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Characterization and Development of Edible Film/Coating from Lesser Yam Starch-Plasticizer Added with Potassium Sorbate or Cinnamon Oil in Affecting Characteristics and Shelf Life of Stored, Coated Strawberry

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Abstract

Starch of lesser yam ('gembili' in Indonesian) has been used as a base for edible film and coating. Potassium sorbate and cinnamon oil are known as strong antimicrobial agents. This research was aimed to investigate the physical and mechanical characteristics of edible film from lesser yam starch-plasticizer formulations added with potassium (K) sorbate or cinnamon oil and its application as coating to strawberries. Incorporation of either K-sorbate or cinnamon oil at higher concentration resulted in reduced tensile strength and elongation with higher water vapor transmission rate (WVTR). The selected edible film formulations were applied as coating on strawberry stored at two conditions: room (28-30°C) and refrigeration temperature (5-6°C). At room temperature, controls had shelf life only for 2 and 4 days and strawberries coated with addition of K-sorbate lasted for 5-6 days, and those with addition of cinnamon oil prolonged for 5-11 days. At refrigeration storage, shelf life of controls was 9 and 18 days whereas K-sorbate-added formulations further prolonged shelf life of strawberries for 19-21 days, and those added with cinnamon oil lasted for 25-26 days. Therefore, all coated, stored strawberries had longer shelf life and more retained strawberries' quality including lower weight loss, higher hardness, and lower microbial count.

Keywords: *cinnamon oil; edible coating; edible film; potassium sorbate; strawberry*

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INTRODUCTION

Lesser yam also known as gembili (Dioscorea esculenta Lour. Burkill) is one of Indonesia's underutilized commodities. The most utilized part is its tubers, which are a good carbohydrate source (Kumar, 2007). Lesser yam has highest yield of starch (21.44%) compared to ganyong (12.93%), suweg (11.56%), and larger yam (4.56%) (Richana and Sunarti, 2004). Lesser yam has a good potential as a base for edible film and coating. Lestari (2014) studied the application of lesser yam starch as edible coating mixed with glycerol or sorbitol as plasticizer and showed that the edible coating extended shelf life of strawberry stored at cold temperature (4°C) up to 28 days. Strawberry (Fragaria ananassa) is a highly perishable fruit with short shelf life due to its high respiration rate, and is also prone to mechanical injuries, temperature, humidity, and fungal attack (Whitaker, 2008; Rahman et al., 2016).

Edible film and coating have been developed intensively in recent years because of its advantages in reducing solid waste and pollution problem, providing moisture barrier, controlling gas exchange and carriers of functional ingredients such as antimicrobials that can prolong shelf life and reduce risk of pathogen growth on food surfaces (Robertson, 2013).

Some antimicrobial agents can be added into edible film and coating such as organic acid and its salt, polypeptides, and essential oils. Potassium sorbate has a GRAS status and is widely used as synthetic antimicrobials (Theron and Lues, 2011). Cinnamon oil has also a GRAS status, and is usually obtained from the bark and leaf where its constituents cinnamaldehyde and eugenol have strong germicidal and fungicidal activity (Weiss, 2002).

Considering the potential of lesser yam starch as edible coating base material in prolonging shelf life as shown by Lestari (2014), the effectiveness of potassium sorbate and cinnamon oil applied as antimicrobials, and the perishability of strawberry, it is hoped addition of chemical and natural antimicrobial agents i.e. potassium sorbate and cinnamon oil to the previous film formulations would further improve physical and mechanical characteristics of the films produced and extend shelf life and quality of strawberries. Therefore, the objectives of this research were to investigate the physical and mechanical characteristics of edible film from lesser yam starch-plasticizer formulations added with potassium sorbate or cinnamon oil and to develop edible coating which would be used to coat strawberry fruits.

RESEARCH METHODS

Main materials used in this research were lesser yam (*gembili*) having complete maturation stage with 7-10 cm in size obtained from Madiun, East Java, ripe strawberry fruits from Ciwidey, West Java, food grade potassium sorbate and cinnamon oil bought from Yogyakarta. Other materials used for starch, and edible film & coating preparations, and for assays were of laboratory and/or food grade. Cultures of *Salmonella* sp., *Escherichia coli*, and *Staphylococcus aureus* were used for antimicrobial activity assay.

Isolation and Purification of Lesser Yam Starch

Lesser yam was verified for its taxonomy and analyzed its proximate composition. Lesser yam starch was prepared based on procedures by Putera (2013) with modification. Firstly, peeling was done under water to remove outer skin and damaged part. Then, the yams were soaked in 0.02% $Na_2S_2O_5$ w/v solution for 10 min with ratio 1:4 (lesser yam: Na_2S_2O5). Soaked yams were then dried on kitchen tissue, weighed, crushed using blender for 1.5 min, and dispersed in 0.02% $Na_2S_2O_5$ solution (1:4). Filtering process was then carried out using cheesecloth to obtain filtrate which contained soluble starch.

Purification process was done by placing the filtrate in refrigerator (4-5°C) for 2.5 h for sedimentation. The supernatant was then discarded and the solid was re-suspended in distilled water. This process was carried out twice before the starch suspension was stored again in refrigerator for 18 h to allow final settling of the starch, after which the supernatant was decanted off. The solid obtained was dried in oven (50 °C) for 18 h followed by grinding using dry blender for 2 min until fine powder formed. Resulted fine powder was further sieved using a sifter 60 mesh (250 μm) to produce finer lesser-yam starch powder which was then analyzed for its moisture content, yield, starch purity, amylose and amylopectin content.

Edible Film Making

Edible film was prepared based on previous optimized starch-plasticizer formulations from Lestari (2014) where combinations of 4.5% starch (St)-2.5% glycerol (Gl), 4.5% St-5.5% sorbitol (So) and 6.5% St-5.5% So were chosen since strawberry coated with these formulations had longest shelf life when stored at refrigeration temperature (5-6 °C), and then they were mixed with a chemical preservative i.e. potassium sorbate of concentrations of 0.15, 0.2 and 0.25% (w/v) or with a natural antimicrobial agent i.e. cinnamon oil of 0.3, 0.5 and 0.7% (w/v). The edible film making method was adopted from Putera (2013) with modification. Firstly, the lesser yam starch powder was weighed to 4.5 or 6.5% (w/v) formulation, and then glycerol (2.5% w/v) or sorbitol (5.5% w/v) was added prior to heating process. The mixture was diluted with warm distilled water (75 °C) until 100 mL and stirred until clear and completely homogenized at 75 °C for 30 min. After that, either potassium sorbate (Ps) 0.15, 0.2, 0.25% (w/v) or cinnamon oil (Co) 0.3, 0.5, 0.7% (w/v) together with emulsifier, lecithin (10% of cinnamon oil used) were added to the heated mixture and further mixed for 15 min. The edible film solution obtained was cooled down first to 50 °C before pouring to a film applicator. Drying in oven was then done at 50 °C for 18 h.

Development of Edible Coating

Coating of strawberry was carried out using selected formulations from edible film with acceptable physical/mechanical characteristics. For potassium sorbate, the film formulations selected were 6.5%St-5.5%So-0.15%Ps (high tensile strength), 6.5%St-5.5%So-0.25%Ps (high elongation), and 4.5%St-

5.5%So-0.15%Ps (low water vapor transmission rate, WVTR). For cinnamon oil, the selected films were made of 6.5%St-5.5%So-0.5%Co (high tensile strength), 4.5%St-5.5%So-0.3%Co (high elongation percentage), and 6.5%St-5.5%So-0.3%Co (low WVTR). Controls were uncoated strawberries and strawberries coated with previous film formulation of lesser yam starch-plasticizer showing longest shelf life (4.5% starch-5.5% sorbitol) (Lestari, 2014).

After washing, strawberries were coated with film solution by a dipping method with 2x exposures. The first dipping was done in 10 s and hung to dry under fan for 30 min. The second dip was then performed for 10 s and let it dry by hanging on pasta racks and further dried using a fan for 1 h followed by storage.

In determining the shelf life and quality of uncoated and coated strawberries, two storage conditions were introduced to strawberry: room temperature (RT) of 28-30°C and refrigeration temperature (RfT) of 5-6°C. To find out the shelf life of strawberry fruits, strawberry coating was done in an identical fashion but within two subsequent different days. On the first day, the strawberry was coated and used as indicator of shelf life by observing microbial spoilage (e.g. white mold infection). On second day, strawberries harvested one-day after were coated and utilized for observation of storage –starting (right after coating and immediately stored) and -ending times (indicator strawberry had spoiled with white mold) of coated strawberry and for analysis (Putera, 2013).

Physical and Mechanical Properties

Thickness of the film produced was determined using digital micrometer while tensile strength and elongation at break of the film samples were measured using Texture Analyzer Lloyd Instrument. The film (2.5x10 cm) was placed between the grips of the equipment, and then pulled at speed 5 mm/s to measure the tensile strength and elongation percentage (Dashipour *et al.,* 2014).

Water Vapor Transmission Rate

Water was placed in beaker glass and covered with edible film sample. Initial weight of beaker glass containing water was weighed. After that, the beaker glass was put in desiccator containing silica gel. Water vapor diffusion from edible film would be absorbed by silica gel. Weight reduction of beaker glass containing water was measured every 1 h for 8 h (ASTM, 1995 with modification).

Weight Loss, Hardness, pH, Total Titratable Acidity, and Total Sugar

Weight loss of strawberry was measured as the percentage loss from initial total weight. The hardness of strawberry was determined using Texture Analyzer-XT plus. The probe used is P/2, 2 mm DIA cylinder stainless. It was conducted at a compression speed of 2 mm/s with probe distance 5 mm (Lestari, 2014). The pH of the strawberry samples was determined using pH meter (AOAC, 2005); whereas the total titratable acidity (TTA) of strawberry samples was determined through NaOH titration and total sugar using the method of Lane-Eynon.

Total Plate Count

Total plate count method was used to determine the microbiological quality by counting the total population of aerobic microorganisms of strawberry. (Mautrin and Peeler, 2001).

Sensory Evaluation

Scoring test was conducted with attributes to be assessed of color, aroma, appearance, and taste using scores from 1 to 5. It was described for color (1-brownish red until 5-very red, aroma (1-off odor and 5-very intense strawberry odor), appearance (1-opaque and 5-very glossy), and taste (1-off taste and 5-very intense strawberry's taste) (Lawless and Heymann, 2010). Hedonic test was also carried out to determine degree of acceptance and preference of coated strawberries from the respondents. The test method used was 7-point hedonic scales from very dislike (1) up to very like (7) (Stone *et al.,* 2012).

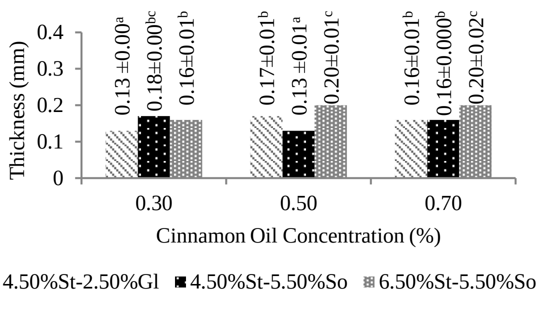
RESULTS AND DISCUSSION

Edible Film Characteristics

Thickness

There was no significant interaction (p>0.05) of starch-plasticizer formulation and concentration of potassium sorbate in affecting the thickness of edible film. The average of thickness was 0.17±0.03 mm indicating that the film thickness was ranging from 0.14-0.20 mm.

The thickness of edible film added with cinnamon oil is shown in Figure 1. There was significant interaction (p≤0.05) of base formulations and cinnamon oil concentration in influencing thickness of edible film. The thinnest film was 0.13±0.01 mm made of combination 4.50% starch (St)-5.50% sorbitol (So) and 0.50% oil; whereas the thickest film was 0.20±0.014 mm obtained from formulation of 6.50% starch-5.50% sorbitol with 0.50% oil.



Note: Different superscripts indicate there is significant difference (p≤0.05)

Figure 1. Thickness of cinnamon oil-added edible film

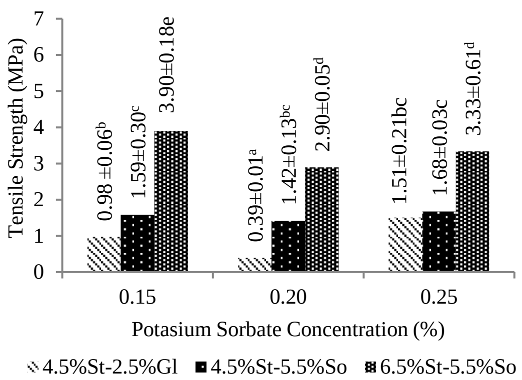


Figure 2. Tensile strength of potassium sorbate-added film

The higher the amount of starch-plasticizer and antimicrobial agent used, the thicker the edible film would be. The result obtained is in line with Kusnadi & Budyanto (2015) that the thickness of edible film was affected by the presence of total dissolved solids.

Tensile Strength

The tensile strength of edible film is shown in Figure 2. There was significant interaction ($p \leq 0.05$) of starch-plasticizer formulations and concentration of potassium sorbate in affecting tensile strength of edible film. The highest tensile strength was 3.90±0.18 MPa resulted from combination of 6.50% starch 5.50% sorbitol and 0.15% K-sorbate while edible film with lowest tensile strength was 0.39±0.01 MPa produced from 4.50% starch-2.50% glycerol and 0.20% K-sorbate, which was significantly different with other formulations. Figure 3 shows the tensile strength of cinnamon oil-added edible film. There was significant interaction ($p \leq 0.05$) of starch-plasticizer formulations and oil concentration in affecting tensile strength of edible film. The highest tensile strength was 3.52±0.25 MPa, achieved by mixture of 6.50% starch-5.50% sorbitol and 0.50% cinnamon oil, which was statistically different with other formulations.

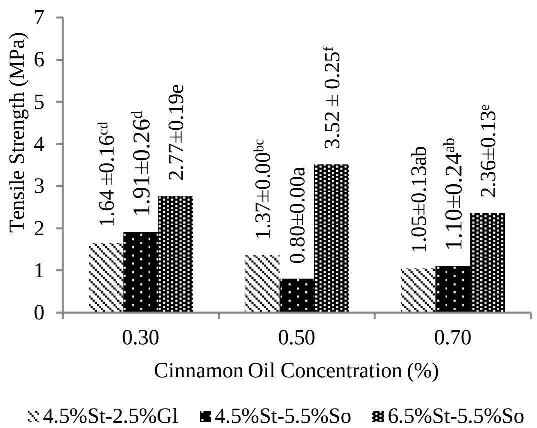


Figure 3. Tensile strength of cinnamon oil-added edible film

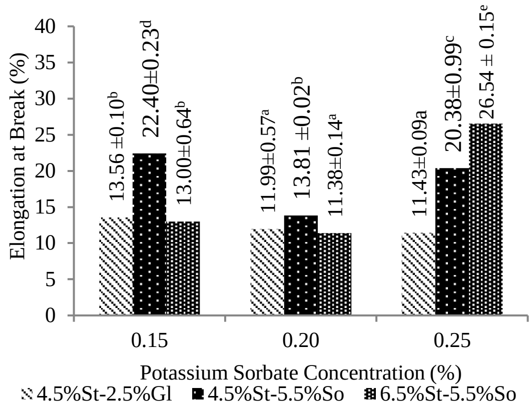


Figure 4. Elongation (%) of potassium sorbate-added edible film

The lowest tensile strength was 0.80±0.02 MPa made of 4.50% starch-5.50% sorbitol and 0.50% oil, showing no significant difference with elongation of film prepared from 4.50% starch-2.50% glycerol-0.70% cinnamon oil and 4.50% starch-5.50% sorbitol-0.70% cinnamon oil.

Elongation

The elongation percentage of potassium sorbate-added edible film is illustrated in Figure 4. There was significant interaction ($p \leq 0.05$) of starch-plasticizer base formulations and K-sorbate concentration in influencing film's elongation percentage. The highest elongation at break was 26.54±0.15% obtained from 6.50% starch-5.50% sorbitol added with 0.25% K-sorbate, which had significant difference with the others.

In general, starch-sorbitol edible films had better elongation than the glycerol ones, but there was no constant pattern on how K-sorbate concentration affecting film elongation. The inconsistency of the result has similar behavior shown by Chowdhury and Das (2013) that addition of potassium K-sorbate ranging 0.10-0.70% could either increase or decrease elongation percentage.

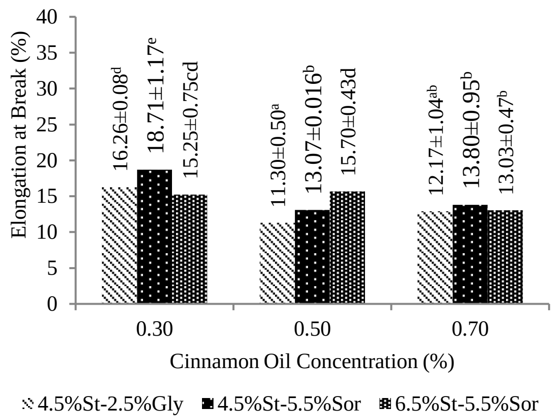


Figure 5. Elongation of cinnamon oil-added edible film

The elongation percentage of edible film incorporated with cinnamon oil is shown in Figure 5. There was significant interaction ($p \leq 0.05$) of starch- plasticizer formulation and oil concentration in affecting elongation of film. The edible film with best elongation was obtained from combination of 4.50% starch-5.50% sorbitol and 0.30% cinnamon oil (18.71±1.17%).

The result shows incorporation of oil at concentration 0.30% in film solution resulted in edible film with better elongation. The result obtained was in accordance with report by Jutaporn *et al.* (2011) that elongation at break of edible hydroxypropyl methyl cellulose (HPMC) added with phayom wood extract experienced reduced elongation as the extract concentration increased.

Water Vapor Transmission Rate

The water vapor transmission rate of potassium sorbate-added edible film is shown in Figure 6. There was significant interaction ($p \leq 0.05$) of starch-plasticizer formulation and concentration of potassium sorbate on WVTR of edible film. The lowest WVTR rate was 0.28±0.02 g.mm/m^2.hour resulted from edible film made of 4.50% starch-2.50% glycerol and 0.15% potassium sorbate, which was not significantly different with 4.50% starch-5.50% sorbitol-0.15% K-sorbate and 6.50% starch-5.50% sorbitol-0.15% K-sorbate.

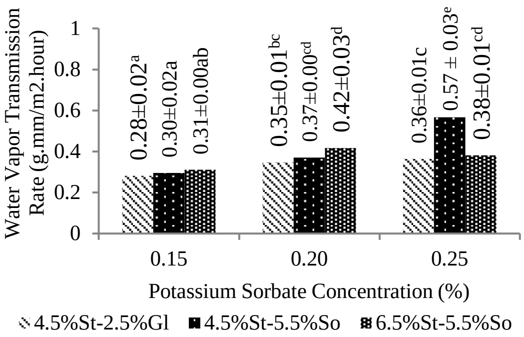


Figure 6. WVTR of potassium sorbate-added film

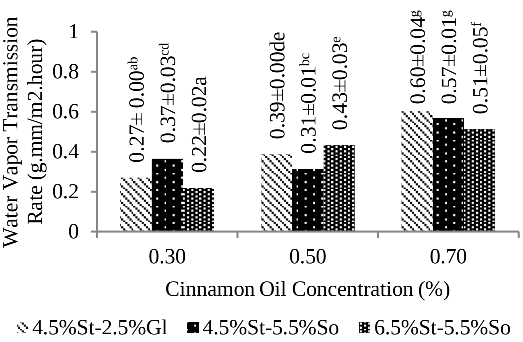


Figure 7. WVTR of cinnamon-oil added edible film

As the concentration of potassium sorbate increased, the WVTR was also higher. This is in line with a report by Chowdhury and Das (2013) that incorporation of K-sorbate would provide permeation of water vapor as a result of disrupted crystalline structure of film polymer network, and hydrophilic groups in film do not have good moisture barrier.

Figure 7 shows the water vapor transmission rate of cinnamon oil-added edible film. The statistical data demonstrates that there was significant interaction ($p \leq 0.05$) of starch-plasticizer formulations and oil concentration in affecting edible film's water vapor transmission rate. The lowest WVTR was 0.22±0.02 g.mm/m^2 hour resulted from edible film made with 6.50% starch-5.50% sorbitol and 0.30% cinnamon oil.

In most cases, the result shows that as the oil concentration increased, the higher the water vapor transmission rate would be. This is consistent with study reported by Souza *et al.* (2013) that increasing glycerol and cinnamon oil content would also increase film permeability despite its hydrophobicity that might act as a barrier in film. Antimicrobial agents lead to loosening of structure's compactness and increasing moisture that passes through the edible film.

Characteristics of Stored, Coated Strawberry

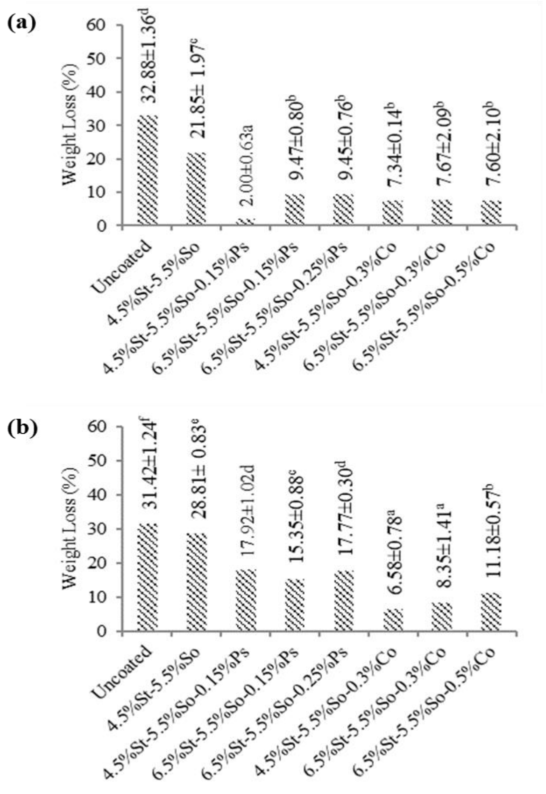
Weight loss

The weight loss of strawberries at storage ending time can be seen in Figure 8. There was significant effect ($p \leq 0.05$) of formulations on weight loss of strawberries stored at either room or refrigeration temperature. At room temperature, the lowest weight loss was 2.00±0.63% observed in strawberries coated with 4.50% starch-5.50% sorbitol-0.15% K-sorbate while the highest weight loss was in uncoated strawberries (32.88±1.36%).

At refrigeration temperature, the lowest weight loss percentage was achieved by strawberries coated with 4.50% starch-5.50% sorbitol-0.30% cinnamon oil (6.58±0.78%) while the highest weight loss was also suffered by the uncoated ones (31.42±1.24%). In general, the results indicate that coating treatments were able to reduce weight loss because the coating itself acted as a barrier on strawberries' surface, delaying water permeation from fruits into the environment, and coating could also maintain gas exchange (O_2 and CO_2) leading to reduced fruits' respiration rate. Strawberries stored at refrigeration temperature had higher weight loss as a result of prolong storage i.e. longer shelf life.

Hardness

The initial hardness of strawberry was tested before assigned at either RT or RfT storage. There was no any significant effect ($p>0.05$) of formulations on strawberries' hardness at pre-storage condition. The average of initial hardness of strawberry was 139.74±25.69 g, which means the hardness was ranging from 114.05 g to 165.43 g.



Note: Different superscripts indicate there is significant difference($p \leq 0.05$)

Figure 8. Weight loss (%) of strawberries after store at (a) room (b) refrigeration temperature

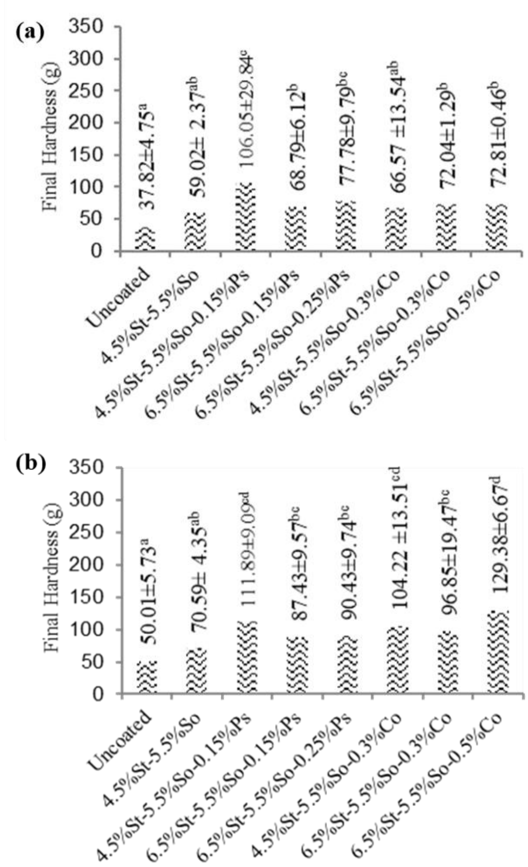


Figure 9. Hardness (g) of strawberries after stored at (a) room (b) refrigeration temperature

Figure 9 shows the final hardness of strawberry after storage period. There was significant effect ($p \leq 0.05$) of formulations in affecting final hardness of strawberries at either room or refrigeration temperature.

At RT storage, strawberries coated with mixture of 4.50% starch-5.50% sorbitol-0.15% K-sorbate had the greatest hardness (106.05±29.84g) while uncoated strawberries had the least hardness (37.82±4.75g) at final condition. At refrigeration temperature, the highest hardness was 129.38±6.67 g from strawberries coated with 6.50% starch-5.50 sorbitol-0.50% oil while the lowest hardness was 50.01±5.73g found in uncoated strawberry, which was not significantly different with the other control (4.50% starch- 5.50% sorbitol).

Edible coating incorporated with antimicrobials shows further protection on firmness loss compared to control. It could take place due to reduction of water loss and/or suppression of pectin breakdown by decreasing microbial count on fruits. Hence, lower metabolic activity in cell wall digestion was achieved leading to firmness retention (Sun *et al.*, 2014).

pH

pH at pre-storage and final condition of strawberry after stored at room temperature was not significantly affected ($p>0.05$) by formulations as shown by the statistical result. Initially, the average pH of strawberries was 3.67±0.19 meaning that the initial pH was varied from 3.48 up to 3.86. The pH of strawberry decreased over storage period at room temperature, and the average final pH was 3.40±0.23 showing that was ranging from 3.17 to 3.63.

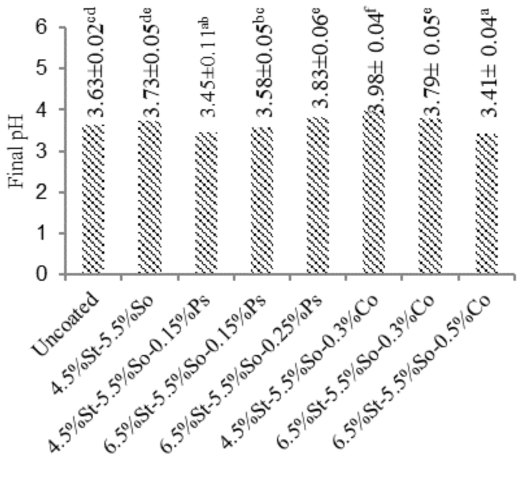


Figure 10. pH of strawberries after stored at refrigeration temperature

This result is in line with a study by Vargas *et al.* (2006) that coating application did not have significant effect on pH of fruits during storage.

The pH value of uncoated and coated strawberries at storage ending time of refrigeration temperature can be seen in Figure 10. There was significant effect ($p \leq 0.05$) of formulations on final pH of strawberries stored at refrigeration temperature. The lowest pH was 3.41±0.04 found in strawberries coated with formulation of 6.50% starch-5.50% sorbitol-0.50% cinnamon oil while the highest pH was 3.98±0.04 for strawberries coated with 6.50% starch-5.50% sorbitol-0.30% oil that was statistically different with strawberries pH from other formulations. A previous study conducted by Moraes *et al.* (2012) shows also a similar trend that there were changes in pH of control samples and fruits coated with alginate and carrageenan, but with a smaller change in pH of coated fruits. The presence of coatings helped in delaying the utilization of organic acid during fruits maturation process.

Total Titratable Acidity

At pre-storage condition, there was significant effect of formulations ($p \leq 0.05$) on strawberries' acidity. The highest acidity was found in strawberries coated with 6.50% starch-5.50% sorbitol-0.25% K-sorbate (0.73±0.09%) while the lowest one was 0.42±0.03% from strawberries coated with combination 4.50% starch-5.50% sorbitol-0.15% sorbate. Strawberries' acidity after storage is exhibited in Figure 11. There was significant effect ($p \leq 0.05$) of formulations in affecting final total acidity of strawberry.

At RT storage, the most acidic strawberries were the ones coated with 4.50% starch-5.50% sorbitol (1.07±0.21%) while strawberries with least acidity were those coated with 4.50% starch-5.50% sorbitol-0.15% K-sorbate (0.45±0.021%). It indicates there was increase in acidity during storage at room temperature. At refrigeration temperature, the lowest acidity value was0.48±0.03%, experienced by strawberry coated with potassium sorbate, and the highest acidity was 0.76±0.13 from strawberries coated with 6.50% starch-5.50% sorbitol-0.50% oil. Besides coating formulations, lower temperature storage also contributes in maintaining acidity of fruits. In general, strawberry fruits usually would experience increased titratable acidity during fruit development, and then it decreased to the minimum during storage as a result of over-ripened stage. Low temperature storage would lead to more maintained titratable acidity. However, the results indicate that there was acid retention as a result of coating application, which slowed down strawberry's respiration and oxidative reaction rate due to coating reducing respiration process (Atress, *et al.*, 2010).

Total Sugar

There was significant effect ($p \leq 0.05$) of formulations on the initial sugar content of strawberries. At storage-starting time, the highest total sugar was 1.93±0.05%, resulted from strawberry coated with 6.50% starch-5.50% sorbitol-0.50% cinnamon oil while the lowest content was 1.63±0.11%, found in strawberries treated with 6.50% starch-5.50% sorbitol-0.25% potassium sorbate.

The final total sugar content of strawberries after storage is shown in Figure 12. The formulation had significant effect ($p \leq 0.05$) on total sugar content in strawberries assigned at two storage conditions. Total sugar content was reduced during storage at room temperature. Strawberry with highest retained sugar was the one treated with 6.50% starch-5.50% sorbitol-0.30% oil (1.62±0.03%).

Refrigeration temperature also contributes to decrease in total sugar for both control and treated samples, but with a smaller change in comparison to the ones at room temperature. The highest sugar content was 1.76±0.01%, achieved by strawberries coated with 6.50% starch-5.50% sorbitol-0.15% K-sorbate that was similar to strawberries treated with 6.50% starch-5.50% sorbitol-0.25% K-sorbate while the lowest sugar content was 1.33±0.04 from strawberries treated with 4.50% starch-5.50% sorbitol 0.3% cinnamon oil.

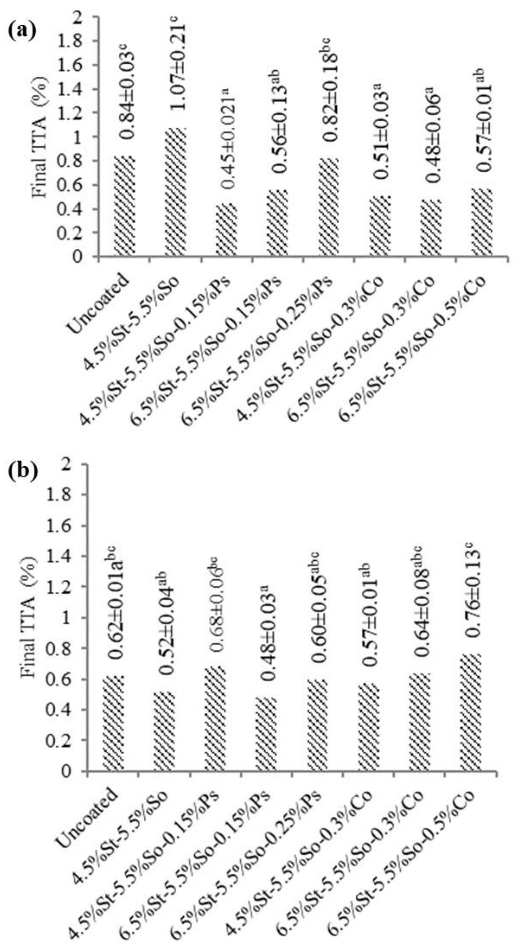


Figure 11. Total titratable acidity of strawberries after stored at (a) room (b) refrigeration temperature

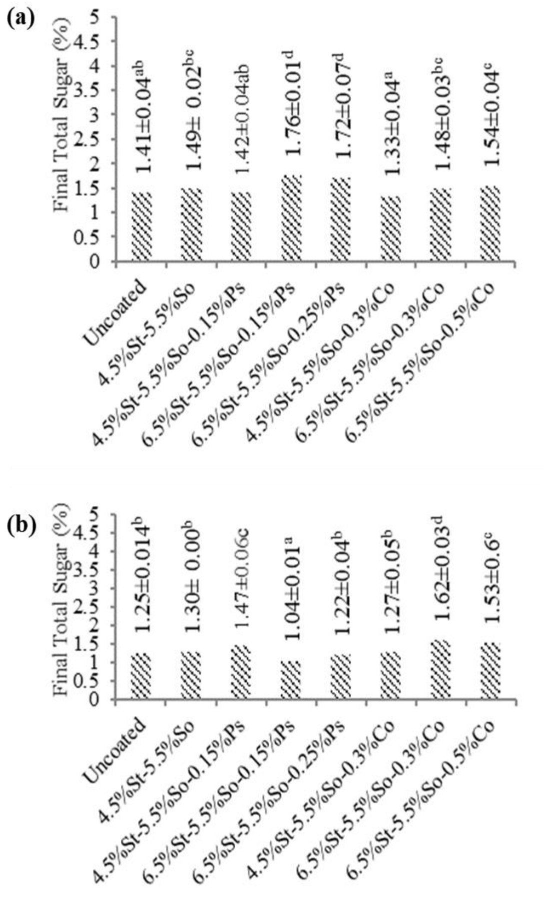


Figure 12. Total sugar (%) of strawberries after stored at (a) room (b) refrigeration temperature

Sugar content would achieve its maximum in the ripe stage, and then it decreased in over-ripened stage. From the results, strawberries total sugar during storage period for both control and coated strawberries, however, modifications of total sugar were slowed down more in coated fruits. This result is consistent with a report by Atress, *et al.* (2010) that total sugar content was decreasing during prolonged storage period as a result of sugar loss through respiration process.

Microbial Count

The formulations did not have significant effect ($p>0.05$) on initial number of bacteria and yeast/mold. The bacteria load was in range of 4.63-4.76 log CFU/g while the total yeast/mold count of strawberries was varied from 4.71 to 4.81 log CFU/g.

Figure 13 shows the total bacteria and yeast/mold counts in strawberries after placed at room temperature where there was significant effect ($p\leq0.05$) of formulations on number of bacteria and yeast/mold of strawberries after stored at room temperature. The lowest total bacteria count was 4.66±0.03 log CFU/g from strawberries coated with 6.50% starch-5.50% sorbitol-0.25% K-sorbate while strawberries coated with 4.50% starch-5.50% sorbitol-0.30% oil had lowest yeast/mold count (4.80±0.01 log CFU/g). The highest microbial count was found in uncoated strawberries.

After refrigeration storage, there was not any significant effect ($p>0.05$) of formulations in affecting final bacteria count. However, there was significant effect ($p\leq0.05$) of formulations on total yeast/mold count (Figure 14). The lowest yeast/mold count was 4.68±0.01 log CFU/g from strawberries treated with 6.50% starch-5.50% sorbitol-0.25% K-sorbate.

Storage period leads to increased number of total bacteria and yeast/mold counts for both uncoated and coated strawberries at room temperature. Nevertheless, total microbial counts in coated strawberries particularly the ones added with either K-sorbate or cinnamon oil were lower than the control ones where both K-sorbate and oil worked by extending the lag phase giving influence on rate and extent of microbial growth. The result is in accordance with Ali (2015) stating that coating formulation containing either potassium sorbate or cinnamon oil would improve antimicrobial activity of coatings at extended storage life.

In general, storage at refrigeration temperature promoted lower microbial count compared to RT storage although there was only small change on number of bacteria and yeast/mold in comparison to the initial condition.

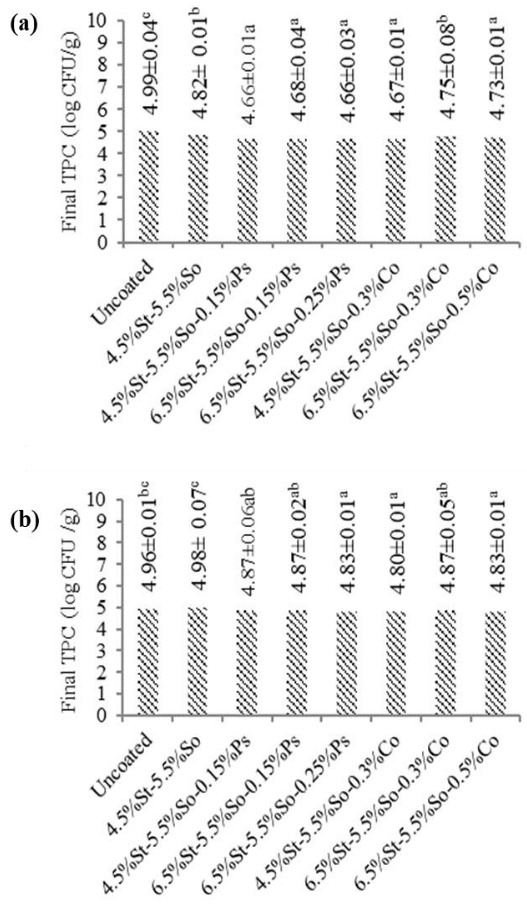


Figure 13. Total (a) bacteria (b) yeast/mold of strawberries after stored at room temperature

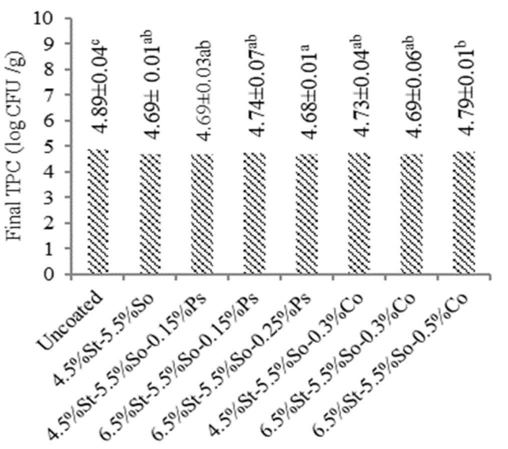


Figure 14. Total yeast/mold of strawberries after stored at refrigeration temperature

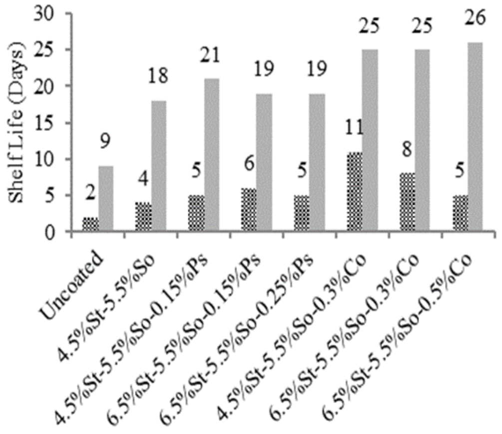


Figure 15. Shelf life of uncoated and coated strawberries, stored at room and cold temperature

This result is coherent with study reported by Sun *et al.* (2014) that addition of cinnamon oil into coating formulations might or might not enhance antimicrobial activities against bacteria and yeast/mold in fruits, and it was also affected by storage time and temperature.

Scoring and Hedonic Values

For the scoring values, there was significant effect ($p \leq 0.05$) of formulations on color, aroma, appearance, and taste intensity of strawberries. For color, strawberries coated with 4.50% starch-5.50% sorbitol were significantly different with the others. Meanwhile, strawberries coated with 6.50% starch-5.50% sorbitol-0.25% were statistically different with other samples for their appearance indicated by slightly opaque characteristic. The intensity of aroma and taste of all strawberries treated with cinnamon oil was significantly different with the controls and the ones coated with addition of potassium sorbate that had typical strawberry's flavor.

For hedonic values, there was a significant effect ($p \leq 0.05$) of formulations on the acceptability of color, aroma, appearance, taste, and overall acceptance. Results show that strawberries coated with 6.50% starch-5.50% sorbitol-0.25% K-sorbate were unfavorable for its color and appearance attributes. Strawberries with formulations containing cinnamon oil were slightly disliked for its aroma and taste attribute and had lower overall acceptance. Application of higher cinnamon oil (0.5%) in coatings contributed the lowest overall acceptance. This result is coherent with a report by Rojas-Grau *et al.* (2009) stating that one of major drawbacks of incorporation of essential oil as antimicrobial agent in edible film and coatings was it could change the original taste of food products with its strong flavor.

Shelf Life

Shelf life of uncoated and coated strawberries stored at room (28-30°C) and refrigeration (5-6°C) temperatures can be seen in Figure 15. For RT storage, the control strawberries, uncoated and coated (4.5%St-5.5%So), had shelf life for 2 and 4 days, respectively, in accordance with previous study reported by Lestari (2014). The addition of potassium sorbate into coating formulation could further extend shelf life of strawberry for 1-2 days. The longest shelf life was obtained from strawberries coated with 6.50% starch-5.50% sorbitol-0.15% K-sorbate (6 days). Adding cinnamon oil as natural preservative could prolong shelf life of strawberry in a higher degree compared to K-sorbate. Strawberries coated with 4.50% starch-5.50% sorbitol-0.30% cinnamon oil had longest shelf life for 11 days at RT storage.

At RfT storage (5-6°C), the first control, uncoated strawberries, exhibited shelf life for 9 days, whereas the second control, coated strawberries without antimicrobials, had 18 days of shelf life. The incorporation of potassium sorbate could extend shelf life of strawberry up to 21 days with coating made of combination 4.50% starch-5.50% sorbitol-0.15% K-sorbate; whereas strawberries coated with addition of cinnamon oil could further prolong strawberry's shelf life up to 26 days (6.50% starch-5.50% sorbitol-0.5% cinnamon oil). It is shown that cinnamon oil was more significant in prolonging shelf life of coated strawberry as also seen at RT storage. The efficacy of antimicrobials depends on several factors such as antimicrobial type and concentration, its processing and post-process storage handling, food storage conditions, and food pH (Rahman, *et al.*, 2007).

CONCLUSIONS

Generally, addition of either potassium sorbate or cinnamon oil decreased value of tensile strength and elongation percentage along with increased water vapor transmission rate of edible film. Interaction between potassium sorbate and starch molecules modified starch network in the film causing disrupted crystalline phase of the film. As for cinnamon oil, the presence of cinnamon oil as lipid component can replace the starch polymers in film matrix leading to reduction of intermolecular interaction between chains of adjacent molecules. It would also increase film permeability since antimicrobial agents lead to loosening of structure's compactness increasing moisture that passed through the edible film.

Edible coatings incorporated with antimicrobials gave higher contribution in maintaining strawberries' quality including lower weight loss, higher hardness, retained pH and acidity, lower total sugar, and lower bacteria and yeast/mold count, in comparison to uncoated and/or coating with starch-plasticizer alone. However, strawberries coated with addition of cinnamon oil had lower acceptance in its taste and aroma attributes.

At RT (28-30°C) storage, the control strawberries (uncoated and coated strawberry with 4.5% starch-5.5% sorbitol) had shelf life for 2 and 4 days, respectively, while coating formulations added with K-sorbate could prolong shelf life of strawberry up to 5 days, and coating formulations incorporated with cinnamon oil further extended shelf life of strawberries until 11 days. On the other hand, at RfT (5-6°C) storage, controls had shelf life for 9 and 18 days, respectively. Strawberry coated with addition of K-sorbate exhibited shelf life up to 21 days while strawberry coated with cinnamon oil formulations had shelf life up to 26 days.

Hence, an incorporation of potassium sorbate or cinnamon oil to lesser yam starch-plasticizer base formulations proved to further prolong shelf life of strawberry with acceptable quality, and in particular the cinnamon oil in the edible coating formulation might be recommended to be used as antimicrobial since it demonstrated better performance as compared to that of potassium sorbate.

REFERENCES

Ali, H.A.E.M, (2015), Effect of coating materials on shelf-life of cold strawberry and apricot fruits, *Doctor of Philosophy* Thesis, Cairo University, Egypt.

American Society for Testing and Materials (ASTM), (1995), Standard Test Method for Water Vapor Transmission of Material, *ASTM Book of Standard*.
Association of Analytical Chemist (AOAC), (2005), Official methods of analysis of the Association of Official Analytical Chemists. 18th ed., *AOAC, Inc*.

Atress, A.S.H., El-Mogy, M.M., Aboul-Anean, H.E., and Alsanius, B.W, (2010), Improving Strawberry Fruit Storability by Edible Coating as A Carrier of Thymol Or Calcium Chloride, *Journal of Horticultural Science & Ornamental Plants*, 2(3), pp. 88-97.

Chowdhury, T. and Das, M, (2013), Effect of Antimicrobials on Mechanical, Barrier, and Optical Properties O\of Corn Starch Based Self-Supporting Edible Film, *IJFS*, 2, pp. 212-223.

Dashipour, A., Khaksar, R., Hosseini H., Shojae-Aliabadi, S., and Ghaanati, K, (2014), Physical, Antioxidant and Antimicrobial Characteristics of Carboxymethyl Cellulose Edible Film Cooperated with Clove Essential Oil, *Zahedan Journal of Research in Medical Sciences*, 16(8), pp. 34-42.

Kusnadi, J. and Budyanto, P, (2015), Antibacterial Active Packaging Edible Film Formulation with Addition Teak (*Tectona grandis*) Leaf Extract, *International Journal of Life Sciences Biotechnology and Pharma Research*, (4):2.

Jutaporn, C.T., Suphitchaya, C., and Thawien, W, (2011), Antimicrobial Activity and Characteristics Of Edible Films Incorporated With Phayom Wood (*Shorea tolura*) Extract, *International Food Research Journal*, 18: 39-54.

Kumar, J, (2007), Lesser Yam. In K. V. Peter. *Underutilized and Underexploited Horticultural Crops*, New India Pub. Agency, New Delhi, pp.57-66.

Lawless, H.T. and Heymann, H, (2010), *Sensory Evaluation of Food: Principles and Practices*. Springer, New York.

Lestari, C., (2014), Karakterisasi *Edible Film* Pati Gembili (*Dioscorea esculenta* lour. Burkill) dengan Penambahan *Plasticizer* Dan Aplikasinya Sebagai *Edible Coating* Pada Stroberi (*Fragaria* ananassa), *STP Thesis* Univeresitas Pelita Harapan, Indonesia.

Mautrin, L and Peeler, J.T, (2001), *BAM: Aerobic Plate Count*, Food and Drug Administration, USA.

Moraes, K.S., Fagundes, C., Melo, M.C., Andreani, P., and Monteiro, A.R, (2012), Conservation of Williams Pear Using Edible Coating with Alginate and Carrageenan, *Cienc. Tecnol. Aliment., Campinas* 32(4), pp. 679-684.

Putera, D.T, (2013), Characterization of Edible Film from Lesser Yam (*Dioscorea esculenta* Lour. Burkill) Starch and Its Utilization as Edible Coating to Strawberry, *STP Thesis*, Universitas Pelita Harapan, Indonesia.

Rahman, S.M, (2007), Handbook of Food Preservation, 2nd ed,. CRC Press, New York.

Rahman, M. Moshiur, Moniruzzaman M., Ahmad, M.R., Sarker B.c., and Alam,M.K, (2016), Maturity Stages Affect The Postharvest Quality and Shelf-Life of Fruits of Strawberry Genotypes Growing In Subtropical Regions, *Journal of the Saudi Society of Agricultural Sciences* 15 (1), pp. 28-37.

Richana, N., and Sunarti, T.C, (2004), Karakterisasi Sifat Fisikokimia Tepung Umbi dan Tepung Pati Dari

Umbi Ganyong, Suweg, Ubikelapa Dan Gembili, *Jurnal Pascapanen* 1(1), pp. 29-37.

Rojas-Grau, M. A, Fortuny, R.S., and Martin-Belloso, O, (2009), Edible Coatings to Incorporate Active Ingredients to Fresh-Cut Fruits: A Review. *Trends in Food Science & Technology*, 20: 438-447.

Robertson, G.L, (2013), *Food Packaging: Principles and Practice,* CRC Press, Boca Raton.

Sanyang, M., Sapuan S., Jawaid, M., Ishak, M., and Sahari, J, (2015), Effect of Plasticizer Type and Concentration on Tensile, Thermal and Barrier Properties of Biodegradable Films Based on Sugar Palm (Arenga Pinnata) Starch, *Polymers* 7, no. 6, pp. 1106-124.

Souza, A.C., Goto, G.E.O., Mainardi, J.A., Coelho, A.C.V and Tadini, C.C, (2013), Cassava Starch Composite Films Incorporated with Cinnamon Essential Oil: Antimicrobial Activity, Microstructure, Mechanical, and Barrier Properties, *LWT - Food Science and Technology* 54: 346-352.

Stone, Herbert, Rebecca N. Bleibaum, and Heather A. Thomas, (2012), *Sensory Evaluation Practices. Academic Press*, London.

Sun, X., Narciso, J., Wang, Z., Ference, C., Bai, J., and Zhou, K, (2014), Effects of Chitosan-Essential Oil Coatings on Safety and Quality of Fresh Blueberries, *Journal of Food Sciences* 79(5).

Theron, M.M., and Lues, J.F.R, (2011), Organic Acids and Food Preservation, CRC Press, Taylor & Francis Group, Boca Raton.

Vargas, M., Albors, A., Chiralt, A., and Gonzalez-Martinez, C, (2006), Quality of Cold-Stored Strawberries as Affected by Chitosan-Oleic Acid Edible Coatings, *Postharvest Biology & Technology* 41: 164-171.

Weiss, E.A, (2002), Spice crops, CABI Publishing, Wallingford.

Whitaker, B.D, (2008). In Bernhard Brückner and S. Grant. Wyllie. *Fruit and Vegetable Flavour: Recent Advances and Future Prospects*, CRC Press, Boca Raton, pp. 103-123.