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Storage stability of spray-dried papaya (*Carica papaya* L.) powder packaged in aluminium laminated polyethylene (ALP) and polyethylene terephthalate (PET)

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Abstract

The physiochemical characteristics and microbiological study of spray-dried papaya powder kept in aluminium laminated polyethylene (ALP) and polyethylene terephthalate (PET) at accelerated storage (38 ± 2°C, 90% relative humidity (RH)) for 7 weeks were evaluated. The final water activity (A_w) of the spray-dried papaya powder did not exceed 0.6 for both packaging materials, which showed that the powder was shelf-stable. The overall adsorbed moisture of spray-dried powder was significantly ($p<0.05$) different for both packaging materials, whereby the moisture content of powder packaged in PET was doubled (13.28%) of those packaged in ALP (6.38%) by the end of 7 weeks storage. A larger increase of hygroscopicity was observed for powder packaged in PET (37.00%) compared to ALP (32.98%). Powder packaged in ALP had good solubility (85.19-97.14%) with storage time, while less than 80.00% solubility for powder kept in PET after 4th week of storage. The flowability of powder was significantly ($p<0.05$) decreased for both packaging materials upon storage. The degree of caking for powder packaged in PET was doubled (86.45%) than of 42.44% (ALP). β-carotene was degraded from an initial of 1.83 µg/g to 0.95 µg/g and 0.16µg/g for powder stored in ALP and PET, respectively. Powder packaged in ALP was microbiological safe as it had a log CFU/ml of 2.67. The results indicated that the powder packaged in ALP was with acceptable qualities and stability. Thus, ALP packaging with storage conditions of 38°C and RH 90% was better suited for keeping spray-dried papaya powder.

Introduction

Papaya (*Carica papaya* L.) is a herbaceous fruit crop belonging to the Caricaceae family (Anuara, 2008). It is believed to originate from the tropics of Americas, specifically from the Southern Mexico, Central America and Northern South America (Klein, 2009). However, it is now widely grow in most tropical countries such as India, South Africa, Sri Lanka, Philippines and Malaysia (Anuara, 2008). Papaya is also called papaw or pawpaw in Africa, Sri Lanka, United Kingdom and Australia; betik in Malayisia; Mamao in Brazil; papali in India; du du in Vietnam; tree melon in Europe and mu gua in China (Oliveira and Vitoria, 2011; Adam *et al.*, 2014).

The dehydration method is a good choice for fruit preservation as it reduces moisture in fruits, which inhibits the growth of microorganism and enzymatic activity, (Jangam *et al.*, 2014; Mishra *et al.*, 2014). Spray drying is one of the techniques used extensively for the production of heat-sensitive fruits and vegetables (Kha *et al.*, 2010; Wong and Chong, 2015). Fruit juice powders have many benefits and economic potentials over the liquid counterparts such as reduced weight or volume, reduced packaging, easier handling, transportation and much longer shelf life (Fazaeli *et al.*, 2012).

The enzyme liquefaction process increases fluidity by breaking down the fruit structure into smaller particles, which eases the separation process (Mutlu *et al.*, 1999; Vaillant *et al.*, 1999). Dehydrated fruit powders require protection against ingress of moisture, oxygen and the loss of volatile flavouring and colour (Jaya and Das, 2005). Fruit powders are exposed to a wide range of environmental conditions such as light, temperature, humidity and oxygen that can trigger several reaction mechanisms which eventually leads to food degradation during storage and distribution (Pua *et al.*, 2008). Storage studies on drum-dried jackfruit powder has been reported by Pua *et al.* (2008) using ALP and metallized co-extruded biaxially oriented polypropylene (BOPP/MCPP) pouches under accelerated storage condition (38 ± 2°C with 50%, 75% and 90% RH) over a 12 week period. Jaya and Das (2005) predicted the shelf life of mango powder packaged in aluminium

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foil-laminated pouches stored under an accelerated storage environment (38 ± 2°C, 90% RH). Potter (1978) reported that accelerated storage involving high humidity and temperature such as 90% RH and 38 ± 2°C can be used to developed moisture and storage time relationship immediately.

Aluminium laminated polyethylene (ALP) is considered as laminates and metallized films. The lamination of aluminium films binds aluminium foil together with paper or plastic such as polyethylene or polypropylene to improve its barrier properties (Marsh and Bugusu, 2007). Lamination of aluminium to plastic enables heat sealibility of the packaging material. It also provides excellent barrier to light and reduce the permeability of oxygen (Abdel-Bary, 2003). The individual components of aluminium laminated polyethylene are recyclable. Polyethylene terephthalate (PET) is a type of polyesters formed by the reaction between dimethyl terephthalate and ethylene glycol (Marsh and Bugusu, 2007). PET provides a good barrier towards gases, moisture, heat, mineral oils, solvents and acids (Hui, 2006).

In this study, papaya powder was produced by adding maltodextrin to the aqueous papaya extract obtained after liquefaction with Pectinex® Ultra SP-L followed by spray drying. The stability of spray-dried papaya powder packaged with aluminium laminated polyethylene (ALP) and polyethylene terephthalate (PET) pouches were studied during accelerated storage (38 ± 2°C with 90% RH) over a 7 week period.

Material and Methods

Materials

Papaya (*Carica papaya* L.) used in this study was purchased from a supermarket in Cheras, Kuala Lumpur, Malaysia. Pectinex® Ultra SP-L was obtained from Novozymes Switzerland AG, Dittingen, Switzerland. Maltodextrin (DE 10-12 was obtained from V.I.S Foodtech ingredient supplies Sdn. Bhd. (Selangor, Malaysia).

Two flexible packaging materials: (I) aluminium laminated polyethylene (ALP) made from 12 µm polyethylene terephthalate (PET) and 70 µm linear low density polyethylene (LLDPE) laminated with 7 µm aluminium (Al); and (II) polyethylene terephthalate (PET) made from 12 µm polyethylene terephthalate (PET), 9 µm silicon oxide SiOx, 15 µm nylon (NY) with 65 µm random copolymer polypropylene (R-CPP). Both type of packaging materials used were purchased from Good & Well Trading Sdn. Bhd. (Selangor, Malaysia). Unit pouches of ALP and PET measuring 9.0 cm x 15.0 cm with a thickness of 10 µm and 8.0 cm x 11.0 cm with a thickness of 17 µm, respectively were used for holding 15 g of the spray-dried papaya powder.

Preparation of spray-dried papaya powder

The papaya fruits were cleaned, peeled, deseeded and cut into small pieces. They were then made into puree through blending at high speed using a blender (Model BL 335, Kenwood, Japan) for 30 seconds until a homogenous puree was obtained. Pectinex® Ultra SP-L (1% v/w) was added into the homogenised papaya puree. The mixture was incubated for 2 hours at 50°C and 100 rpm using a water bath (Memmert Lab Companion, Germany). The enzyme in the treated puree was deactivated at 95ºC for 5 minutes. The liquefied papaya puree was then sieved by using a muslin cloth to yield an aqueous papaya extract (Tan, 2014).

The obtained aqueous papaya extract was then added with 20% (w/w) maltodextrin (DE 10-12) at a ratio of 1:1. The inlet temperature, aspirator rate, pump rate, air flow rotameter and the pneumatic nozzle cleaner speed of the spray dryer (Model B-290, Büchi, Switzerland) were kept constant at 150°C, 100%, 20%, 40 mm and 6, respectively (Wong *et al*., 2015). The spray-dried papaya powder obtained was then stored in either ALP or PET pouches.

Assessment of stability of spray-dried papaya powder

The papaya powder (15 g) packed in ALP and PET pouches were heat sealed using a pulse sealer. Two desiccators (30 cm) with 90 ± 2% RH were prepared using saturated salt solution of potassium nitrate (KNO_3). Twenty four pouches (three batches of spray-dried papaya powder) from each packaging material were stored in each desiccator. The desiccators were placed in two incubators maintained thermostatically at 38 ± 2°C under dark conditions. These conditions are often used for storage study of dry powder as indicated by Pua *et al*. (2008); Kumar and Mishra (2004); Potter (1978). The changes of the physiochemical characteristics and microbiological test were evaluated at 0, 1, 2, 3, 4, 5, 6 and 7 weeks intervals. Each determination was triplicates form three batches of spray-dried papaya powder.

Water activity

The water activity (A_w) of the samples was measured by using a water activity meter (AquaLab Pre, Decagon Devices, USA) at 25 ± 1°C (Quek *et al*., 2007).

Moisture content

The moisture content of the powder was

determined based the method from AOAC (1984).

Water solubility index (WSI)

The WSI was determined according to Cano-Chauca *et al.* (2005) with slight modifications. One gram of spray-dried papaya powder was dissolved in 100 ml of distilled water. A 25 ml aliquot was then transferred to a pre-weighed aluminium dish and oven-dried at 105°C until a constant weight was obtained. The solubility was calculated as the weight difference.

Hygroscopicity

Hygroscopicity of the spray-dried papaya powder was determined according to the method by Cai and Corke (2000) with some modifications. One gram of each sample was weighed in Petri dishes. The Petri dishes were placed in a desiccators containing a saturated solution of ammonium sulphate, $(NH_4)_2SO_4$ with RH of 90%. After one week, samples were weighed and hygroscopicity was expressed as g of adsorbed moisture per 100 g dry powder (g/100 g).

Degree of caking

The degree of caking was determined according to the method by Ramachandran *et al.* (2014). Five gram of spray-dried papaya powder was weighed and put into a sieve. The % degree of caking was calculated as the weight difference.

Flowability

The flowability of powder was determined using the method described by Chauhan and Patil (2013). A funnel with a narrow stem was mounted 20 mm above a piece of paper. Spray-dried papaya powder was poured into the funnel and allowed to pass through the funnel into a fine stream to form a conical heap until the top of the powder heap touched the end of the funnel stem. The base of the powder heap was outlined with a pencil and the powder was removed. The angle of repose was calculated by the formula as follows:

$$\text{Tan } \theta = \frac{\text{height of stem base (mm)}}{\text{(radius of base of powder heap (mm)} - \text{radius of funnel stem (mm)}}$$

Where θ = angle of repose

β-carotene content

The method used for carotenoid extraction was adapted from Kha *et al.* (2010) with some modifications. β-carotene solution (5-25 µg/g) was used to construct the standard curve. Total β-carotene content of the spray-dried papaya powder was spectrophotometrically determined at 450 nm and expressed based on β-carotene equivalents (µg/g powder).

Colour characteristics

The colour of spray-dried papaya powder was measured using Hunter Laboratory Colorimeter (Model SN 7877, Ultra-scan, Hunter Associates Laboratory, Virginia). L, a and b values of the spray-dried papaya powder were measured. The total colour difference (ΔE) was calculated using the following equation:

$$\text{Difference in colour } (\Delta E) = \sqrt{(L_i - L_t)^2 + (a_i - a_t)^2 + (b_i - b_t)^2},$$

where L_i, a_i, and b_i are the initial L, a, and b values for the spray-dried papaya powder and L_t, a_t, and b_t are the corresponding values for stored spray dried papaya powder.

Total plate count

The total plate count method was adapted from Lu *et al*. (2011). Total viable colonies formed were counted and the total number of viable cells was calculated as:

$$\text{Number of viable cells/mL} = \frac{\text{no of Colonies}}{\text{volume of inoculum x dilution factor}}$$

Statistical Analysis

All the experiments were conducted in triplicate and results were presented as mean values with standard deviations. Different means values were analyzed using Tukey's test, one-way analysis of variance (ANOVA) and least significant difference (LSD) at p<0.05 was calculated using Minitab software version 17.0 (Minitab 17, Pennsylvania, USA).

Results and Discussion

Water activity

From Table 1, the water activity of spray-dried papaya powder significantly (p<0.05) increased during storage from an initial of 0.16±0.00 A_w to 0.28±0.01 Aw for ALP and 0.48±0.01 A_w for PET, respectively. The results for A_w of the spray-dried papaya powders were consistent with the findings carried out by Dak *et al.* (2014). They stated that the A_w of the oven dried and drum dried apple peel powders increased with the increased of storage time. PET showed a greater degree of increase in water activity compared to ALP (Table 1). This shows that ALP is a more effective packaging material in preventing the increase of water activity.

Other than that, it was found that the aluminium

Table 1. Water activity, moisture content and water solubility index of spray-dried papaya powder packaged in ALP and PET stored at 38 ±2°C for 7 weeks

Storage time (Week)	Water activity (A_w)		Moisture content (%)		Water solubility index (%)	
	ALP	PET	ALP	PET	ALP	PET
0	0.16 ± 0.00^{aA}	0.16 ± 0.01^{aA}	2.40 ± 0.05^{aA}	2.40 ± 0.05^{aA}	97.14 ± 0.47^{aA}	97.14 ± 0.47^{aA}
1	0.17 ± 0.01^{bA}	0.24 ± 0.02^{bB}	2.56 ± 0.03^{aA}	4.56 ± 0.09^{bB}	94.30 ± 0.37^{bA}	94.30 ± 0.46^{bA}
2	0.19 ± 0.01^{bA}	0.28 ± 0.01^{cB}	3.47 ± 0.04^{bA}	6.54 ± 0.27^{cB}	92.97 ± 0.60^{cA}	92.91 ± 0.73^{cA}
3	0.21 ± 0.01^{cA}	0.30 ± 0.01^{cB}	3.93 ± 0.07^{cA}	8.89 ± 0.10^{dB}	92.50 ± 0.51^{dA}	81.79 ± 0.47^{dB}
4	0.25 ± 0.00^{dA}	0.35 ± 0.02^{dB}	4.50 ± 0.07^{dA}	9.65 ± 0.13^{eB}	90.86 ± 0.26^{eA}	79.48 ± 0.47^{eB}
5	0.27 ± 0.01^{eA}	0.40 ± 0.02^{dB}	5.19 ± 0.17^{eA}	10.25 ± 0.48^{eB}	88.83 ± 0.19^{efA}	76.12 ± 0.20^{fB}
6	0.27 ± 0.01^{eA}	0.46 ± 0.02^{eB}	6.01 ± 0.08^{fA}	11.19 ± 0.20^{fB}	86.99 ± 0.68^{fA}	71.65 ± 0.54^{gB}
7	0.28 ± 0.01^{eA}	0.48 ± 0.01^{eB}	6.38 ± 0.03^{gA}	13.28 ± 2.28^{gB}	85.19 ± 0.67^{gA}	69.12 ± 0.28^{hB}

^{a}Means ± standard deviations with different superscripts within a column are significantly different at $p<0.05$.
^{A}Means ± standard deviations with different superscripts within a row are significantly different at $p<0.05$.
Each value represents triplicate analyses of the samples (n=3).

foil above 17 µm in thickness could be considered as a total barrier towards gases, moisture and light. Aluminium foil between 6 to 9 µm which could not be regarded as a total barrier was also more superior to other polymeric materials such as PET (Pua *et al*., 2008). This statement was further supported by the results obtained whereby papaya powder packaged in ALP with a thickness of 10 µm, showed a lesser extent of increase in water activity as compared to powder packaged in PET with a thickness of 17 µm. Hence, ALP could be regarded as a better barrier in preventing the increase of water activity in spray dried papaya powder as compared to PET.

The A_w values for the spray-dried papaya powders were less than 0.6 (Table 1), and can thus be considered to be quite stable against microbial, browning, hydrolytic reaction, lipid oxidation, auto-oxidation and enzymatic activity (Caliskan and Dirim 2013). According to Quek *et al*. (2007), high water activity in products leads to shorter shelf life due to high free water for biochemical degradations.

Moisture content

The moisture content of spray-dried papaya powder packaged in PET significantly ($p<0.05$) increased about 5.5 times as compared to only 2.2 times increment for powder packaged in ALP by the end of 7 weeks storage (Table 1). Similar results were reported by Yu *et al.* (2013), whereby the moisture gained by the spray-dried bovine colostrums powder stored in PET was higher than those stored in ALP. This was probably due to the packaging used (PET) which may not have provided an effective barrier against oxygen and water vapour (Juliana *et al.*, 2013).

The moisture contents of the spray-dried papaya powders packaged in ALP in the present study were between 2.40 to 6.38 (Table 1). However, powders packaged in PET exhibited moisture contents above 10% after storage for 5 weeks. Moisture content below 10% is adequate to ensure that the fruit powder produced is microbiologically safe (Ng *et al.*, 2012).

Kumar and Mishra (2004) reported that the moisture content of mango soy fortified yoghurt powder during accelerated storage (38±1°C, 90±1% RH) was gradually increased when packaged in high-density polypropylene (HDPP) and ALP. Pua *et al.* (2008) suggested that the increased of moisture content for drum dried jackfruit powders packaged in both ALP and metallized co-extruded biaxially oriented polypropylene (BOPP/MCPP) over 12 weeks accelerated storage (38°C; 50%, 75% and 90% RH) was due to the migration of water vapour from storage environment into the packaging material.

According to Pua *et al.* (2008), the water vapour transmission rate of ALP packaging material which was laminated with 7 µm of aluminium was 1.21 x 10^{-6} kg/m^2/day, whereas the water vapour transmission rate of PET packaging material of 17µm was approximately 2.0 x 10^{-6} kg/m^2/day at 38°C and 90% RH. A higher value of water vapour transmission rate of PET packaging showed that it had a greater permeability towards moisture gained during the storage of the spray-dried papaya powder. Results (Table 1) show that ALP, which had a lower value of water vapour transmission rate exhibited a higher protective barrier against moisture content compared to PET.

Water solubility index (WSI)

Water solubility index is one the most utilised parameters to verify the capacity of a powder to remain in a homogenous mixture with water (Vissotto *et al.*, 2006). An ideal powder will wet quickly, thoroughly and dissolve without lumps (Santhalakshmy *et al.*, 2015). There was a significant ($p<0.05$) decreased in WSI for all the spray-dried papaya powders packaged in both ALP and PET from an initial of 97.14% to

Table 2. Hygroscopicity, degree of caking and flowability and β-carotene content of spray-dried papaya powder packaged in ALP and PET stored at 38 ±2°C for 7 weeks

Storage time (Week)	Hygroscopicity (%)		Degree of caking (%)		Flowability (°)		β-carotene content (μg/g)	
	ALP	PET	ALP	PET	ALP	PET	ALP	PET
0	24.57 ± 0.53^{aA}	24.57 ± 0.53^{aA}	10.64 ± 0.93^{aA}	10.64 ± 0.93^{aA}	39.64 ± 1.45^{aA}	39.64 ± 1.45^{aA}	1.83 ± 0.01^{aA}	1.83 ± 0.01^{aA}
1	24.63 ± 0.45^{aA}	24.94 ± 0.60^{aA}	16.93 ± 2.82^{bA}	37.45 ± 5.97^{bB}	43.61 ± 0.68^{bA}	47.53 ± 1.61^{bA}	1.76 ± 0.03^{bA}	1.63 ± 0.01^{bA}
2	25.44 ± 0.06^{bA}	28.34 ± 0.53^{bB}	34.97 ± 2.06^{cA}	50.85 ± 1.39^{cB}	45.99 ± 1.14^{cA}	48.63 ± 1.63^{bB}	1.65 ± 0.04^{cA}	1.56 ± 0.02^{cA}
3	27.26 ± 0.21^{cA}	30.69 ± 0.10^{cB}	37.64 ± 0.50^{dA}	53.66 ± 0.81^{dB}	47.98 ± 0.85^{cA}	54.72 ± 2.25^{cB}	1.47 ± 0.04^{dA}	1.00 ± 0.00^{dB}
4	28.36 ± 0.59^{dA}	31.58 ± 0.20^{dB}	38.93 ± 0.28^{eA}	75.02 ± 4.46^{eB}	51.81 ± 0.92^{dA}	71.22 ± 1.50^{dB}	1.38 ± 0.02^{eA}	0.86 ± 0.02^{eB}
5	29.18 ± 1.10^{dA}	32.39 ± 0.31^{eB}	39.38 ± 0.54^{eA}	84.33 ± 0.41^{fB}	52.78 ± 1.25^{dA}	78.84 ± 0.97^{eB}	1.25 ± 0.01^{fA}	0.45 ± 0.03^{fB}
6	31.14 ± 2.70^{dA}	35.37 ± 0.78^{fB}	41.37 ± 1.12^{fA}	85.05 ± 0.21^{gB}	54.68 ± 1.51^{dA}	84.97 ± 0.61^{fB}	1.13 ± 0.05^{gA}	0.27 ± 0.03^{gB}
7	32.98 ± 0.64^{dA}	37.01 ± 0.63^{gB}	42.44 ± 0.81^{fA}	86.45 ± 0.44^{hB}	57.97 ± 0.82^{eA}	92.79 ± 5.41^{gB}	0.95 ± 0.02^{gA}	0.16 ± 0.00^{hB}

[a] Means ± standard deviations with different superscripts within a column are significantly different at p <0.05.
[A]Means ± standard deviations with different superscripts within a row are significantly different at p<0.05.
Each value represents triplicate analyses of the samples (n=3).

85.19% and 69.12%, respectively. The decreased of powder solubility was related to the residual moisture in the powder, being less soluble when moisture content was high (Goula and Adamopoulos, 2005).

ALP as a better barrier towards water vapour compared to PET would reduce the moisture content gained and increased the water solubility property of spray-dried papaya powder. Hence, it can be concluded that ALP exhibits better characteristics in retaining the water solubility index of spray-dried papaya powder after 7 weeks of storage.

An inverse relationship was obtained for moisture content and solubility for all powders with the storage time (Table 1). The decreased of solubility in powders may have occurred because of the sugar crystallization that happened due to the relative humidity and storage temperature (Costa *et al*., 2013).

The spray-dried papaya powder (69.12-97.14%) was more soluble than the spray-dried tomato powder (17.65-26.30%) (Sousa *et al*., 2008) and spray-dried gac powder (36.91-38.25%) (Kha *et al*., 2010). Similar behaviour to the present study, but with higher results was reported by Endo *et al.* (2007), who observed a reduction in solubility for spray-dried passion fruit powder from 99.15-98.61% stored at room temperature for 180 days.

Hygroscopicity

Hygroscopicity represents the rate of change in moisture content (Chiou and Langrish, 2007). It was preferable to be low as high hygroscopicity indicates the higher tendency of the powder to absorb moisture and cause stickiness (Tonon *et al*., 2008). The hygroscopicity of spray-dried papaya powder kept in ALP and PET ranged from 24.57-32.98% and 24.57-37.01%, respectively. These values were lower than those spray-dried Amaranthus powder produced with DE10 (40.9%) by Cai and Corke (2000).

Powder hygroscopicity was increased significantly ($p<0.05$) for PET throughout 7 weeks of storage. However, insignificant increase of powder hygroscopicity was observed from 4th week to 7th week for powder packaged in ALP. A larger increase of hygroscopicity in the powder packaged in PET could be due to the migration of water vapour from the storage environment into the packaging material.

Degree of caking

According to Table 2, the degree of caking for spray-dried papaya powders packaged in ALP was 42.44±0.81% by the end of storage, which was approximately half of 86.45±0.44% for papaya powder packaged in PET pouches. Similar observation was obtained by Yu *et al.* (2013), whereby spray-dried bovine colostrums powder had a higher degree of caking packaged in ALP as compared to those packaged in PET. This was probably due to ALP pouches provide a better barrier to water vapour and temperature from the surrounding (Yu *et al.*, 2013). In addition, powder with high hygroscopicity will has the tendency to absorb moisture from the surrounding easily, which resulted in stickiness of powder and eventually causing caking of powder. Liu *et al*. (2010) and Ramachandran *et al*. (2014) also reported the increased of in degree of caking during their storage studies for spray-dried tomato powder and oven-dried papaya powder, respectively.

Flowability

Flowability is the ability of powder to flow freely which is measured as the angle of repose. From Table 2, the angles of repose for spray-dried papaya powders were increased significantly ($p<0.05$) for both packaging materials with storage time. These results were consistent with those reported by Chauhan and

Table 3. Total colour change, L, a and b value of spray-dried papaya powder packaged in ALP and PET stored at 38 ±2°C for 7 weeks

Storage time (Week)	Total colour change (?E)		L value		a value		b value	
	ALP	PET	ALP	PET	ALP	PET	ALP	PET
0	-	-	93.01 ± 0.54^{aA}	93.01 ± 0.54^{aA}	1.09 ± 0.13^{aA}	1.09 ± 0.13^{aA}	10.70 ± 0.27^{aA}	10.70 ± 0.27^{aA}
1	0.46 ± 0.03^{aA}	3.77 ± 0.24^{aB}	92.72 ± 0.20^{bA}	89.96 ± 1.65^{bA}	1.22 ± 0.15^{bA}	2.03 ± 0.68^{bB}	10.71 ± 1.58^{aA}	13.09 ± 1.54^{bA}
2	3.45 ± 0.03^{bA}	11.81 ± 0.11^{bB}	91.24 ± 0.20^{cA}	83.64 ± 8.61^{cA}	1.46 ± 0.13^{bA}	2.81 ± 0.23^{bB}	13.62 ± 0.35^{bA}	17.68 ± 2.45^{cA}
3	5.39 ± 0.05^{cA}	27.38 ± 0.05^{cB}	90.47 ± 0.22^{cA}	73.58 ± 1.39^{dB}	1.68 ± 0.04^{cA}	7.59 ± 0.47^{cB}	15.45 ± 0.29^{cA}	28.85 ± 1.65^{dB}
4	5.92 ± 0.02^{dA}	33.61 ± 0.06^{dB}	90.15 ± 0.25^{cA}	70.12 ± 1.15^{eB}	1.70 ± 0.04^{cdA}	8.43 ± 0.70^{cB}	15.85 ± 0.17^{cA}	34.12 ± 3.50^{eB}
5	8.22 ± 0.01^{eA}	40.74 ± 0.15^{eB}	88.75 ± 1.20^{cA}	66.52 ± 1.62^{fB}	1.80 ± 0.02^{dA}	10.59 ± 2.09^{cB}	17.71 ± 0.40^{dA}	39.96 ± 0.74^{fB}
6	9.68 ± 0.05^{fA}	52.34 ± 0.14^{fB}	87.23 ± 2.07^{dA}	55.83 ± 3.47^{gB}	1.81 ± 0.53^{eA}	16.82 ± 0.73^{dB}	18.42 ± 0.45^{dA}	41.15 ± 0.40^{gB}
7	16.22 ± 0.16^{gA}	56.30 ± 0.11^{gB}	83.53 ± 0.18^{eA}	51.03 ± 0.59^{hB}	1.27 ± 0.14^{bA}	18.17 ± 0.42^{eB}	23.80 ± 0.45^{eA}	44.03 ± 0.05^{hB}

[a] Means ± standard deviations with different superscripts within a column are significantly different at $p < 0.05$.
[A]Means ± standard deviations with different superscripts within a row are significantly different at $p<0.05$.
Each value represents triplicate analyses of the samples (n=3).

Patil (2013) for the spray-dried mango milk powder during storage. The reduction in flowability during storage of fruit powders could have been caused by the low molecular weight sugar found in fruits, which tends to have high molecular mobility which could easily lose its free flowing (Jaya and Das, 2004).

β-carotene content

β-carotene concentration for spray-dried papaya powder kept in ALP and PET reduced from an initial of 1.83 µg/g to 0.95 µg/g and 0.16 µg/g, respectively as shown in Table 2. The main reason for these findings is due to thermal degradation and oxidation as the storage conditions for powders in the present study was higher than room temperature (38±2°C). Carotenoids are susceptible to heat, light, oxygen and can suffer autioxidation as their structure contains a conjugated double bond system over the entire length of the polyene chain (Britton, 1995; Ghosh, 2012).

Hymavathi and Khader (2005) also reported the decreased in β-carotene for vacuum-dried mango milk powder during storage while Costa *et al*. (2013) observed a reduction in β-carotene with storage time from 12.75 mg/100 g to 6.50 mg/100 g for spray-dried passion fruit powder stored for 360 days at room temperature.

Colour characteristics

Colour is an important attribute because it is usually the first property the consumer observes (Sáenz *et al*., 1993). The initial Hunter *L, a, b* values of spray-dried papaya powder were determined to be 93.01, 1.09 and 10.70, respectively (Table 3). The powder gradually became darker over time. This observation was also reflected by the increasing of Hunter a values, decreasing of Hunter *L* values and b values. These results were in agreement with those reported by Pua *et al*. (2008) for the drum-dried jackfruit powder during storage.

The total colour difference (ΔE) of the spray-dried papaya powder was significantly ($p<0.05$) affected by the type of packaging material and storage period (Table 3). After storage of 7 weeks, there was a greater colour change (56.30) in papaya powder stored under accelerated condition (38ºC, 90% RH) in PET as shown in Table 3. The colour changes was significantly ($p<0.05$) lower in ALP packaged powder than the PET packaged powder, which was obviously due to the permeability of the packaging material to water vapour and oxygen. Moreover, residual air remaining in the package may cause oxidation that lead to colour changes during storage.

Total plate count

Total plate count was carried out to detect the presence of any viable microorganism in spray-dried papaya powder during storage and it can provide a general indication of the microbiological quality of food. There was a significant ($p<0.05$) increased of total plate count with storage time (Table 4). However, the value of log CFU/mL 2.67±0.01 or 470.98 CFU/mL for papaya powder packaged in ALP was lower than 10^6 CFU/mL that established by the NSW Food Authority (2009) guidelines for ready-to-eat food. Similar observations were found by Yang (2014) and Chauhan and Patil (2013) in the storage study of honey-dew melon juice and convective dried mango milk powder, respectively.

Conclusions

Choosing a suitable packaging material that can ensure a longer shelf life of food product is very important for food manufacturing industries. Packaging materials significantly ($p<0.05$) influenced spray-dried papaya powder's water

Table 4. Total plate count (log CFU/ml) of spray-dried papaya powder packaged in ALP and PET stored at 38 ±2°C for 7 weeks

Storage time (Week)	Total Plate count (log CFU/mL)	
	ALP	PET
0	2.34±0.02[aA]	2.37±0.02[aA]
1	2.41±0.01[aA]	4.21±0.08[bB]
2	2.43±0.01[bA]	5.36±0.01[cB]
3	2.47±0.01[cA]	6.19±0.02[dB]
4	2.50±0.01[dA]	7.10±0.03[eB]
5	2.56±0.03[eA]	7.00±0.09[eB]
6	2.66±0.02[fA]	7.28±0.04[fB]
7	2.67±0.01[fA]	7.61±0.22[gB]

[a] Means ± standard deviations with different superscripts within a column are significantly different at p <0.05.
[A]Means ± standard deviations with different superscripts within a row are significantly different at p<0.05.
Each value represents triplicate analyses of the samples (n=3).

activity, moisture content, water solubility index, hygroscopicity, degree of caking, flowability and colour. This study suggested that ALP pouch was better suited for keeping spray-dried papaya powder as it preserves most of the physiochemical properties and microbiological stable.

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