

Utilisation of palm – based and beeswax coating on the postharvest-life of guava (*Psidium guajava* L.) during ambient and chilled storage

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Abstract

Guava is a climacteric fruit which has high nutritional content. It is a highly perishable fruit, undergoes rapid postharvest ripening in a few days under ambient condition. This paper aims to determine the effect of palm stearin and palm kernel olein blends on maintaining the quality of guava during storage. Two different coating formulations of palm stearin (PS) and palm kernel olein (PKOo) blends (1:1 and 3:2) were analysed for their slip melting point (SMP), cohesiveness, viscosity and density. Beeswax was used as a commercial coating for comparison while the uncoated guava was used as control. These coatings were applied onto guavas by hand-wipe technique using a sponge. Guavas were dried in corrugated fibre board boxes and stored in an air-conditioned room maintained at 20°C while a chiller maintained at 10°C was used for chilled temperature. Coating pick up, thickness and surface area were measured while guava properties were analysed for coating effect on weight loss, O₂ and CO₂ gases, firmness and glossiness during storage at ambient temperature (20°C) for 21 days and chilled temperature (10°C) for 30 days. Microstructure analysis was conducted within 2 days of coating at ambient temperature (20°C). The results obtained indicated that 1:1 PSPKOo blends had higher cohesiveness compared to beeswax. Both PSPKOo blends significantly ($p < 0.05$) slowed the increases of weight loss and yellowness and slowed the decline of glossiness, lightness and greenness of guava at day 21 of 20°C of storage temperature, hence preserving the guava better compared to those coated with beeswax.

Keywords

Palm stearin
palm kernel olein
guava
edible coating

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Introduction

Edible coating is a transparent film that covers the food item and acts as a barrier to humidity and oxygen. There are several types of edible coatings such as carbohydrate, protein, lipid and combinations of all these types materials. Lipids are the possible materials for making coatings for fresh or further processed foods to extend their shelf life (Maria *et al.*, 2009a). Palm stearin (PS) is the solid fraction obtained by fractionation of palm oil after crystallisation at a controlled temperature. Pantzaris (2000) reported that it is not used directly for edible purposes due to its high melting point ranging from 44 to 56°C. The production of edible coating requires fat blends such as palm kernel olein (PKOo) that are able to impart plasticity. Palm kernel olein which has low melting temperature is obtained from the fractionation of palm kernel oil.

Guava is a climacteric fruit (Eliane *et al.*, 2005)

and because of the delicate nature it has short postharvest life. It is highly perishable and undergoes rapid postharvest ripening in a few days under ambient condition (Hashem and Alamri, 2009). Fruit ripening is characterised by green colour loss (Eliane *et al.*, 2005), rot development, softening, wilting and loss of brightness. Malaysia exported nearly 27317 MT of guava valued at USD 5,309,000 which represented 3.28% of the world market, giving it a rank of 18 in the world import market (FAMA, 2006). However, the production of guava in Malaysia is not sufficient to meet domestic demand as the country is still importing guava from Thailand. Quezada *et al.* (2005) reported the use of biopolymers from microbial origin obtained with low cost nutrients applied on Mexican guava and apricot. These biopolymers were found to increase the shelf life of the fruits by at least three days compared to the uncoated fruits, at 25°C and 50-70% RH. This study was conducted to determine the effectiveness of PSPKOo blends as edible coatings compared to beeswax commercial coating. The 1:1

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and 3:2 of PSPKOO blend ratios were chosen as both blends were observed to slow the respiration gases of guavas from a previous experiment conducted at Universiti Teknologi MARA, Shah Alam, Malaysia.

Materials and Methods

Raw materials.

Refined, bleached and deodorised medium-hard (RBD) palm stearin (PS) (SMP 53.4°C, IV 40.3) and palm kernel olein (PKOO) (SMP 23.4°C, IV 24.2) were obtained from Sime Darby Jomalina Sdn. Bhd. Klang, Malaysia and Cargill Specialty Oils and Fats Sdn. Bhd, Port Klang, Malaysia, respectively. The oils and fats were stored at 5°C prior to use. Beeswax was purchased from SIGMA (Missouri, USA). All the chemicals used were of analytical or HPLC grade and were purchased from SIGMA-Aldrich Co. (Missouri, USA).

Fruits

Fresh guavas were obtained from a commercial farm, Sui Yuan Fruit Trading, in Ladang Bikam, Bidor, Perak, Malaysia. The guavas of maturity index 2 were carefully selected to obtain uniform weight of approximately 400-405g, size, shape, colour and free from injuries. The fruits were packed in small boxes and transported to the laboratory in Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia. The fruits were stored in the chiller at 10°C prior to use.

Fruits preparation

Guavas were prepared using the procedure described by Lerdthanangkul and Krochta (1996) with some modifications. Initially, fruits were washed with 0.5% potassium sorbate for disinfection purposes, and then rinsed with water. After rinsing, the fruits were blotted dry with paper towels. Lipid coating was applied manually on the dried guava fruits by using a commercial sponge of 4 cm x 4 cm x 4 cm size. Excess coating was allowed to drain off. Fruits were coated with 1:1 and 3:2 PSPKOO blends and air dried at ambient temperature (20°C). Beeswax coating was used as a comparison of commercial coating material. After coating, guavas were dried in corrugated fibre board boxes and stored in an air-conditioned room maintained at 20°C while a chiller maintained at 10°C was used for chilled temperature storage.

Coating preparation

The PS and PKOO were melted at 60°C while beeswax was melted at 65°C in an oven prior to use. The PS:PKOO were mixed in proportions of 1:1 and

3:2. Beeswax was diluted with distilled water in the ratio of 6:4 (beeswax: distilled water). Ten percent of soy lecithin was added into the beeswax as an emulsifier.

Determination of slip melting point (SMP)

The SMP of the coating blend was determined according to MPOB Test Method (2004). At least three clean glass capillary tubes capillary tubes open at both ends, about 80 mm long, having an external diameter of 1.4 mm to 1.5 mm and an internal diameter of 1.0 mm to 1.2 mm. were initially dipped into a completely melted oil sample to a depth of 10 mm. The tubes were then chilled until the oil sample was solidified prior to placing them in a test tube and held in a beaker of water equilibrated at 10°C for 16 h in a thermostated water bath (Huber, Offenburg, Germany). The capillary tubes were subsequently removed from the test tube and attached to a thermometer with a rubber band such that the lower ends of the tubes were at the same level as the bottom of the mercury bulb of the thermometer. A thermometer was suspended in a beaker containing 400 mL of boiled distilled water. The thermometer was immersed in the water to a depth of 30-mm. The initial temperature of the water bath was adjusted to between 8 to 10°C below the expected SMP of the oil sample. The water bath was agitated using a magnetic stirrer and heat was supplied at the rate of 1°C/min and then reduced to 0.5°C/min. The temperature at which the sample in the tubes started to melt and become clear is defined as the SMP. The difference between values of the measurement carried out by the same analyst on the same test sample shall not exceed 0.8°C for palm oil and 0.5°C for palm kernel olein and palm stearin.

Texture profile analysis (TPA) and viscosity

The cohesiveness of samples were measured using texture profile analysis (TPA) with a Texture Analyser, TA.XT2i (Stable Micro Systems, Surrey, UK). A load cell of 5 kg and a 5 mm cylindrical plunger at a constant penetration speed of 2 mm/min (TPA) was used with three penetrations per blend. A PIVI Portable viscometer (Softfraser Instrument, Villemandeur, France) was used to measure the viscosity of blends at 60°C.

Specific gravity or density analysis

For density analysis, specific gravity (SG) of the coating blends was measured according to MPOB Test Method (2004) using SG bottles. An empty SG bottle was weighed and then filled with the blend. The bottle was closed with a stopper which had a capillary bore, then cooled to 7°C for 24 hours. The

SG bottle was then warmed to room temperature until expansion ceased while the outside of the bottles was wiped and cleaned. Weight of the bottle with the coating blends was also recorded. Specific density was calculated by using the ratio of weight of blend after warming to the weight of initial blend.

Determination of coating pick up, coating thickness and surface area of guava

The coating characteristics were determined according to the method of Patel and Bhattacharya (2002) with some modifications. The total pickup of the coating material was calculated as follows.

$$\text{Coating pick up} = \frac{\text{Wt of guavas after coating} - \text{Wt of guavas before coating}}{\dots\dots\dots} \text{Equation 1}$$

Determination of coating thickness, the average of coating on each fruit was calculated as follows.

$$\text{Thickness} = \frac{\text{Total coating blend pickup}}{\text{Density of coating blend} \times \text{Surface area of guava}} \dots\dots\dots \text{Equation 2}$$

Surface area determination of fresh guava was performed according to the method of Wongsapat and Ampawan (2008) with some modifications using the white cellophane tape method. The tape was cut by a razor knife into several small pieces ranging from 2 to 4 cm. Each section of the tape was placed all over the surface area of a fresh guava, then all sections were removed and then placed on a sheet of paper. The total surface area of the fresh guava was then calculated.

Weight loss measurement.

Weight loss occurred due to the transfer of water vapour from the guava to the air. This was determined by weighing the guava on a digital balance (Sartorius Universal, Edgewood, New York) immediately after coating. It was reported as percentage loss in weight based on the original mass.

Determination of O₂ and CO₂ concentrations

For headspace gas analysis, guava from each treatment was placed in an individual airtight container which was sealed for 2 hours just before measurement. The container was previously flushed with nitrogen gas to remove traces of O₂. The percentage concentrations of CO₂ and O₂ in the headspace of the containers were recorded using a gas analyser (MOCON Headspace Analyser, Mineapolis, USA). Three fruits per treatment were used in the

analysis.

Determination of ethylene gas

Five millilitres (ml) of the atmosphere from the headspace of guava containers were withdrawn by using a gas tight syringe (5 ml). Each container consists of 3 fruits. Identification of ethylene production was made by comparison with ethylene standard (Scotty Analysed Gases, Pennsylvania, US). Ethylene gas was analysed using a Gas Chromatograph (GC) (Agilent 7890A, Shanghai, China) equipped with a Flame Ionisation Detector (FID). The capillary column used for ethylene was Agilent HP- Plot/Q. The column and detector temperatures were 60°C and 180°C, respectively. Results from means of triplicate determinations for each one of the replicate samples were expressed as ppm.

Firmness measurement

Firmness of guavas was determined using a Texture Analyser, TA.XT2i (Stable Micro Systems, Surrey, UK). A load cell of 5 kg and a 5 mm cylindrical plunger at a constant penetration speed of 2 mm/min was used. Each fruit was penetrated at 9 different locations.

Determination of glossiness

For glossiness, the reflectance measurement of fruit shine was measured in glossiness value using a portable spectrophotometer CM 2500d (Konica Minolta, Tokyo, Japan) fitted with 8 mm apertures. For each experiment, ten measurements per fruit were made. The guavas were stored at 20°C from day 0 until 21 and at 10°C from day 0 until 30.

Surface colour measurement

Fruit surface colour was determined on each individual guava per treatment using a CR-400 chromameter (Konica Minolta, Tokyo, Japan) with a standard C illuminant. The beam diameter was 11 mm with a viewing angle of 0°. A white calibration plate was used for calibration to determine L value (lightness or brightness), a* value (redness or greenness) and b* value (yellowness or blueness).

Microstructure analysis

Microstructure of the guava coated surface was analysed using a Field Emission Scanning Electron Microscope (FESEM, Zeiss Supra 40VP). Rectangular pieces (6 mm x 3 mm with thickness of 1 mm) of the coated guava obtained from the phloem tissue were cut for the observation of both the film-coated guava surface and the cross-sections of this same surface. The samples were examined using an accelerating voltage of 10 kV. Thickness

measurements were randomly taken along different sections of the coated layer.

Physical appearance

The appearance of guavas was recorded using a digital camera of 12.8 megapixel (Sony, Tokyo, Japan). The appearance was observed at day 0, 1, 5, 7, 14, 21 and 30.

Statistical analysis

Mean values and standard deviations were obtained using the GLM procedure in SAS Software (Release 9.0, SAS Institute Inc., Cary, NC, 2002). Significant ($p < 0.05$) different means were separated using Duncan's multiple range test.

Results and Discussions

Slip melting point (SMP), cohesiveness, viscosity and density of coating

The SMP, cohesiveness, viscosity and density of beeswax, 1:1 and 3:2 PSPKOo coating blends are shown in Table 1. All coating had SMPs well above body temperature (37°C) and were in semi-solid form during application on guavas. The SMP increased with an increase in the amount of palm stearin (PS) in the blends. Beeswax had the highest SMP (48°C) due to high percentage of palmitate ($\sim 70\%$) (Monedero et al., 2009). The lowest SMP was observed in 1:1 PSPKOo blend since it has lower PS than 3:2 PSPKOo blend. This blend (1:1 PSPKOo blend) showed a higher cohesiveness compared to beeswax application on fruits due to the liquid portion of PKOo. This could control the respiration of guavas hence prolonging their shelf-life. This finding agreed with those of Maria et al. (2009a) who reported that edible coating formulations must be wet and spread uniformly on the fruits' surface and has adequate cohesion formed after drying to function properly. The SMP of beeswax was higher than that of 1:1 PSPKOo blend and it was less cohesive. Hence, the beeswax coating was less effective in controlling the guava's respiration due to brittleness of coating during storage. For density results, the surface solid density increased with the solid concentration of the film-forming dispersions. Similar findings were observed by Maria et al. (2009b). There were no significant difference ($p > 0.05$) for viscosity for all the coating.

Coating pick up and coating thickness and surface area of guava

The result obtained on coating pick up and coating thickness and surface area of guava are shown in Table 2. There were no significant difference ($p > 0.05$) for

Table 1. Slip melting point (SMP), cohesiveness, viscosity and density of beeswax and PSPKOo coating blends

Samples	SMP ($^{\circ}\text{C}$)	Cohesiveness		Density (g/ml)
		(F)	Viscosity	
Beeswax	$48.00 \pm 0.00^{\text{A}}$	$0.28 \pm 0.001^{\text{B}}$	$29.03 \pm 0.68^{\text{A}}$	$0.88 \pm 0.00^{\text{A}}$
1:1 PSPKOo blend	$43.33 \pm 0.00^{\text{C}}$	$0.94 \pm 0.40^{\text{A}}$	$31.4 \pm 1.39^{\text{A}}$	$0.85 \pm 0.00^{\text{A}}$
3:2 PSPKOo blend	$44.89 \pm 0.38^{\text{B}}$	$0.56 \pm 0.20^{\text{BA}}$	$30.6 \pm 3.33^{\text{A}}$	$0.87 \pm 0.01^{\text{A}}$

Means with the same capital letters down the column were not significantly different ($p < 0.05$). Means \pm SD were from triplicate measurements.

Table 2. Thickness, coating pickup and surface area of guava coated with beeswax and PSPKOo blends

Samples	Thickness (mm^2)	Coating pickup (g)
Beeswax	$4.58 \times 10^{-5} \pm 8.00 \times 10^{-6}^{\text{A}}$	$0.12 \pm 0.02^{\text{A}}$
1:1 PSKOo blend	$2.99 \times 10^{-5} \pm 1.46 \times 10^{-5}^{\text{A}}$	$0.06 \pm 0.01^{\text{A}}$
3:2 PSPKOo blend	$7.10 \times 10^{-5} \pm 2.67 \times 10^{-5}^{\text{A}}$	$0.16 \pm 0.08^{\text{A}}$

Means with same capital letters down the column were not significantly different ($p < 0.05$). Means \pm SD were from triplicate measurements.

all samples which meant that the solid component in all the blends did not influence the coating thickness, coating pick up and surface area. These results did not correlate with the results obtained for cohesiveness ie. higher cohesiveness in the 1:1 PSPKOo blends did not result in higher coating pick-up or thickness. Since cohesiveness refers to the force of attraction between molecules of the same substance, hence the higher cohesiveness in 1:1 PSPKOo blend (Table 1) only contributed to the high tendency of each blend molecules to stick to each other rather than stick onto guava's surface.

Weight loss of guava

Weight loss of guava was due to respiration process during ripening whereby fruit takes in oxygen and gives out carbon dioxide. This process made the fruit become shrinks and causes reduce in weight. Figure 1 (a) and (b) shows the guava coated with 1:1 and 3:2 PSPKOo blends significantly slowed the weight loss of guavas by 45.89% (at 20°C) and 7.68% (at 10°C), compared to beeswax at day 21 of storage. Higher weight loss which occurred during fruit ripening at 20°C storage was due to fruits losing weight when their metabolic rate increases. The metabolic rate accelerates with an increase in temperature around the produce, resulting in loss of water and associated reduction in weight. The high temperature storage leads to physical damage due to tissue breakdown and increase in fruit softening. This condition increased the respiration process hence the weight loss will be increased. This result agreed with that of Thanh (2006) who found that temperatures above 20°C could result in abnormal physiological

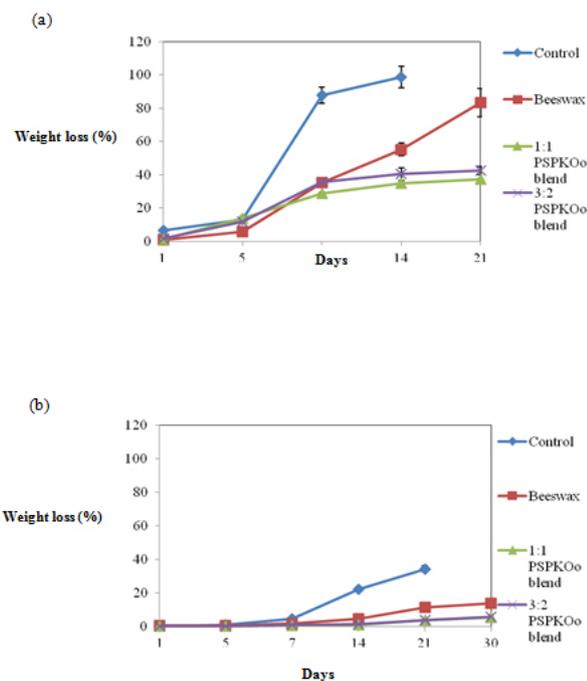


Figure 1. Weight loss of guava coated with beeswax, 1:1 and 3:2 PSPKOo blends at (a) ambient (20°C) and (b) chilled (10°C) temperature storage. Means±SD were from triplicate measurements

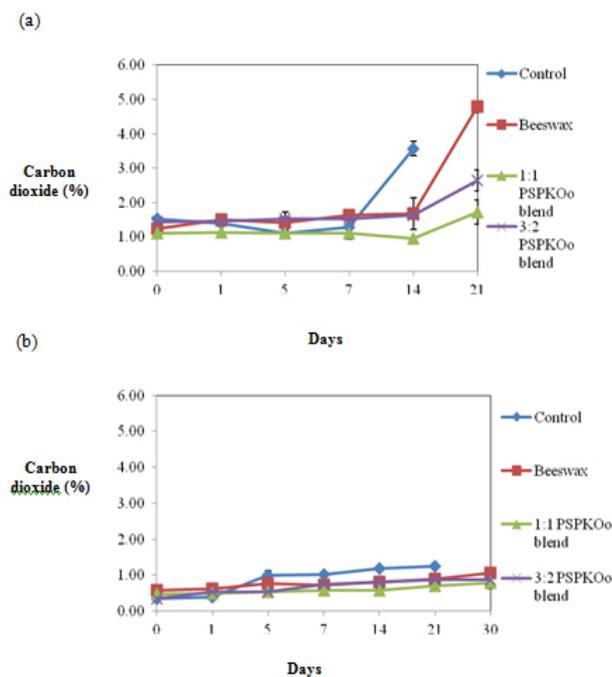


Figure 3. Carbon dioxide concentration of guava coated with beeswax, 1:1 and 3:2 PSPKOo blends at (a) ambient (20°C) and (b) chilled (10°C) temperature storage. Means±SD were from triplicate measurements

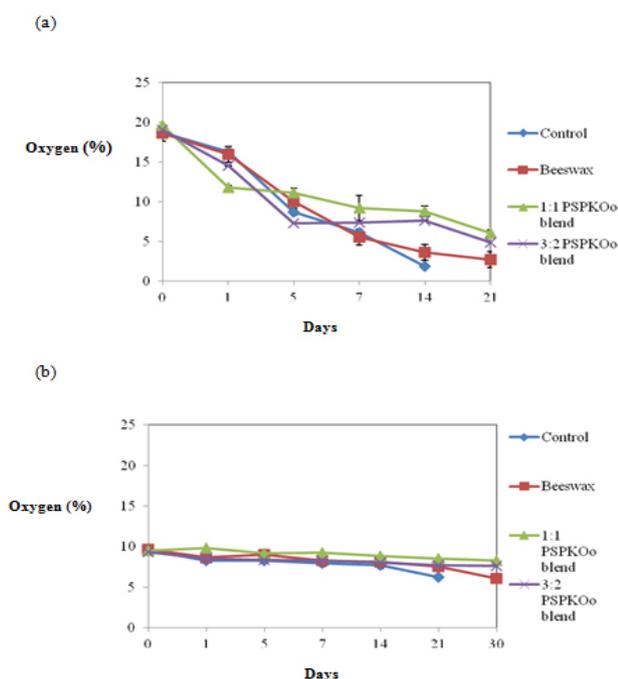


Figure 2. Oxygen concentration of guava coated with beeswax, 1:1 and 3:2 PSPKOo blends at (a) ambient (20°C) and (b) chilled (10°C) temperature storage. Means±SD were from triplicate measurements

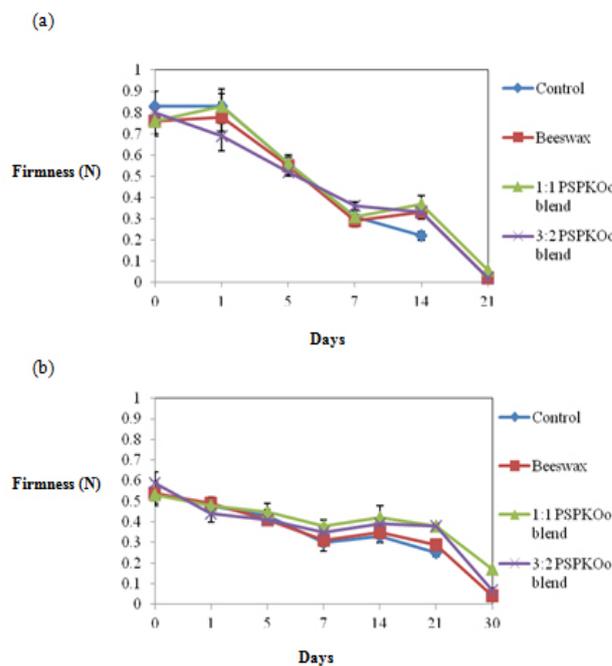


Figure 4. Firmness of guava coated with beeswax, 1:1 and 3:2 PSPKOo blends at (a) ambient (20°C) and (b) chilled (10°C) temperature storage. Control was uncoated guava. Means±SD were from triplicate measurements

processes in fresh produce. The major process in this regard is respiration through which water is lost to the immediate surroundings of the produce and hence, a reduction in weight. However, there were no significant ($p>0.05$) difference between 1:1 and 3:2 PSPKOo blends. Similar trends were also observed for guavas during chilled storage. Generally, the

PSPKOo blends have higher hydrophobic content which caused higher moisture barrier efficiency. This is related to the fatty acids in the palm oil products which forms a continuous stable layer on the food surface based on their high polarity (Daniel and Yanyun, 2007). Lower temperature storage reduced the respiration gases by lowering fruits metabolism

(Kasim and Kasim, 2011).

Oxygen, CO₂ and ethylene gas concentrations.

Generally, O₂ declined while CO₂ increased during ripening at 20°C as shown in Figures 2 (a) and 3 (a). Oxygen and CO₂ gases are related to the respiration of fruit during ripening. The higher rate of respiration is due to high temperature (20°C) increased the burning assimilates for fruit maintenance of guava. For guava stored at 20°C, the O₂, decreased from day 0 until day 21 (Figure 2 a). For both storage temperatures, the PSPKOo blends slowed the decline of O₂ when compared to beeswax which started from day 1 for 20°C and day 5 for 10°C storage. This is related to the cohesiveness of PSPKOo blend coating that made it stick onto guava's surface, hence slowing the rate of O₂ gas vapour into the fruit.

The low temperature storage (10°C) heavily influenced metabolic activity of fruit tissues and organs such as slowing down the respiration process. The result showed that at day 21, the chilled storage of 1:1 PSPKOo blend coating could slow the decline of O₂ gas concentration compared to ambient storage up to 28.45% (Figure 2). During low temperature storage (10°C), rate of respiration is lower in fruit cell compared to high temperature. High respiration within high temperature storage (20°C) resulted in fruit tissue deterioration.

Figure 3 shows the coating application slowed the increase of CO₂ at both storage temperatures. The 1:1 PSPKOo blend significantly ($p < 0.05$) slowed CO₂ release from guava by 63.88% compared to beeswax at day 21 (20°C), while from 20°C to 10°C showed it was 59.54% lower. Overall, guavas stored at day 14 until day 21 at 20°C temperature showed high deterioration compared to chilled temperature storage. This is related to high CO₂ produced by guava during that duration. Internal gas atmosphere modification has been suggested to be the cause of reduced CO₂ production by all the coated fruits (beeswax and PSPKOo blend). In this regard, the gas barrier properties and permeability selectivity (the ratio of $PCO_2 = PO_2$ permeation coefficient) of the edible coating applied to the skin surface and their dependence on temperature will play an important role in the changes in endogenous O₂ and CO₂ levels (Guillaume *et al.*, 2010).

Ethylene gas production is related to the ripening of fruits. Table 3 (a and b) shows the ethylene gas produced by guava stored at 20°C and 10°C. Generally, there were no significant ($p > 0.05$) difference for all coating treatments compared to uncoated samples. These were due to small amounts of ethylene gas ranging from 0.03 to 0.6 ppm produced by guava fruits from day 1 until 30. Ethylene gas was

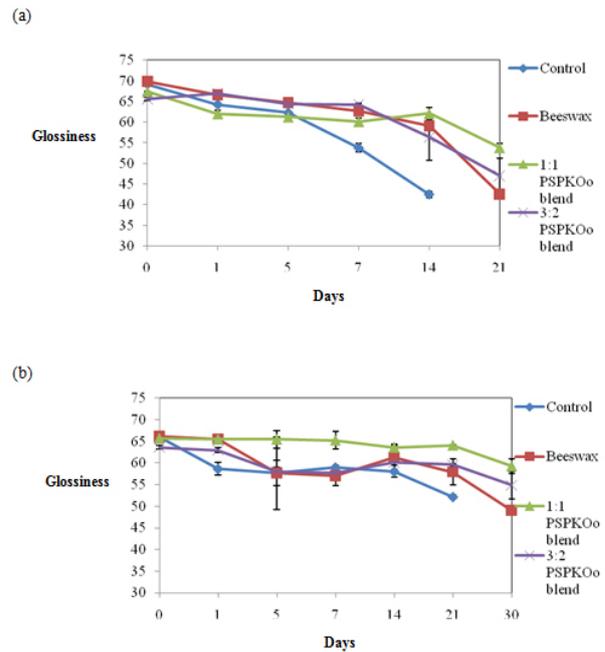


Figure 5. Glossiness of guava coated with beeswax, 1:1 and 3:2 PSPKOo blends at (a) ambient (20°C) and (b) chilled (10°C) temperature storage. Means \pm SD were from triplicate measurements

only detected on day 5 and 7 for 20°C and 10°C of storage, respectively.

Firmness, glossiness and firmness of guava

Figure 4 (a and b) shows the changes in guava firmness of beeswax and PSPKOo blend during storage for day 21 and 30 at 20°C and 10°C, respectively. The firmness started to decrease when the fruits started to decay and softening occurred. This condition is indicated in Tables 4 and 5 whereby black spots were observed at day 7 (20°C) and day 14 (10°C) for guava coated with beeswax. Generally, coatings exerted a beneficial effect on fruit firmness such that, by the end of the storage period at day 14 for 20°C storage and at day 21 for 10°C storage, all the treatments gave rise to fruits with significantly ($p < 0.05$) higher flesh firmness values than uncoated fruits. The highest loss of firmness was from the uncoated guava storage at 20°C from day 1 until day 7. At this duration, the uncoated fruit dropped by 62.65% at 20°C and 37.50% at 10°C. Overall, the less firm ones was guava coated with beeswax at day 7 stored at 20°C. However, the uncoated guava was spoilt and softened and the firmness measurement ended at day 21 (20°C) and day 21 (10°C). The increase in pectin solubilisation and disruption of the xyloglucan–cellulose microfibril networks of guava fruit moderated by increases in the activities of exo polygalacturonase (PG), pectin methylesterase, β -(1 \rightarrow 4)-glucanase and β -galactosidase has been proposed to be associated with the rapid softening of fruit (Singh and Pal, 2007) especially during guava

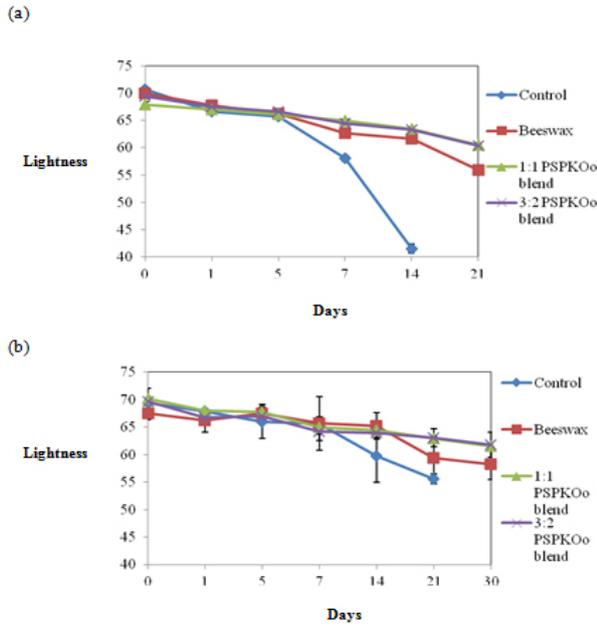


Figure 6. Lightness of guava coated with beeswax, 1:1 and 3:2 PSPKOO blends at (a) ambient (20°C) and (b) chilled (10°C) temperature storage. Means±SD were from triplicate measurements

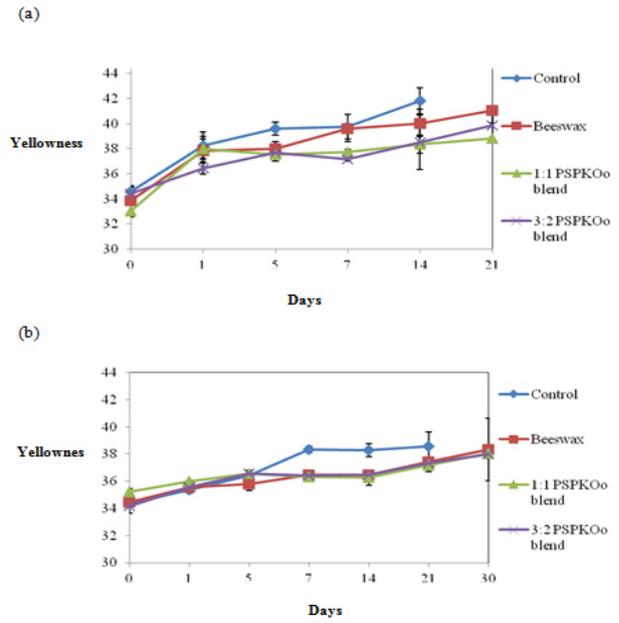


Figure 8. Yellowness of guava coated with beeswax, 1:1 and 3:2 PSPKOO blends at (a) ambient (20°C) and (b) chilled (10°C) temperature storage. Means±SD were from triplicate measurements

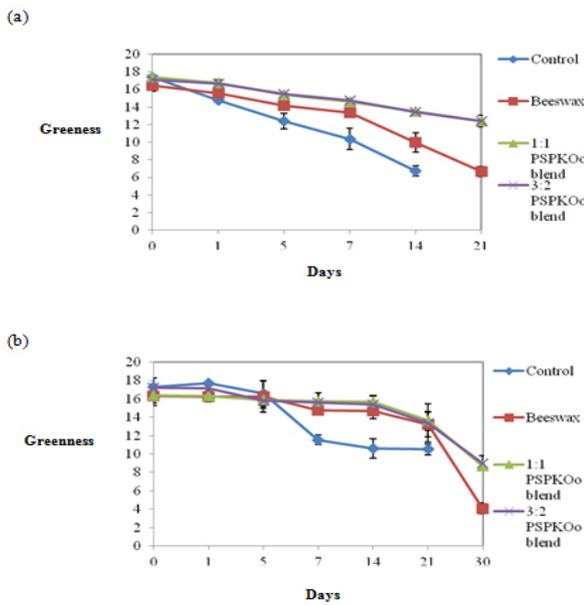


Figure 7. Greenness of guava coated with beeswax, 1:1 and 3:2 PSPKOO blends at (a) ambient (20°C) and (b) chilled (10°C) temperature storage. Means±SD were from triplicate measurements

storage at ambient temperature.

Figure 5 (a and b) shows that glossiness values of guavas decreased with storage time for all coatings. At day 21 and 30, guava coated with beeswax (20°C) showed lower gloss value. Generally, there were no differences for both PSPKOO blends at the end of all storage conditions. At the end of the storage, the 1:1 PSPKOO blend coating at 10°C temperature could still maintain the highest glossiness at 64.11 gloss value at day 21. However, there were no significant difference ($p > 0.05$) between 1:1 and 3:2 PSPKOO blends. The high temperature caused higher

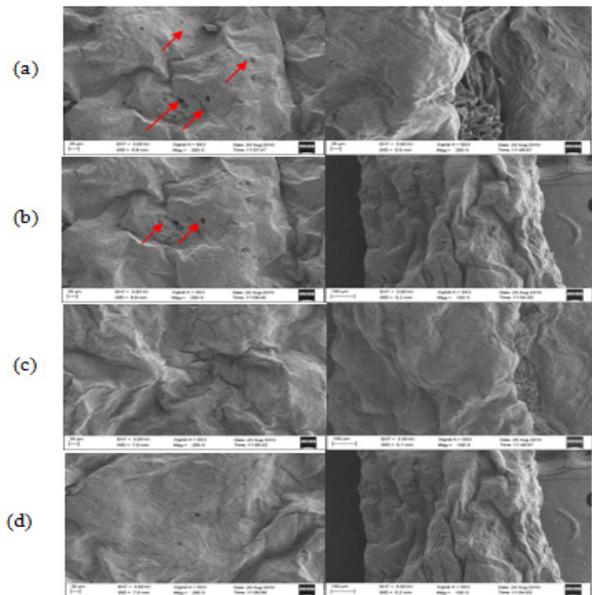


Figure 9. Microstructure of guava. (a) Uncoated (b) Beeswax coating (c) 1:1 PSPKOO blend coating and (d) 3:2 PSPKOO blend coating. Photomicrographs on the right side represent cross section while the left represents surface area. All have magnification of 200x

deterioration of guava and led to black spot because of fungus. This resulted in lower gloss values when compared to low temperature storage.

The colours of guavas are shown in Figures 6, 7 and 8. Lightness, greenness and yellowness measurement showed that there were no significant difference ($p > 0.05$) for both PSPKOO blends at the end of both storage temperatures. The lightness of guava decreased with storage time. Both PSPKOO blends maintained the lightness of guava while the uncoated guava had the highest decrease from day 7 to 14 by 28.54% and 8.95% at 20°C and 10°C, respectively

Table 3. Ethylene gas concentration (ppm) of guava coated with beeswax and PSPKOo blends at (a) ambient (20°C) and (b) chilled (10°C) temperature storage

Samples/Days	Days					
	0	1	5	7	14	21
Control	ND	ND	0.24±0.02 ^{AB}	0.34±0.00 ^{AB}	0.72±0.02 ^{AB}	Ripe
Beeswax	ND	ND	0.15±0.01 ^{AB}	0.26±0.06 ^{AB}	0.56±0.00 ^{AB}	0.60±0.06 ^{AB}
1:1 PSPKOo blend	ND	ND	0.03±0.00 ^{AB}	0.13±0.00 ^{AB}	0.23±0.00 ^{AB}	0.25±0.00 ^{AB}
3:2 PSPKOo blend	ND	ND	0.10±0.00 ^{AB}	0.07±0.00 ^{AB}	0.21±0.01 ^{AB}	0.43±0.06 ^{AB}

Samples/Days	Days						
	0	1	5	7	14	21	30
Control	ND	ND	ND	0.31±0.01 ^{AB}	0.40±0.01 ^{AB}	0.41±0.01 ^{AB}	Ripe
Beeswax	ND	ND	ND	0.09±0.00 ^{AB}	0.15±0.01 ^{AB}	0.26±0.06 ^{AB}	0.53±0.03 ^{AB}
1:1 PSPKOo blend	ND	ND	ND	ND	ND	ND	0.02±0.01 ^{AB}
3:2 PSPKOo blend	ND	ND	ND	ND	0.12±0.01 ^{AB}	0.18±0.02 ^{AB}	0.19±0.01 ^{AB}

N.D = Not detected. Means with same small letters across the row were not significantly different ($p < 0.05$). Means with same capital letters down the column were not significantly different ($p < 0.05$). Means±SD were from triplicate measurements

Table 4. Physical appearance of guavas stored at 20°C

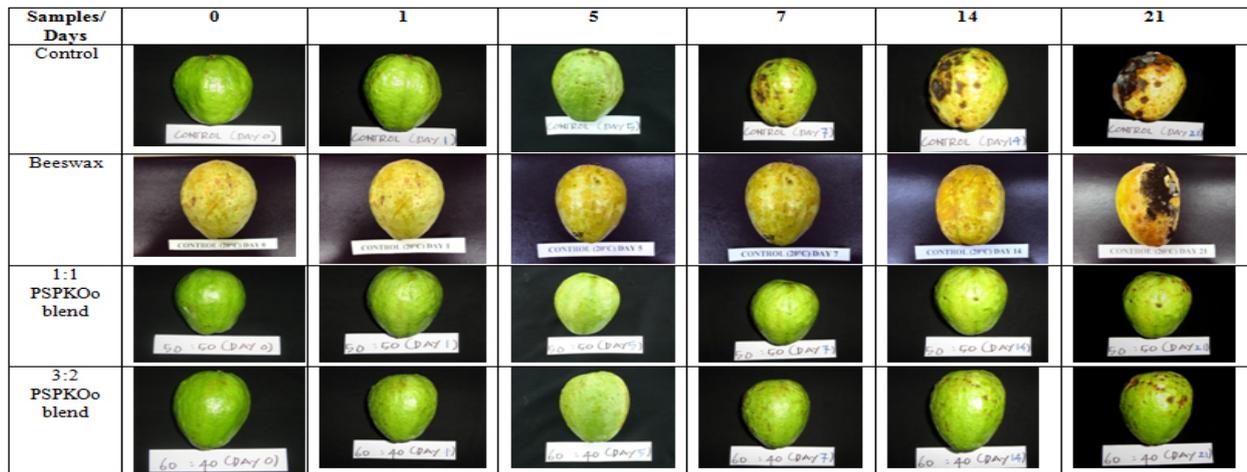
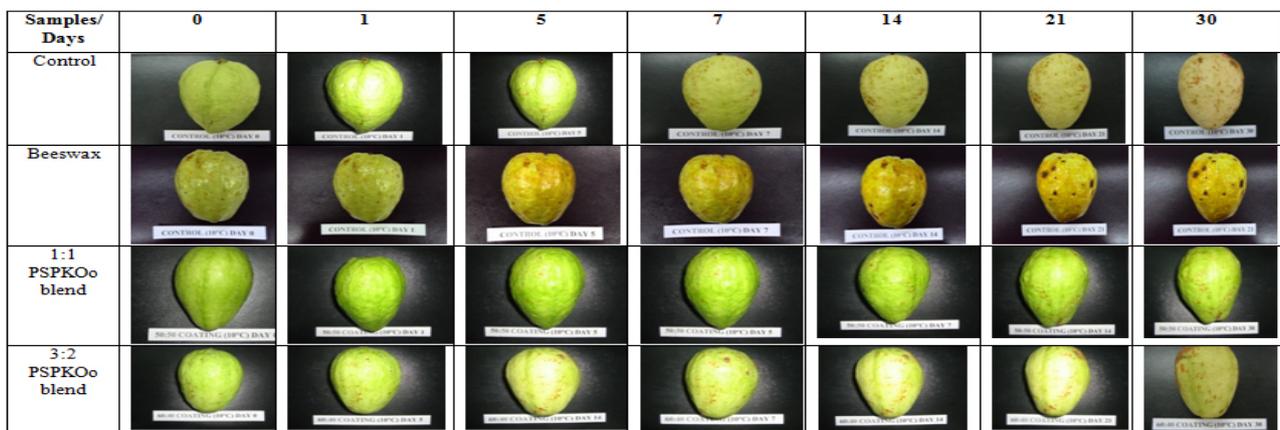


Table 5. Physical appearance of guavas stored at 10°C temperature



(Figure 7). Beeswax coating gave a higher decrease in green colour of guava for both storage temperatures at days 21 compared to PSPKOo coating (Figure 8). The highest drop was from day 21 to 30 by 69.04% at 20°C storage. This could be due to the beeswax coating being not effective in delaying the ripening of mature guava compared to PSPKOo blend coating.

The yellowness of guava is shown in Figure 8 (a and b). Generally the yellowness increased with storage time for both storage temperatures due to ripening of fruits. The yellowness of uncoated guava increased significantly ($p < 0.05$) starting from day 5 at 20°C storage. For 20°C storage, beeswax increased the yellowness by 5.13% compared to 3:2 PSPKOo blend at the end of the storage (day 21). However,

at the end of 10°C storage (day 30), there was no difference ($p > 0.05$) for all guava treated samples.

Microstructure of coated guavas surface

In order to study the homogeneity of coating distribution on the guava surface, the coated samples with beeswax, 1:1 and 3:2 PSPKOo blends were selected to be microscopically studied. The micrographs were obtained by Field Emission Scanning Electron Microscope (FESEM) of a radial profile for the guava slice surface. The results were analysed to quantify guava surface and cross sections properties that were effectively covered by the beeswax and PSPKOo blends. Figure 9 (a, b and c) shows selected micrographs taken for the different

samples coated with PSPKOO blends and beeswax.

It was observed that samples coated with 1:1 PSPKOO blend showed uniform coating distribution, since it was impossible to see any non-coated cellular structure while pores were not observed in these coated samples. The higher percentage of covered surface relates to the higher water vapour resistance which slowed respiration process as observed in Figures 2 and 3. This indicated that the extensibility of the liquid dispersion on the covered sample surface plays an important role in limiting water migration from the samples (Villalobos-Carvajal *et al.*, 2009). The better barrier properties to water transport of the coating obtained from PSPKOO blends dispersions were explained by both, the extensibility of the liquid on the guava surface and the formation of larger lipid aggregates on the coating surface, all of which limited water transfer more effectively. For cross-sections, coating with formulations beeswax, 1:1 and 3:2 were applied by simple rubbing. The final thickness of coatings applied by rubbing could be estimated from micrographs and it ranged from 10 to 50 μm . The higher cohesiveness for both PSPKOO blends (as discussed in Table 1) increased adhesion to the sample surface.

Physical appearance

The physical appearances of guavas are shown in Tables 4 and 5 for 20°C and 10°C storage, respectively. Generally, for both storage temperatures the PSPKOO blends resulted in better appearance when compared to beeswax coating and uncoated fruits. For ambient storage (20°C), the uncoated guavas showed the appearance of black spots at day 7 while the other coatings showed black spots at day 14. Guava stored at chilled temperature (10°C) could retain acceptable appearance until day 30. However, the black spots started to appear from day 14 for beeswax coating. The beeswax colour was influenced by the skin colour of guava as the coating changed the colour of guava into yellow. Hence, the guava coated with beeswax turned to undesirable colour.

Conclusions

Beeswax had the highest SMP and lowest in cohesiveness of blends compared to 1:1 PSPKOO blend. Hence it was not effective in slowing the respiration of guava. Generally, lower storage temperature of guava at 10°C slowed the increasing of CO₂ and maintained better glossiness of guava compared to storage at 20°C. The 1:1 PSPKOO blend slowed the decline of O₂ significantly by 54.66% and 9.60% while maintaining the glossiness of guava by 20.89% and 9.61% for 20°C and 10°C storage

temperatures at day 21, respectively. There were no significant differences between 1:1 and 3:2 PSPKOO blend for weight loss, ethylene gas, firmness, lightness, greenness and yellowness of guava for both storage temperatures at day 21. For both storage temperature both 1:1 and 3:2 PSPKOO blends resulted in better appearance of guava when compared to beeswax coating and uncoated fruits. Generally for both storage temperatures both PSPKOO blends showed a potential as commercial coating in prolonging the postharvest-life and preserving the appearance of guava.

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