ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

Original Research Article

Innovative Watermelon Postharvest and Process Engineering System: Cleaning, Sizing, and Puree Processing for Market Enhancement

Masniza Sairi[1]*, Zainun Mohd Shafie[1], Badaruzzaman Mohamad Noh[1], Wan Mohd Fariz Wan Azman[1], Hasmin Hakim Hasbullah[1], Saiful Azwan Azizan[1], Afiqah Aina Rahim[1], Nur Azlin Razali[2], Teoh Chin Chuang[1]

[1]Engineering Research Centre, MARDI Headquarters, Persiaran MARDI-UPM, 43400 Serdang, Selangor, masniza@mardi.gov.my, szainun@mardi.gov.my, badar@mardi.gov.my, wmfariz@mardi.gov.my, hhhasbullah@mardi.gov.my, asazwan@mardi.gov.my, afiqah@mardi.gov.my, cchin@mardi.gov.my

[2]Horticulture Research Centre, MARDI Headquarters, Persiaran MARDI-UPM, 43400 Serdang, Selangor, nurazlin@mardi.gov.my

*Corresponding author: Masniza Sairi, Engineering Research Centre, MARDI Headquarters, Persiaran MARDI-UPM, 43400 Serdang, Selangor; masniza@mardi.gov.my

Abstract: In this research, a watermelon postharvest and process engineering system was designed, developed, and assessed its performance. The watermelon postharvest engineering system integrates a mechanised cleaning and a robotic sizing system with a capacity of 100-120 fruits/h, targeting fresh watermelon for the export market. The cleaning efficiency was 90%, whereas the sizing efficiency was 100%. Adding 250 ppm sodium dichloroisocyanurate in water during the cleaning process can extend the storage life of watermelon up to five weeks. The application of vacuum suction cups in the robotic sizing system did not cause any mechanical injury to the watermelon. The integration of mechanised cleaning (inclusive sanitation treatment) and robotic sizing systems is novel in Malaysia's watermelon postharvest engineering system. The system maintains good quality, reduces losses, and expands the market potential of watermelon. On the other hand, the watermelon mechanised puree processing system consists of a watermelon peeler, extractor, pasteuriser, and targeted watermelon puree production for small and medium enterprises (SMEs). Watermelon peeler, extractor and pasteuriser have a capacity of approximately 1 peeled watermelon/min, 430 kg watermelon puree/h, and up to 90 L watermelon puree/batch, respectively. The mechanised watermelon puree processing system showed the potential to diversify local agricultural products. The developed system can benefit fresh watermelon exporters and puree producers regarding market expansion.

Keywords: mechanised cleaning; robotic sizing; peeler; extractor; pasteuriser

Received: 3rd November 2023

Accepted: 23rd May 2024

Available Online: 3rd June 2024

Published: 23rd October 2024

Citation: Sairi, M., Mohd Shafie, Z., Mohamad Noh, B., *et al*. Innovative watermelon postharvest and process engineering system: Cleaning, sizing, and puree processing for market enhancement. *Adv Agri Food Res J* 2024; 5(2): a0000494. https://doi.org/10.36877/aafrj.a0000494

1. Introduction

Malaysia's fruit industry has grown rapidly in recent decades due to increased local and global demand, in addition to government efforts through various initiatives and policies such as the National Agrofood Policy 2.0 (DAN 2.0). Recently, Malaysia has focused on increasing the production of premium fruits for export purposes, in addition to the local market. Watermelon (*Citrullus lanatus*) is one of the selected agricultural commodities under the category of premium fruits in Malaysia. In 2022, Malaysia has produced 135,682 metric tons (MT) of watermelon with Kelantan, Johor, and Pahang states as the top producers (DOA, 2023). Watermelon exhibits Malaysia's largest export volume in 2020, amounting to 45,300 MT with the Middle East, China, Singapore, and Japan as the top importing countries.

The prior requirement for companies to export watermelons is the need to obtain a phytosanitary certificate from the Department of Agriculture (DOA), Malaysia. In order to obtain the phytosanitary certificate, the fruit must be weed- and soil-contamination-free. A previous study by Richards & Beuchat (2005) discovered that postharvest losses of cantaloupe (family: *Cucurbitacea*, similar to melons) were dominated by microbial contamination.

The robotic industry was developed to assist and replace human labour where the common agricultural practices are dirty, repetitious, high load, dangerous and require high precision (Blanes *et al.*, 2011). In the past few decades, global research emphasised the trends in the application of robots (IR 4.0) in agriculture such as greenhouse operation, harvesting, postharvest handling and processing. The employment of robots can assist in the postharvest handling of agricultural products in which foreign labourers are generally employed in this activity. Over 70 % of companies in the USA have invested in robot applications in the harvesting and post-harvest handling of fruit products (Samtani *et al.*, 2019).

In Malaysia, generally, the processes of watermelon cleaning and sizing were conducted manually. The exported watermelons are between 4 and 12 kg/fruit. The large and heavy watermelons introduced physical injury risk to the operators during the manual cleaning and sizing processes. In addition, the manual cleaning process poses a risk of cross-contamination.

In this case, a watermelon postharvest engineering system comprising mechanised cleaning (inclusive sanitation treatment) and a robotic sizing system focusing on the export market has been developed by the Engineering Research Centre, MARDI.

On the other hand, the use of watermelon cannot be limited to fresh consumption due to its short shelf life. Thus, watermelon puree production is suggested, which, later can be used to produce watermelon-based foods and drinks. Watermelon puree production involves other processes such as rind removal, flesh extraction and filtration, puree pasteurisation and storage (Sairi *et al.*, 2010). It needs proper and hygienic processing methods to ensure a longer shelf life. Even though the fruit puree processing system has been established, the watermelon puree industry in Malaysia is still relatively new and has great potential.

The Engineering Research Centre, MARDI, has proposed a cost-effective watermelon puree process engineering system as a model for Small and Medium Enterprises (SMEs) to explore the watermelon puree production industry which caters for the complete processing of peeling, extraction and pasteurisation processes.

The objectives of this research are to design, develop and assess the performance of watermelon postharvest and process engineering systems. The system performance was evaluated based on the cleaning and sizing efficiencies, and watermelon quality evaluation due to mechanised cleaning and robotic sizing processes. Furthermore, mechanised watermelon puree processing system was evaluated based on peeling, extracting and pasteurising performances. Together with that, physicochemical analysis of the watermelon and watermelon puree were also evaluated.

2. Materials and Methods

2.1 Mechanised Cleaning and Robotic Sizing System Performance Evaluation

The watermelon postharvest engineering system integrates a mechanised cleaning and a robotic sizing system for fresh watermelon (Figure 1). The system was developed in Engineering Research Centre, MARDI, Selangor, and comprises of five primary sections: cleaning and sanitising chamber, drying chamber, weighing module, robotic arm with vacuum suction cups, and sizing table. The system performance evaluation was conducted based on cleaning and sizing efficiencies as reported by Mohd Shafie *et al.* (2022). The weighing module consisted CB004 load cell and a DAT1400 load cell controller (Pavone, Italy). Prior to the cleaning efficiency study, soil dirt was placed on selected positions on the watermelon surface. The cleaning efficiency was based on traces of soil dirt on the watermelon surface post-cleaning process. In the case where no traces of soil dirt were observed on the selected positions on the watermelon surface, the fruit was considered clean and vice versa. On the other hand, the sizing efficiency was based on the number of fruits at the correct size lane on the sizing table (Mohd Shafie *et al.*, 2022). A total of 100 watermelon samples with three replications were used in the study. Watermelon samples used in the study were procured from local suppliers; Melon Master Sdn. Bhd., Kuala Lumpur.

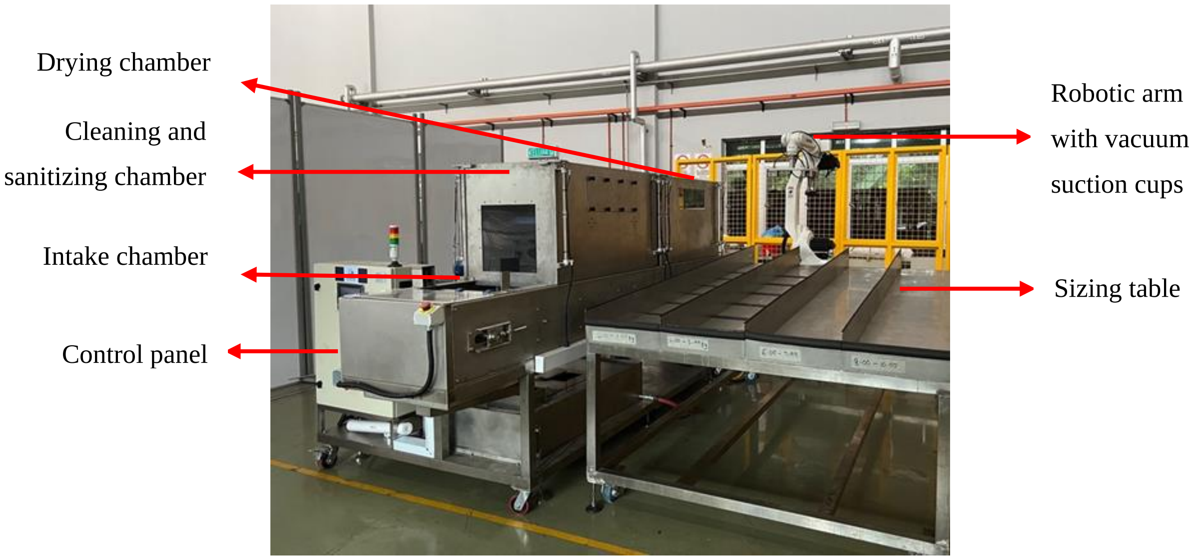

Figure 1. Mechanised cleaning and robotic sizing system

In mechanised cleaning system, watermelon was placed on a roller conveyor in the intake chamber and moved by the roller conveyor into the cleaning chamber with a brushing mechanism for the cleaning and sanitation process using water and 250 ppm sodium dichloroisocyanurate solution (FoodGUARD, Malaysia). Subsequently, the watermelon is moved by the roller conveyor to the drying chamber to evaporate the water on the fruit skin surface using compressed air. The watermelon was then moved for the weighing process using a load cell to determine the watermelon size. On the other hand, manual cleaning was conducted by soaking watermelon in a washing tank containing sodium dichloroisocyanurate solution (250 ppm) for 30 s. Sizing was carried out based on weight as Malaysian Standard MS: 1028 (2005) (Table 1) (FAMA, 2008).

In the robotic sizing system, it will send information on the watermelon weight to the robotic arm. In the case where the watermelon weight is less than 6 kg, the robotic arm will lift the fruit using one vacuum suction cup. For watermelons exceeding 6 kg in weight, the robotic arm will lift the fruit using two vacuum suction cups. The robotic arm moves the watermelon from the weighing chamber to the sizing table based on the fruit size category.

Watermelons that were sorted by size were then placed into corrugated fibre board (CFB) boxes with a maximum weight of 15 kg/box. The boxes were then transferred from the sizing table to the cold room for storage. The cold room was set to a temperature of 10°C with a relative humidity of 65–70 %.

Table 1. Watermelon size classification (FAMA, 2008)

Size	Weight (kg)
Small	2.00 to 3.99
Medium	4.00 to 5.99
Large	6.00 to 7.99
Extra Large	≥ 8.00

2.2 Watermelon Quality Evaluation

The assessment of mechanised cleaning effect towards watermelon quality was conducted by storing three sets of watermelon samples (T1: System cleaned; T2: Manual cleaned; T3: Control) at an ambient temperature of 27°C for 5 weeks with weekly retrieval. The control sample is the sample without the cleaning process. Assessment of the vacuum suction cup in the robotic sizing system effect towards watermelon quality was conducted by storing two sets of watermelon samples (T1: Control; T2: Robotic arm) at a temperature of 25°C for 4 weeks with weekly retrieval. The control sample is the manually handled sample during the sizing process.

The watermelon firmness was determined using TA.XTplus texture analyser (Stable Micro Systems, UK), fitted with a flat stainless-steel cylindrical probe (P2N). The weight loss (% fresh weight basis) was calculated as the difference between initial fruit weight and fruit weight after 1, 2, 3, 4, and 5 weeks of storage. The experimental design was a completely randomised design (CRD). Data were analysed using Statistical Analysis System (SAS) version 9.4 (SAS Software Institute, Cary, NC, USA). A confidence interval of 95% was used for all calculations ($p \leqslant 0.05$).

2.3 Mechanised Puree Processing System Performance Evaluation

In the research, emphasis is given to the selection of technology, machines, or equipment in accordance with the concept of cost-effectiveness, portability and minimal space consumption to suit SMEs in Malaysia. Cost-effectiveness refers to affordable machines with low operational cost; portability refers to simple and mobile machines (generally incorporated with wheels for ease of movement); minimal space consumption refers to small-size machines that suit SME premises.

The mechanised watermelon puree processing system consists of TS-P80 vertical single-head watermelon peeler (Tengsheng Machinery, China), DRB-MN130 extractor (Daribo, China), and 100 L electric pasteuriser (Gems, China). The system was procured from the commercially available technology in the market and its performance was evaluated.

The system was targeted at producing 100 L watermelon puree per batch. The selection of peeler, extractor and pasteuriser was based on factors such as cost-effectiveness, portability and minimal space consumption, as mentioned previously.

The watermelon peeler is a pneumatic operated system, and has adjustable peeling height and diameter of 10 cm to 50 cm, and 10 cm to 30 cm, respectively. The extractor has an extraction capacity of 200 kg to 300 kg/h, and a screen size of 0.6 mm (Azizan *et al.*, 2022). The main components of the watermelon peeler are the control panel, cutting blade and fruit holder (Figure 2). The main component of the extractor is the extraction chamber filter. On the other hand, the main components of pasteuriser are the control panel, heating element and stirrer. System performance evaluation was conducted based on efficiency and yield (Aviara *et al.*, 2013; Azizan *et al.*, 2023).

$$Extraction\ efficiency, E_e = \frac{W_p}{xW_f} \times 100\ \% \qquad (1)$$

$$Yield, Y = \frac{W_p}{W_p + W_w} \times 100\ \% \qquad (2)$$

where W_p is the mass of puree extracted (or peeled watermelon flesh), W_w is the mass of waste, W_f is the mass of watermelon fed, and x is juice constant. The juice constants for peeled and unpeeled watermelons were 0.91 and 0.88, respectively (Aviara *et al.*, 2013).

The electric pasteuriser used water as the heating medium. The optimum temperature for the pasteurisation process is 65°C for 10 min as microbial control. The pasteuriser required 30 min to heat watermelon puree from room temperature to 65°C with a capacity of up to 90 L of watermelon puree/batch.

Watermelon samples (F1 hybrid seedless watermelon) used in the mechanised watermelon puree processing system study were procured from local suppliers in Pasar Borong Selangor. Figure 3 shows the process flow of mechanised watermelon puree processing system.

Prior to the performance evaluation, the watermelon physical characteristics such as size and rind thickness were also evaluated. The watermelon sizes (height, width, vertical diameter, and horizontal diameter) were measured using a measuring tape. The rind thickness was measured using SEB-DC-024 digital Vernier calliper (SEB, China) at five different locations to examine size variations. Before rind thickness measurement, watermelon samples (*n* = 20) were cut lengthwise into two sections (Davis, 2005). The rind comprises the green outer skin and white flesh. In addition, a colour test was conducted on the watermelon puree produced using a CR-400 chroma meter (Konica Minolta, Japan) to obtain the value of L*, a* and b*. L* value represents lightness from 0 (black) to 100 (white). On the other hand, a* represents the red-green component, and b* represents the yellow-blue component.

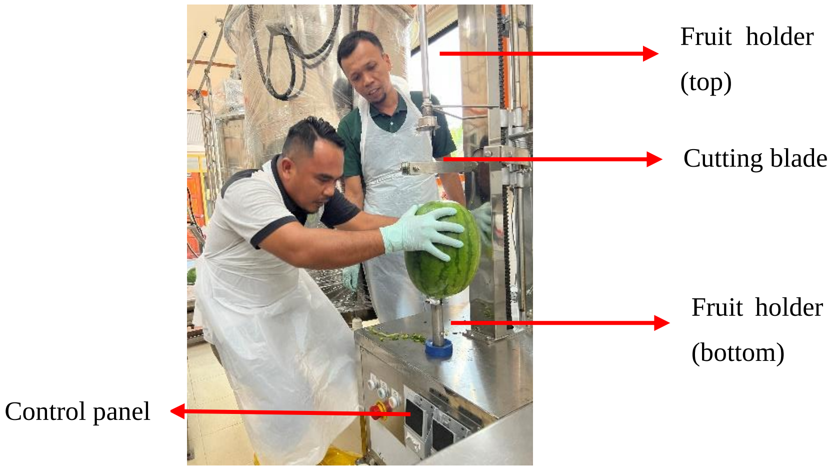

Figure 2. Watermelon peeling process

Clean watermelon using washing tumbler

↓

Peel watermelon rind using watermelon peeler

↓

Extract watermelon puree using extractor

↓

Pasteur watermelon puree using electric pasteuriser

↓

Pack watermelon puree into 5 kg nylon-polyethylene (PE) laminated bag

↓

Store watermelon puree in cold room or chest freezer

↓

Clean machines and equipment used and processing areas

Figure 3. Mechanised watermelon puree processing flow

3. Results and Discussions

3.1 Mechanised Cleaning and Robotic Sizing System

The developed mechanised cleaning and robotic sizing system has a capacity of 100-120 fruits/h. The watermelon mechanised cleaning system showed that cleaning efficiency can achieve 90%, thus improvement to the brush design was needed. The current brush design was uniform in height; the proposed brush design will have a higher brush height at both ends. This proposed design was to ensure that the brush can reach the tip of the fruit, thus increasing the cleaning efficiency.

The mechanised cleaning did not cause any mechanical injury (external and internal) to the watermelon. Conversely, watermelons that were cleaned by the manual approach exhibited a more pronounced bruising effect after 3 weeks of storage; fungal infections were pronounced in control fruits. Meanwhile, the cleaning process did not produce an apparent effect in terms of watermelon flesh colour, endocarp firmness and the weight loss percentage for all three treatments (data not shown). Moreover, the addition of 250 ppm sodium dichloroisocyanurate solution during the cleaning process can extend the storage life of watermelon up to the 5th week as previously reported by the research team (Mohd Shafie *et al.*, 2022). A similar result was reported by Svoboda *et al.* (2016) where the watermelon and cantaloupe shelf life were extended due to the application of tested washing solutions onto their surfaces. The cleaning and sanitation treatment is recommended to extend the shelf life of watermelon (Razali *et al*., 2022).

Moreover, the robotic sizing system exhibited 100% size classification efficiency where the robotic arm can transfer watermelon from the weighing area to the sizing table according to the fruit size category accurately. The robotic arm will lift the fruit using either one (<6 kg) or two (>6 kg) vacuum suction cups depending on the weight of the watermelon.

The effect of the robotic arm application during the size classification process on the quality and shelf life of watermelon was also studied. The application of vacuum suction cups in the robotic sizing system did not cause any mechanical injury to the watermelon (Table 2). No visible bruises and fungal infections were observed on the watermelon surface in contact with the suction cup for up to 4 weeks of storage at 25°C.

Furthermore, the application of a vacuum suction cup did not affect the watermelon's internal quality in terms of endocarp/flesh colour and firmness, and physicochemical compositions (such as total soluble solid, total titratable acidity and ascorbic acid content) as compared to the control sample (data not shown). This might be due to the thick watermelon rind (Mohamad Noh *et al.*, 2023). A similar finding was also observed by Blanes *et al.* (2011) where the effect of vacuum suction cup application towards fruit deterioration (bruise, tear, and break) was low.

The development of the mechanised cleaning and a robotic sizing system for fresh watermelon by MARDI proved advantageous as the system reduced physical injury risk to operators due to the large and heavy watermelons, and eased the processes during the manual cleaning and sizing.

Table 2. Effect of vacuum suction cup on watermelon bruising, fungal infection on the stalk, fungal infection on the surface, and overall acceptability rating (score 1–5) during 4 weeks storage.

Characteristics	Week	Control	Robotic arm
Bruising	0	+	+
	2	++	+
	4	+	+
Fungal infection on the stalk	0	-	-
	2	-	-
	4	-	-
Fungal infection on the surface	0	-	-
	2	-	+
	4	-	-
Overall acceptability	0	5	5
	2	5	4
	4	3	3

Abbreviations: Score of symptoms based on each fruit (*n*=3): negative=no trace; +=slightly affected; ++=moderately affected; +++=badly affected; Overall acceptability ratings: 5=Excellent, 4=Good, 3=Acceptable, 2=Poor, 1=Very poor

3.2 Mechanised Puree Processing System

Watermelon exhibited the physical characteristics of height, width, vertical diameter, horizontal diameter, and rind thickness of 27.33 ± 3.54 cm, 20.96 ± 3.55 cm, 79.94 ± 7.09 cm, 69.39 ± 4.62 cm, and 1.46 ± 0.27 cm, respectively. The watermelon peeling process required 52.84 ± 9.33 s per fruit inclusive of the manual handling process for watermelon insertion and removal at the holder. The watermelon peeler exhibited a peeling efficiency of approximately 77.43 ± 2.44%. Peeling efficiency varies based on watermelon size and rind thickness, and can be improved by adjusting the cutting blade position to remove the maximum white flesh on watermelon. The yield (peeled watermelon) obtained was 73.64 ± 0.99%. A previous study reported that watermelon consists of three main components which are pulp, skin, and seed. Watermelon flesh comprises approximately 68% of the fruit weight, while skin and seed are 30% and 2%, respectively, which varies based on varieties (Muhamad, 2015).

On the other hand, watermelon extractor has a capacity of 7.27 ± 1.47 kg watermelon puree/min. It also exhibited an extracting efficiency of 82.71 ± 1.11 %, and a yield (watermelon puree) of 60.74 %.

In this study, the pasteurisation process was conducted at 65°C for 10 min. A previous study reported that the pasteurisation process used was at 69°C for 30 min to reduce vegetative microorganisms and enzyme activity (Sairi *et al.*, 2010). Meanwhile, Wang *et al.* (2018) reported a low-temperature long-time (LTLT) watermelon juice pasteurisation process of 60°C for 30 min.

The colour test conducted exhibited no significant difference in watermelon samples before and after the pasteurisation process with a total colour difference value (ΔE) of 1.94 against the initial value of L, a, and b. On the other hand, a previous study on watermelon juice pasteurisation treatment between ultrahigh temperature (UHT, pasteurised at 135°C for 2 s) and LTLT (pasteurised at 60°C for 30 min) recorded that the colour difference was below 6.5, and was statistically similar (Wang *et al.*, 2018).

Table 3. Mechanised watermelon puree processing system performance

Machine	Processing rate	Efficiency
TS-P80 vertical single-head watermelon peeler	52.84 ± 9.33 s/fruit	77.43 ± 2.44 %
DRB-MN130 extractor	7.27 ± 1.47 kg puree/min	82.71 ± 1.11 %
100 L electric pasteuriser	90 L puree/batch	-

4. Conclusions

The watermelon mechanised cleaning, robotic sizing and mechanised puree processing system demonstrated good functionality and performance. The mechanised cleaning and robotic sizing system that has a capacity of 100–120 fruits/h exhibited no apparent effects towards watermelon mechanical injury. The addition of 250 ppm sodium dichloroisocyanurate solution during the cleaning process further extended the storage life of watermelon up to five weeks. The reliance on manual labour can be reduced with the application of the robotic arm. The mechanised watermelon puree processing system inclusive of a watermelon peeler, extractor and pasteuriser has a capacity of approximately 1 peeled watermelon/min, 430 kg watermelon puree/h, and up to 90 L watermelon puree/batch, respectively; served as a model for SMEs. The developed system showed potential to benefit the fresh watermelon exporter and watermelon puree producer for market expansion. The mechanised watermelon puree processing system proposed would able to diversify local agricultural products that have the potential to be exported abroad, and to increase the income of agricultural entrepreneurs through increased demand for watermelon production. The development of an automated packing system post mechanised cleaning and robotic sizing system for fresh watermelon is suggested for future research. An export trial of watermelon cleaned and sized using the developed system will be beneficial. In addition, research on the development of products from watermelon puree is also recommended.

Author Contributions: Masniza Sairi: conceptualization, writing, review, and editing of the manuscript, supervision, and project administration. Zainun Mohd Shafie, Badaruzzaman Mohamad Noh, Wan Mohd Fariz Wan Azman, Hasmin Hakim Hasbullah, Saiful Azwan Azizan, Afiqah Aina Rahim and Nur Azlin Razali: methodology, data collection, data curation, and writing the manuscript. Teoh Chin Chuang: conceptualization, supervision, and project administration.

Funding: This work was funded by the MARDI's 12th Malaysia Plan Development Fund with grant number P-RM521.

Acknowledgements: The authors would like to express utmost gratitude to MARDI for the research fund and facilities.

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

References

Aviara, N. A., Lawal, A. A., Nyam, D. S., *et al*. (2013). Development and performance evaluation of a multi-fruit juice extractor. *Global Journal of Engineering, Design and Technology*, *2*(2), 16–21.

Azizan, S. A., Wan Azman, W. M. F., Rahim, A. A., *et al*. (2023). Performance evaluation of watermelon juice extracting machine. *Advances in Agricultural and Food Research Journal, 4*(1). https://doi.org/10.36877/aafrj.a0000350

Azizan, S. A., Wan Azman, W. M. F., Rahim, A. A., *et al*. (2022). Teknologi sistem mekanisasi pemprosesan puri tembikai berkos efektif. *CONFERTECH 2022*, Ipoh, Perak, 8-10 Nov. 2022

Blanes, C., Mellado, M., Ortiz, C., *et al*. (2011). Technologies for robot grippers in pick and place operations for fresh fruits and vegetables. *Spanish Journal of Agricultural Research*, *9*(4),1130–1141. https://doi.org/10.5424/SJAR/20110904-501-10

Davis, A. R., Penelope, P. V. (2005). Rootstock effects on plant vigor and watermelon fruit quality. *Cucurbit Genetics Cooperative Report*, *28*, 39–42.

[DOA] Department of Agriculture Malaysia (2023). *Booklet Statistik Tanaman (Sub-sektor Tanaman Makanan) 2023*. Putrajaya: DOA.

[FAMA] Federal Agricultural Marketing Authority (2008). *Siri Panduan Kualiti 36 Jenis Komoditi Sayur-sayuran dan Buah-buahan*. Batu Caves, Selangor: FAMA.

Mohamad Noh, B., Razali, N. A., Teoh, C. C., *et al*. (2023). Penggunaan lengan robot dalam penggredan buah tembikai. *Advances in Agricultural and Food Research Journal* *4*(1). https://doi.org/10.36877/aafrj.a0000307

Mohd Shafie, Z., Mohamad Noh, B., Sairi, M., *et al*. (2022). Integrated mechanized cleaning and robotic grading system for watermelon packing house operation. *MARDI Science and Technology Exhibition 2022*, Selangor, 18–19 Oct. 2022.

Muhamad, N. F. H., Wan Zainon, W. N. Z., Kormin, S., *et al*. (2015). Halwa kulit tembikai, *Buletin Teknologi MARDI*, *8*, 17–23.

Razali, N. A., Wan Ibrahim, W. M., Sairi, M., *et al*. (2022). Surface sanitation as a recommended treatment to improve the safety and shelf life of watermelon. *AFOB Malaysia Chapter International Symposium 2022*, Langkawi, Kedah, 18-21 Sept. 2022

Richards, G. M., Beuchat, L. R. (2005). Infection of cantaloupe rind with Cladosporium cladosporioides and Penicillium expansum, and associated migration of Salmonella poona into edible tissues. *International Journal of Food Microbiology*, *103*(1), 1–10. https://doi.org/10.1016/j.ijfoodmicro.2004.05.023

Sairi, M., Ismail, M. Z., Mohd Ramli, S. H., *et al*. (2010). Mechanisation of watermelon juice processing, *Buletin Teknologi Makanan MARDI*, *7*, 41–48.

Samtani, J. B., Rom, C. R., Friedrich, H. *et al*. (2019). The status and future of the strawberry industry in the United States. *Horttechnology*, *29*(1), 11–24. https://doi.org/10.21273/HORTTECH04135-18

Svoboda, A., Shaw, A., Wilson, L., *et al*. (2016). The effects of produce washes on the quality and shelf life of "cantaloupe" (Cucumis melo var. cantalupensis) and "watermelon" (Citrullus lantus var. lanatus). *Journal of Food Quality*, *39*(6), 773–779. https://doi.org/10.1111/jfq.12229

Wang, Y., Li, W., Ma, Y., *et al*. (2018). Effect of thermal treatments on quality and aroma of watermelon juice. *Journal of Food Quality*, *7*. 1–7. https://doi.org/10.1155/2018/9242675