



STORAGE STABILITY OF KUINI POWDER IN TWO PACKAGING ALUMINUM LAMINATED POLYETHYLENE AND POLYETHYLENE TEREPHTHALATE

(Kestabilan Penyimpanan Serbuk Kuini dalam Dua Pembungkusan Polietilena Berlapis Aluminum dan Polietilena Tereftalat)

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Abstract

Kuini fruit is a type of tropical mango with a strong aroma. It has yellow-orange colored pulp with a green peel. Due to its short life and seasonal harvest, kuini can be converted into powder, which is more stable and versatile to be added later as a food ingredient. The powder needs to be stable during storage prior to consumption or usage. In this study, the storage stability of spray-dried kuini powder is investigated. The kuini powder was placed in two different packaging materials: aluminum laminated polyethylene (ALP) and polyethylene terephthalate (PET). Then, it was stored under accelerated conditions (48 ± 1 °C, $90 \pm 1\%$ RH). The physicochemical properties of packaged powder were evaluated each week for a total of 7 weeks and included color, hygroscopicity, moisture content, water activity, degree of caking, flowability, water solubility index, and carotenoid. Our results show that after 7 weeks in storage, kuini packaged in ALP pouches has better properties such as lower moisture content (13.33), water activity (0.43), and hygroscopicity (23.37), when compared to PET packaging (24.77 moisture content, 0.50 water activity, and 28.00 hygroscopicity). These properties have also influenced an increase in caking and presented difficulties in solubilization when packaged in PET. In addition, the stored kuini powder packaged in PET pouches showed a greater color difference (9.40) and lower carotenoid content ($16.90 \mu\text{g/g}$), when compared to what was stored in ALP, i.e. it was more stable. From its physicochemical properties, it can be concluded that ALP is better than PET in protecting the stored powder from degradation. Hence, when compared to PET, ALP is more suitable as a packaging material for kuini powder.

Keywords: packaging; powder, storage stability, physicochemical properties, kuini

Abstrak

Buah kuini adalah sejenis mangga tropika dengan aroma yang kuat. Ia mempunyai pulpa berwarna kuning-oren dengan kulit hijau. Oleh kerana jangka hayatnya yang pendek dan ianya buah bermusim, kuini boleh diubah menjadi serbuk, yang lebih stabil dan serbaguna untuk ditambahkan sebagai bahan makanan. Serbuk perlu stabil semasa penyimpanan sebelum penggunaan atau penggunaan. Dalam kajian ini, kestabilan penyimpanan serbuk kuini kering semburan disiasat. Serbuk kuini diletakkan dalam dua bahan pembungkusan yang berbeza: polietilena berlapis aluminium (ALP) dan tereftalat polietilena (PET). Kemudian, ia disimpan dalam keadaan dipercepat (48 ± 1 °C, $90 \pm 1\%$ RH). Sifat fizikokimia serbuk yang dibungkus dinilai setiap minggu

selama 7 minggu dan termasuk warna, higroskopian, kandungan kelembapan, aktiviti air, tahap kek, aliran, indeks kelarutan air, dan karotenoid. Hasil kajian kami menunjukkan bahawa setelah penyimpanan selama 7 minggu, kuini yang dibungkus dalam bungkusan ALP mempunyai sifat yang lebih baik seperti kandungan lembapan yang lebih rendah (13.33), aktiviti air (0.43), dan higroskopian (23.37), jika dibandingkan dengan pembungkusan PET (kandungan air 24.77, 0.50 aktiviti air, dan 28.00 higroskopian). Sifat-sifat ini juga mempengaruhi peningkatan kek dan menunjukkan kesukaran dalam larutan ketika dibungkus dalam PET. Di samping itu, serbuk kuini yang disimpan dalam bungkusan PET menunjukkan perbezaan warna yang lebih besar (9.40) dan kandungan karotenoid yang lebih rendah (16.90 $\mu\text{g/g}$), jika dibandingkan dengan apa yang disimpan di ALP, iaitu lebih stabil. Dari sifat fizikokimia, dapat disimpulkan bahawa ALP lebih baik daripada PET dalam melindungi serbuk yang tersimpan dari degradasi. Oleh itu, jika dibandingkan dengan PET, ALP lebih sesuai sebagai bahan pembungkus untuk serbuk kuini.

Kata kunci: pembungkusan, serbuk, kestabilan simpanan, sifat fizikokimia, kuini

Introduction

Kuini fruit is a type of tropical mango with a unique aroma and a green outer part. It is rich in nutrients and it provides about 83 kcal per 100 g of water, with 23 mg per 100 g of vitamin c, and with about 1888 g of carotenes content [1, 2]. Kuini is an excellent source of vitamins c and a [3]. It has been reported to contain the following isoflavones: daidzein and genistein [4]. Low-temperature storage is a common way to extend storage life as well as lowering the respiration rate and production of ethylene, which makes for the fresh consumption of kuini fruit [5]. Kuini is currently an underutilized fruit in Malaysia. The bioactivity of its flesh and peel were investigated to better assess its economic potential [6]. It can also be fermented [7] and added with probiotics as a functional juice drink [8].

Due to its seasonal nature and short shelf life, it can be converted into powder to have a longer shelf life from spray-drying, which is a common method [9]. Spray-drying transforms feed from a liquid into powder form [10, 11]. Spray-drying has been employed in the conversion of many high-sugar rich fruits into various types of fruit powder. Spray-drying with maltodextrin, which acts as carrier to prevent stickiness, which can be seen in production of *terung asam*, Sarawak pineapple, *cempedak*, and papaya fruit powder [12–15]. It was reported that maltodextrin enhances the properties of powders by developing the following characteristics: lower hygroscopicity and better flow ability [16].

Packaging materials for powders are essential, because they protect it during handling and storage. Pua et al. [17] reported that accelerated storage involving high humidity and temperatures such as 90% relative

humidity (RH) and 38 ± 1 °C can be used to determine moisture ingress and storage time quicker. Kumar and Mishra [18] conducted a storage study of mango soy fortified yogurt powder in aluminum laminated polyethylene (ALP) and high-density polypropylene (HDPP) pouches. ALP is considered as a laminate and metallized film. The lamination of aluminum films binds aluminum foil together with paper or plastic such as polyethylene or polypropylene to improve its barrier properties [19]. Lamination of aluminum to plastic or paper enables heat sealability, provides an excellent barrier for light, and reduces the permeability of oxygen [20]. The individual components of ALP are recyclable. PET is a type of polyesters formed by the reaction between dimethyl terephthalate and ethylene glycol [19]. PET provides a good barrier against gases, moisture, heat, mineral oils, solvents, and acids [23]. ALP has a water vapor transmission rate (WVTR) of 1.21×10^{-6} kg/m²/day at 38 °C, 90% RH; whereas, the water vapor transmission rate of PET packaging material of 17 μm was approximately 2.0×10^{-6} kg/m²/day at 38 °C and 90% RH.

This study determines the storage stability of kuini powder using two different packaging materials: ALP and PET, which were used to determine the physicochemical properties under accelerated storage for a total of 7 weeks. The physicochemical properties of stored powder were analyzed and included color, hygroscopicity, moisture content, water activity, degree of caking, water solubility index, and carotenoid content.

Materials and Methods

Materials: Fruit samples

The kuini fruit (*Mangifera Odorata*) was purchased from a local market located in Selayang, Malaysia (Figure 1). The fruit samples were selected based on roundness and each with length of 9-12 cm, diameter of 5-9 cm, no bruising, and a strong odor. The kuini was vacuum-packed and placed in a freezer at -20°C prior to usage. It was then transferred to a 4°C refrigerator and thawed at room temperature for 2 hours before the juice was extracted.



Figure 1. Fresh kuini fruit

Preparation of kuini juice

The kuini fruit were peeled and deseeded. The kuini pulp were blended in a high-speed blender (Warring, USA), and then diluted with a water 1:2 to a total soluble solids (TSS) content of 12°Brix. The kuini juices were then filtered using filter cloth.

Spray-drying of kuini juice

Before spray-drying, 20% (w/w) maltodextrin was added into kuini juice (300 g), and the mixture was homogenized using prepared spray-drier feed (Ika, Germany). A mini spray-dryer (B-290, Büchi, Switzerland) was employed for spray-drying the kuini juice. The aspirator setting was set at 100%, nozzle speed at 5, and the air compressor was set at 40 nm. The spray-dryer was set with an inlet temperature of 160°C [15]. After the temperature was achieved, the spray-dryer feed was pumped into the spray-dryer drying chamber where it is atomized and dried. The kuini powder produced was then gathered in a collection vessel attached to the spray-dryer.

Accelerated storage of kuini powder

The kuini powders were separately packaged in ALP and PET pouches (80 mm x 70 mm). They were sealed using heat before being placed in a desiccator ($90\pm 1\%$ RH with saturated solution of ammonium sulfate) at $38\pm 1^{\circ}\text{C}$. The of kuini powder were then analyzed at 7 days intervals for up to 49 days [18].

Physicochemical analysis of kuini powder

Color

The color of the kuini powder was measured using a colorimeter (Hunter Associates Laboratory Inc, USA)[21] that was utilized via EasyMatch QV-ER. After calibration with the white and black tile, the sample cup with kuini powder was placed on the sample port, and L^* , a^* , b^* values were recorded. Total color difference was determined shown in the Equation 1 [17].

Hygroscopicity (HG)

Two grams of kuini powder was placed in a desiccator, which was pre-filled with a saturated solution of ammonium sulfate. After 1 week, the aluminum cups were weighed, and the hygroscopicity of powder was then calculated by as g of moisture per 100 g of dry solids, as in the Equation 2 [12].

Moisture content (MC)

Kuini powder was then weighed and dried in an oven (Memmert, Germany) at 105°C for 24 hours; after which, the sample powder was weighed [22]. The moisture content was calculated as in thr Equation 3.

Water activity (a_w)

A LabMaster Water Activity Meter was used to measure the water activity of the spray-dried powder [13].

Degree of caking (DC)

Kuini powder (3 g) was transferred into a sieve and shaken for 5 min. The weight of the powder remaining in the sieve was then measured [23]. The degree of caking (DC) was calculated using Equation 4.

Flowability (F)

A plastic funnel with a narrow stem was mounted exactly 2 cm above a piece of paper. Kuini powder, which flowed through the funnel and formed a powder

heap. The radius of the powder heap (circle) was then calculated, and the angle of repose was estimated, as in Equation 5 [24].

Water solubility index (WSI)

Kuini powder (1 g) was added with 10 mL of distilled water and then placed in a water bath at 37 °C for 30 minutes. It was then centrifuged for 10 minutes (Eppendorf, Germany) and the remaining supernatant collected and oven-dried for 5 hours at 105 °C. The water solubility index was calculated with Equation 6 [25].

Carotenoid content

Kuini powder (3 g) was added to 10 mL of distilled water. The mixture was held for 30 minutes, then another 20 mL of cold acetone was added before holding for another 15 minutes. It was then poured into a Büchner flask and filter in a vacuum. The extraction and filtration was repeated twice. Petroleum ethylene (20 mL) and one-third of the solution was poured into a

separatory funnel. Distilled water (300 mL) was added and then the colorless layer was discarded. This was repeated twice before being filtered through 15 g of sodium sulfate. The collected yellow pigment was next subjected to a rotary evaporator at 35 °C and then measured with a spectrophotometer at 450 nm [21]. The standard curve was plotted along the beta-carotene standard and with the following equation: $y = 0.0666x + 0.0752$, $R^2 = 0.985$.

Statistical analysis

All analyses were done in triplicate ($n = 3$). All results were put into a table. Mean and the standard deviation was determined for each analysis and analyzed using PASW Statistics 18 (ANOVA). Differences were considered statistically significant at $p \leq 0.05$.

$$\text{Total color difference} = \sqrt{(L_0^* - L^*)^2 + (a_0^* - a^*)^2 + (b_0^* - b^*)^2} \quad (1)$$

where L_0^* , a_0^* , b_0^* are lightness, redness, and yellowness values of week zero kuini powder and L^* , a^* , and b^* are the lightness, redness, and yellowness values for each week.

$$\text{Hygroscopicity} \left(\frac{g}{100g} \right) = \frac{\text{Final weight of sample (g)} - \text{Initial weight of sample (g)}}{\text{Initial weight of sample (g)}} \times 100g \quad (2)$$

$$\text{Moisture content (\%)} = \frac{\text{weight of initial powder (g)} - \text{weight of dry powder (g)}}{\text{weight of initial powder (g)}} \times 100\% \quad (3)$$

$$\text{Degree of caking} = \frac{\text{powder collected from the sieve}}{\text{initial weight of powder}} \times 100\% \quad (4)$$

$$\tan \theta = h / \left(r - \frac{1}{2\alpha} \right) \quad (5)$$

where, θ is defined as angle of repose, h is height of stem base (2cm), r is radius of the base of powder heap, and α is diameter of funnel stem.

$$\text{Water solubility index} = \frac{\text{weight of dried powder}}{\text{weight of original powder}} \times 100\% \quad (6)$$

Results and Discussion

Color

Color of food is a critical sensory attribute for product acceptance because it influences purchase intent and taste perception [26]. According to HunterLab [27], the higher the L* value, the brighter or whiter the sample is, and it is from black (0) to white (100). Figure 2a shows that the lightness (L*) value of kuini powder packaged in ALP and PET pouches under accelerated storage conditions for 7 weeks. Figure 2a also shows that the lightness (L*) value of kuini powder packed in ALP was reduced from 88.52±0.36 (week 0) to 84.89±0.94 (week 7), indicating that kuini powder on week 7 had a darker color when compared to week 0. Whereas for the PET packaging, the results showed that the degree of lightness (L*) of kuini powder was reduced steadily (week 6 = 85.26±0.64), and then followed by a larger reduction at week 7 (83.46±1.54). Color change with storage time was significantly affected by packaging material and storage time [18], where the ALP packaging had a better color based on L* value when compared to PET packaging. Hunter L, a, b values of mango soy fortified yoghurt powder decreased during accelerated storage and were significantly ($p < 0.01$) affected by packaging material and storage time. After storage for 49 days, a greater color change occurred in MSFY powder packaged in HDPP when compared to ALP [28].

Figure 2b shows the variation in a* value of kuini powder packaged in ALP and PET pouches under accelerated storage conditions for 7 weeks. According to HunterLab [27], if a* value increased, which shows that the color will be more reddish. For ALP packaging at week 1, a* value were 0.47±0.12, and then increased to 0.65±0.12 at week 2; while the increase from week 2 to week 4, and week 4 to week 7 were insignificant ($p > 0.05$). PET packaging followed a similar trend as ALP, except for a major increase at week 7. This result agrees with Kumar et al. [18], who reported that mango soy fortified yogurt powder in ALP pouches have a significantly higher a* value when compared to HDPP

packaging, indicating that ALP better maintains the color of powder after 7 weeks of accelerated storage. According to Chauhan et al. [24], powder that was stored in an oven at temperature 40°C and with a relative humidity of 90% RH will have a higher a* value and a lower b* value.

Conversely, the b* value of kuini powders decreased (Figure 2c) and total color difference increased (Figure 2d) with storage time. These tables show that there is almost no difference between the packaging types. Wong and Lim [29] also reported that after storage of 7 weeks, there was a greater color change (56.30) in papaya powder stored under accelerated condition (38 °C, 90% RH) in PET when compared to ALP (16.22). This can be explained by the permeability of the packaging material to water vapor and oxygen. Moreover, residual air remaining in the package may cause oxidation, which led to color changes during storage.

Hygroscopicity (HG), moisture content (MC) and water activity (aw)

In this study, ammonium sulfate was used to create a high relative humidity for the kuini powder. The purpose of creating a high humidity environment for kuini powders is to test the ability of powder to absorb water [28]. Figure 3a describes the storage stability of hygroscopicity (HG) of kuini powder packaged in ALP and PET under accelerated storage conditions for 7 weeks. The hygroscopic percentages for kuini powder packaged in ALP pouches (22.37±1.16 g/100g) were increased but not as much as in PET pouches (28.00±1.60g/100g). This result agrees with Yu et al. [31], whereby spray-dried bovine colostrum powder had a higher degree of caking when packaged in ALP when compared to PET. This was probably due to ALP pouches providing a better barrier to water vapor and temperature [20]. Additionally, powder with high HG has a tendency to absorb moisture easily, which results in the stickiness of powder and eventually causes the powder to cake.

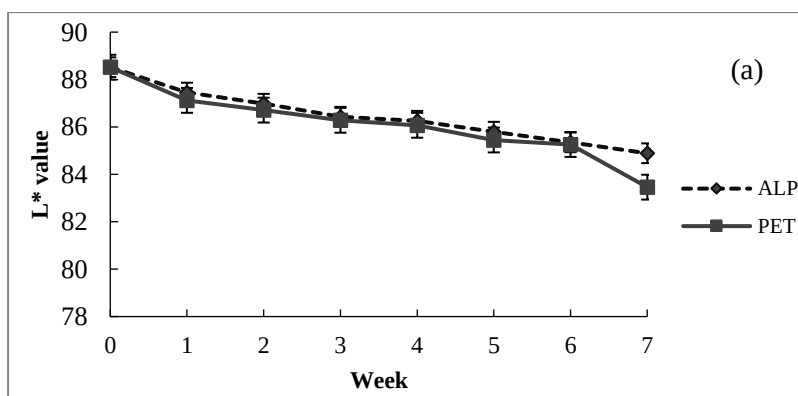
The kuini powder packed moisture content was 2.81 ± 0.74 at week 0. It was packed in ALP and PET and showed an increase in moisture content with an increase in storage time with the moisture content at 11.44% higher than ALP pouches after 7 weeks of storage (Figure 3b). The moisture uptake depends on the water vapor permeability of the packaging film [17]. ALP packaging had a better barrier for water permeability and the kuini powder were not high in moisture content.

The moisture gained by powders packaged in PET pouches was higher than in ALP pouches during the 90-day storage period, mainly due to the higher water vapor permeability of PET pouches, indicating that ALP pouches provided a better barrier to water vapor for SDBC powders [29] while Mridula et al. [32] also reported the moisture gained by two sattu samples in laminated aluminum foil pouches was lower than in low density polyethylene pouches. This was probably due to the packaging used (PET) and it may not have provided an effective barrier against oxygen and water vapor [29].

The higher value of water vapor transmission rates for PET packaging showed that it had a greater permeability against moisture gained during storage. Wong and Lim [29] noted the moisture content of powder packaged in PET was double (13.28%) those packaged in ALP (6.38%) by the end of 7 weeks storage for papaya

powder. Aluminum foil thicker than $17 \mu\text{m}$ could be considered a total barrier against gases, moisture, and light. Aluminum foil with a thickness between $6\text{--}9 \mu\text{m}$ could not be regarded a total barrier and was also superior to other polymeric materials such as PET [17]. Further, the results obtained showed that papaya powder packaged in ALP with a thickness of $10 \mu\text{m}$ showed a tempered increase in water activity when compared to powder packaged in PET with a thickness of $17 \mu\text{m}$.

Kumar et al. [18] have reported that the moisture gain by powder packed in the HDPP pouches was greater than for ALP pouches. Figure 3c illustrates the change in water activity (a_w) for ALP and PET pouches under accelerated storage conditions for 7 weeks. Although powder packaged in either packaging showed an increase in water activity, the increase was greater for kuini powder in packaged in PET. At week 0, the water activity (a_w) in kuini powder was 0.24 ± 0.003 . After 7 weeks, the powder in ALP and PET packaging were 0.43 ± 0.00 and 0.50 ± 0.02 , respectively. Hence, they are each considered microbiologically stable [23]. Dak et al. [33] and Wong and Lim. [29] also reported that ALP showed a lessened increase in water activity when compared to HDPP and PET. Thus, ALP could be a more effective packaging material in the prevention of increases in water activity.



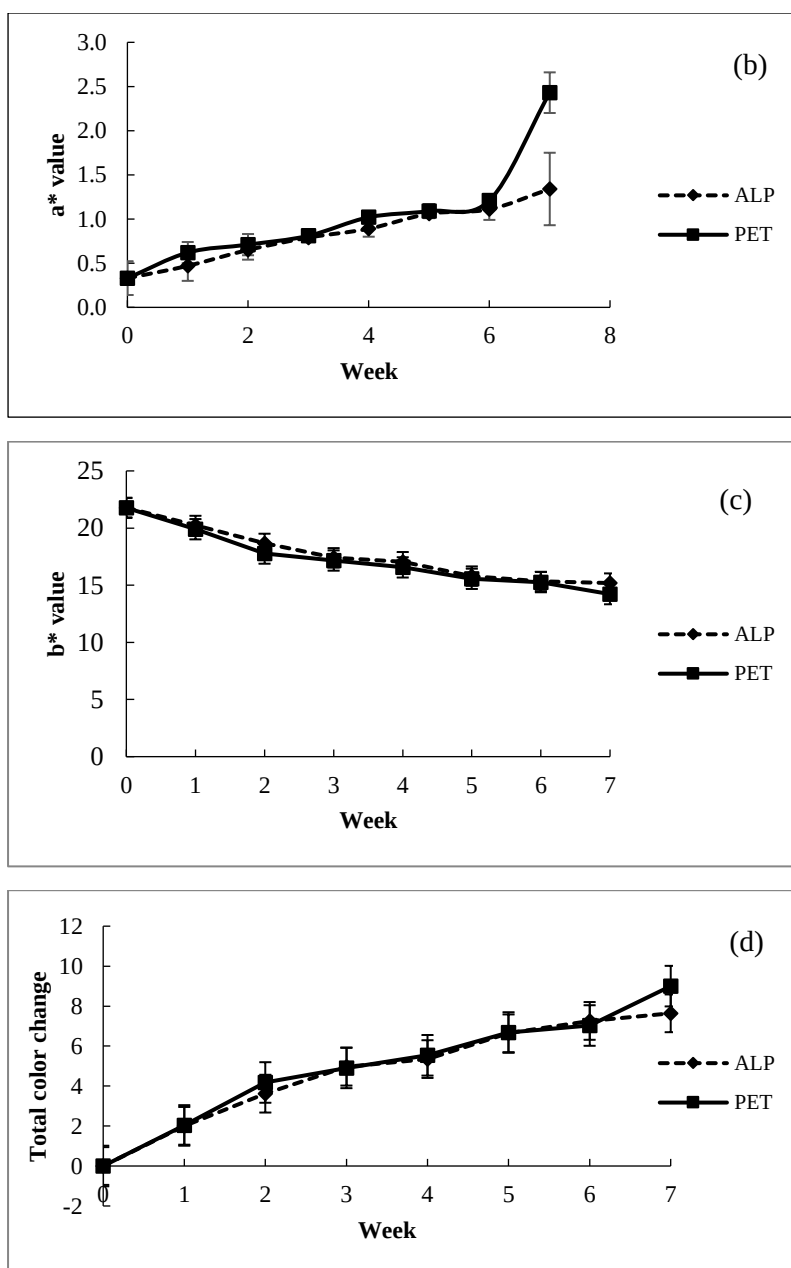


Figure 2. (a) L* value, (b) a* value, (c) b* value, and (d) Total color different of kuini powder packaged in ALP and PET pouches under accelerated storage conditions for 7 weeks

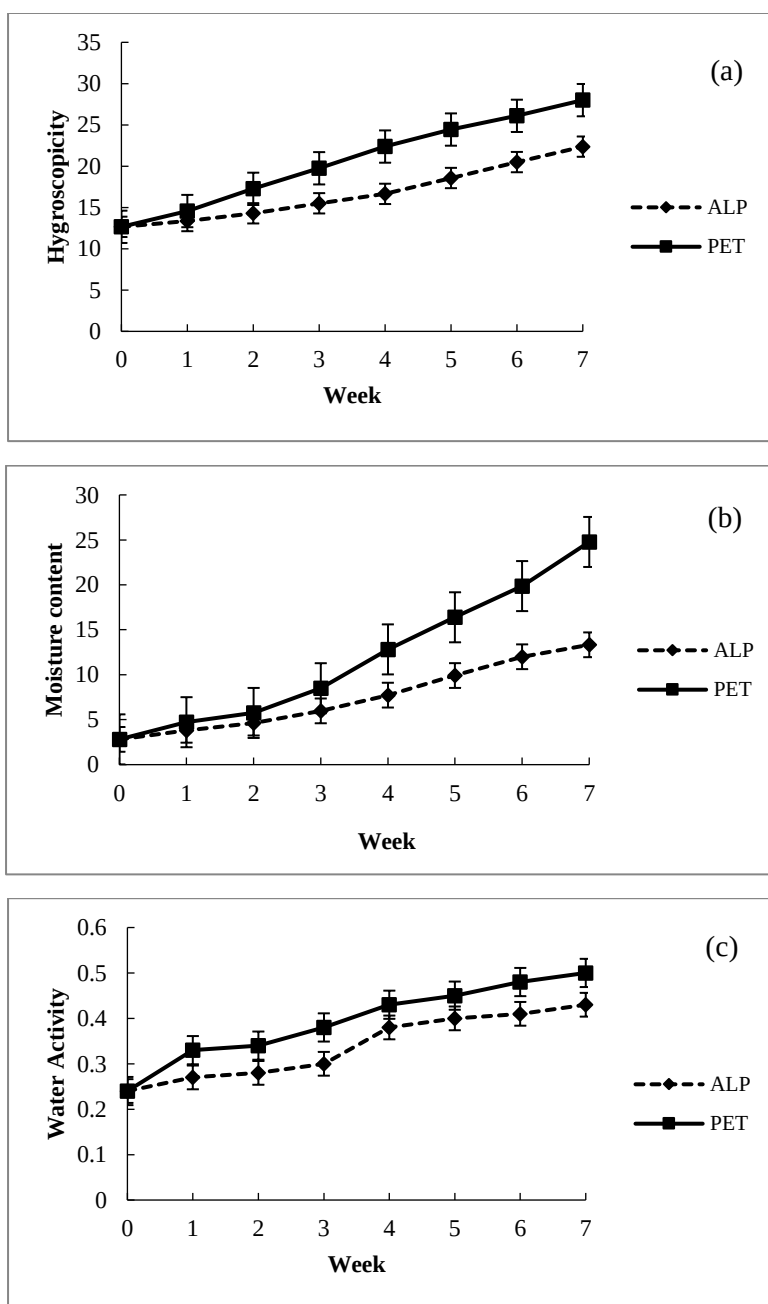


Figure 3. (a) Hygroscopicity, (b) moisture content, and (c) water activity (a_w) of kuini powder packaged in ALP and PET pouches under accelerated storage conditions for 7 weeks

Degree of caking, flowability, and water solubility index (WSI)

Figure 4a shows the variation in the degree of caking of kuini powder packaged in ALP and PET pouches under accelerated storage conditions for 7 weeks. The

difference between the initial week and the first week was not significant ($p > 0.05$); followed by a gradual increase and with the degree of caking increasing in ALP when compared to PET. After week 7, the degree of caking for ALP packaging was 9.95% and PET

packaging was 28.89%. ALP pouches had a greater barrier of moisture, which helps to prevent clumps from forming. According to Hui [34], the caking of powder may occur due to moisture absorption, crystallization of sugar components, and softening of the surface by heat.

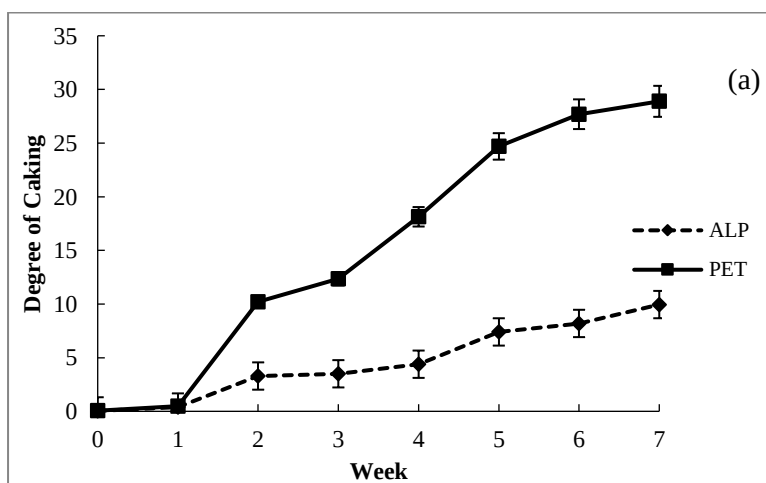
The angle of repose measures the angle of the heap's slope and indicates its flowability [35, 36]. Figure 4b describes the variation in flowability of kuini powder packaged in ALP and PET pouches under accelerated storage conditions for 7 weeks. Figure 4b shows that the angle of repose for ALP packaging had a lower value compared to PET packaging at week 7. The change in particle structure is attributed to moisture absorption during storage, because it increases the powder's cohesiveness and leads to a reduction in flowability [24]. Lai et al. [37] showed that the larger the mean particle size, the more difficult for the powder to flow, and the higher angle of repose.

Figure 4c shows the change in water solubility index (WSI) of kuini powder packaged in ALP and PET pouches under accelerated storage conditions for 7 weeks. Further, Figure 4c shows that the WSI for kuini powder packaged in ALP pouches was 73.33 ± 1.72 at week 0. ALP packaging showed that on week 7 that the WSI of the powder was 11.66% higher than the powder packaged in PET.

Carotenoid content

The β -carotene is a major dietary precursor of vitamin A [38]. Figure 5 describes the variation in carotenoid content for kuini powder packaged in ALP and PET pouches under accelerated storage conditions for 7 weeks. Generally, a decrease of carotenoid content was observed when the storage time increased. The carotenoid content of kuini powder in each packaging showed no significant difference ($p > 0.05$) from week 0 to week 5. However, after week 5, the carotenoid reduction was found to be more prominent in kuini powder packaged in PET. At the end of storage (week 7), the kuini powder in ALP and PET were 76.9% and 65.5%, respectively. Kołakowska and Sikorski [39] showed that temperature can cause faster decomposition of alpha- and beta-forms than other carotenoids. In our study, the powders were stored at 38 °C, which is also the main influence on carotenoid loss.

Hymavathi and Khader [40] reported significant differences between metallized polyester/polyethylene (MPP) and polyester poly (PP) packaging in the loss of b-carotene in mango powder during storage. The percent loss of b-carotene was higher in powder packaged in PP pouches compared to MPP pouches throughout the storage period due to higher oxygen permeability of PP pouches compared to MPP. Wong and Lim reported [27] that β -carotene was degraded from an initial of 1.83 $\mu\text{g/g}$ to 0.95 $\mu\text{g/g}$ and 0.16 $\mu\text{g/g}$ for powder stored in ALP and PET, respectively.



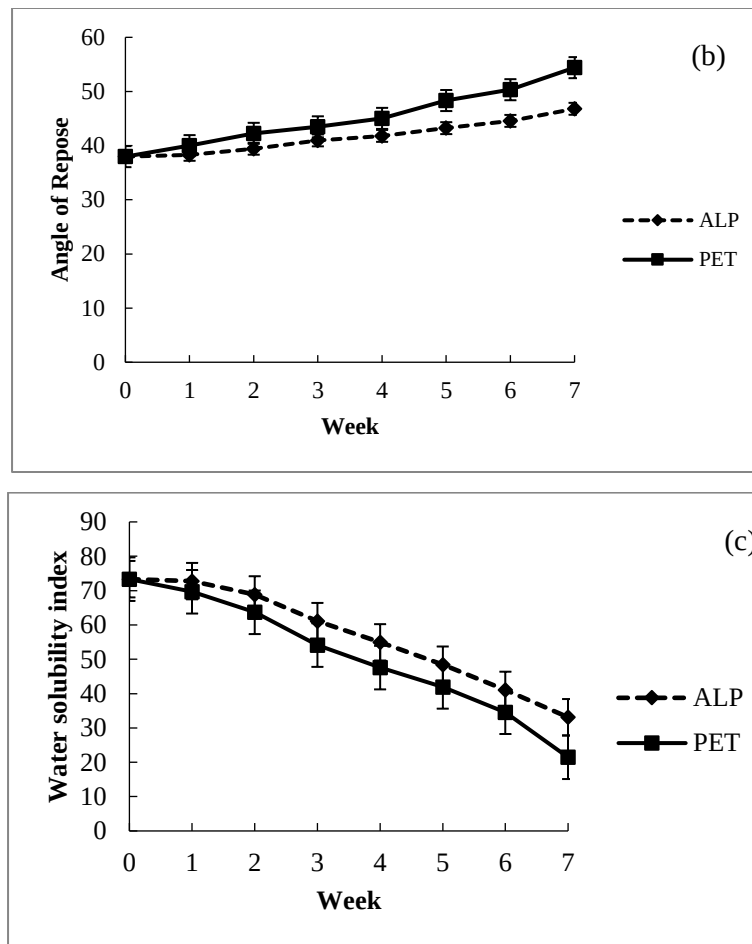


Figure 4. (a) Degree of caking, (b) flowability, and (c) water solubility index (WSI) of kuini powder packaged in ALP and PET pouches under accelerated storage conditions for 7 weeks

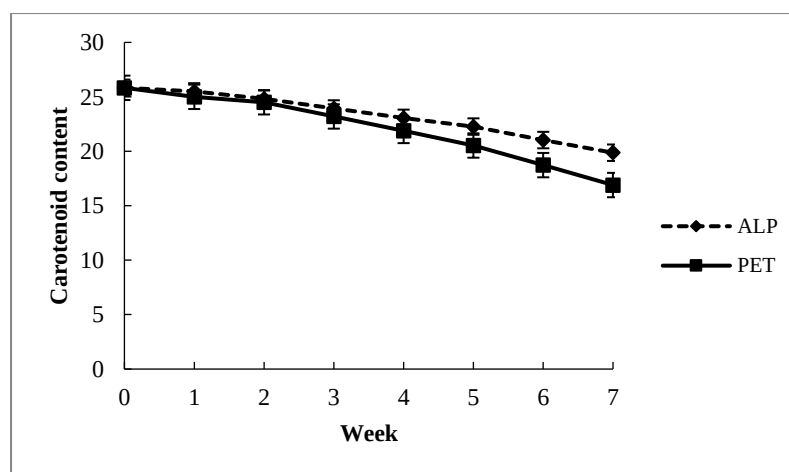


Figure 5. Variation in carotenoid content of kuini powder packaged in ALP and PET pouches under accelerated storage conditions for 7 weeks.

Conclusion

Kuini fruit (*Mangifera odorata*) is an aromatic tropical fruit that is yellow in color in its pulp and has a green peel. In this research, the storage stability of kuini powder in ALP and PET under accelerated storage conditions at temperature 38 ± 1 °C and relative humidity 90% RH for 7 weeks. The physicochemical analyses were carried out to determine the packaging material properties. With accelerated storage, powder in both packaging types had increases in water activity, moisture content, flowability, degree of caking, and hygroscopicity; while showing decreases in WSI and carotenoid content. ALP is better than PET in retaining moisture content, WSI, water activity, carotenoid content, flowability, degree of caking, and hygroscopicity. This study has shown that ALP packaging has better protection in terms of stability. The comparison can serve as guidance in packaging selection for fruit powder.

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