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Original Research Article

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

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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

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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.

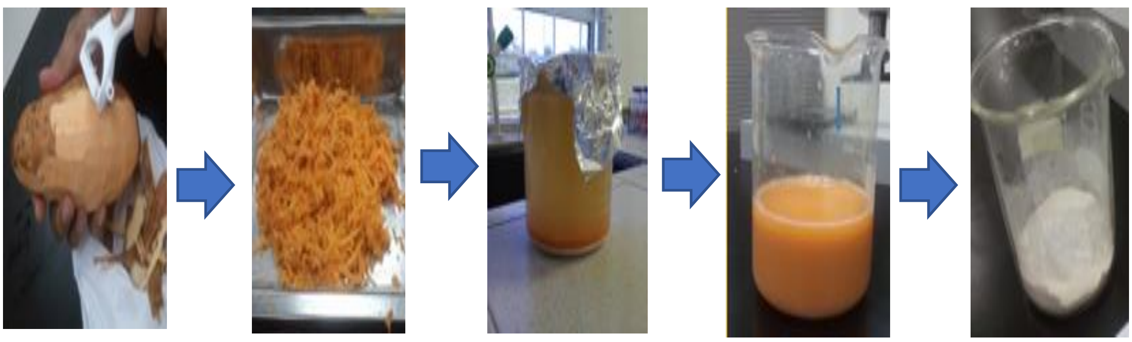
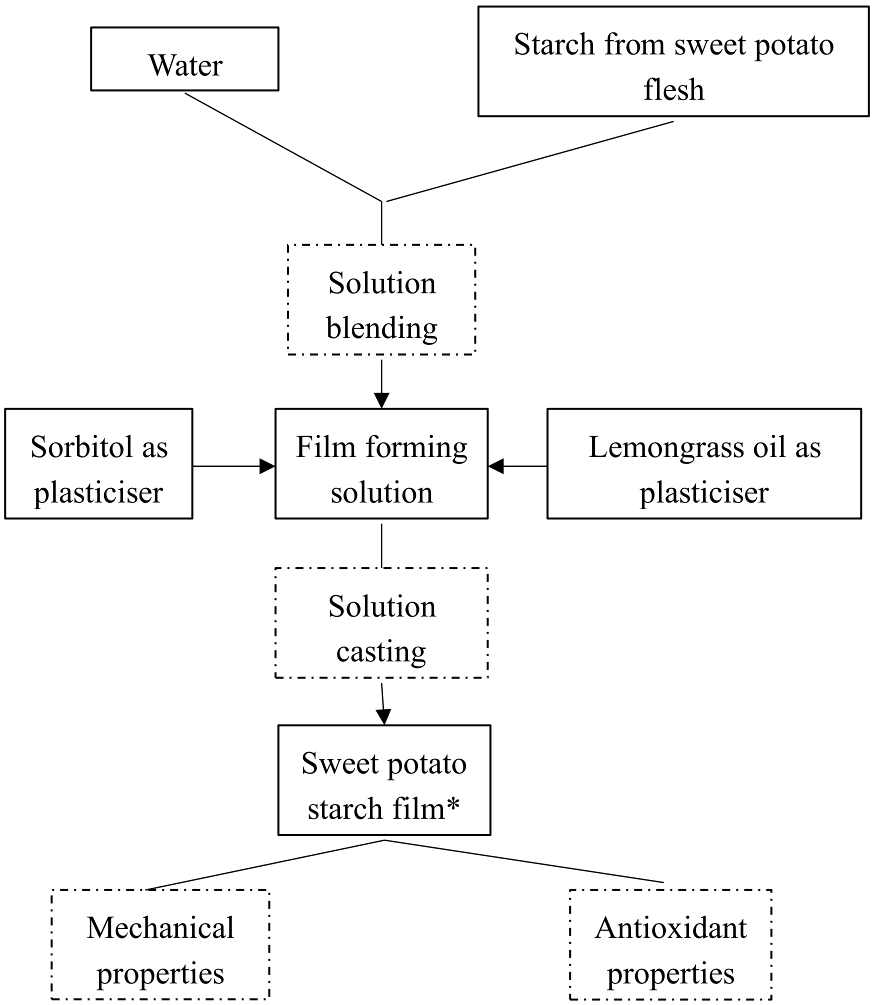


Figure 1. Extraction of starch powder from sweet potato flesh.

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.

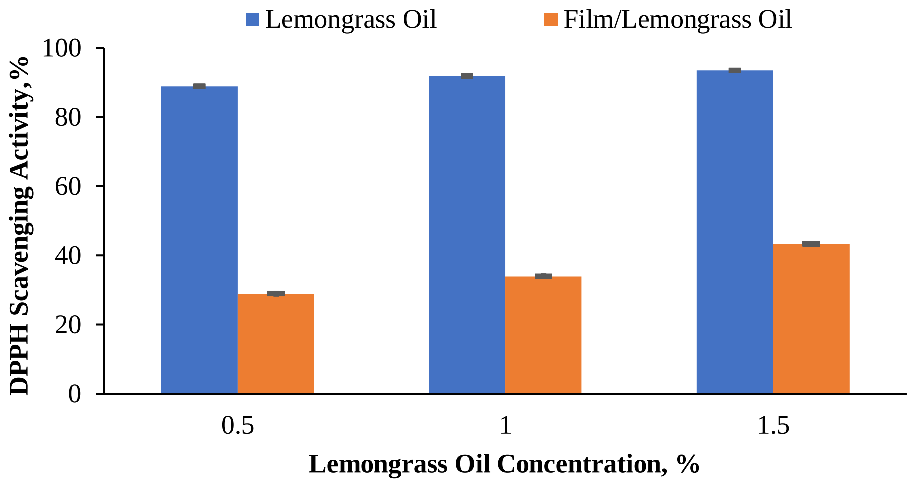


Figure 5: DPPH radical scavenging activity of SPS film with lemongrass oil and lemongrass oil from R & M Chemicals.

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.

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