be determined according to the spray boom size of the tested UAV. The sampling point available on the sampling platform structure could be fixed either at the grid of 0.5 m x 0.5 m or 1 m x 1 m sampling points.

2.2.5 Deciding the type of evaluation

There are two types of evaluation tests that can be carried out using this testing facility. The first type was to evaluate the downwash pressure of the UAV blades with the pitot tube sensors located at the grid measurement points. The second type was to evaluate the droplet deposition of the UAV sprayer boom with water-sensitive paper located at the grid measurement points. All the available pressure sensors on the sampling platform must be replaced with the water-sensitive papers if the conducted test was set to continue after the evaluation of the downwash pressure.

2.2.6 Acquiring downwash flow field

The downwash flow field could be recorded while the UAV was under hovering and moving modes. For hovering, the UAV at the specific height and the RPM (refer to sections 2.2.2 and 2.2.3) was set to be located in the middle of the sampling area. Pressure sensors would be set to collect the readings of the downwash pressure. In order to obtain a complete 3D profile spectrum of pressure readings, the test was repeated at different height of sampling platform.

In order to acquire the downwash flow field while UAV was moving, the RPM of the UAV blades as specified in section 2.2.3 had to be set to the desired moving speed and payload. In addition, the height and speed of the moving carriage of the testing facility had to be set accordingly (section 2.2.2). As the moving carriage with the tested UAV moves along the railing beam, the pressure sensors located on the sampling platform structure would capture the downwash pressure readings and record the capture readings on the data acquisition system at the same time. The same test had to be repeated in order to get the 3D downwash pressure profile at different levels of height by increasing or lowering the sampling platform structure of the testing facility. All pressure data recorded would be analyzed using MATLAB software (The MathWorks, Inc).

2.2.7 Verifying the droplet deposition

To measure the distribution of droplet deposition, water-sensitive papers were fixed at all available points on the sampling platform. As explained in sections 2.2.2 and 2.2.3, the application parameters such as blades RPM, height and speed of the carriage were to be set accordingly. The UAV spraying tank should be earlier filled with the spray chemicals and the spray system had to be set to run at 10 sec under a still position before the start of the test to ensure that the flow was stable. All water-sensitive papers should be collected immediately upon the completion of the UAV test run. Each of the collected water-sensitive papers need to be scanned using a portable scanner and then analyzed using the droplet deposition imaging system ‘DepositScan’ by USDA developed by Zhu *et al.* (2011).

The information that could be gathered from this test includes swath width and droplet distribution profile (droplet spectrum in µm) such as the number of droplet per area and concentration of deposition per area (µL/cm^2). The deposition result could then be matched to the downwash data and would be used to determine the optimum application parameters for the UAV in the later actual field spraying operation.

3. Preparing Report

The test report to be prepared would include detail documentation on the technical specification of the test drone and related picture or technical drawing of the test drone, spraying application parameters (i.e. release height and travel speed), spray system technical specifications (i.e. spray pressure, flow rate, application rate, nozzle type, nozzle distance, and the number of nozzle), spraying material specifications (i.e. temperature of spraying materials and its physical properties), ambient conditions (i.e. air temperature, relative humidity and atmospheric pressure) and the details results from the evaluation.

4. Expected Result

With the establishment of this Indoor UAV testing facility, the downwash airflow and spraying performance of any agricultural UAV could be determined to allow proper recommendations on the flying requirements of the UAV in order to achieve an efficient agricultural spraying operation.

The testing facility is expected to be a platform for the UAV industry to improve the current UAV or to design a new UAV with the best combinations of configurations and spraying system to maximize spraying efficiency. The testing facility could also allow for a detailed study of the development and evaluation of the new chemical spray formulations for aerial spraying using UAV.

5. Conclusion

In this paper, an indoor test facility was designed and developed to evaluate agricultural UAVs in hovering and forward motion modes for their downwash airflow and spraying performance. The rail support structure with the carriage was designed to carry the UAV and the sampling platform was constructed under the rail structure to collect data on the downwash pressure and the spray distribution of the test UAV. A standard testing procedure was formulated to provide the performance evaluations to undergo under the same standard protocols.

The rig could also be used to carry out a detailed study on the development and evaluation of new chemical spray formulations for aerial spraying using UAV and as a testing platform for the UAV industry.

Author Contributions: writing—original draft preparation, S.A. Ismail.; writing—review and editing, S.A. Ismail, A.Yahya, A.S. Mat Su, N. Asib, and A. Mohd Mustafah.

Funding: This work was funded from the Matching-Grant Putra with grant number 9300461.

Acknowledgments: The researchers would like to thank Poladrone Sdn. Bhd. and Advansia Sdn.Bhd. for the UAV and its accessories, advices, and assistance.

Conflicts of Interest: The authors declare no conflict of interest.

References

Chen, S. D., Lan, Y. B., Li, J. Y., *et al*. (2017). Effect of wind field below unmanned helicopter on droplet deposition distribution of aerial spraying. *International Journal of Agriculture & Biological Engineering*. 10(3), 67–77.

Cong, H., Jiyu, L., Yubin, L., *et al*., (2018). Design and experiment of a wind speed detection equipment with wind pressure conversion near ground. *Journal of South China Agricultural University*, *39*(1), 105–111 ref.21.

Faiçal, B.S., Pessin, G., Ueyama, J., *et al.,* (2017). An adaptive approach for uav-based pesticide spraying in dynamic environments. *Computers and Electronics in Agriculture, 138,* 210–223.

Feng, T., Qi, L., Chang-liang, L., *et al*., (2018). Measurement of downwash velocity generated by rotors of agriculture drones. *INMATEH Agricultural Engineering*, *55*(2), 141–150.

Giles, D. K., & Billing, R. (2014). Unmanned aerial platforms for spraying: Deployment and performance. *Aspects of Applied Biology,12*, 63–69.

He, X. K., Bonds, J., Herbst, A., *et al.,* (2017). Recent development of unmanned aerial vehicle foor plant protection in East Asia. *International Journal of Agricultural and Biological Engineering*, *10*(3),18–30.

Hofman, V., & Solseng, E., (2017). *Reducing spray drift. NDSU Extension Service*. Retrieved from https://www.ag.ndsu.edu/publications/crops/reducing-spray-drift/ae1210.pdf

Huang, Y., Hoffmann, W.C., Lan, Y., *et al*. (2009). Development of a spray system for an unmanned aerial vehicle platform. *Applied Engineering in Agriculture,* 25(6),803–809.

Huang, Y., Thomson S. J., Hoffmann, W.C., *et al.,* (2013). Development and prospect of unmanned aerial vehicle technologies for agricultural production management. *International Journal of Agricultural and Biological Engineering*, *6*(3),1 –10.

Meivel, S., Maguteeswaran, R., Gandhiraj, N., *et al.,* (2016). Quadcopter uav based fertilizer and pesticide spraying system. *International Academic Research Journal of Engineering Sciences*, *1*(1), 8–12.

Morley, C. G., Broadley, J., Hartley, R., *et al*. (2017). The potential of using unmanned aerial vehicles (UAVs) for precision pest control of possums (*Trichosurus vulpecula*). *Rethinking Ecology*, *2*, 27–39.

Puig, E., Mcfadyen, A., & Gonzalez, F. (2018). Advances in unmanned aerial systems and payload technologies for precision agriculture. In Chen G, *Advances in Agricultural Machinery and Technologies* (pp. 133–155). Boca Raton: CRC Press.

Pscheidt J. W. (2012). *Improving spray efficiency*. Pest management handbook. Retrieved from https://pnwhandbooks.org/plantdisease/pesticide-articles/improving-spray-efficiency.

Qin, W. C., Qiu, B. J., Xue, X. Y., *et al*. (2016). Droplet deposition and control effect of insecticides sprayed with an unmanned aerial vehicle against plant hoppers. *Crop Protection*, *85*, 79–88.

Teske M. E., Wachspress D. A., & Thistle H. W. (2018). Prediction of aerial spray release from UASs. *Transaction of the ASABE*, *61*(3), 909–918.

Wang, S. L., Song, J. L., He, X. K., *et al*. (2017). Performances evaluation of four typical unmanned aerial vehicles used for pesticide application in China. *International Journal of Agriculture & Biological Engineering*, *10*(4), 22–31.

Wu, Y., Qi, L., Zhang, H., *et al.,* (2019). Design of UAV downwash airflow field detection system based on strain effect principle. *Sensors*, *19*(1), 1–18. doi:10.3390/s19112630.

Yang, F. B., Xue, X. Y., Zhang, L., *et al*. (2017). Numerical simulation and experimental verification on downwash air flow of six-rotor agricultural unmanned aerial vehicle in hover. *International Journal of Agricultural and Biological Engineering*, *10*(4), 41–53.

Yang, F. B., Xue, X., Cai, C., *et al.* (2018). Numerical simulation and analysis on spray drift movement of multirotor plant protection unmanned aerial vehicle. *Energies*, *11*(9), 1–20. doi:10.3390/en11092399.

Zhang, P., Deng, L., Lyu, Q., *et al*. (2016). Effect of citrus tree shape and spraying height of small unmanned aerial vehicle on droplet distribution. *International Journal of Agricultural and Biological Engineering*, *9* (4), 45–51.

Zhang, S. C., Xue, X. Y., Sun, Z., *et al*. (2017). Downwash distribution of single rotor unmanned agricultural helicopter on hovering state. *International Journal of Agricultural and Biological Engineering*, *10*(5), 14–24.

Zheng, Y., Yang, S., Liu, X., *et al.* (2018). The computational fluid dynamic modelling of downwash flow field for a six-rotor UAV. *Frontiers of Agricultural Science and Engineering, 5*(2), 159–167. doi: https://doi.org/10.15302/J-FASE-2018216.

Zhu, H., Salyani, M., Fox, R. D. *et al.* (2011). A portable scanning system for evaluation of spray deposit distribution. *Computers and Electronics in Agriculture*, 76, 38–43. https://doi.org/10.1016/j.compag.2011.01.003.

MALAYSIAN SOCIETY OF AGRICULTURAL AND FOOD ENGINEERS

ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

HH PUBLISHER

Original Research Article

Rice Bran of Different Rice Varieties in Malaysia: Analysis of Proximate Compositions, Antioxidative Properties and Fatty Acid Profile for Data Compilation

Nurul Najihah Ilias[1], Norazatul Hanim Mohd Rozalli[1*], Nguyen Hoang Thuy Vy[2], Eng Hui Yi[1]

[1]Food Technology Division, School of Industrial Technology, Universiti Sains Malaysia, 11800, Minden, Pulau Pinang, Malaysia, najihah.ilias89@student.usm.my, norazatulhanim@usm.my, huiyi_eng@student.usm.my

[2]Faculty of Food Technology, Nong Lam University - Ho Chi Minh City, Linh Trung Ward, Thu Duc district, Ho Chi Minh City, 15125390@st.hcmuaf.edu.vn

*Corresponding author: Norazatul Hanim Mohd Rozalli, Food Technology Division, School of Industrial Technology, Universiti Sains Malaysia, 11800, Minden, Pulau Pinang, Malaysia; norazatulhanim@usm.my

Abstract: The research aims to investigate the difference in rice bran compositions of three major paddy varieties in Malaysia, which are MR 220 CL2, MR 219 and MR 297. The proximate compositions, antioxidative properties and fatty acid profile of the rice bran were compared. Stabilization of rice bran of all varieties was conducted in prior to the extraction of rice bran oil (RBO) by using the Soxhlet extraction. Fatty acid compositions consisted in RBO of each variety were analysed by using gas chromatography-mass spectrometry (GC-MS). Results on proximate compositions showed that MR 297 was the highest in the content of moisture (3.90 ± 0.29 %), fat (22.52 ± 0.09 %), protein (12.70 ± 0.53 %) and crude fiber (3.65 ± 0.26 %). MR 297 variety also exhibited the highest antioxidant activity, which indicated by the highest amount of total phenolic content (TPC) and ferric reducing antioxidant power (FRAP) compared to the other two varieties. Three components of fatty acids: palmitic acid; oleic acid; linoleic acid have made up around 90% of the total fatty acids of the RBO for all varieties. The RBO also contains ideal fatty acid compositions with more unsaturated compared to saturated fatty acid, which makes it suitable to be used as a healthy edible oil. Results of this study can provide significant nutritional information for future investigations on the conversion of this agro-waste into valuable products for animals and human benefits.

Keywords: rice bran; proximate compositions; antioxidant; fatty acid; rice; rice bran oil

Received: 24th November 2020

Accepted: 24th December 2020

Available Online: 30th December 2020

Citation: Ilias NN, Mohd Rozalli NH, Vy NHT, *et al.* Rice bran of different rice varieties in Malaysia: Analysis of proximate compositions, antioxidative properties and fatty acid profile for data compilation. Adv Agri Food Res J 2020; 1(2): a0000164. https://doi.org/10.36877/aafrj.a0000164

1. Introduction

The increasing interest in the relationship between health and food, results in the increment of formulation studies about functional products. Among the emerging source that is being explored is rice bran, which is produced from the milling process of brown rice. This process removes the outer brown layer in white rice processing (Eyarkai Nambi *et al.*, 2017). Rice bran is an indispensable, abundantly available and less expensive which exist in a soft and fluffy off-white powdery material. Around 2.7 million metric tons (MT) of paddy were averagely produced in Malaysia from the year 2014 to 2017 (Ministry of Agriculture, 2018). From this amount, rice bran constitutes around 8–10% of total rice production (Sereewatthanawut *et al.*, 2008; Salehi & Sardarodiyan, 2016), which signifies its abundance in Malaysia. However, it is currently underutilized, since it is either being disposed or used as an animal feed (Iqbal, *et al.*, 2005; Bhosale & Vijayalakshmi, 2015).

Despite its abundance, rice bran has been considered as an excellent source of nutrients (65% of beneficial nutrients) among other rice by-products. It is reported that rice bran was rich in protein (11–17%), carbohydrate (34-62%), fat (11–18%), crude fiber (10%), ash (9%), vitamins and trace minerals (Kumari *et al.*, 2018). It is also an important source of antioxidants due to the presence of γ-oryzanol, tocopherols, and tocotrienols, which can help in disease prevention and promoting good health (Alauddin *et al.*, 2017; Chakraborty & Budhwar, 2018). Rice bran and rice bran oil have profound health benefits contributed by its antioxidant's compounds, which are also important in improving the storage stability of food. Antioxidant properties were also responsible in lowering the cholesterol besides the contribution of fatty acid compositions. One of the rice bran components, identified as defatted rice bran, has a notable potential in the food industry, especially in the development of functional foods such as fermented cereals (Aktaş & Akın, 2020; Murai *et al.*, 2020), functional bakery products (Hu *et al.*, 2009; Saccotelli *et al.*, 2017) and low-fat meatballs (Hu & Yu, 2015). Rice bran oil (RBO), another portion of rice bran is also potential sources of edible oil, which can be extracted around 12–18.5% from the crude rice bran (Saikia & Deka, 2011). RBO is encompasses of an ideal amount of unsaturated and saturated fatty acids, which contributes to the shifting towards the utilization of RBO as an edible oil in several countries like Bangladesh, Taiwan, Japan and a few Western countries (Ahmad Nayik *et al.*, 2015; Lai *et al.*, 2019). Besides its potential health benefits, RBO is highly preferred, since it is an excellent cooking medium contributed by its nutritional superiority, longer shelf life, abundant micronutrients, high stability at higher temperature, appealing flavour and alternative to bakery shortening (Liang *et al.*, 2014).

In Malaysia, new paddy varieties are developed to fulfil certain requirements other than ensuring the improvement of paddy quality time to time. The innovation needs to be implemented and adopted to increase the country's rice production, meet the consumers' demand and to produce paddy with high resistance against diseases, which then contributed to a good environmental well-being (Hussain *et al.*, 2012). Various types of local and imported paddy in Malaysia have been studied by previous research, which are emphasized on their nutritional compounds (Nori *et al.*, 2009; Thomas *et al.*, 2015; Hashmi & Tianlin, 2016), physico-chemical properties (Sam Lum, 2017), agronomic and soil's physico-chemical characteristics (Hanafi *et al.*, 2009) and morphological features (Ruslan *et al.*, 2018). However, to date, only few researchers have published their work focusing on the utilization of rice bran as a by-product from rice production in Malaysia. The effect of milling degree towards the nutritional compositions of rice bran (MR 220) has been reported by Rosniyana *et al.* (2007; 2009). Oryzanol content of several types of rice bran from different paddy varieties in Malaysia has been investigated by Azrina *et al.* (2008). Besides, the effect of extraction conditions towards the yield and properties of rice bran oil from different varieties have been studied in the previous report compiled by Daud *et al.* (2018).

Therefore, this study has attempted to further investigate the nutritional compositions of rice bran and its oil component extracted from paddy varieties in Malaysia. Additionally, this project is in line with Malaysia's Paddy and Rice Strategy 2011-2020, which intensifies the use of rice by-products. Information regarding beneficial compound in the rice bran extracted from this research paves a good way for the particular industries like food and agricultural to further plan suitable processing steps and products to be produced. Hence, this study aims to identify the chemical compositions of stabilized rice bran from three major paddy varieties in Malaysia, in term of its proximate compositions and antioxidative properties. Besides that, fatty acid profiles of the oil portions extracted from each rice bran variety were also analysed. Differences in the nutritional and fatty acid compositions among the paddy varieties were also discussed in this study.

2. Materials and Methods

2.1 Sample and Reagents

In total, three types of paddy varieties were used; MR 220 CL2, MR 219 and MR 297, as the samples of this study. All paddy varieties were obtained from local seed company in Tanah Merah, Pendang, Kedah. All chemicals used were procured from Merck or Sigma–Aldrich (Darmstadt, Germany) unless stated otherwise and were of analytical grades.

2.2 Sample Preparation

Rice bran was processed by milling 40 kg of paddy by using a 50 kg-capacity rice mill at the Malaysian Agricultural Research and Development Institute (MARDI) station, Bukit Raya, Kedah. Upon production, samples of rice bran were collected and stored in the dry ice in cold box containers. The samples were immediately processed by screening through 500 µm sieve to obtain uniform particle size. Each variety was processed separately. The initial moisture content was determined using a method by AOAC (2012).

2.3 Stabilization of Rice Bran

The stabilization of rice bran was done by using Autoclave Sterilizzazione Usata, 100L (Guangdong, China) at 120°C for 20 min according to the method described by Rosniyana *et al.* (2009). Stabilization step was done to increase the sustainability of the rice bran for long-term storage as well as to improve the availability of bioactive components. The stabilization process was done immediately after the sieving step. Then, the sample was dried at 60°C to reduce the moisture content to less than 5%.

2.4 Production of Rice Bran Oil (RBO)

Rice bran oil (RBO) was extracted by using a Soxhlet method adapted from Abdul Khalil *et al.* (2016) with slight modifications, using n-hexane as the extraction solvent. 5 g of rice bran samples were placed in a thimble and inserted in a Soxhlet extraction unit, which was connected to a reaction flask containing 250 mL n-hexane. The extraction was then conducted at 75°C for 90 min (Ferreira-Dias *et al.*, 2003). The resulting oil (RBO) extracted from the samples were collected and kept in 4°C.

2.5 Chemical Analysis of Rice Bran

Stabilized rice bran was analysed for chemical properties such as moisture, protein, fat, crude fiber and ash following the procedures of AOAC (2012) and the total carbohydrate was calculated by the difference method.

$$\text{Total carbohydrate (\%)} = 100 - [\text{crude protein (\%)} + \text{crude fiber (\%)} + \text{crude fat (\%)} + \text{total ash (\%)}] \quad (1)$$

2.6 Estimation of Antioxidant Activity

2.6.1 Extraction of total antioxidants

Extraction was carried out following the method suggested by Arab *et al.* (2011). 5g of stabilized rice bran was extracted using 20 mL of methanol at room temperature for 3 hours in an electrical shaker MaxQ 4000 Incubator, Thermo Fisher (Waltham, M.A. USA). The residue was re-extracted twice and was filtered through Whatman (No.1) filter paper. The extracts from each procedure were combined and dried using rotary evaporator at 50°C.

2.6.2 Determination of total phenolic content (TPC)

Total phenolic content was determined colourimetrically according to a method described by Singleton and Rossi (1965) with slight modifications. 1 mg/mL of crude rice bran extract was prepared. 20 μL of the extract was mixed with 100 μL of Folin–Ciocalteu reagent and subsequently, 1.58 mL of distilled water was added. The mixture was mixed vigorously and 300 μL of (20% w/v) sodium carbonate was added and vortexed. The absorbance was measured at 765 nm by using UV-vis spectrophotometer Shimadzu UV-2600i (Kyoto, Japan) after leaving to stand at room temperature (dark environment) for 2 hours. The results were expressed as g of gallic acid equivalents (GAE) per 100 gram of rice bran using gallic acid (0.01–0.05 mg/ml) as the standard curve. The following formula was used to calculate the total phenolic content (TPC):

$$TPC = c \times V/m \quad (2)$$

c is sample concentration from the calibration curve (mg/mL), V is volume (mL) of the solvent use for extraction and m is weight (g) of dried sample

2.6.3 Scavenging effect on 2,2-Diphenyl-1-picrylhydrazyl (DPPH)

The antioxidant activity was determined following the method described by Heinonen *et al.* (1998) with slight modifications. 0.1 mL of extract was mixed with 3.9 mL of 60 µM DPPH solution in methanol in the test tube and vortexed. The mixture was kept at room temperature in a dark environment for 30 min, prior to measurement of the absorbance at 51.7nm. Higher free radical scavenging activity was indicated by the lower absorbance of the reaction mixture. Scavenging effect can be calculated using the following formula:

$$\text{DPPH scavenging activity (\%)} = \frac{(Ac-As)}{Ac} \times 100 \quad (3)$$

where As and Ac is the absorbance (at 517 nm) of sample and control solution, respectively.

2.6.4 Reducing power using Ferric Reducing Antioxidant Power (FRAP) assay

Method of Luqman *et al.* (2009) was used to determine ferric reducing antioxidant power (FRAP). 3 mL of freshly prepared FRAP reagent (25 mL of acetate buffer: 300 mM, pH 3.6; 2.5 mL 2,4,6-Tri(2-pyridyl)-s-triazine (TPTZ) solution: 10 mM TPTZ in 40 mM HCl and 2.5 mL of $FeCl_3$: 20 mM in water solution) was added to 200 µL extract to initiate the reaction. After 30 min of incubation in a 37°C water bath, the absorbance was observed at

593 nm. Standard curve (mg/mL) was prepared by using iron (II) sulphate, $FeSO_4.7H_2O$ and the results were expressed as mg $FeSO_4$ per grams of rice bran.

2.7 Fatty Acid Profile

Transesterification was carried out to produce fatty acid methyl esters (FAME) based on the method of Ichihara and Fukubayashi (2010) with minor modifications. Approximately 0.1 g of rice bran oil (RBO) from each variety was dissolved in 0.2 mL of chloroform. This was followed by the addition of 2 mL methanol and 0.1 mL of concentrated HCl (35%, w/w) to the lipid solution which resulted in the final volume of 2.3 mL. The sample was tightly closed and after vortexed, the sample was heated in a water bath at 100°C for 1 hour. Following the procedure, the sample was left to cool to room temperature before 2 mL of hexane and 2 mL of distilled water was added for extraction of FAMEs. After the phase separation, the hexane phase was evaporated under nitrogen stream and the residue was dissolved again using 0.1 mL of hexane and 1 µL of this solution was injected for GC-MS analysis. To separate and quantify the esterified fatty acid mixture, GC-MS QP 2010 by Shimadzu (Kyoto, Japan) equipped with split injector and capillary column of BPX70 (30 m × 0.25 mm × 0.25 µm) was used. Helium was utilized as the carrier gas at a flow rate of 1.03 mL/min. The injector and detector temperatures were set to 230°C. The chromatographic conditions for separation were 50°C, as the initial column temperature, raising to 170°C at a flow rate of 4°C/min and holding during 5 min. The second step involved the increment at a heating rate of 2°C/min to 220°C and held for 10 min. The peaks were identified and compared by relating them to the recognized standards.

2.8 Statistical Analysis

Statistical analysis of the results obtained in this study were subjected to a One-way analysis of variance (ANOVA) by using SPSS software (SPSS version 17.0 SPSS Inc., Wacker Drive, Chicago, IL, USA). The level of significance was determined at $p < 0.05$.

3. Results

3.1 Proximate Compositions

The proximate compositions of rice bran from three rice varieties, which are locally grown in Malaysia are shown in **Table 1**. Analysis of variance (ANOVA) showed that there were significant differences ($p < 0.05$) in several proximate compositions of all rice varieties. Moisture content was recorded to vary within the range of 3.18-3.90%. It is also observed that there were no significant differences recorded for crude fibre content between all types of bran. In Table 1, it is shown that MR 297 contains the highest amount of fat (22.52 %), protein (12.70 %), fiber (3.65 %) and moisture content (3.90 %) compared to other varieties, while the ash and carbohydrate contents were ranged between 8.97% to 10.08 %, and 50.71 to 51.99 %, in all varieties, respectively. Overall, in this study, MR 297 demonstrated the highest amount of chemical compositions compared to MR 219 and MR220 CL2.

Table 1. Variations in proximate conditions for different types of varieties

Rice bran variety	**Proximate compositions (%)**					
	Fat	Protein	Ash	Crude fibre	Moisture	Carbohydrate
MR 220 CL2	20.32±0.10^{c}	9.92±0.30^{a}	8.97±0.15^{c}	2.83± 0.73^{a}	3.18± 0.36^{b}	51.99±0.05^{b}
MR 219	21.84±0.54^{b}	10.64±0.60^{b}	10.08±0.12^{a}	3.13± 0.70^{a}	3.60± 0.21^{ab}	50.71±0.12^{a}
MR 297	22.52±0.09^{a}	12.70± 0.53^{b}	9.31±0.08^{b}	3.65± 0.26^{a}	3.90± 0.29^{a}	50.71±0.09^{a}

Mean ± standard deviation (n = 9), means followed by the same superscript are not statistically significant at the 5% level.

3.2 Antioxidant Activities

The total phenolic content (TPC) of the methanolic extracts of rice bran from all varieties is shown in Figure 1. From the figure, it can be depicted that MR 220 CL2 (0.042 g GAE/100 g bran) and MR 297 (0.047 g GAE/100 g bran) showed no significant difference (p<0.05) between the content of TPC in their methanolic extracts, while the lowest amount of TPC is shown by MR 219 (0.021 g GAE/100 g bran).

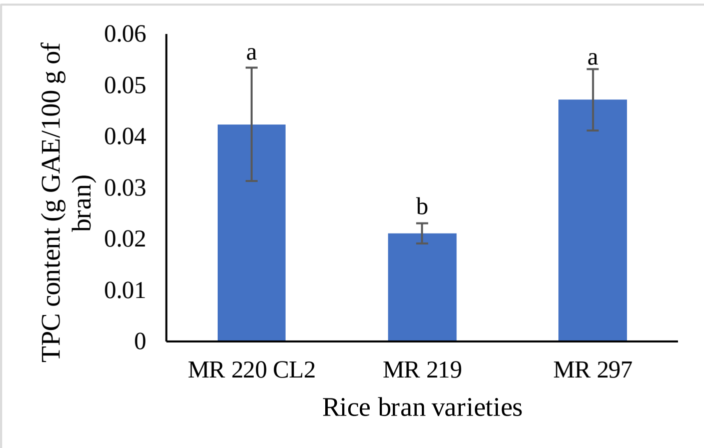


Figure 1. TPC contents (g GAE/100 g of bran). Mean ± standard deviation (n = 3). TPC content with different letter between the rice bran varieties are significantly different (p < 0.05)

The scavenging activity of crude methanolic extracts from three varieties of rice bran is shown in Figure 2. From the figure, DPPH scavenging activity of MR 297 (4.0072%) was significantly different ($p < 0.05$) from MR 219, but no significant difference from MR 220 CL2 (4.6915%) was observed.

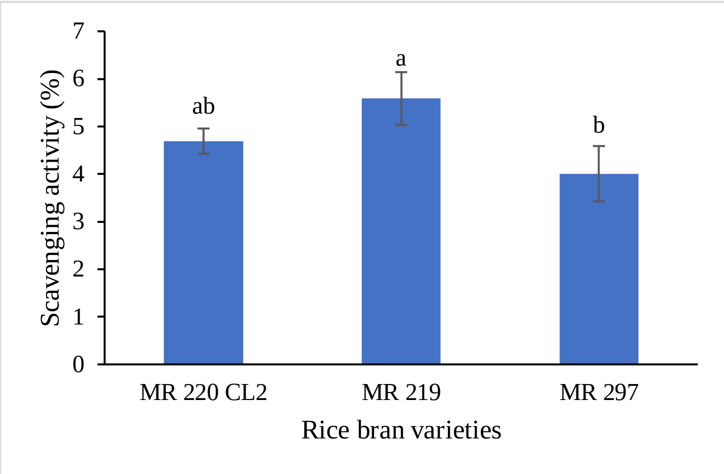


Figure 2. Scavenging activities of rice bran of all varieties based on DPPH analysis. Mean ± standard deviation ($n = 3$). Scavenging activity with different letter between the rice bran varieties are significantly different ($p < 0.05$)

MR 219 has the highest DPPH scavenging activity (5.5893%). In comparison with TPC, MR219 contains the highest DPPH scavenging activity, but the lowest in TPC value. The third antioxidant analysis that was conducted in this study was the ferric reducing antioxidant power (FRAP) assay. The result was calculated from the $FeSO_4$ calibration curve, with $R^2 = 0.9991$. The reducing capability of all rice bran extracts are represented by a graph in Figure 3. It is clearly shown that MR 297 (3.6803 mmol L^{-1}/g of bran) has the highest capability in reducing the Fe+++/tripyridyl-s-triazine (TPTZ) complex followed by MR 220 CL2 and MR 219. In this study, positive correlations between the amount of TPC and the ferric reducing capability of all rice bran varieties were observed.

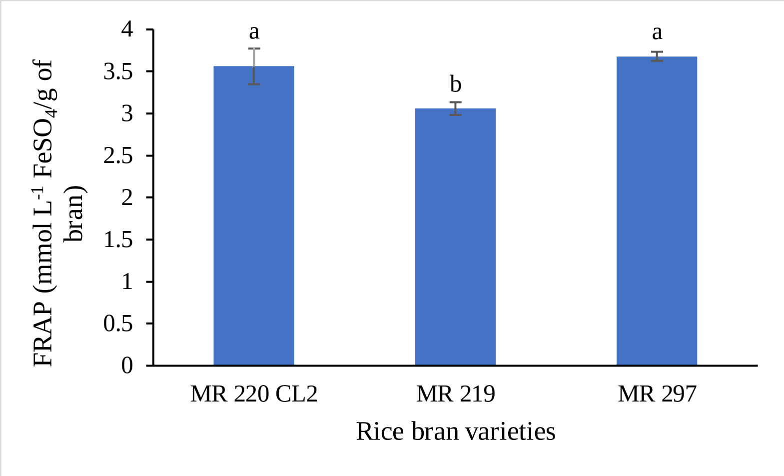


Figure 3. FRAP assay of all varieties. Mean ± standard deviation (n = 3). FRAP content with different letter between the rice bran varieties are significantly different ($p < 0.05$)

3.3 Fatty Acid Profile

The fatty acid profiles obtained for the rice bran oil (RBO) that were extracted from three different rice varieties (MR 220 CL2, MR 297 and MR 219) are presented in **Table 2**. The results showed that the RBO from all varieties were dominated by the high percentage of monounsaturated fatty acid (MUFA) followed by polyunsaturated fatty acid (PUFA) and saturated fatty acid (SFA). It was also observed that all three varieties were consisted of three major fatty acids in RBO, which were palmitic acid (SFA), oleic acid (MUFA) and linoleic acid (PUFA). The results concluded that RBO from MR 219 is the best oil to be used, since it contains the highest MUFA and PUFA, while showing the least amount of SFA as compared to the other varieties.

Table 2. Fatty acids profiles of three varieties of rice bran oil.

Fatty acid	**Lipid numbers**	**Group**	**Relative abundance (%)**		
			MR 220 CL2	MR 219	MR 297
Myristic acid	C14:0	SFA	0.48	0.55	0.44
Palmitic acid	C16:0	SFA	23.92	19.20	23.81
Palmiteloic acid	C16:1	MUFA	ND	0.04	ND
Stearic acid	C18:0	SFA	3.76	3.23	3.08
Oleic acid	C18:1	MUFA	33.52	37.07	34.92
Linoleic acid	C18:2	PUFA	27.07	29.61	27.38
α-Linoleic acid	C18:3	PUFA	0.86	0.96	0.85
Arachidic acid	C20:0	SFA	0.57	0.74	0.54
Behenic acid	C22:0	SFA	0.26	0.25	0.26
Erunic acid	C22:1n	MUFA	ND	ND	0.23
Lignoceric acid	C24:0	SFA	0.41	0.43	0.34
Hexadecadienoic acid	C16:2n4	PUFA	ND	0.27	0.27
Others			9.15	7.46	7.88

Fatty acid	Lipid numbers	Group	Relative abundance (%)		
			MR 220 CL2	MR 219	MR 297
SFA			29.4	24.4	28.47
MUFA			33.52	37.11	35.15
PUFA			27.93	30.84	28.50

Abbreviations: SFA-saturated fatty acid; MUFA-monounsaturated fatty acid; PUFA-polyunsaturated fatty acid; ND – not determined

4. Discussion

Chemical analysis on the proximate compositions can provide useful information on the main components of certain food. Among the compositions analysed in proximate analysis were moisture, protein, fiber, fat, ash and carbohydrate (Satter *et al.*, 2014; Verma & Srivastav, 2017). The amount of moisture obtained in all rice bran varieties were in agreement with the studies reported by Bhosale and Vijayalakshmi (2015) (4.30%) and Chakraborty and Budhwar (2018) (4.18%). The moisture content of food should be considered by food manufacturers for several reasons. Moisture plays a significant role in measuring the quality, preservation and resistance of certain material to deterioration. It is also necessary to be measured so that the content of other constituents can be calculated on a uniform basis. It was suggested by Mercer (2008) that the lower moisture contents as observed in this study satisfies the minimum value of moisture (<10%) for long-term storage, which can prevent microbial growth as well as insect infestation.

Unlike other macronutrients such as lipid and carbohydrate, proteins are necessary in the formation of biomolecules rather than its function as a source of energy. The amount of ash content present in the food samples indicates the level of essential minerals. Carbohydrate contents were high (>50%) in all varieties, thus showing rice bran as a good source of carbohydrate. The data obtained for protein, carbohydrate and ash contents satisfied the range of basic chemical components of rice bran reported by Kumari *et al.* (2018). High amount of fat content in rice bran also found by Rosniyana *et al.* (2007) and Issara and Rawdkuen (2018), which lies between the range of 20% to 26%. High nutritional compositions observed in MR 297 had revealed its potential as a promising rice bran source of functional food. In Malaysia, MR 297 is a new paddy variety which were released in 2016. This variety can be easily obtained since it is the second largest variety cultivated in the main season of 2017/2018. The planted area is about 31.6% from the total cultivated paddy in that year (Hosnan, 2019; Omar *et al.*, 2019).

Phenolic content is one of the major group of compounds that plays an important role in antioxidative action especially as free radical terminators (Awika *et al.*, 2003; Oviasogie *et al.*, 2009). According to Du *et al.* (2013), phenolic compounds in rice comprises of several flavonoid components like kaempferol, myricetin, catechin and quercetin. Study done by

Iqbal *et al.* (2005) stated that the amount of TPC in 80% methanolic extract of different rice bran varieties originated from Pakistan were ranged from 0.250 to 0.397 g GAE/100 g. Chatha *et al.* (2006) had also revealed that TPC of four varieties of rice bran indigenous to Pakistan ranged from 0.251–0.359 g GAE/100 g bran. Comparable TPC contents were reported by Muntana and Prasong (2010) from the methanolic extracts of rice bran from Thai rice cultivars (red, white and black rice), which were ranging from 0.089–0.122 g GAE/100 g of bran.

In 2,2-Diphenyl-1-picrylhydrazyl (DPPH) assay, higher free radical-scavenging activity was indicated by lower absorbance of the reaction mixture. Radical-scavenging activity was expressed as the percentage of inhibition of free radical by the sample (Thirunavukkarasu *et al.*, 2011). Negative correlation observed between TPC and scavenging activity of MR 219 can be supported by Tawaha *et al.* (2007), which discovered that the amount of TPC was not a direct indicator of the total amount of antioxidants that might be present in the extract. Besides that, Prior *et al.* (2005) also emphasized the different role of Folin-Ciocalteu assay and free radical scavenging assay in which the former gives a crude estimation of the TPC present in an extract, whereas the latter is not only specific to polyphenols. The inverse correlation between TPC and DPPH was also reported in the study done by Ruslan *et al.* (2018) regarding the antioxidant potential of two varieties of sesame seed from Indonesia.

Ferric reducing antioxidant power (FRAP) assay is a measurement of the ability of antioxidant capacity to reduce the Fe+++/tripyridyl-s-triazine (TPTZ) complex, to the ferrous form under acidic conditions (pH 3.6) (Luqman *et al.*, 2009). Several studies reported the FRAP assay of bran from other sources such as wheat bran which ranged from 21.5 to 36.1 mmol L^{-1} sulfate/g (Saad Smuda *et al.*, 2018) and 85.06–109.12 µmol/g dm in wheat grain (Durazzo *et al.*, 2015). In comparison with the previous studies mentioned, the antioxidative properties of rice bran resulted from the antioxidant analysis in this study were lowered by approximately 90%. The variation in the nutritional compositions of rice bran might be explained by the influenced of cultivation area, distribution of chemical composition, anatomy and geometry of grains, environmental variability, stabilization technique used and the milling process (Malekian *et al.*, 2000; Rosniyana *et al.*, 2007).

Fatty acid analysis of an oil is of primary importance to be determined by both manufacturers and consumers in order to evaluate the quality of the edible oil used. An ideal amount of monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA) and saturated fatty acids (SFA) are required as an indicator of the oil quality and appear to be critical to avoid any adverse effect in any level of fat intake (Hayes, 2002). The balanced proportions of MUFA, PUFA and SFA in all varieties observed in this study were in agreement with the research conducted by Bakota *et al.* (2014) and Orsavova *et al.* (2015).

The studies reported that a balanced amount of SFA, MUFA and PUFA of rice bran was ranging from 18.4–25.5 %, 38.4–42.3 % and 33.6–39.2 %, respectively. Gopala Krishna *et al.* (2006), Pal and Pratap (2017) and Mas'ud *et al.* (2017) also found that palmitic, oleic and linoleic acid were among the three main fatty acids compositions consisted in RBO. Higher proportion of palmitic acid (SFA) in palm oil (44%) (May & Nesaretnam, 2014) had pointed out the advantage of RBO over this commonly-used oil. Additionally, a higher relative percentage of oleic acid were observed in this study against the previous oil in research such as sunflower oil (28%), pumpkin seed oil (24.9%), wheatgerm oil (12.7%) and coconut oil (6.2%) (Orsavova *et al.*, 2015). This fatty acid profile of RBO has placed the oil at an advantage over other vegetable oils. According to FAO and WHO (1993), oleic, linoleic and linolenic acids are among the essential fatty acids required for physiological functions, growth and body maintenance. Unlike saturated fatty acids (SFA), unsaturated fatty acids (MUFA and PUFA), which are largely present in RBO for all three varieties are beneficial due to its nutritional and health benefits. Other than useful as an edible oil for frying and baking, consumption of RBO can reduce heart related diseases, which is associated with cholesterol (Law, 2000).

5. Conclusions

From the present work, it can be concluded that rice bran is a good source of proteins, carbohydrate, fibre and fatty acids. All these compositions indicate the capability of rice bran to be utilized in the development of nutraceuticals and functional food. Rice bran oil (RBO) extracted from all varieties showed an ideal composition of saturated, monosaturated and unsaturated fatty acids. MR 297 was found having the highest proximate compositions and antioxidative properties, while rice bran oil (RBO) from MR 219 variety showed the highest amount of unsaturated fatty acids compared to other varieties. Further detailed research into amino acids and antioxidant components of rice bran are recommended to create a strong nutritional database for rice bran and its oil derivatives of local varieties.

Author Contributions: Conceptualization, N.H.M.R. and N.N.I.; Methodology, N.N.I. and N.H.T.V.; Experimental and Data Analysis, N.H.T. V., N.N.I., and E.H.Y.; Writing - original draft preparation, N.N.I.; Writing - review and editing, N.H.M.R.

Funding: This research was funded by Fundamental Research Grant Scheme (FRGS) (203.PTEKIND.6711703) of Universiti Sains Malaysia, Pulau Pinang.

Acknowledgments: This work was supported by Fundamental Research Grant Scheme (FRGS) (203.PTEKIND.6711703) grant from Ministry of Higher Education (MOHE) Malaysia. The researchers would like to thank all staffs of MARDI, Bukit Raya, Pendang, Kedah (Director of MARDI Kedah: Dr. Md. Akhir Bin Hamid, Manager of MARDI Pendang: Encik Ahmad Nasre Bin Othman, Research Officer: Puan Wan Khairiah Binti Mohd Noor, Staff: Encik Muhamad Rejab Bin Ahmad and Encik Adli Adinda Bin Amid) for their assistance in the processing of raw materials and providing related information.

Conflicts of Interest: The authors declare no conflict of interest.

References

Abdul Khalil, H.P.S., Md. Sohrab Hossain, Nur Amiranajwa, A.S., *et al.* (2016). Production and characterization of the defatted oil palm shell nanoparticles. *Sains Malaysiana*, *45*(5), 833–839.

Ahmad Nayik, G., Majid, I., Gull, A., *et al.* (2015). Rice bran oil, the future edible oil of India: A mini review. *Rice Research: Open Access*, *03*(4), 1–3. https://doi.org/10.4172/2375-4338.1000151

Aktaş, K., Akın, N. (2020). Influence of rice bran and corn bran addition on the selected properties of tarhana, a fermented cereal based food product. *LWT- Food Science and Technology*, *12*9, 1–6. https://doi.org/10.1016/j.lwt.2020.109574

Alauddin, M., Islam, J., Shirakawa, H., *et al.* (2017). Rice bran as a functional food: An overview of the conversion of rice bran into a superfood/functional food. In *Superfood and Functional Food - An Overview of Their Processing and Utilization*. https://doi.org/10.5772/66298

AOAC. (2012). *Official Methods of Analysis*. Association of Official Analytical Chemist. Washington, D.C.

Arab, F., Alemzadeh, I. & Maghsoudi, V. (2011). Determination of antioxidant component and activity of rice bran extract. *Scientia Iranica*, *18*(6), 1402–1406. doi:https://doi.org/10.1016/j.scient.2011.09.014

Awika, J. M., Rooney, L. W., Wu, X., *et al.* (2003). Screening methods to measure antioxidant activity of sorghum (*Sorghum bicolor*) and sorghum products. *Journal of Agricultural and Food Chemistry*, *51*(23), 6657–6662. doi:https://doi.org/10.1021/jf034790i

Azrina, A., Maznah, I. & Azizah, A. H. (2008). Extraction and determination of oryzanol in rice bran of mixed herbarium UKMB ; AZ 6807 : MR 185, AZ 6808 : MR 211 , AZ6809 : MR 29. *ASEAN Food Journal, 15*(1), 89–96.

Bakota, E. L., Winkler-Moser, J. K. & Liu, S. X. (2014). Evaluation of a rice bran oil-derived spread as a functional ingredient. *European Journal of Lipid Science and Technology*, *116*(5), 521–531. doi:https://doi.org/10.1002/ejlt.201300259

Bhosale, S., & Vijayalakshmi, D. (2015). Processing and nutritional composition of rice bran. *Current Research in Nutrition and Food Science*, *3*(1), 74–80. doi:https://doi.org/10.12944/CRNFSJ.3.1.08

Chakraborty, M., & Budhwar, S. (2018). Nutritional and therapeutic value of rice bran. *International Journal of Green and Herbal Chemistry*, *7*(3), 1–10. doi:https://doi.org/10.24214/ijghc/gc/7/3/45161

Chatha, S. A. S., Anwar, F., Manzoor, M., *et al.* (2006). Evaluation of the antioxidant activity of rice bran extracts using different antioxidant assays. *Grasas y Aceites*, *57*(3), 328–335. doi:https://doi.org/10.3989/gya.2006.v57.i3.56

Daud, N. S. M., Zaidel, D. N. A., Lai, K. S., *et al.* (2018). Crude oil yield and properties of rice bran oil from different varieties as affected by extraction conditions using soxhterm method. *Arabian Journal for Science and Engineering*, *43*(11), 6237–6244. doi:https://doi.org/10.1007/s13369-018-3438-1

Du, J., Yang, T., Ceng, Y.W., *et al.* (2013). Determination of flavonoid in rice grain by HPLC. *J of Plant Genetic Resources, 13*(5), 896–900.

Durazzo, A., Casale, G., Melini, V., *et al.* (2015). Evaluation of antioxidant properties in cereals: Study of some traditional italian wheats. *Foods*, *4*, 391–399. doi:https://doi.org/10.3390/foods4030391

Eyarkai Nambi, V., Manickavasagan, A., Shahir, S. (2017). Rice milling technology to produce brown rice. In

Brown Rice (pp. 3–21). https://doi.org/10.1007/978-3-319-59011-0_1

FAO, WHO. (1993). Fats and oils in human nutrition. In *Report of a joint expert consultation organised by Food and Agriculture Organization of the United Nations and the world Health Organization Rome*, 19-26 October. 10:19-26.

Ferreira-Dias, S., Valente, D. G., & Abreu, J. M. F. (2003). Comparison between ethanol and hexane for oil extraction from *Quercus suber* L. fruits. *Grasas y Aceites*, *54*(4), 378–383. doi:https://doi.org/10.3989/gya.2003.v54.i4.225

Gopala Krishna, A. G., Hemakumar, K. H., & Khatoon, S. (2006). Study on the composition of rice bran oil and its higher free fatty acids value. *JAOCS, Journal of the American Oil Chemists' Society*, *83*(2), 117–120. doi:https://doi.org/10.1007/s11746-006-1183-1

Hanafi, M. M., Hartinie, A., Shukor, J., *et al.* (2009). Upland rice varieties in Malaysia: Agronomic and soil physico-chemical characteristics. *Pertanika Journal of Tropical Agricultural Science, 32*(2), 225–246.

Hashmi, M. I., & Tianlin, J. S. (2016). Minerals contents of some indigenous rice varieties of Sabah Malaysia. *International Journal of Agriculture*, *2*, 31–34.

Hayes, K. C. (2002). Dietary fat and heart health: in search of the ideal fat. *Asia Pacific Journal of Clinical Nutrition*, *11*(Suppl), 394–400. doi:https://doi.org/10.1046/j.1440-6047.11.s.7.13.x

Heinonen, I. M., Lehtonen, P. J., & Hopia, A. I. (1998). Antioxidant activity of berry and fruit wines and liquors. *Journal of Agricultural and Food Chemistry*, *46*(1), 25–31. doi:https://doi.org/10.1021/jf970489o

Hosnan, A. (2019). Anim Agro Technology: *Varieti Padi Popular Di Malaysia*. Retrieved on 7th February 2020 from http://animhosnan.blogspot.com/2019/04/varieti-padi-popular-dimalaysia.html.

Hu, G., Huang, S., Cao, S., *et al.* (2009). Effect of enrichment with hemicellulose from rice bran on chemical and functional properties of bread. *Food Chemistry*, *115*(3), 839–842. doi:https://doi.org/10.1016/j.foodchem.2008.12.092

Hu, G., & Yu, W. (2015). Effect of hemicellulose from rice bran on low fat meatballs chemical and functional properties. *Food Chemistry*, *186*, 239–243. doi:https://doi.org/10.1016/j.foodchem.2014.07.063

Hussain, Z., Mokhtar, A., Amzah, B., *et al.* (2012). Enam varieti padi popular MARDI. *Buletin Teknologi MARDI*, *1*, 1–10. Retrieved on 2nd February 2020 from http://ebuletin.mardi.gov.my/index.php/arkib/64-2012/bil-1-2012/251-2012-01-02.

Ichihara, K. & Fukubayashi, Y. (2010). Preparation of fatty acid methyl esters for gas-liquid chromatography. *Journal of Lipid Research*, *51*(3), 635–640. doi:https://doi.org/10.1194/jlr.D001065

Iqbal, S., Bhanger, M. I., & Anwar, F. (2005). Antioxidant properties and components of some commercially available varieties of rice bran in Pakistan. *Food Chemistry*, *93*(2), 265–272. doi:https://doi.org/10.1016/j.foodchem.2004.09.024

Issara, U., & Rawdkuen, S. (2018). Instant organic rice bran milk: A nutritional quality aspect. *International Food Research Journal*, *25*(4), 1600–1605.

Kumari, N., Khetarpaul Vinita, N., & Rani, P. (2018). Nutrient composition of full fat and defatted rice bran. *Asian Journal of Dairy and Food Research*, *37*(1), 77–80. doi:https://doi.org/10.18805/ajdfr.DR-1277

Lai, O. M., Jacoby, J. J., Leong, W. F., *et al.* (2019). Nutritional studies of rice bran oil. In: L.-Z. Cheong, X. Xu (Eds.), *Rice Bran and Rice Bran Oil*, *AOCS Press* (2019), pp. 19–54. 10.1016/B978-0-12-812828-2.00002-0

Law, M. (2000). Dietary fat and adult diseases and the implications for childhood nutrition: An epidemiologic approach. *The American Journal of Clinical Nutrition, 72*(5), 1291–1296. doi:https://doi.org/10.1093/ajcn/72.5.1291s

Liang, Y., Gao, Y., Lin, Q., *et al*. (2014). A review of the research progress on the bioactive ingredients and physiological activities of rice bran oil. *European Food Research and Technology*, 238, 169–176. https://doi.org/10.1007/s00217-013-2149-9

Luqman, S., Kumar, R., Kaushik, S., *et al.* (2009). Antioxidant potential of the root of *Vetiveria zizanioides* (L.) *Nash*. *Indian Journal of Biochemistry & Biophysics*, *46*(1), 122–125. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/19374265

Malekian, F., Rao, R. M., Prinyawiwatkul, W., *et al.* (2000). *Lipase and lipoxygenase activity, functionality, and nutrient losses in rice bran during storage* (pp. 1–68). Bulletin No. 870. Baton Rouge: LSU Agricultural Center, Louisiana Agricultural Experiment Station.

Mas'ud, F., Mahendradatta, M., Laga, A., *et al.* (2017). Component, fatty acid and mineral composition of rice bran oil extracted by multistage with hexane and ethanol. *International Journal of Scientific & Technology Research*, *6*(11), 63–69. Retrieved from www.ijstr.org

May, C. Y., & Nesaretnam, K. (2014). Research advancements in palm oil nutrition. *European Journal of Lipid Science and Technology*, *116*(10), 1301–1315. doi:https://doi.org/10.1002/ejlt.201400076

Mercer, D. G. (2008). Solar drying in developing countries: Possibilities and pitfalls. In: Robertson, G.L. & Lupien, J.R. (Eds), *Using Food Science and Technology to Improve Nutrition and Promote National Development*, (pp 1–11). International Union of Food Science & Technology.

Ministry of Agriculture. (2018). *Statistik Tanaman (Sub-sektor Tanaman Makanan)*. Retrieved on February 2, 2020 from http://www.doa.gov.my/index/resources/aktiviti_sumber/sumber_awam/maklumat_pertanian/perangkaan_tanaman/booklet_statistik_tanaman_2018.pdf.

Muntana, N., & Prasong, S. (2010). Study on total phenolic contents and their antioxidant activities of Thai white, red and black rice bran extracts. *Pakistan Journal of Biological Sciences*, *13*(4), 170–174. doi:https://doi.org/10.3923/pjbs.2010.170.174

Murai, T., Jin, S., Itoh, M., *et al*. (2020). Analysis of steryl glucosides in rice bran-based fermented food by LC/ESI-MS/MS. *Steroids, 158,* 1–7. https://doi.org/10.1016/j.steroids.2020.108605

Nori, H., Sani, S.A., & Tuen, A. A. (2009). Chemical and physical properties of Sarawak (East Malaysia) rice straws. *Livestock Research for Rural Development. 21* (22). Retrieved on 2nd February 2020, from http://www.lrrd.org/lrrd21/8/nori21122.htm

Omar, S. C., Shaharudin, A., &Tumin, S. A. (2019). *The Status of the Paddy and Rice Industry in Malaysia*. Retrieved on 2nd February 2020 from http://www.krinstitute.org/assets/contentMS/img/template/editor/20190409_RiceReport_Full%20Report_Final.pdf

Orsavova, J., Misurcova, L., Vavra Ambrozova, J., *et al.* (2015). Fatty acids composition of vegetable oils and its contribution to dietary energy intake and dependence of cardiovascular mortality on dietary intake of fatty acids. *International Journal of Molecular Sciences, 16*(6), 12871–12890. doi:https://doi.org/10.3390/ijms160612871

Oviasogie, P. O., Okoro, D., & Ndiokwere, C. L. (2009). Determination of total phenolic amount of some edible fruits and vegetables. *African Journal of Biotechnology*, *8*(12), 2819–2820. Retrieved from http://www.academicjournals.org/AJB

Pal, Y. P., & Pratap, A. P. (2017). Rice bran oil: A versatile source for edible and industrial applications. *J. Oleo Sci*, *66*(6), 551–556. doi:https://doi.org/10.5650/jos.ess17061

Prior, R. L., Wu, X., & Schaich, K. (2005). Standardized methods for the determination of antioxidant capacity and phenolics in foods and dietary supplements. *Journal of Agricultural and Food Chemistry, 53,* 4290–4302. doi:https://doi.org/10.1021/jf0502698

Rosniyana, A., Hashifah, M. A., & Norin, S. A. S. (2007). The physico-chemical properties and nutritional composition of rice bran produced at different milling degrees of rice. *J. Trop. Agric. and Fd. Sc., 35*(1), 99–105.

Rosniyana, A., Hashifah, M. A., & Norin, S. A. S. (2009). Nutritional content and storage stability of stabilised rice bran – MR 220 . J. *Trop. Agric. and Fd. Sc., 37*(2), 163–170.

Ruslan, R., Aznan, A. A., Azizan, F. A., *et al.* (2018). Extraction of morphological features of Malaysian rice seed varieties using flatbed scanner. *International Journal on Advanced Science, Engineering and Information Technology, 8*(1), 93–98. doi:https://doi.org/10.18517/ijaseit.8.1.2752

Saad Smuda, S., Sobhy, Mohsen, M., *et al.* (2018). Bioactive compounds and antioxidant activities of some cereal milling by-products. *J Food Sci Technol., 55*(3), 1134–1142. doi:https://doi.org/10.1007/s13197-017-3029-2

Saccotelli, M. A., Conte, A., Burrafato, K. R., *et al.* (2017). Optimization of durum wheat bread enriched with bran. *Food Science and Nutrition*, *5*(3), 689–695. doi:https://doi.org/10.1002/fsn3.448

Saikia, D., & Deka S C. (2011). Cereals: from staple food to nutraceuticals. *International Food Research Journal*, *18,* 21-30.

Salehi, E.A, & Sardarodiyan, M. (2016). Bioactive phytochemicals in rice bran : Processing and functional properties. biochemistry. *An Indian Journal*, *10*(3), 1–10.

Sam Lum, M. (2017). Physicochemical characteristics of different rice varieties found in Sabah, Malaysia. *Transactions on Science and Technology*, *4*(2), 68–75*4*. Retrieved from http://transectscience.org/

Satter, M. A., Ara, H., Jabin, S. A., *et al.* (2014). Nutritional Composition and Stabilization of Local Variety Rice Bran BRRI-28. *International Journal of Science and Technology, 3*(5), 306–313.

Sereewatthanawut, I., Prapintip, S., Watchiraruji, K., *et al.* (2008). Extraction of protein and amino acids from deoiled rice bran by subcritical water hydrolysis. *Bioresource Technology*, *99*(3), 555–561. doi:https://doi.org/10.1016/j.biortech.2006.12.030

Singleton, V. L.& Rossi, J. A. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *American Journal of Enology and Viticulture, 16*(3), 144–158.

Tawaha, K., Alali, F. Q., Gharaibeh, M., *et al.* (2007). Antioxidant activity and total phenolic content of selected Jordanian plant species. *Food Chemistry*, *104*(4), 1372–1378. doi:https://doi.org/10.1016/j.foodchem.2007.01.064

Thirunavukkarasu, P., Ramanathan, T., Shanmugapriya, R., *et al.* (2011). Antioxidant and free radical scavenging effect of *Acanthus ilicifolius*. *Research Journal of Applied Sciences, 6*(3), 218–222. doi:https://doi.org/10.3923/rjasci.2011.218.222

Thomas, R., Bhat, R., & Kuang, Y. T. (2015). Composition of amino acids, fatty acids, minerals and dietary fiber in some of the local and import rice varieties of Malaysia. *International Food Research Journal*, *22*(3), 1148-1155.

Verma, D. K., & Srivastav, P. P. (2017). Proximate composition, mineral content and fatty acids analyses of aromatic and non-aromatic Indian rice. *Rice Science, 24*(1), 21–31. doi:https://doi.org/10.1016/j.rsci.2016.05.005

ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

Review Article

Dabai Fruit: Postharvest Handling and Storage

Siti Hajar Ariffin[1,2*], Rosnah Shamsudin[1,2], Intan Syafinaz Mohamed Amin Tawakkal[1,2]

[1]Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400, Serdang, Selangor, Malaysia

[2]Laboratory of Halal Services, Halal Products Research Institute, Universiti Putra Malaysia, 43400, Serdang, Selangor, Malaysia

*Corresponding author: Siti Hajar Ariffin, Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400, Serdang, Selangor, Malaysia; hajarariffin@upm.edu.my

Abstract: Dabai (*Canarium odontophyllum*) or also known as 'Sarawak olive' is one of the potential indigenous seasonal fruits commonly found in Sarawak. Due to its high nutritional contents, it has wide potential to be marketed locally and exported internationally. Dabai is very delicate and highly perishable. The shelf life of dabai is usually 3 days when stored in room temperature (27°C). Improper storage and handling lead to the reduction of quality and shelf life of the fruit throughout storage. There is still a limitation on the information of postharvest, storage and handling, quality and shelf life of dabai. Studies on quality and shelf life affected by storage treatment and packaging are necessary for optimising shelf life and minimising quality loss of the fruit. This could ensure further potential development of the fruit locally and internationally.

Keywords: Dabai; *Canarium odontophyllum*; Sarawak olive; nutritional values; harvesting, storage; handling

Received: 13rd September 2020

Accepted: 14th October 2020

Available Online: 31st October 2020

Citation: Ariffin SH, Shamsudin R & Tawakkal ISMA. Dabai Fruit: Postharvest handling and storage. Adv Agri Food Res J 2020; 1(2): a0000126. https://doi.org/10.36877/aafrj. a0000126

1. Introduction

1.1. Origin

Dabai (*Canarium odontophyllum)* which is also known as 'Sarawak olive' is an indigenous seasonal fruit that can only be found in Borneo Island, especially Sarawak. In Malaysia, the medium-sized tree grows naturally along river banks in Sarikei, Limbang, Sibu, and Kapit (Ding, 2011). The tree grows upright up to 21 m high and has thin, large pinnate leaves. Fresh leaves form in red velvet or green colour. Branchlets have resinous ducts and petioles. The flower is 10 mm long and is white-yellow (see Figure 1). Depending on the local weather, dabai usually available from May till June and December till January every year (Chua & Daniel, 2017).

Figure 1. From left, dabai tree, dabai stem and leaves (HealthBenefits) and dabai flowers (Cangao, 2014).

Dabai has bright potential to be economic crop in the state. Being a popular indigenous fruit in Sarawak, it has wide potential to be marketed locally and exported internationally. Among all states in Malaysia, with 38 varieties of fruits, plantation of dabai covered the highest hectarage with 1,439.40 ha. That contributes to 26% of total hectarage for plantation of fruit crops in Malaysia (Table 1) (Department of Agriculture Malaysia, 2017).

Table 1. Hectarage of fruit crops by state and type in Malaysia (Department of Agriculture Malaysia, 2017).

NEGERI *State*	Keluasan *Hectareage* (Ha)
JOHOR	903.8
KEDAH	132.7
KELANTAN	363.4
MELAKA	328.4
NEGERI SEMBILAN	161.3
PAHANG	462.1
PERAK	100.8
PERLIS	17.0
PULAU PINANG	5.7
SELANGOR	96.8
TERENGGANU	93.8
SEM. MALAYSIA *Peninsular Malaysia*	**2,665.6**
SABAH	722.3
SARAWAK	2,111.5
W.P. LABUAN	2.1
MALAYSIA TIMUR *East Malaysia*	**2,835.9**
MALAYSIA	**5,501.5**

Jenis Buah *Type of Fruits*		Keluasan *Hectareage* (Ha)
Abui	*Pouteria*	-
Anggur	*Grape*	0.40
Avocado	*Avocado*	41.70
Bacang	*Horse Mango*	68.02
Bambangan	*(Bambangan)*	27.80
Belunu	*(Belunu)*	7.80
Belimbing Buluh	*(Belimbing Buluh)*	41.44
Belimbing Hutan	*(Belimbing Hutan)*	0.01
Bidara Siam	*Jujube*	-
Berangan	*(Berangan)*	7.00
Buah Ajaib	*Miracle Fruit*	-
Dabai	*(Dabai)*	1,439.40
Durian Belanda	*Sour-sop*	443.99
Gajus	*Cashew*	1.69
Jambu Air	*Water Rose Apple*	404.35
Jambu Air Mawar	*Water Rose Apple*	27.51
Kabung/Enau	*(Kabung/Enau)*	16.00
Kedondong / Amra	*(Kedondong / Amra)*	50.28
Kelubi	*(Kelubi)*	0.44
Keranji	*(Keranji)*	-
Kundang	*(Kundang)*	1.38
Kuini	*(Kuini)*	930.63
Lemon	*(Lemon)*	46.00
Longan	*(Longan)*	92.49
Markisa	*Passion Fruit*	72.60
Mata Kucing	*Cat's Eye*	103.67
Mentega	*(Mentega)*	0.90
Mesta	*(Mesta)*	28.48
Nona Kapri	*Custard Apple*	3.00
Nona Srikaya	*Sweet-sop*	1.60
Pisang Kaki	*Diospryros*	13.70
Rambai	*(Rambai)*	60.17
Sentol	*(Sentol)*	2.87
Strawberi	*Strawberry*	38.61
Sukun	*Breadfruit*	54.72
Tarap	*(Tarap)*	404.40
Tembikai Susu/Melon	*Honey Dew*	745.53
Tembikai Wangi	*Rock Melon*	322.91
JUMLAH	*Total*	**5,501.49**

1.2. Fruit Structure and Physical Properties

Immature dabai fruit is white, and when ripened, it turns to purplish pink and powdery black. The fruit is oblong, olive-like in form, and have thin, edible skin. The fruit has 20–25 mm wide fleshy and oblong to ellipsoidal drupe, about 35–40 mm long. The dark purple skin covers the yellowish-white flesh, and the flesh wraps around the subtriangular-shaped seed. A rough shell protects the seed, which can be eaten as a nut (Figure 2). The pulp is between 54–60% by weight of the fruit and contains 41.3% of moisture whereas the kernel covers about 35–40% of the fruit weight (Cangao, 2014).

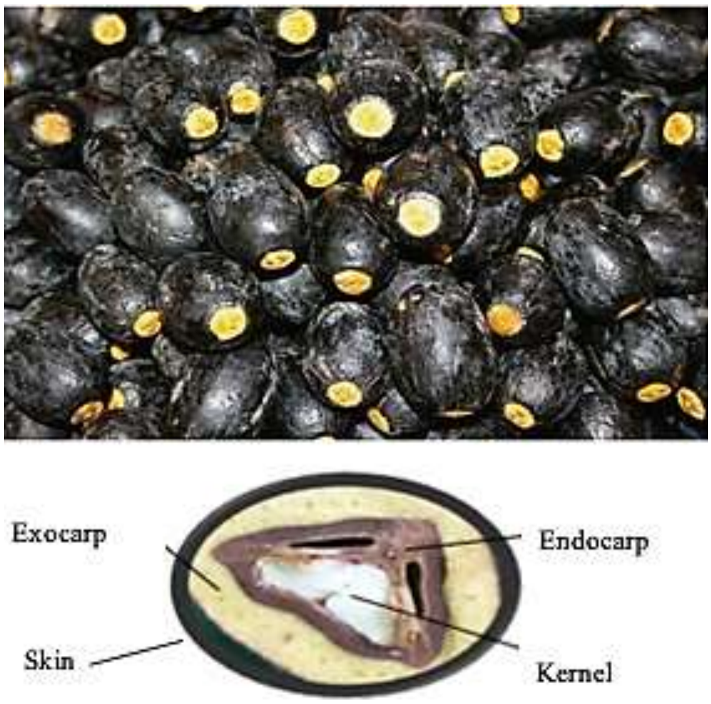


Figure 2. Above, ripe dabai fruit (HealthBenefits, n.d.) and bottom its cross-section (Cangao, 2014).

Study on physical properties of different genotypes of dabai was conducted by (Chua *et al.*, 2015). The information on the physical properties of dabai fruit can be used as baseline information for further processing application, such as appropriate technologies development for processing. In a study reported by Chua *et al.* (2015), there were six genotypes of dabai fruits which were *Besar*, *Biasa*, *Jernah*, *Bujur*, *Seluang*, and *Bulat*. The size and shape and fruit fraction mass of six dabai fruit genotypes were tabulated in Table 2 and Table 3, respectively. Fruit length (cm), width (cm), and thickness (cm) represent the physical properties of the fruit, sphericity index (%) and aspect ratio (%) represent the shape of the fruit. On the other hand, individual weight of whole (g), seed (g), skin (g), pulp (g), and kernel (g) represent the mass of the fruit.

Table 2. Size and shape of six dabai fruit genotypes (*n* = 10). Table obtained from Chua *et al*. (2015).

	Fruit length (cm)	Fruit width (cm)	Pulp thickness (cm)	Sphericity index (%)	Aspect ratio (%)
Besar	3.60 ± 0.15b	2.58 ± 0.22a	0.43 ± 0.07a	42.91 ± 2.88b	71.57 ± 5.82b
Biasa	3.07 ± 0.23c	2.10 ± 0.17c	0.35 ± 0.05b	42.46 ± 1.68b	68.44 ± 3.88bc
Jernah	3.00 ± 0.11c	1.94 ± 0.08d	0.28 ± 0.03c	39.17 ± 1.49c	63.77 ± 4.60cd
Bujur	3.98 ± 0.20a	2.40 ± 0.13b	0.36 ± 0.03b	37.73 ± 0.95c	60.38 ± 3.55d
Seluang	2.90 ± 0.07c	1.94 ± 0.10d	0.22 ± 0.03c	36.97 ± 1.46c	66.89 ± 3.09c
Bulat	3.01 ± 0.14c	2.63 ± 0.15a	0.43 ± 0.03a	49.94 ± 0.90a	87.42 ± 3.75a

Means in the same column with the same letter are not significantly different ($p > 0.05$)

Table 3. Fruit fraction mass of six dabai fruit genotypes (*n* = 10). Table obtained from Chua *et al*. (2015).

Dabai genotype	Total fruit mass (g)	Total seed mass (g)	Skin mass (g)	Pulp mass (g)	Kernel mass (g)	Total edible portion (%)
Besar	15.33 ± 1.63a	5.84 ± 0.41a	1.45 ± 0.32a (9.46%)	8.04 ± 1.28a (52.45%)	1.33 ± 0.14a (8.68%)	70.59a
Biasa	10.23 ± 2.07b	3.83 ± 0.80c	0.78 ± 0.25a (7.62%)	5.62 ± 1.18b (54.94%)	0.94 ± 0.23b (9.19%)	71.75a
Jernah	7.41 ± 0.68c	2.83 ± 0.28d	1.21 ± 0.20a (16.33%)	3.36 ± 0.29c (45.34%)	0.48 ± 0.04d (6.48%)	68.15b
Bujur	15.28 ± 2.16a	6.48 ± 1.02a	1.10 ± 0.19a (7.20%)	7.71 ± 1.20a (50.46%)	1.08 ± 0.10b (7.07%)	64.73c
Seluang	7.60 ± 0.53c	3.50 ± 0.25cd	0.85 ± 0.10a (11.18%)	3.25 ± 0.33c (42.76%)	0.69 ± 0.08c (9.08%)	63.02c
Bulat	13.31 ± 1.10a	4.78 ± 0.34b	1.11 ± 0.32a (8.34%)	7.42 ± 1.13a (55.75%)	0.96 ± 0.14b (7.21%)	71.30a

Means in the same column with the same letter are not significantly different ($p > 0.05$)

1.3. Harvesting and Agronomic Characteristics

Dabai fruits are ready to be harvested when the immature white fruit turns purplish-black. The fruits are usually harvested in the morning and during dry weather (Lau & Fatimah, 2007). Usually, a sickle is attached to the end of a long bamboo pole to cut the terminal branches of the fruit panicles. A net is located under the tree to collect the falling fruits and branches. Fruits are removed manually from their pedicels and transported to the market in well-ventilated baskets (Ding, 2011).

There are three development stages of dabai fruit which are immature, semi-mature, and mature (Figure 3). The maturity development stages were reported to have effects on the physical and nutritional values of dabai fruit. The colour of dabai fruit changes from white to reddish-black-white, and purplish-black during the three development stages, with fat content, increased from 15.8% to 24.6% and 27.6% during immature, semi-mature, and mature stage respectively. On the other hand, fibre content was found to decrease from 22.1% to 17.9% and 14.6% whereas protein also decreased from 10.8% to 9.8%, and 9.2% from immature to mature stage. The carbohydrate was found to be almost similar throughout the stages (43.7%, 40.9%, and 42.5%) while the moisture content was found to decrease by 11% from immature to mature stage (Yuon & Brooke, 2006).

It has been reported that fat, fibre, protein and carbohydrate contents of the mature fruit change while they are retained on the tree for two months. Thus, it has been suggested that the best time to harvest dabai is about two (2) weeks after full maturity when the fruits are at their optimal physical appearance while at the same time having favourable fat and protein contents (Yuon & Brooke, 2006).

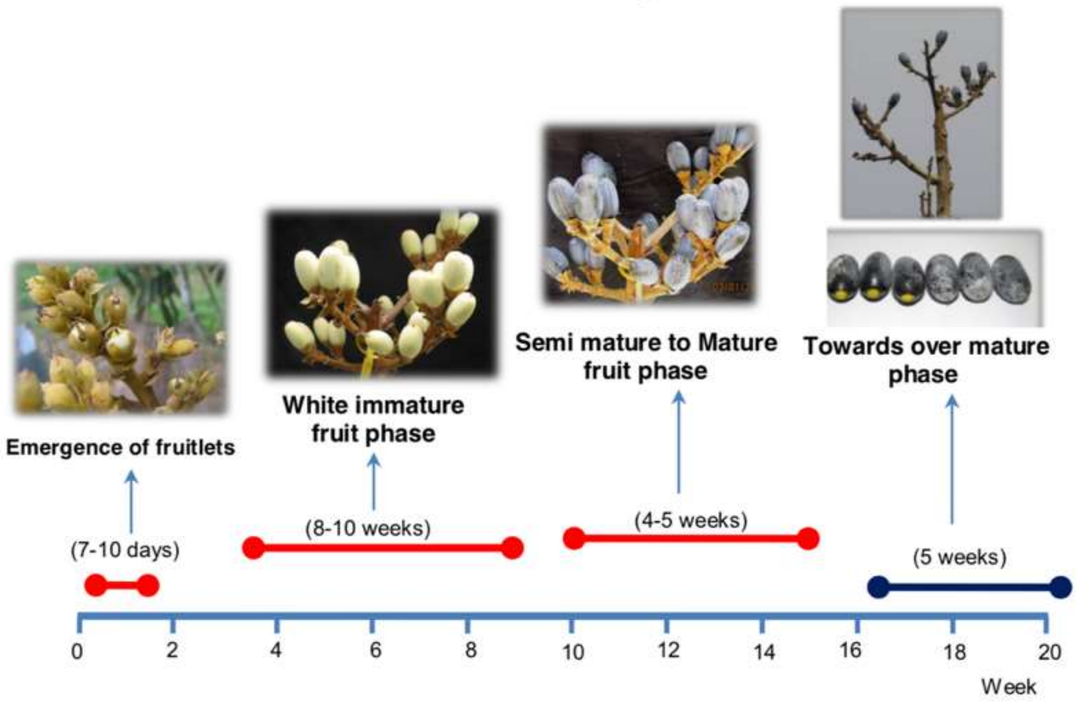


Figure 3. Timeline chart of dabai fruit during maturation process. Image taken from (Yuon & Brooke, 2006).

1.4. Health Benefits and Nutritional Values

Dabai fruit is highly beneficial for health. It acts as an antioxidant that helps in preserving the skin from ageing and protecting skin from sun damage. The calcium content promotes bone mass in grown children as well as young adults. The magnesium could be very beneficial to the cardiovascular system by reducing the risk of coronary heart diseases. The lipid content helps to produce energy and providing support for vital organs. The anthocyanin aids as an anti-inflammatory, and the phenolic compounds could help in cancer prevention and act as antioxidants (Dezatie, 2013). Example of nutritional values found in dabai is tabulated in Table 4.

The fresh pulp of dabai (for 100 g) contains 339 kcal energy, 22.1 g carbohydrates, 4.3 g crude fibre, 3.8 g protein, 2.3 g ash, and 26.2 g fat. Dabai oil produced from the pulp has comparable nutrient content with 40% saturated and monounsaturated fatty acids and 12–13% polyunsaturated fatty acids. The kernel contains 499.36 kcal energy, 47.24 g carbohydrates, 15.80 crude fibre, 10.75 protein, 3.35 g ash, and 26.20 g fat (Cangao, 2014). The dark purple skin was found to have the highest antioxidant activity at 89.31% (Cangao, 2014).

Potential healthy cooking oils could be developed from pulp and kernel oils of dabai due to their good fatty acid composition and high antioxidant properties (Azlan *et al.*, 2010). As for the peel, it was recommended to be a major source of natural antioxidants (Shakirin *et al.*, 2010). Apart from that, there was also a study reported on the potential use of defatted dabai peel on future nutraceuticals line (Khoo *et al.*, 2013). The study showed that the highest antioxidant capacities and oxidative stress inhibition effect were found in defatted dabai peel. The defatted dabai peel elevates cellular antioxidant enzymes (SOD and GPx) and inhibits lipid peroxidation (plasma MDA) in rabbits (Khoo *et al.*, 2013). Most significant antioxidant activities with highest anthocyanin, flavonoids and total phenolic contents were found in purple dabai from Kapit ($p < 0.01$) (Chew *et al.*, 2011).

Table 4. Nutritional values of dabai fruit. Data obtained from Hoe and Siong (1999).

Nutritional aspect	Nutritional value
Energy	339 kcal 100 g−1 edible portion
Phosphorus	65 mg 100 g−1 edible portion
Ferum	1.3 mg 100 g−1 edible portion
Potassium	810 mg 100 g−1 edible portion
Magnesium	106 mg 100 g−1 edible portion
Calcium	200 mg 100 g−1 edible portion
Protein	3.8%
Carbohydrate	22.1%
Ash	2.3%
Crude fibre	4.3%
Fat	26.2%

2. Postharvest Handling

Regardless of its hard texture, dabai is a highly perishable fruit. The shelf life of dabai is usually 3 days when stored in room temperature (27°C) (Ding, 2011). After that, the fruit will still be edible, but the skin of the hard fruit will wrinkle. The short shelf life of dabai fruit resulted in limitation for potential marketing. Usually, the fruit is marketed locally or exported to nearby towns in Sabah and Brunei. Due to this restricted market, dabai price tends to crash due to the over-supply of the fruit during peak crop seasons (Ding, 2011). It has been reported that by packing the fruit in polyethene bags, the shelf life of dabai could be prolonged up to 8 days when stored at 14°C (Jugah, 2006). A study also claimed that the shelf life of dabai could be prolonged when stored at 5°C and water loss could be minimised by coating the fruit with thin layer of edible oil (Voon, 2003). In other study, dabai fruit was vacuum-packed and frozen for 6 months and the frozen fruits were thawed by using hot water at 100°C instead of warm water. Although the fruit is still acceptable, freezing has affected the taste and appearance by resulting in less creamy taste and poorer physical appearance (Lau & Fatimah, 2007).

Usually, in the market, people put dabai fruit in a big-open box and ready for a sale (Figure 4). The high surrounding temperature (27–30°C) and open gaseous exchange between these highly perishable fruits and the surrounding air lead to the short shelf life of dabai fruit (Ding & Tee, 2011). Further studies are still necessary to find the best storage and packaging conditions that could help to maintain the quality and extend the shelf life of dabai fruit, thus open the opportunity for greater market scale and export potential.

Figure 4. Dabai for sale at the roadside. Image taken from Bingregory (2007).

3. Dabai Fruit in Food and Health Products

Traditionally, dabai is prepared by immersing the fruit in lukewarm water for 15 minutes to soften the fruit. This step will enhance the smooth-creamy texture and rich flavour of the fruit (Ding, 2011). The flesh of dabai fruit is enjoyed with the skin while the hard seed is removed. It is then eaten with sugar and/or soy sauce to enhance the taste of the fruit. It can be enjoyed as part of a meal or as a savoury snack. Sauce made from dabai fruit has also been introduced and found to be acceptable among consumers (Nazri *et al.,* 2015) and this shows potential innovation of dabai for food product development. Various food products have been developed to maintain a continuous supply of dabai during the off-season. Some examples of the food products are dabai pickles, mayonnaise, seasoning paste, dipping sauce, drinks, and frozen pulp (Chua & Daniel, 2017).

Good quality of fat was extracted from dabai. Oleic (18:1), linoleic (18:2) and palmitic (16:0) acids are the most abundant fatty acids in the fruit, and the percentage is found comparable to palm oil (Azlan *et al.,* 2010). Pulp and kernel oils from dabai have been tested to study the effects of oxidative stress, lipid profile, and lipid peroxidation on healthy rabbits. The kernel oil enhanced superoxide dismutase (SOD) and total antioxidant status (TAS) and reduced plasma total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C) levels. The pulp oil enhanced SOD, glutathione peroxidase (GPx) and plasma TAS, increased HDL-C, and reduced LDL-C, TG, and thiobarbituric acid reactive substances (TBARS) levels. Considering the use of kernel and pulp oils as part of a diet could be beneficial in improving antioxidant and lipid profile (Shakirin *et al.,* 2012). This study shows the potential use of oils extracted from dabai fruit to be the alternative to present vegetable oil.

In the medical fields, dabai fruit extract was tested on obese-diabetic (Ob-db) rats, and it was found that the extract improves lipid profile and has a short-term glucose-lowering effect (Mokiran *et al.,* 2014). The fruit extract was able to reduce plasma cholesterol and low-density lipoprotein (LDL-c) and plasma glucose level while at the same time increased high-density lipoprotein (HDL-c) level (Mokiran *et al.*, 2014). It could be a potential alternative in treating obese patients.

4. Conclusion

Dabai is a highly nutritious fruit that has a potential and promising market value. Improper handling of dabai fruit leads to quality and shelf life reduction. Proper handling and packaging of the fruit are necessary in order to maintain the quality and extend the shelf life of the fruit. There is still a limitation on the information of the postharvest, storage and handling, quality and shelf life on dabai fruit. Further works that cover quality and shelf life such as the effect of storage treatment and packaging on dabai is necessary to study the respiration rate of dabai fruit thus optimising shelf life and minimising quality loss of the fruit. It could ensure further development of the fruit locally and internationally. Kinetic degradation and mathematical modelling could also be implemented to predict the quality and shelf life of the fruit on a large scale. Valued food product innovations also could be further developed to utilise the use of the fruit during the off-season.

Supplementary Materials: The following are available online at http://www.journals.hh-publisher.com/index.php/AAFRJ//xxx/s1, Figure 1, Figure 2, Figure 3, Figure 4-SHA, List of Tables_SHA

Funding: The authors would like to thank the Ministry of Higher Education of Malaysia, for providing financial support under the Fundamental Research Grants Scheme (FRGS) (Project Number: 07-01-19-2201FR) and the Sarawak Biodiversity Centre.

Conflicts of Interest: The authors declare no conflict of interest, and also the funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

Azlan, A., Prasad, K. N., Khoo, H. E., *et al.* (2010). Comparison of fatty acids, vitamin E and physicochemical properties of *Canarium odontophyllum* Miq. (dabai), olive and palm oils. *Journal of Food Composition and Analysis*, *23*(8), 772–776. https://doi.org/10.1016/j.jfca.2010.03.026

Bingregory. (2007). Dabai for Sale at the Roadside. Retrieved October 10, 2019, from https://www.flickr.com/photos/21227234@N00/364543169/in/photostream/

Cangao, C. A. (2014). The dabai story: Experience in commercializing an underutilized fruit. Retrived from https://www.itfnet.org/v1/2014/03/the-dabai-story-experience-in-commercializing-an-underutilized-fruit/

Chew, L. Y., Prasad, K. N., Amin, I., *et al.* (2011). Nutritional composition and antioxidant properties of *Canarium odontophyllum* Miq. (dabai) fruits. *Journal of Food Composition and Analysis*, *24*(4–5), 670–677. https://doi.org/10.1016/j.jfca.2011.01.006

Chua, H. P., Nicholas, D., & Yahya, M. N. A. (2015). Physical properties and nutritional values of dabai fruit (C*anarium odontophyllum*) of different genotypes. *Journal of Tropical Agriculture and Food Science, 43*(1), 1–10. https://doi.org/10.13140/2.1.2944.3366

Chua, H. P., & Daniel, N. (2017). Dabai, specialty fruit of Sarawak. Retrieved from https://blogmardi.wordpress.com/2017/02/13/dabai-specialty-fruit-of-sarawak/

Department of Agriculture Malaysia. (2017). *Statistik Tanaman Buah-Buahan Malaysia*. Putrajaya, Malaysia.

Dezatie. (2013). Dabai fruit and its contains. Retrieved from http://dezatiee.blogspot.com/2013/12/dabai-fruit-and-its-contains.html

Ding, P. (2011). Dabai (*Canarium odontophyllum* Miq.). *Postharvest biology and technology of tropical and subtropical fruits* (34–42) Woodhead Publishing Limited. https://doi.org/10.1016/B978-1-84569-735-8.50003-6

Ding, P., & Tee, Y. K. (2011). Physicochemical characteristics of dabai (*Canarium odontophyllum* Miq.) fruit. *Fruits*, *66*(1), 47–52. https://doi.org/10.1051/fruits/2010040

HealthBenefits. (n.d.). Know About the Dabai. Retrieved May 16, 2020, from https://www.healthbenefitstimes.com/know-about-the-dabai/nggallery/image/12773

Hoe, V. B., & Siong, H. . (1999). The nutritional value of indigenous fruits and vegetables in Sarawak. *Asia Pacific Journal of Clinical Nutrition*, *8*, 24–31.

Jugah D. J. (2006). Study on the effect of packaging and temperature on improving the shelf life of dabai (*Canarium odontophyllum*). In Proceedings of *Technical Session, Research Officers' Conference 2006*, 7–9 September 2006, Kuching, Sarawak, Malaysia.

Khoo, H. E., Azlan, A., Nurulhuda, M. H., *et al.* (2013). Antioxidative and cardioprotective properties of anthocyanins from defatted Dabai extracts. *Evidence-Based Complementary and Alternative Medicine*, *2013*, 1–13. https://doi.org/10.1155/2013/434057

Lau C. Y. & Fatimah O. (2007). Cold storage of dabai fruit (*Canarium odontophyllum* Mig.): Effect of packaging methods and storage duration on quality. In Proceedings of the *Sarawak Fruit Seminar*, 7–8 August 2007, Sibu, Sarawak, Malaysia.

Mokiran, N. N., Ismail, A., Azlan, A., *et al*. (2014). Effect of dabai (*Canarium odontophyllum*) fruit extract on biochemical parameters of induced obese-diabetic rats. *Journal of Functional Foods*, *8*(1), 139–149. https://doi.org/10.1016/j.jff.2014.03.007

Nazri, M., Rahman, A., Azimah, N., *et al.* (2015). Product development of kembayau (*Canarium odontophyllum*) exotic fruit sauce. *Journal of Tropical Resources and Sustainable Science*, *3*(1), 19–28.

Shakirin, F. H., Azlan, A., Ismail, A., *et al.* (2012). Protective effect of pulp oil extracted from *Canarium odontophyllum* Miq. fruit on blood lipids, lipid peroxidation, and antioxidant status in healthy rabbits. *Oxidative Medicine and Cellular Longevity*, *2012*, (1–9). https://doi.org/10.1155/2012/840973

Shakirin, F. H., Prasad, K. N., Ismail, A., *et al.* (2010). Antioxidant capacity of underutilized Malaysian

Canarium odontophyllum (dabai) Miq. fruit. *Journal of Food Composition and Analysis*, *23*(8), 777–781. https://doi.org/10.1016/j.jfca.2010.04.008

Voon B. H. (2003). Indigenous fruits for commercial exploitation. In Proceedings of *In-house Seminar on New Crops with Potential for Commercialization*, 7–8 August 2003, Sg. Paoh Agriculture Training Centre, Sarikei, Sarawak, Malaysia.

Yuon, L. C., & Brooke, P. (2006). *Changes to dabai fruit during maturation process*. Agriculture Research Centre, Semongok, Sarawak, Malaysia.

ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

Review Article

Potential Application of Laser-Based Imaging Technology in the Quality Evaluation of Agricultural Products: A Review

Philip Donald Cabuga Sanchez[1, 3*], Norhashila Hashim[1*], Rosnah Shamsudin[2], Mohd Zuhair Mohd Nor[2]

[1]Department of Biological and Agricultural Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

[2]Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

[3]Department of Agricultural and Biosystems Engineering, College of Engineering and Geosciences, Caraga State University, Ampayon, Butuan City 8600, Philippines

*Corresponding author: P. D. C. Sanchez, Department of Biological and Agricultural Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia; Department of Agricultural and Biosystems Engineering, College of Engineering and Geosciences, Caraga State University, Ampayon, Butuan City 8600, Philippines; philchez94@gmail.com

Abstract: Non-destructive quality evaluation of agricultural products particularly during postharvest stage has been a primary concern in recent years. The laser-based imaging technology is one of the most promising non-invasive tools which demonstrate potential ability to replace the conventional methods of quality monitoring that are time-consuming, expensive, laborious, inaccurate and most of all destructive. Hence, in this paper, we briefly reviewed the potential application of laser-light backscattering imaging technique (LLBI) as a non-destructive quality evaluation tool applied in agricultural products. This review mainly reports the current knowledge on the successful implementations of the LLBI in measuring the various quality-related attributes of agricultural products under different postharvest conditions such as in drying, storage, sorting, maturity identification and defect detection. The basic components, uses and considerations of the techniques are highlighted in this paper. Moreover, the advantages, drawbacks, measurement methods, data analysis applied as well as the accuracies obtained are briefly summarized.

Keywords: agricultural products; laser-based imaging; non-destructive; postharvest; quality evaluation

Received: 18th September 2020

Accepted: 19th October 2020

Available Online: 02nd November 2020

Citation: Sanchez PDC, Hashim N, Shamsudin R, *et al*. Potential application of laser-based imaging technology in the quality evaluation of agricultural products: A review. Adv Agri Food Res J 2020; 1(2): a0000127. https://doi.org/10.36877/aafrj.a0000127

1. Introduction

In recent years, the high demand for fresh, healthy and defect-free agricultural products is associated with the corresponding demand of rapid and non-destructive quality evaluation techniques. In most cases, the quality of the fresh productions are more important for consumers and food processors rather than its cost (Sanchez *et al.,* 2020a). In fact, the market sales of ready-to-use fresh fruits and vegetables have grown rapidly due to the changes in consumers' attitude in accepting or rejecting the product (Rico *et al.,* 2007). Thus, it is necessary to monitor regularly and control the quality of fresh productions in order to meet the quality standards as well as the consumer requirements (Ruiz-Altisent *et al.*, 2010). However, the quality evaluation of fresh productions are still being approached using conventional procedures. These procedures were reportedly time consuming, inefficient, laborious, costly and destructive in nature (Chen *et al.*, 2013; Sanchez *et al.*, 2020a). As a matter of fact, one of the most devastating effects of destructive measurement is that the produce is lost after the measurement has been carried out (Nicolai *et al.,* 2009). Thus, to overcome the drawbacks and challenges of destructive methods, non-destructive optical based technologies have been adopted and developed for the quality inspection of various agricultural and food products based on the optical measurements in the visible or near-infrared (NIR) regions (Abbott, 1999). These optical-based methods can be used with high precision, minimum labor and low operating cost (Rady & Guyer, 2015).

One of the most promising non-destructive optical-based technologies is the laser-light backscattering imaging (LLBI) technique. LLBI is an emerging spectral imaging tool that is known for an effective monitoring capability without touching the samples and offering low instrumentation cost at high accuracy (Mollazade & Arefi, 2017). LLBI technique can acquire spectral information from a sample through a deep penetration of light which makes it unique among other imaging methods. Aside from that, other optical-based imaging techniques have not been commercially and industrially utilized as compared with LLBI due to various limitations such as unsatisfactory performance, adaptability issues, and high cost of instrumentations (Adebayo *et al.,* 2016; Mollazade & Arefi, 2017). Moreover, LLBI has been reportedly efficient and potentially alternative machine vision technique with powerful spectral readings (Hashim *et al.,* 2013; Lorente *et al.,* 2013). Hence, the application of LLBI in agricultural and food industries is of growing interest in recent decades.

Over the past 10 years, LLBI has been approached by several research groups in monitoring the quality indices of various agricultural and food products. In fact, there have been numerous comprehensive reviews published complementary with this work who reported the potential applicability of diverse imaging methods in the non-destructive quality inspection of various horti-food products. However, the said reviews critically discussed the application of different imaging techniques on a specific food product/s with less discussions about LLBI. Say for instance, Chen *et al.* (2013) focused on the description, differences and trends of various optical imaging techniques. Adebayo *et al.* (2017) widely discussed the applications of laser light, multispectral, and hyperspectral backscattering imaging techniques in different food products while Rady & Guyer (2015) focused mainly in potato, Mohd Ali *et al.* (2017a) in watermelons and Sanchez *et al.* (2020a) in potatoes and sweet potatoes. Thus, it is the primary objective of the current work to report the current knowledge on the successful implementations of LLBI in various agricultural products. This paper will be of great help in the agricultural sector particularly in the marketing chain of fresh produce wherein proper sorting and grading is required. Likewise, this specific review in LLBI will be beneficial for the food processing and research institutions working on the developments of the technology for further online implementations.

2. Laser-light backscattering imaging (LLBI)

2.1 Basic concepts of LLBI

Generally, the backscattering imaging technology adopts the principle of capturing the scattered light of photons projected into the food material (Figure 1). According to Mireei *et al.* (2010), a turbid or semi-transparent material like agricultural products will allow the passage of light through its body at a specific wavelength. This occurrence manifests that when a light hits a crop tissue, 4 % of the light will be reflected back to the atmosphere while the rest will penetrate and is being absorbed, transmitted or scattered back (diffuse reflectance) to the incident point (Birth, 1976). Mohd Ali (2017) mentioned that the reflected light is distributed into three (3) types such as the regular, external diffuse, and scattering (Figure 1). The interaction of light during penetration in the crop tissue carries useful information about the structure of the material which is essential in measuring the quality of the produce (Hashim *et al.*, 2014; Mollazade *et al.*, 2012; Onwude *et al.*, 2018). In other words, this method possessed a simultaneous estimation of the absorption and scattering coefficients of the captured light from the material being examined.

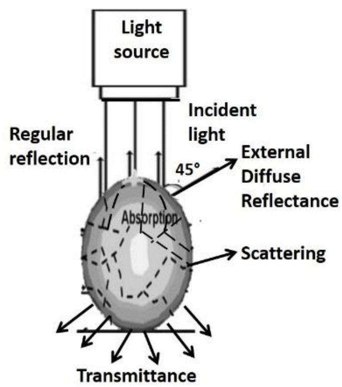


Figure 1. Schematic representation of the distribution of light in agricultural products (Mohd Ali, 2017).

Absorption coefficient (μa) and reduced scattering coefficients (μs') are two of the most important optical properties of the backscattering technique (Zude-Sasse *et al.*, 2019).

The decreasing rate of the light intensity when passing through the surface of a food material corresponds to the measure of the absorption coefficient while the fraction of scattered light per unit distance in the material belongs to the scattering coefficient (Mollazade *et al.,* 2012). Absorption and scattering coefficients uphold the principle that when a scattered light returns to its point of origin, it can only be described by considering the interference effects. Irimpan *et al.* (2008) added that the scattered lights with theme-reversed paths will interfere constructively and these interfering occurrences will enhance the photon projection and reduces the diffusion effect. The enhanced photons will later be extracted for the quantification of the physicochemical attributes of the material.

According to Mollazade & Arefi (2017), the backscattering imaging technique can acquire thousands of spectra per sample and based on the light source and imaging unit used, it can be divided into three categories which include laser-light backscattering imaging (LLBI), hyperspectral backscattering imaging (HBI), and multispectral backscattering imaging (MBI). Each of these imaging techniques is differentiated based on the illumination source and imaging set-up (Adebayo *et al.,* 2017). Theoretically, the use of LLBI is similar to that of HBI and MBI but only differs with the number of wavelengths applied. However, the LLBI technique is utilized for quantifying the scattering light at a specific wavelength rather than considering a wide range of wavebands (Mollazade *et al.,* 2012). With this particular reason, the LLBI is more advantageous and recommended to use since a single light source is always coherent and the system becomes easy to adjust and assemble. Thus, the LLBI is possible for the quality evaluation of various agricultural products utilizing the scattering and absorption effects.

2.2 Basic components of LLBI

An LLBI system is basically consist of two (2) major components: a light source and an imaging unit. A light source is designed to provide continuous light beam while the imaging unit is intended to acquire high quality of backscattered images. In the light source, the size of the laser beam and the incident angle between the sample and the beam have to be considered to provide distortion-free images (Hashim *et al.,* 2013; Lorente *et al.,* 2015). Meanwhile, the imaging unit is primarily provided with a camera; charge-coupled device (CCD), complementary metal oxide (CCMO) and monochromatic are three (3) of the most commonly adopted cameras in the LLBI system (Mohd Ali, 2017). As a whole, the basic parts of an LLBI system as shown in Figure 2 includes a computer system, camera, laser emitting diode, sample platform, supporting frame, and the sample being examined.

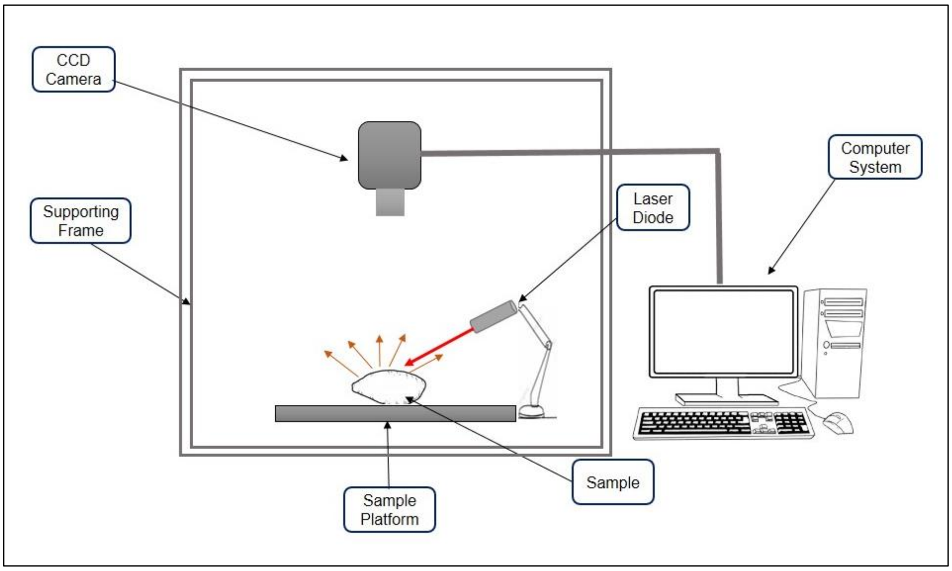


Figure 2. Schematic diagram of the basic components of an LLBI system (Sanchez *et al.,* 2020b).

According to Adebayo *et al.* (2017), one of the most important considerations in using the LLBI technique for non-invasive quality evaluation of food products is the appropriate selection of laser wavelength. Choosing the appropriate wavelength for a particular food product is of uppermost important in order to obtain a more precise measurement (Gunasekaran *et al.,* 1985). On the report of Adebayo *et al.* (2017), they have found that the food product quality could be quantified by utilizing the laser wavelengths from visible to NIR (400-1,000) as established in several former studies. It is then suggested that the 620 nm to 1,010 nm wavelength exhibited good potential for soluble solids content (SSC) and texture property measurements while 900 nm is suitable for moisture content (MC) measurement.

Another part that has to be considered in the application of LLBI technique is the laser beam size. Lasers with the larger beam size are known to provide good light distribution but could be disadvantageous for the backscattering properties as photons do not travel along the same path ways (Lu, 2004). Likewise, the light distribution from smaller beam sizes are concentrated but the light intensities are reduced which may result to a poor scattering area. Thus, proper selection of laser source sizes is important. Zulkifli *et al.* (2019) added that vigilant selection of laser source wavelength must be highly considered to obtain a good light signal.

Also, the incident angle between the food material and the laser source must be appropriately considered. The reason behind this is to minimize the oversaturation effect of the light intensity and to refrain the irrelevant reflection back to the camera. Based on review, an incident angle of 15° to 22º has been applied in the former LLBI studies which resulted to an easier image processing procedure (Adebayo *et al.,* 2016) and distortion-free images (Hashim *et al.,* 2013; Hashim *et al.,* 2014; Lorente *et al.,* 2013; Mohd Ali *et al.,* 2017b; Onwude *et al.*, 2018; Zulkifli *et al.*, 2019). Thus, proper LLBI configuration must be of high regard to have soft and precise quality-based optical measurements that are free from uncertain variations.

3. Applications of LLBI in Various Agricultural Products

In this part, the practical applications of LLBI technique across the various agricultural products are discussed. As shown in Table 1, the list of previous and recent literatures concerning the implementation of LLBI method under different study considerations applied such as the type of agricultural product, postharvest handling, wavelength selection range, data analyses applied and the corresponding accuracies obtained are summarized. It can be clearly seen that the exploitation of LLBI in the quality and safety evaluation of several agricultural products is paralleled with the different multivariate analytical methods. Multivariate analysis is a very crucial part in establishing the relationships between the extracted backscattering parameters and the reference quality parameters of the agricultural product being examined. Elmasry & Nakauchi (2016) stated that the mathematical, statistical, and modelling approaches are vital for the image-based analytical measurements. However, it is notable that the potential ability of LLBI technique has been viable across the different pre and post-harvest handling. Most applications of LLBI were concentrated on quantifying the quality of fruits and vegetables during fresh harvest, drying, storage, as well as in the decay detection and ripeness or maturity identification.

Say for instance, LLBI has been potentially approached by Hashim *et al.* (2013) in monitoring the chilling injuries of bananas when stored at a chilling temperature of 6 °C for a period of two days. The study showed a promising result as defined by the coefficient of determination (R^2) of over 0.90 between the reference quality attributes (visual assessment, chlorophyll index and water content) and the extracted backscattering properties. This assessment was supported by a good classification analysis with over 90 % accuracy as established both from the Linear Discriminant Analysis (LDA) and Quadratic Discriminant Analysis (QDA). Zulkifli *et al.* (2019) expanded the analysis into prediction and classification of the ripening stages of the same crop (banana) during storage. Based on the results, a high correlation effect ($R^2 > 0.90$) was also obtained between the measured total soluble solids and color properties of banana against the LLBI parameters. The technique also showed a high classification ability in sorting the fruit into ripe and unripe groups with over 90 % accuracy as established both from the LDA and PCA. The two studies implemented in the same crop but of different data analysis used only implied that regardless of the multivariate data analysis employed, LLBI technique provided accurate and favorable results.

Likewise, the non-destructive quality detection of apples using LLBI has been investigated by Zude *et al.* (2006), Qing *et al.* (2008), and Mollazade *et al.* (2013). The authors examined the same quality parameters (SSC and firmness) of the fruit and multivariate data analysis (PLSR) but somehow differed on the wavelength of the laser source used (Table 1). As formerly stated, different laser wavelength may give dissimilar results in the analysis as LLBI mainly possessed light scattering properties. Accordingly, all of the laser source used with wavelength ranges from 600 to 1,100 nm gave a good indicative results in quantifying the firmness and SSC of apples establishing a correlation factors against the backscattering properties of $R>0.80$. However, Qing *et al.* (2008) observed that the wavelength intensities in a range of 750 nm to 900 nm are less affected by the absorption of the fruit tissues while wavelength range between 780 nm to 880 nm will provide information mainly on the light scattering of the crop tissue. Thus, among all the three comparative results, the smaller wavelength used (660 nm) provided the highest correlation effect of $R^2 =0.887$ as found in the study of Mollazade *et al.* (2013). Recently, Wu *et al.* (2020) also demonstrated a good classification model in detecting the defects of apples based on their backscattering images. A convolutional neural network (CNN) theory was employed in analyzing the extracted properties achieving an accuracy of over 90 % recognition rate. Hence, these results showed that LLBI can be potentially applied in the non-invasive quality inspection of agricultural products particularly in apples.

Moreover, LLBI has also been explored in monitoring the quality changes of other fruits as affected by the postharvest handling such as during drying of papaya (Udomkun *et al.*, 2014), storage of plums (Mollazade *et al.*, 2013; Kalaj *et al.*, 2016), pears (Adebayo *et al.*, 2016; Zude-Sasse *et al.*, 2019) and watermelons (Mohd Ali *et al.*, 2017b). Other cases include the decay detection in citrus (Lorente *et al.*, 2013), estimating the maturity levels of cacao (Lockman *et al.*, 2019) and oil palm fresh fruit bunch (Mohd Ali *et al.*, 2020).

Table 1. Summary of LLBI applications in various agricultural products.

Product	Experimental Consideration	Quality Parameter	Data Analysis	Wavelength (nm)	Accuracy	Author/s
Apple	Fruit Maturity	SSC and Firmness	PLSR	400-1,100	$R^2 > 0.80$ Classification: > 90 %	Zude *et al.* (2006)
Apple	Storage	SSC and Firmness	PLSR	680-980	$R^2 > 0.70$	Qing *et al.* (2008)
Apple	Fresh Harvest	Defect Detection	CNN	635	Accuracy = 92.50 %	Wu *et al.* (2020)
Apple, Plum, Tomato, Mushroom	Storage	Firmness	PLSR	660	$R^2 = 0.887$ (Apple) $R^2 = 0.790$ (Plum) $R^2 = 0.919$ (Tomato) $R^2 = 0.816$ (Mushroom)	Mollazade *et al.* (2013)
Citrus	Storage	Decay Detection	GLP, LDA, PCA	532-1,060	$R^2 = 0.998$ Classification: > 90 %	Lorente *et al.* (2013)
Banana	Storage	Chilling Injury	MLR, LDA, QDA	660-785	$R^2 > 0.90$ Classification: > 90 %	Hashim *et al.* (2013)
Papaya	Drying	MC, Shrinkage, Color	MLR	532-780	$R^2 > 0.90$	Udomkun *et al.* (2014)
Plum	Storage	Firmness, SSC, Color, MC	MLR	532-785	R > 0.70	Kalaj *et al.* (2016)
Pears	Storage	Firmness, SSC	PLSR	532-830	R > 0.80	Adebayo *et al.* (2016)

Potato	Storage	MC, Firmness, Defect Detection	ANN	635	Classification: > 90 %	Babazadeh *et al.* (2016)
Potato	Fresh Harvest	Stones and Clods Discrimination	LDA	405-980	Classification: > 98 %	Geng *et al.* (2019)
Dry-cured Ham	Drying	MC and Texture	MLR	532-635	R > 0.60	Fulladosa *et al.* (2017)
Watermelon	Storage	Firmness, SSC, Color, pH, MC	PLSR	658	$R^2 > 0.90$	Mohd Ali *et al.* (2017b)
Sweet Potato	Drying	MC, Color	PCA, PLSR	658	$R^2 > 0.70$ Classification: > 90 %	Onwude *et al.* (2018)
Sweet Potato	Storage	MC, SSC, Color, Texture	MLR	658, 780	R > 0.85	Sanchez *et al.* (2020b)
Banana	Storage	Ripening/Maturity, Color, TSS	LDA, MLR, PCA	658	$R^2 > 0.70$ Classification: > 90 %	Zulkifli *et al.* (2019)
Pear	Storage	Firmness, MC, SSC	Regression	1,060	$R^2 > 0.60$	Zude-Sasse *et al.* (2019)
Cacao	Fresh Harvest	Firmness, Color	LDA, MLR	658, 705	$R^2 > 0.755$ Classification: >90 %	Lockman *et al.* (2019)
Oil Palm	Maturity Level	Oil Content, Color	PCA, PLSR	658	$R^2 > 0.80$ Classification: > 85 %	Mohd Ali *et al.* (2020)

R-correlation coefficient; **R^2**- coefficient of determination; **MC**- moisture content; **SSC**- soluble solids content; **TSS**- total soluble solids; **pH**- titratable acidity; **ANN**- artificial neural network; **CNN**- convolutional neural network **GLP**-Gaussian Lorentzian Product; **LDA**-Linear discriminant analysis; **MLR**- multi-linear regression; **PLSR**- partial least squares regression; **PCA**- principal component analysis; **QDA**- quadratic discriminant analysis.

Similarly, the potential ability of LLBI has been extended in the quality monitoring of various vegetable crops. This include the classification, decay detection and discrimination of clods and stones in freshly harvested potatoes (Babazadeh *et al.*, 2016; Geng *et al.*, 2019) as well as during drying of sweet potatoes (Onwude *et al.*, 2018). In the case of sweet potato, the capability of LLBI technique as examined by Onwude *et al.* (2018) focused mainly on predicting the MC and color changes of the flesh during drying. However, monitoring the physicochemical properties of the whole sweet potato roots during storage is highly important considering particularly the differences in varieties (Md Saleh *et al.*, 2018). Thus, this has brought the further interest of Sanchez *et al.* (2020b) in investigating the feasibility of LLBI in evaluating the quality changes of different sweet potato varieties during storage. Based on the study conducted, it was found that the LLBI can adequately predict the quality parameters of different sweet potato varieties such as the MC, SSC, color and textural properties with R>0.70. Results of the study also showed that the changes in the backscattering properties were related to that of the measured quality attributes and microstructural properties of the samples. Therefore, a baseline data was established concerning the potential ability of LLBI in quantifying the structural properties of an agricultural product.

Recently, Mohd Ali *et al.* (2020) investigated the potential of LLBI in combination with computer vision in rapidly determining the maturity levels of oil palm fresh fruit bunches. The study specifically determined the variations of color and oil content of the oil palm fruit at different maturity levels. Results of the study have indicated that the combined LLBI and computer vision (Red-Green-Blue imaging) methods were able to detect the quality changes of the oil palm fruit at different maturity levels as defined by the $R^2>0.80$ for both oil content and color (L^*, a^*, b^*) values. The combined optical techniques demonstrated a high potential in classifying the samples according to their maturity levels with over 90 % accuracies as described by the PCA. This review has emphasized the good potential of LLBI in combination with other optical-based methods for the non-destructive quality evaluation of agricultural products. Thus, it can be inferred that the LLBI technique has been proven effective and potentially viable in different implementations. However, the technique still has the room for advancements and developments for a more rapid and accurate quality measurements of agricultural and food products.

4. Conclusion

This paper reviews and reports the available literatures relate to the application of LLBI technique in various quality-related measurements of agricultural products. The LLBI has the capability to replace the conventional methods of quality inspection that are mostly destructive and laborious in nature. The application of laser-based imaging technology in quantifying the quality-related indices of various agricultural products have shown potential ability of the method as a rapid non-destructive optical tool. Moreover, the integration of laser-based imaging in other optical imaging techniques are also feasible and can be further implemented for future developments. Thus, the non-destructive quality evaluation of several agricultural products can be potentially approached by means of LLBI method which is rapid, more accurate, user-friendly and economically viable.

Acknowledgements: The authors acknowledge the financial support received from the Southeast Asian Regional Center for Graduate Studies and Research in Agriculture (SEARCA) under the Graduate Education Institutional Development (GEID) and the Department of Biological and Agricultural Engineering, Faculty of Engineering, Universiti Putra Malaysia (UPM) for providing the facilities for this research under the Putra Grant, GP-IPB (Vot. No.: 9660-301). The authors also acknowledge the Caraga State University (CSU), Butuan City, Philippines for the study leave privilege granted to Engr. Philip Donald C. Sanchez.

Conflicts of Interest: The authors declare no conflict of interest and also the funders had no role in the design of the study, in the writing of the manuscript, or in the decision to publish the research output.

References

Abbott, J. (1999). Quality measurements of fruits and vegetables. *Postharvest Biology and Technology*, 15, 207–225.

Adebayo, S. E., Hashim, N., Abdan, K., *et al.* (2016). Application and potential of backscattering imaging techniques in agricultural and food processing — A review. *Journal of Food Engineering, 169*, 155–164.

Adebayo, S. E., Hashim, N., Hass, R., *et al.* (2017). Using absorption and reduced scattering coefficients for non-destructive analyses of fruit flesh firmness and soluble solids content in pear (*Pyrus communis* 'Conference') — An update when using diffusion theory. *Postharvest Biology and Technology, 130*, 56–63.

Babazadeh, S., Moghaddam, P. A., Sabatyan, A., *et al.* (2016). Classification of potato tubers based on solanine toxicant using laser-induced light backscattering imaging. *Computers and Electronics in Agriculture, 129*, 1–8.

Birth, G. S. (1976). How light interacts with foods. In: Gaffney, J. J. Jr. (Ed.), Quality Detection in Foods. *American Society for Agricultural Engineering*, St. Joseph, MI, 6–11.

Chen, Q., Zhang, C., Zhao, J., *et al.* (2013). Recent advances in emerging imaging techniques for non-destructive detection of food quality and safety. *Trends in Analytical Chemistry, 52*, 261–274.

Elmasry, G. & Nakauchi, S. (2016). Image analysis operations applied to hyperspectral images for non-invasive sensing of food quality — A comprehensive review. *Biosystems Engineering, 142*, 53–82.

Fulladosa, E., Rubio-Celorio, M., Skytte, J. L., *et al.* (2017). Laser-light backscattering response to water content and proteolysis in dry-cured ham. *Food Control, 77*, 235–242.

Geng, J., Xiao, L., He, X., *et al.* (2019). Discrimination of clods and stones from potatoes using laser backscattering imaging technique. *Computers and Electronics in Agriculture, 160*, 108–116.

Gunasekaran, S., Paulsen, M. R., & Slove, G. C. (1985). Optical methods for non-destructive quality evaluation of agricultural and biological materials. *Journal of Agricultural Engineering Research, 32*(3), 209–241.

Hashim, N., Janius, R., Rahman, R. A., *et al.* (2014). Changes of backscattering parameters during chilling injury in bananas. *Journal of Engineering Science and Technology, 9*(3), 314–325.

Hashim, N., Pflanz, M., Regen, C., *et al.* (2013). An approach for monitoring the chilling injury appearance in bananas by means of backscattering imaging. *Journal of Food Engineering, 116*(1), 28–36.

Irimpan, L., Dann, V. J., Krishnan, B., *et al.* (2008). Backscattering of laser light from colloidal silica. *Laser Physics 18*(7), 882–885.

Kalaj, Y. R., Mollazade, K., Herppich, W., *et al.* (2016). Changes of backscattering imaging parameter during plum fruit development on the tree and during storage. *Scientia Horticulturae, 202*, 63–69.

Lockman, N. A., Hashim, N., & Onwude, D. (2019). Laser-based imaging for cocoa pods maturity detection. *Food and Bioprocess Technology, 12*, 1928–1937.

Lorente, D., Zude, M., Regen, C., *et al.* (2013). Early decay detection in citrus using laser-light backscattering imaging. *Postharvest Biology and Technology, 86*, 424–430.

Lorente, D., Zude, M., Idler, C., *et al.* (2015). Laser-light backscattering imaging for early decay detection in citrus fruit using both a statistical and a physical model. *Journal of Food Engineering, 154*, 76–85.

Lu, R. (2004). Multispectral imaging for predicting firmness and soluble solids content of apple fruit. *Postharvest Biology and Technology, 86*, 424–430.

Md Saleh, R., Karim, N., Hensel, O., *et al.* (2018). Mathematical modeling of adsorption isotherms of Malaysian variety of purple flesh sweet potato at different temperatures. *Thermal Science and Engineering Progress, 7*, 326–330.

Mireei, S., Mohtasebi, S., Massudi, R., *et al.* (2010). Feasibility of near-infrared spectrescopy for analysis of date fruits. *International Agrophysics, 24*, 351–356.

Mohd Ali, M. (2017). Characterization of optical parameters in seeded and seedless watermelon using laser-induced backscattering imaging. *Master Thesis, Universiti Putra Malaysia.*

Mohd Ali, M., Hashim, N., Bejo, S. K., *et al*. (2017a). Rapid and nondestructive techniques for internal and external quality evaluation of watermelons: A review. *Scientia Horticulturae*, *225*, 689–699.

Mohd Ali, M., Hashim, N., Bejo, S. K., *et al.* (2017b). Quality evaluation of watermelon using laser-induced backscattering imaging during storage. *Postharvest Biology and Technology, 123*, 51–59.

Mohd Ali, M., Hashim, N., & Abdul Hamid, A. S. (2020). Combination of laser-light backscattering imaging and computer vision for rapid determination of oil palm fresh fruit bunches maturity. *Computers and Electronics in Agriculture, 169,* 105235.

Mollazade, K. & Arefi, A. (2017). LightScatter: A comprehensive software package for non-destructive monitoring of horti-food products by monochromatic imaging-based spatially-resolved light scattering technology. *Computers and Electronics in Agriculture*, *142*, 597–606.

Mollazade, K., Omid, M., Tab, F. A., *et al.* (2012). Principles and applications of light backscattering imaging in quality evaluation of agro-food products: A review. *Food and Bioprocess Technology, 5*(5), 1465–1485.

Mollazade, K., Omid, M., Tab, F. A., *et al.* (2013). Analyses of texture-based features for predicting mechanical properties of horticultural products by laser light backscattering imaging. *Computers and Electronics in Agriculture*, *98*, 34–45.

Nicolai, B. M., Bulens, I., De Baerdemaeker, J., *et al.* (2009). Non-destructive evaluation: Detection of external and internal attributes frequently associated with quality and damage. In W. Florkowski (Ed.). *Postharvest handling: A systems approach* (pp 421–441). Elsevier Inc.

Onwude, D., Hashim, N., Abdan, K., *et al.* (2018). Combination of computer vision and backscattering imaging for predicting the moisture content and colour changes of sweet potato (*Ipomoea Batatas* L.) during drying. *Computers and Electronics in Agriculture, 150,* 178–87.

Qing, J., Ji, B., & Zude, M. (2008). Non-destructive analyses of apple quality parameters by means of laser-induced light backscattering imaging. *Postharvest Biology and Technology*, *48,* 215–222.

Rady, A., & Guyer, D. (2015). Rapid and/or non-destructive quality evaluation methods for potatoes: A review. *Computers and Electronics in Agriculture, 117*, 31–48.

Rico, D., Martin-Diana, A. B., Barat, J. M., *et al.* (2007). Extending and measuring the quality of fresh-cut fruit and vegetables: A review. *Trends in Food Science and Technology 18*(7), 373–386.

Ruiz-Altisent, M., Ruiz-Garcia, L., Moreda, G. P., *et al.* (2010). Sensors for product characterization and quality of specialty crops—A review. *Computers and Electronics in Agriculture, 74*, 176–194.

Sanchez, P. D. C., Hashim, N., Shamsudin, R., *et al*. (2020a). Applications of imaging and spectroscopy techniques for nondestructive quality evaluation of potatoes and sweet potatoes: A review. *Trends in Food Science and Technology 96*, 208–221.

Sanchez, P. D. C., Hashim, N., Shamsudin, R., *et al*. (2020b). Quality evaluation of sweet potatoes (*Ipomoea batatas* L.) of different varieties using laser light backscattering imaging technique. *Scientia Horticulturae, 260*, 108861.

Udomkun, P., Nagle, M., Mahayothee, B., *et al*. (2014). Laser-based imaging system for non-invasive monitoring of quality changes of papaya during drying. *Food Control*, *42*, 225–233.

Wu, A., Zhu, J., & Ren, T. (2020). Detection of apple defect using laser-induced light backscattering imaging and convolutional neural network. *Computers and Electrical Engineering*, *81*, 1–9.

Zude-Sasse, M., Hashim, N., Hass, R., *et al.* (2019). Validation study for measuring absorption and reduced scattering coefficients by means of laser-induced backscattering imaging. *Postharvest Biology and Technology*, *153*, 161–168.

Zude, M., Herold, B., Roger, J. M., *et al.* (2006). Non-destructive tests on the prediction of apple fruit firmness and soluble solid content on tree and shelf life. *Journal of Food Engineering, 77,* 254–260.

Zulkifli, A., Hashim, N., Abdan, K., *et al*. (2019). Application of laser-induced backscattering imaging for predicting and classifying ripening stages of "Berangan" bananas. *Computers and Electronics in Agriculture*, *160*, 100–107.

ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

Review Article

Adoption of IR4.0 in Agricultural Sector in Malaysia: Potential and Challenges

Rabiah Mat Lazim[1], Nazmi Mat Nawi[1, 2, 3*], Muhammad Hairie Masroon[1], Najidah Abdullah[1], and Maryani Mohammad Iskandar[1]

[1]Department of Biological and Agricultural Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor.

[2]Smart Farming Technology Research Centre (SFTRC), Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor.

[3]Institute of Plantation Studies, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor.

*Corresponding author: Nazmi Mat Nawi, Department of Biological and Agricultural Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor; nazmimat@upm.edu.my

Abstract: Agriculture remains as one of the most important economic sectors in Malaysia, which provides an employment for more than 1.6 million people. However, the growth of this sector can be hampered by a small-scale production, limited technological application, declining number of arable lands, environmental degradation due to climate change, rapid urbanization and aging farmers. In order to improve the competitiveness of agricultural sector, farmers are encouraged to fully utilize modern technologies in their farms. In this context, adoption of industrial revolution 4.0 (IR4.0) in an agricultural sector could offer many benefits, especially in minimizing the production costs and improving the quality of products. Thus, this review focuses on the adoption strategies of IR4.0 in an agricultural sector in Malaysia. A suitability of enabling technologies such as Internet of Things (IoT), autonomous robot, big data analytics and artificial intelligent. which are pillars for IR4.0 are individually evaluated. The readiness of the agricultural industry in Malaysia to embrace this new concept is also discussed. The review also investigates the potentials and possible challenges would be faced by the industry in embracing IR4.0. The recommendations are also targeted towards our fellow farmers, industrial players and policy makers to ensure a smooth adoption of IR4.0 in agricultural sector in Malaysia.

Keywords: agriculture; IR4.0; production; autonomous robot; Internet of Things (IoT); enabling technologies.

Received: 14th September 2020

Accepted: 4th November 2020

Available Online: 14th November 2020

Citation: Mat Lazim R, Mat Nawi N, Masroon MH, *et al.* Adoption of IR4.0 in agricultural sector in Malaysia: Potential and challenges, Adv Agri Food Res J 2020; 1(2): a0000140. https://doi.org/10.36877/aafrj. a0000140

1. Introduction

Agriculture remains as one of the most important economic sectors in Malaysia,which provides an employment for more than 1.6 million people (Dardak, 2015). In 2017, this sector contributed around 8.2%, which was equivalent to RM 1.2 trillion (USD 314.5 billion) of national Gross Domestic Product (GDP), where oil palm (46.6%) and other agricultural produce (18.6%) as the main contributors (DOS, 2018). Agriculture is regarded as one of the most important components under the National Key Economic Areas (NKEA), due to its potential to accelerate economic growth by creating more job and increasing income for farmers. In the latest, 11th Malaysian Plan: 2016–2020, modernization and transformation of the agricultural sector is given a priority in order to guarantee food security, increase crop productivity, increase farm profitability, strengthen agro-food supply chain and enhance related support and delivery services for all stakeholders (Bujang & Bakar, 2019).

Generally, agricultural sector in Malaysia can be divided into two categories, namely: food crops and industrial crops (Ng, 2016). In one hand, food crops refer to the production of vegetables, fruits, tubers, and grain crops which are dominantly grown by smallholders. In another hand, industrial crops refer to the production of commodity crops like oil palm, rubber, tea and cocoa which are normally planted by large estates or companies.

Several national initiatives have been implemented to enhance the farm productivity by addressing issues such as volatile prices, unfavorable market outlook, threat of pests and diseases, sustainable use of fertilizers and pesticides and ageing farmers (Nordin, 2018). However, the agro-food sector in particular, facing structural and supply-side challenges due to scarcity of land, labour, input and capital (Ahmad & Suntharalingam, 2009). At the regional level, limiting factors for the growth of agricultural sector are contributed by a small-scale production, limited technological application, declining number of arable lands, scarcity of water resources, environmental degradation due to climate change, rapid urbanization and labour shortage (Dung & Hiep, 2017).

To overcome these problems, precision agriculture (PA) technique has been proposed to be implemented in the agricultural sector. PA is defined as an integrated, information and production-based farming systems, which could increase the efficiency, productivity and profitability, as well as reducing undesirable excessive chemical application that could negatively impact the environment,thus reducing profitability (Liaghat & Balasundram, 2010). Recently, due to the advancement of technology, while PA is implemented to measure in-field variability, smart farming concept is introduced, which goes beyond PA by management-based tasks, not only on location, but also on data, which have been enhanced by context, situation awareness and triggered by real-time events (Wolfert *et al*., 2014). Smart farming refers to the application of Internet of Things (IoT) and cloud computing technology to collect real-time data and connect sensors with smart machines so that farm management will be data-driven and data-enabled system (Sundmaeker *et al*., 2016). This real-time intelligent assisting system is important feature to carry out farm operation, which is always subjected to abrupt environmental change due to unfavorable weather or disease. Figure 1 summarizes the concept of smart farming along the management cycle as a cyber-physical system (CPS), indicating that smart devices which are connected to the internet can control the farm system (Sung, 2018).

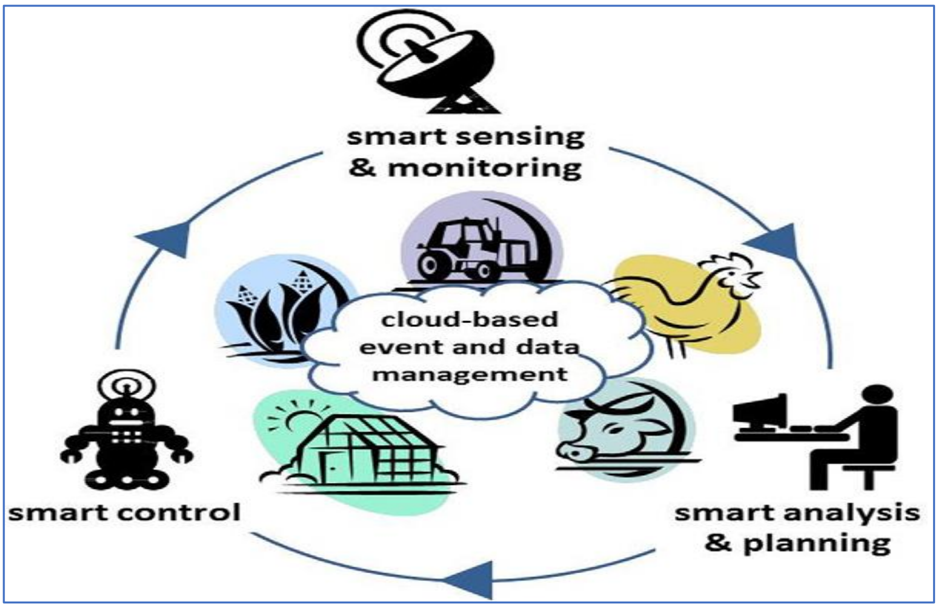


Figure 1. The cyber-physical environment for smart farming concept (Wolfert *et al.*, 2014).

The application of smart farming is in-line with the advent of industrial revolution 4.0 (IR4.0). Even though the revolution was meant for manufacturing sector, this revolution can also be adopted as a new approach into agricultural industry. In fact, agricultural industry has also undergone revolution in several stages. According to Dung and Hiep (2017), the first stage began in the early 20th century, is characterized by a low productivity and labor-intensive farming system. The second stage, which was known as the Green Revolution, is characterized by an efficient agronomic management practices with a higher yield potential and growing returns to scale at all levels. The third stage is characterized by farming industries with a higher efficiency and profitability, which enhanced the quality of the products. The fourth stage happened in parallel with similar evolution in the industrial world, which is pronounced as IR4.0. In terms of definition, agricultural revolution 4.0 (AR4.0) stands for the integrated internal — (within the farm) and external — (outside the farm, which includes suppliers, customers, service providers and *etc*.) networking related to a particular farming operation. This revolution will observe the digital information from all farm sectors to be electronically collected, processed, transmitted, analyzed and shared with all people involved in the supply chain.

Adoption of IR4.0 into agriculture could reduce the cost of crop inputs, increase the value of the products and sustain healthy environment. To realize these benefits, farmers are encouraged to use modern and appropriate technologies, which are more economical and efficient than the conventional technologies. The selected technologies must be suitable with the climate, weather and soil conditions of the farm. The application of the technologies should also be able to ensure constant production without jeopardizing the biodiversity, environment, ecosystem and human health (Dung & Hiep, 2017). Thus, this paper aims to review the potential application of IR4.0 for sustainable agricultural development in Malaysia. This review provides a brief introduction to IR4.0, its enabling technologies, potential applications and challenges in adopting this revolution in Malaysia.

2. Technological Readiness for the Agricultural Industry in Malaysia

Paddy and oil palm are the major crops in Malaysia. Thus, the government and related industries have given a special attention to modernize and revolutionize the production systems of these crops. In order to increase the yield and farm efficiency, smart farming has been introduced to assist farmers in utilizing modern machinery and technologies in their farming activities. To date, due to the availability and affordability of the technologies, there are many studies have been published regarding the application of sensing and IoT technologies in supporting the adoption of smart farming either in paddy or in palm oil productions (Mekala & Viswanathan, 2017; Rajeswari *et al.,* 2017). The use of these technologies could allow several agricultural parameters to be monitored in order to improve the crop yield, reduce cost and optimize inputs such as environmental conditions, growth status, soil status irrigation, pest and fertilizers, weed management and greenhouse gas emission (Nukala *et al.,* 2016).

In the paddy production, several studies have been published regarding the adoption of smart farming in the development of spatial decision support system for efficient management of paddy farms. For example, Kamal and Amin (2010) developed a Geographical Information System (GIS), a user-interface technique for monitoring and scheduling daily crop water requirement for paddy. In terms of image sensing technology, Jamil and Bejo (2014) investigated the potential use of thermal imaging camera to differentiate between husk and seeds of paddy. Recently, an autonomous robot such as drone has been employed as a platform to carry imaging sensor to get an overall survey and view of the farming area (Tripicchio *et al.,* 2014). The latest application for smart farming in paddy crop management is developed by Athirah *et al.* (2020). In their study, the authors developed the mobile application known as Padi2U that have multiple features in one platform. This application contains aerial images, normalized difference vegetation index (NDVI) and red, green, blue (RGB) map as inputs. The map can be used by farmers to manage their paddy field according to good agricultural practices.

In the oil palm plantation, remote sensing is the core technology employed to support the adoption of smart farming. Remote sensing has been used in various applications including land cover classification, automatic tree counting, change detection, age estimation, above ground biomass estimation, carbon estimation, pest and disease detection and yield estimation (Chong *et al.*, 2017). There are three main technologies used in remote sensing to obtain these data namely Global positioning systems (GPS), GIS and satellite images. In addition, light detection and ranging (LiDAR) sensors were also used in oil palm plantation to obtain geographic information and the soil elevation map (Shafri *et al.*, 2012). Soil electrical conductivity (EC) mapping was also used in plantation area to obtain soil characteristics and properties including chemical and physical properties (Aimrun *et al.*, 2007). Kalantar *et al.* (2017) applied unmanned aerial vehicle (UAV) as a platform for remote sensing application in taking stock of the number of palm trees. Another application of smart farming was proposed by Ishak *et al.* (2011) who developed intelligent system for automated weeding for oil palm plantation. Chong *et al.*, (2017) also applied multiple sensors to measure various temporal parameters such as age, breed, rainfall and soil fertility to estimate the yield for oil palm.

Based on the above evidence, it can be suggested that most of the technologies needed for IR4.0 are readily available and accessible by the industries. Thus, the industries would not face a major problem in adopting IR4.0. Their experiences in implementing smart farming technologies would provide a very good foundation to embrace IR4.0. Since IR4.0 is an extended version of smart farming, most of the sensors and data acquisition equipment which are used for smart farming can also be applied for the adoption of IR4.0. The most important thing for IR4.0 is how to make the sensors communicate among them under CPS.

3. Industrial Revolution 4.0 (IR 4.0)

IR4.0 refers to the convergence of artificial intelligence and data technology to provide a new solution to industrial and manufacturing problems across the globe, by integrating cyber and physical fields (Sung, 2018). The term IR4.0 is originated from industrial revolution, which begun with revolution 1 (invention of steam engine), revolution 2 (invention of electrical power), revolution 3 (invention of sensor and actuator) and revolution 4 (connectivity between sensors through CPS) (Kagermann *et al.*, 2013). Figure 2 shows the progress of industrial revolution from revolution 1 to revolution 4.

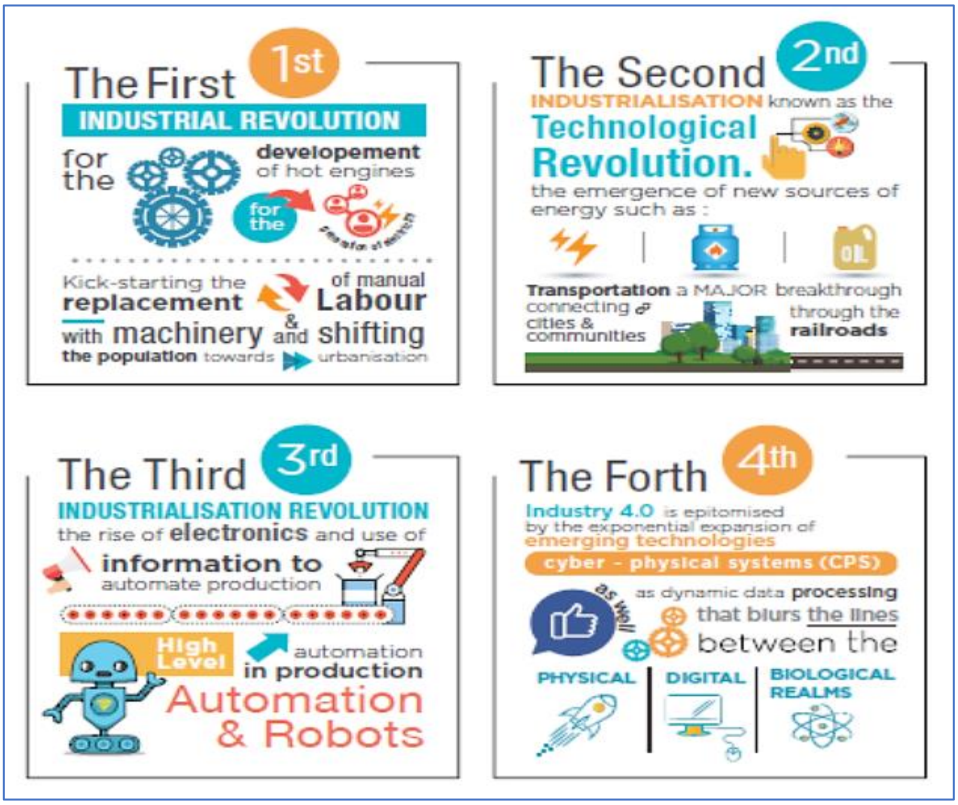


Figure 2. Stages involved in industrial revolution (MPC, 2018).

CPS is the main characteristic of IR4.0, which refers to a combination of physical and cybernetic systems (Lee *et al.*, 2015). These two systems can control everything that happens in the physical impacts on the virtual and vice versa (Lee, 2010). In manufacturing, CPS enables the development of autonomous productive processes through communication between sensors and smart machines using decision algorithms, which will allow the systems to decide on their configuration and their path in the production line (Lee *et al.*, 2015). IR4.0 typically involves the use of software (apps) to synchronize the physical and digital entities in order to stimulate and innovate industrial efficiency. The apps can also be used to enhance the connectivity between humans and machines, thus, increasing the manufacturing efficiency. In other words, IR4.0 can digitize, automate and interconnect all the processes within the production lines.

Nowadays, IR4.0 has been adopted in many sectors including telecommunication, automobile, energy, manufacturing services, security, medicine, robotics and agriculture (Hellinger & Seeger, 2011). In terms of management sectors, IR4.0 was utilized in the digitalization of accounting service, digitalization of legal service and digitalization of human resource management services. More specific examples include fully automated production process in factory, the process of loading or unloading containers at ports, robot waiters in restaurants, remotely managing the power of buildings from smart phones or other devices (Sung, 2018).

4. Enabling technologies for IR4.0

IR4.0 is about modern revolution, in which information and communication technology (ICT) is utilized as one single system. The revolution is growing due to existing of several enabling technologies such as artificial intelligence, big data analytics, augmented reality, IoT, cloud computing, autonomous robots, system integration, simulation and a few more (Figure 3). Details description of the enabling technologies are provided in Table 1. For agriculture, the major enabling technologies are IoT and sensors, which could enhance the implementation of smart farming that involve several field operations such as yield monitoring, diagnosing insect pests, measuring soil moisture, diagnosing harvest time, and monitoring crop health status. IR4.0 could also potentially be applied to remotely control all crop sensors at a field using mobile devices.

IR4.0 would permit smart devices with built-in intelligence to be connected to conventional tools (e.g. rain gauge, tractor, implement, sensor, notebook) in order to create an autonomous system, which is capable to execute autonomous actions or doing this remotely. By adopting IR4.0, workers will minimally involve in the whole process especially at a higher intelligence level, while the operational activities will be performed by smart machines or robotics. Thus, connectivity and IoT are the key factors for the success of this transformation.

Table 1. Pillar of enabling technologies for the adoption of IR4.0.

No.	Pillar	Description
1.	Additive manufacturing	Producing a product from new materials using 3D printing technology. For example, producing artificial bone from composite materials.
2.	Artificial intelligence (AI)	Application of machine learning to develop computer programs that can train actuator/robot to perform a duty as described by programmer. AI technology can be used to build a smart plant factory, in which data from supply chains, design teams, production lines and quality control are linked to form a highly integrated and intelligent systems.
3.	Big data analytics (BDA)	Analysis of data collected by sensors and observe the trend of the data to make real-time decision. BDA can be applied to improve product quality, energy efficiency and perform predictive maintenance.
4.	Advanced materials	Development of new materials and nano-structures components with better durability and strength. For example, material with good shape retention and thermoelectric efficiency.
5.	Cybersecurity	The communication level in many industries is becoming complex and strongly connected. Thus, digital security becomes a critical aspect to protect any online system from being hacked by outsiders.
6.	Simulation	Simulation is applied by engineers to predict the product behaviour under different conditions. In a field, simulation in used to predict crop yield due to

		different agronomical practices and varied climatic condition. Simulation is performed to find the optimal way to produce a crop.
7.	Cloud computing	With the availability of cloud computing system, small companies can access cloud service on rental basis to leverage cloud-based product design, simulation, AI and big data solutions to improve their production.
8.	Augmented reality	Augmented reality can be used to deliver part replacement instructions to maintenance staff in the field.
9.	Internet of things (IoT)	IoT is the platform which connect different sensors at one time. IoT can be combined AI and big data to develop autonomous systems which can transform crop production.
10.	Autonomous robots	Autonomous robots such as drone or unmanned tractor can perform their jobs based on the prescribed order programmed to them. Autonomous robot can think, act and react autonomously similar to common human movements.
11.	System integration	System integration is created to share the data and information amongst the industry players. The system exists within the industry value chain and also across multiple value chains.

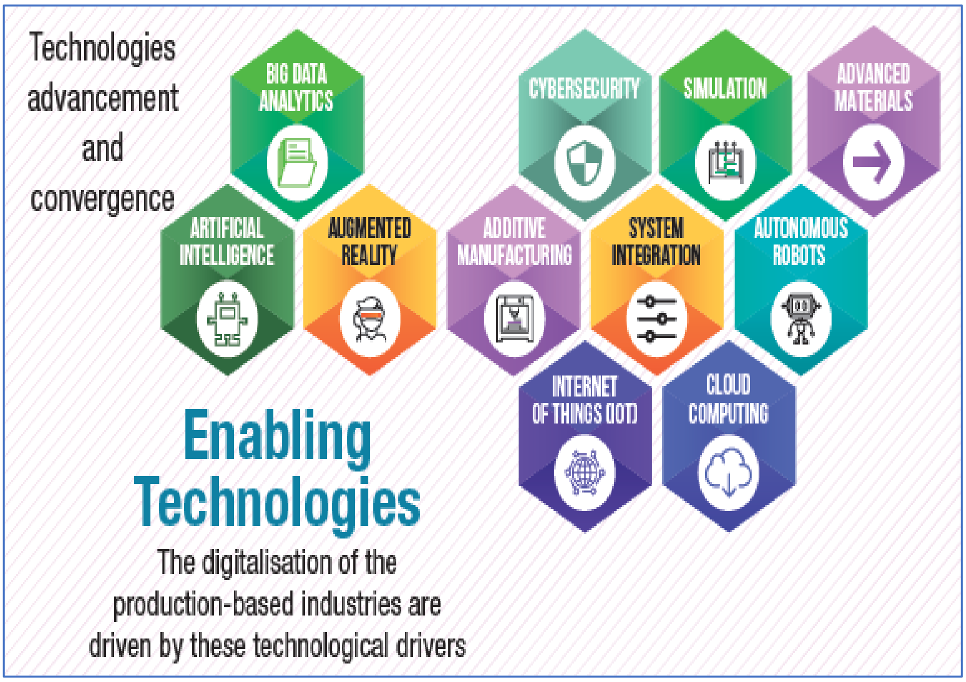


Figure 3. Enabling technologies for adoption of IR4.0 (MITI, 2018).

Another important pillar for IR4.0 in agriculture is an autonomous robotic. An autonomous robot is typically programmed to move in the field on assigned routes and is able to make decision in facing different situations or obstacles. Modern autonomous robot can also imitate human movements and recognizes the external environment for accurate responses. Ideally, agricultural robot should be designed to effectively work in the open-field system, closed processing facility, and livestock production environment. The use of autonomous robotics could improve productivity through automation, unmanned farming, and the promotion of eco-friendly farming (Sung, 2018).

5. Potential benefits of IR4.0 in agriculture

At present, there are only 5% of the world's population, who involves in agriculture, where majority of them are elderly. To overcome this problem, several developed nations such as the US, Germany and Japan are trying to modernize their agricultural sector through mechanization, automation, and digitalization. As a result, the future farming is expected to evolve into high-tech industries, which will fully embrace IR4.0, benefiting from the advent of artificial intelligence, IoT, robotics and big data analytics. IR4.0 could facilitate the development of a modern multi-tasking farm machinery equipped with multiple sensors, which is capable of performing several farm operations and recorded different field data in a single run. This modern technology will certainly catch the interest of younger generations to involve in agriculture. In Malaysia, out of 13.9 million youngsters in the country, only 15% of them involve in agricultural industries.

The adoption of IR4.0 will enhance the implementation of PA in the agricultural sector. Comprehensive improvement in this sector can be gained, when IR4.0 facilitate the development of the optimized agricultural system which connects production, distribution, and consumption. This system will ensure that there is no crop will be wasted because it will be produced according to the current demand.

Since agricultural sector can severely be affected by the weather, the industry is highly dependent on intelligence and wisdom, including human experience to predict the weather condition. Thus, application of IR4.0 in dealing with weather-related problems would be very useful. For example, IR4.0 can offer a simulation model to precisely predict the oncoming weather pattern so that farmers can be ready with a proper mitigation plan. IR4.0 can also be considered as an agro-friendly revolution.

IR4.0 could also benefit medium and large plantation sectors by lowering their production costs because it can offer complete or partial changes in production and operational activities. A lower production costs may lead to a lower price, thus making our plantation products to be more competitive in the international market. As a result, more competitive exports have the potential to boost export volume and stimulate the Malaysian economy. In other words, IR4.0 could improve the competitiveness of Malaysian exports, thereby raising our Gross Domestic Product (GOP).

IR4.0 also has a potential to expand the traditional agriculture into different fields, such as culture, welfare, and tourism. IR4.0 can be a platform to convert an agricultural into agro-tourisms activities, such as combining agriculture with games and leisure, human welfare agriculture in the age of aging, and agricultural activities with plants and animals (Anonymous, 2016). It is expected that IR4.0 would also enhance the traditional agriculture into modern agriculture in all aspects, including crop production, distribution, and consumption.

Agricultural facility such as a plant factory would be the first system to be modernized by smart farming technologies during IR4.0. IR4.0 technologies could effectively control the growth environment of the planted crops. Farmers who manage the facility should be able to monitor the growth status of the planted crops by using mobile devices from their offices, without physically going to the facility. This technology could increase the farm profits due to precise control and optimal prescription of agriculture. Ideally, IR4.0 would also permit all sensors and smart machines in the facility to be automated or remotely controlled. As shown in Figure 4, for open-field farming, IR4.0 can be fully utilized for monitoring the crop growth, analyzing data and carrying out variable rate application using smart farm machinery.

Monitoring the area for crop growth environment may include the health status of crops, climatic information, environmental information and growth information. By having enough data on crop growth, weather and available farm machinery, farmers can develop a simple simulation model to help them to maximize farm production and minimize the possible hazard due to unfavorable weather condition, natural disasters, system-errors and other external factors.

Any crop data from the farm, which is monitored and collected can be analysed for the decision-making. All collected data is accumulated, processed, and analysed as big data. Big data analytics will make it possible to collect environmental data during cultivation through an agricultural service platform. Then, a precise decision can be made from the data in a way that surpasses human intelligence, wisdom, and experience. The information can be used to evaluate market sale trends according to market preference analysis, and then the data (the cultivation environment, pest information, climate and weather information, soil fertility, topographical relevance, *etc*.) can be fed back to farmers to optimize production environments (Sung, 2018).

IR4.0 would also bring change to the distribution of agricultural product. The technology could supply useful background information of the product such as the prices, climate information, place of origin, variety, and intended customers, which would help to establish an effective supply and demand system. In this way, farmers or the government can adjust timing for planting and harvesting to stabilize prices of the product.

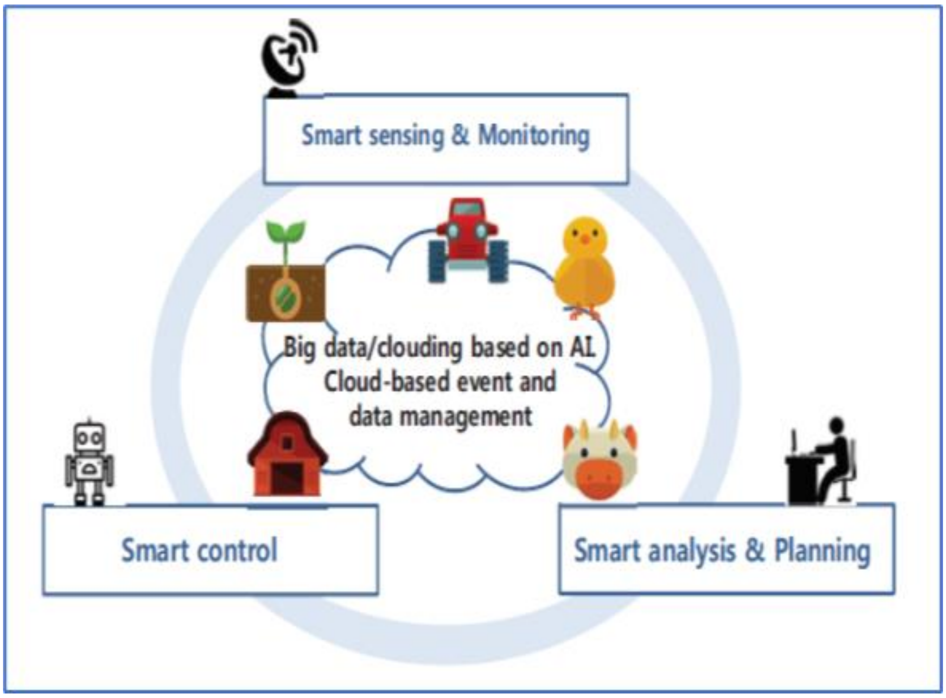


Figure 4. The Fourth Industrial Revolution and changes in agricultural production (Lee, 2017).

6. Challenges for Adoption of IR4.0 Into Agriculture

Although the adoption of IR4.0 could offer great benefit to the industry, but the actual adoption by farmers would take a long time. Harun *et al.* (2015) conducted a survey among farmers and concluded that most of the local farmers were reluctant to change or adapt to new techniques. This is because, most of the farmers, which majority are elderly, normally refuse to change their farming practices due to lack of awareness and interest. To date, many farmers are still not fully aware of the importance and advantages of IR4.0. Thus, in order to promote IR4.0 to farmers, creating awareness among them and relevant stakeholders is very necessary. Awareness and interest can be built through training, seminar, product demonstration, technical visit and subsidy award. Businesses and industrial players can play a role in improving the readiness and accessibility of the available modern technologies to rural farmers. Government agencies can build a testing platform for testing various sensors and technologies related to IR4.0, to help farmers quickly learn about the revolution.

IR4.0 has a potential to be developed to replace human intelligence by creating an autonomous robot, which can substitute labour. An increased in automation implies that employment opportunities may be reduced especially for the jobs, which requires repetitive tasks. This is good news for agricultural sector which faces a shortage in labour force. However, for other industries, extensive use of robot will minimize the number of their staff, resulting in an increase number of unemployment. However, through proper training in IR4.0-related program such as sensor integration, programming and data analysis, people will have high chance to be hired by the companies, which will implement IR4.0.

The implementation of IR4.0 will require huge financial investment. Bujang and Bakar (2019) reported that the technological adoption in Malaysia will be a challenging issue because of the cost factor. The initial cost is needed to develop an infrastructural framework that facilitates IR4.0, as well as transformative costs to adapt the technology. Thus, the government can offer incentives to companies that are willing to transform. This not only has the benefit of reducing cost of transformation, but also has the advantage of increasing the rate of transition to IR4.0. However, for the long term implication, the efficiency and innovation gains from IR4.0 could significantly outweigh the deployment and transformation costs. A study can also be conducted to identify, which sectors have the most potential to benefit from IR 4.0. An identified sector should be given the priority for the investment. It is also suggested to identify which activities are more suitable for automation.

The government must also facilitate the construction of the necessary infrastructure to meet the requirements for transition to IR4.0. One of the most important things for IR4.0 is the Internet service which have better coverage and speed nationwide especially in rural areas (Dlodlo & Kalezhi, 2015). Good internet service is very important to fully capitalize on IoT, cloud computing and big data analytics. Lastly, the fifth-generation (5G) communication network, the Internet network infrastructure and the cloud service system must maintain support for these technologies, in order to allow them to easily integrate into the agricultural industry.

7. Conclusion

IR4.0 which are supported by enabling technologies could offer an opportunity to modernize Malaysian agricultural sector to be more competitive, efficient, profitable and sustainable. This innovative technological advancement would allow farmers to produce agricultural product at a lower cost, but at a better quality. This review presented some key features of IR4.0 and how it can be adopted in agricultural production in Malaysia. A suitability of enabling technologies such as IoT, autonomous robot, big data analytics and artificial intelligent, which are among the pillars for IR4.0 are individually evaluated. The review has also investigated the potentials and possible challenges would be faced by the industry in embracing IR4.0. Recommendations are also provided for farmers, industrial players and policy makers to make sure a smooth adoption of IR4.0 into agricultural sector in Malaysia.

Author Contributions: Conceptualization, N.M.N. and M.H.M.; resources, N.A., R.M.L., and M.C.M.I.; writing—original draft preparation, M.H.M., N.A., and M.C.M.I.; writing—review and editing, N.M.N and R.M.L.

Funding: This work was funded by the Universiti Putra Malaysia under Putra Grant Scheme with vot number 9635700.

Conflicts of Interest: The authors declare no conflict of interest.

References

Ahmad, T. A. T., & Suntharalingam, C. (2009). Transformation and economic growth of the Malaysian agricultural sector. *Economic and Technology Management Review, 4*, 1–10.

Aimrun W, Amin M. S. M., Ahmad D., *et al.* (2007). Spatial variability of bulk soil electrical conductivity in a Malaysian paddy field: key to soil management. *Paddy and Water Environment*, *5*(2), 113–121.

Anonymous (2016). *The fourth industrial revolution and agriculture*. Republic of Korea: Korea Institute of Planning and Evaluation for Technology in Food, Agriculture and Forestry.

Athirah, R. N., Norasma, C. Y. N., & Ismail, M. R. (2020). Development of an android application for smart farming in crop management. In *IOP Conference Series: Earth and Environmental Science*, *540*(1), 012074.

Bujang, A. S. & Bakar, B. A. (2019). Precision agriculture in Malaysia. *Proceedings of International Workshop on ICTs for Precision Agriculture, 6–8 August 2019,* 91–104. Mardi Headquarters, Selangor, Malaysia.

Chong, K., Kanniah, K D, Pohl, C., *et al.* (2017). A review of remote sensing applications for oil palm studies. *Geo-Spatial Information Science*, *20*(2), 184–200.

Dardak, R A (2015). Transformation of agricultural sector in Malaysia through agricultural Policy. *Malaysian Agricultural Research and Development Institute (MARDI), Malaysia.*

Dlodlo, N., & Kalezhi, J. (2015). The internet of things in agriculture for sustainable rural development. *In 2015 international conference on emerging trends in networks and computer communications (ETNCC), IEEE.* pp. 13–18.

DOS. (2018). Malaysia Selected Agricultural Indicators. *Department of Statistics Malaysia*, 2018.

Dung, L. T., & Hiep, N. T. H. (2017). The revolution of agriculture 4.0 and sustainable agriculture development in Vietnam. *Proceedings of International Conference on Emerging Issues in Economics and Business in the Context of International Integration National Economics University Press Hanoi*, December 2017.

Harun, R., Suhaimee Y, Amin, M Z M., *et al.* (2015). Benchmarking and prospecting of technological practices in rice production. *Economic and Technology Management Review*, 10b, 77–88.

Ishak, W., Hudzari, R., *&Ridzuan, M.* (2011). Development of variable rate sprayer for oil palm plantation. *Bulletin of the Polish Academy of Sciences. Technical Sciences*, *59*(3), 299–302.

Jamil, N., & Bejo, S. K. (2014). Husk detection using thermal imaging technology. *Agriculture and Agricultural Science Procedia*, *2*, 128–135.

Kagermann, H., Wahlster W., *& Helbig, J.* (2013). Recommendations for implementing the strategic initiative Industries 4.0: *Final Report of the Industries 4.0 Working Group*.

Kalantar, B., Idrees, M. O., Mansor, S., *et al.* (2017). Smart counting–oil palm tree inventory with UAV. *Coordinates*, *13*(5), 17–22.

Kamal, R. M., & Amin, M. S. M. (2010). GIS-based irrigation water management for precision farming of rice. *International Journal of Agricultural and Biological Engineering*, *3*(3), 27–35.

Lee, E. A. (2010). CPS foundations. *In Proceedings of the 47th Design Automation Conference, June*, 737–742.

Lee, J. R. (2017). The fourth industrial revolution and future agriculture. Republic of Korea: *Science and Technology Policy Institute;* 2017.

Lee, J., Bagheri, B., & Kao, H. A. (2015). A cyber-physical systems architecture for industry 4.0-based manufacturing systems. *Manufacturing Letters, 3,* 18–23.

Liaghat, S., & Balasundram, S. K. (2010). A Review: The role of remote sensing in precision agriculture. *American Journal of Agricultural and Biological Sciences, 5*(1), 50–55.

Mekala, M. S., & Viswanathan, P. (2017). A survey: Smart agriculture IoT with cloud computing. In *2017 international conference on microelectronic devices, circuits and systems (ICMDCS), IEEE,* 1–7.

MITI, (2018). Industry 4wrd: National policy on Industry 4.0. *Ministry of International Trade and Industry (MITI),* 2018.

MPC, (2018). The Race towards Industry 4.0: Malaysia Productivity Corporation (MPC), 2018.

Ng, C. (2016). What it means to be a farming smallholder in Malaysia. *UTAR Agriculture Science Journal*, *2*, 40–48.

Nordin, K. A. (2018). Agriculture: Addressing Food Security in Malaysia. The Edge Markets, 2018. https://www.theedgemarkets.com/article/agricultureaddressing-food-security-malaysia.

Nukala, R., Panduru, K., Shields, A., *et al.* (2016). Internet of Things: A review from 'Farm to Fork'. *In 27th Irish Signals and Systems Conference (ISSC). IEEE.* 1–6.

Rajeswari, S., Suthendran, K., & Rajakumar, K. (2017). *A smart agricultural model by integrating IoT, mobile and cloud-based big data analytics*. In 2017 international conference on intelligent computing and control (I2C2), IEEE, 1–5.

Shafri, H. Z., Ismail, M. H., Razi, M. K. M., *et al.* (2012). Application of LiDAR and optical data for oil palm plantation management in Malaysia. In *Lidar Remote Sensing for Environmental Monitoring XIII, International Society for Optics and Photonics.* 8526.

Sundmaeker, H., Verdouw, C., Wolfert, S., *et al.* (2016). *Internet of food and farm 2020. Digitising the Industry-Internet of Things connecting physical, digital and virtual worlds.* River Publishers, Gistrup/Delft, 129–151.

Sung, J. (2018). *The fourth industrial revolution and precision*. Agriculture Automation in Agriculture — Securing Food Supplies for Future Generations. http://dx.doi.org/10.5772/intechopen.71582

Tripicchio, P., Unetti, M., Giordani, N., *et al.* (2014). A lightweight slam algorithm for indoor autonomous navigation. In *Proceedings of the 2014 Australasian Conference on Robotics and Automation* (ACRA 2014), 2–4.

Wolfert, J., Sørensen, C.G., & Goense, D. (2014). *A future internet collaboration platform for safe and healthy food from farm to fork.* Global Conference (SRII), 2014 Annual SRII. IEEE, San Jose, CA, USA.

HH PUBLISHER

HH ACADEMIC
(002672130-K)
PT. 321 Tingkat 1,
Jalan Bandar, 71000,
Port Dickson, Negeri Sembilan.
Tel: +60 12-359 0809
Email: inquiries@hh-publisher.com
Website: www.journals.hh-publisher.com/index.php/AAFRJ/index

eISSN 2735-1084