Changes in quality attributes of pink guava *(Psidium guajava)* powder with respect to different drying techniques and maltodextrin concentrations

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Abstract

Implication of drying techniques in preservation of fruit juice has huge advantage in quality control and packaging sector. The objective of this research was to investigate the effect of drying techniques and maltodextrin concentrations on physicochemical attributes of pink guava powder. Pink guava puree was dried at -110ºC and 0.001 mbar by freeze drying and at 170ºCinlet air temperature and 350 ml/hr feed flow rate by spray drying with 10-20% maltodextrin concentration (MDC). The drying methods (DM) and MDC had significant effect on powder properties. Spray drying was more effective reducing the moisture content and water activity to 2.86% and 0.377, respectively, whereas, freeze drying was more suitablein the retention of color, lycopene and vitamin C. Spray drying was more economic method compared to freeze drying. Overall, spray-dried pink guava powder produced with 20% MDC had better quality than that of freeze-dried powder in terms of lowest moisture content (2.17%), lowest water activity (0.33), highest glass transition temperature (215ºC), less electricity and time consumption, anda moderate retention of lycopene and vitamin C.

Introduction

Pink guava or *Psidium guajava* is belongs to the family of Myrtaceae, which are grown in abundance in many tropical and sub-tropical regions over the world and renowned as "apple of the tropics" (Yadava, 1996). It is highly rich in lycopene, vitamin C, fiber, minerals, and excellent color and flavor (Rodriguez-Amaya *et al*., 2008). Pink guava contains higher antioxidants than white guava (Yadava, 1996; Flores *et al*., 2015). It is reported as the most effective in anti-inflammatory, hepato-protective, anticancer and antioxidant activity (Ojowole, 2006; Flores *et al*., 2013).Asian countries are in the leading position in the production of guava fruit. India, China, Thailand and Pakistan are the topmost fresh guava producer over the world (Worldatlas, 2011). Furthermore, Malaysia has about 500 hectares pink guava plantation in Perak, which is the world single largest pink guava plantation that contributes around 15% of the world pink guava puree production and exports to Japan, USA, Australia, Philippines, Korea, Canada, Singapore and New Zealand (SDB, 2009). However, fresh guava is very perishable andthe ripening increases after harvesting due to the rise of ethylene production and respiration rate. It reaches its climacteric peak within 4 to 5 days of post-harvest that leads to poor firmness and quality deterioration (Basseto *et al*., 2005). Guava fruits are also very susceptible to chilling damage and diseases; it bound the possibility of commercial aspects of fresh pink guava (Bashir and Abu-Goukh, 2003). In contrast, guava fruit juice can be stored from weeks to several months, while the fruit juice powders could be preserved from several months to year based on packaging treatments (Walkling-Ribeiro *et al*., 2009; Chauhan, and Patil, 2013; Henríquez *et al*., 2013). The application of fruit powders into varieties of food formulations is increasing day by day due to the high stability and capability of high nutritional value per gram powder. Furthermore, highly nutritional and regular microstructural fruit powder is also desired in the pharmaceuticals and cosmetic industries. Therefore, production of pink guava juice powder could be a good choice in food and pharmaceutical industries.

Recently, a variety of drying methods are being used on industrial scale. The most successful methods for fruit powder production are freeze drying, foam mat drying and spray drying, which has enormous

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benefits in terms of volume reduction, decrease in packaging and transportation costs, nutrient retention, and elongation of the shelf life (Chopda and Barrett, 2001). Spray drying is widely used in the food and pharmaceutical industries, as it involves short heat treatment, which is mostly needed for heat-sensitive products (Yousefi *et al.*, 2011). In contrast, freeze drying is recognized as the best method for the preservation of bioactive compounds(Barbosa-Cánovasand Ortega-Rivas, 2005). Stickiness is one of the major problems in spray drying, which leads to wall deposition difficulties (Bhandari *et al.*, 1997). This is due to the low glass transition temperature of drying sample. The addition of maltodextrin in the sample can reduce the stickiness problem, and at the same time, protect the heat sensitive compounds, such as lycopene, β-carotene, vitamin C(Quek *et al.*, 2007). The concentration of maltodextrin may affect the moisture content, particle size, bulk density and other properties of powder. Several studies had been performed concerning the effect of spray drying conditions on pink guava powder (Shishir *et al.*, 2015, 2016), none have been reported how the other drying techniques affect the physico-nutritional quality of pink guava powder compared to spray drying.

Therefore, this study is aimed at comparative investigation on the effect of drying techniques on pink guava powder focusing on several physical properties and the retention of vitamin C, lycopene andcolor properties, i.e. L^*(lightness), a^*(redness) and b^*(yellowness). The findings of this study could be more beneficial to the commercial production of pink guava powder and to undertake the drying of others fruits and vegetables juices in order to obtain desired level of physicochemical properties.

Materials and Methods

Raw materials and chemicals

Pink guava puree was obtained from Sime Darby Beverages Sdn Bhd. (Malaysia) and maltodextrin DE 10 from Bronson and Jacobs Pvt. Ltd. (Australia). Acetone, n-hexane, meta-phosphoric acid and butylatedhydroxytoluene from Friendemann Schmidt (Australia), ethanol from MerchKGaA (Germany), acetic acid and 2,6- dichlorophenol indophenol from Sigma-Aldrich Chemie GmbH (Germany) and L-ascorbic acid from R and M marketing (U.K) were collected.

Sample preparation and drying

The pink guava puree was diluted with distilled water and added sugar at a ratio of 1:2.33:0.27 (v/v/w). The total solid content was maintained at 10.0±0.1°Bx, sieved through a 250 μm sieve and subsequently added maltodextrin to the juice sample at concentrations of 10, 15 and 20% (w/v). Then the samples were homogenized at 5000 rpm for 8 min using Homogenizer (Wise Mix HG-15A, Daihan Scientific, Co. Ltd., Korea) (Carrillo-Navas *et al.*, 2011). A 300 ml sample was subjected to spray drying using a spray dryer (Lab plant SD-05, Lab plant UK Ltd., UK). The spray dryer consists of a drying chamber 215 mm×500 mm long, 0.5 mm diameter pressure nozzle and co-current air flow system. The inlet temperatureof 170°C, feed flow rate of 350 ml/hr, compressor air pressure of 2.0 barand feed temperature of 25°C were maintained.During the spray drying, the outlet temperature, drying air flow rate and room temperature were monitored at 96±2°C of 47±1 m³/hrand 25±1°C, respectively. In contrast, freeze drying was carried out at -110ºC and 0.001 mbar pressure using Bench-top freeze dryer (Coolsafe 110-4, Labogene APS Industrivej, Denmark). Prior to freeze drying, the sample was placed to deep freezer at -20ºC for 1 day to reduce the temperature of the sample. In order to determine the drying process yield and cost estimation, the drying runs (spray and freeze drying) were replicated twice. The physicochemical analyses were triplicated. After drying, powders were tightly packed in polyethylene bag and kept in desiccator for 24 hours and then stored in refrigerator at 5 ºC for analysis.

Physical properties

The moisture content analysis was performed by the method of AOAC (1990). Around two gram of powder was taken to determine the water activity by using electronic water activity meter (FA-ST Lab, GBX Instrumentation Scientifique, France) at approximately 25ºC(Zhang *et al.*, 2015).The particle size was determined by using particle size analyzer (Mastersizer 2000, Malvern Instruments Ltd., U.K.) (Tze *et al.*, 2012). The particle size was expressed as D[4,3], the mean diameter over the volume distribution (Tonon *et al.*, 2008). The glass transition temperature of the powders was determined by using differential scanning calorimeter (DSC 7, Perkin Elmer, USA). The powder (around 5-10 mg) was scanned in a hermitically sealed 20 μl DSC aluminum pan. An empty aluminum pan was used as a reference. The purge gas used was dry nitrogen (20 ml/min). The rate of thermal scanning was carried out in 2 steps such as i) Isothermal at -20ºC for 1 min; and ii) Heat scanning from -20ºC to 250ºC at 10ºC/min(Shrestha *et al.*, 2007). The cost analysis was carried outfor the production of 1 kg pink guava powder from the summation of the price of raw material (pink guava

puree) and electricity used in aspect of Malaysia and estimated in Malaysian currency (Ringgit).

The drying yield was estimated at the relationship between the ratio of solid mass of the powder and solid mass of the drying sample(León-Martínez *et al.*, 2010). The following equations (on the basis of solid mass ratio) were used to determine the process yield, i.e. equation 1 is for freeze drying (FD) and equation 2 for spray drying (SD).

$$Powder\ Yield,\ Y = \frac{(W - \langle X_{wb} \times W \rangle)}{F_v T_s} \times 100 \qquad (1)$$

$$Powder\ Yield,\ Y = \frac{(W_2 - W_1) - X_{wb}(W_2 - W_1)}{F_v T_s} \times 100 \qquad (2)$$

where, W = weight of the powder, X_{wb} = moisture content (wb) of the powder, F_v = Volume of the drying sample, T_s= total solid content of the drying sample, and W_1 and W_2 = weights of the powder bottle before and after spray drying, respectively.

The color of the powders was measured carefully by using a color reader (CR-10, Konica Minolta Sensing Ltd., Japan). In order to obtain the L^*(lightness), a^*(green/red), b^*(blue/yellow), c^*(chroma), h^*(hue angle), the lens of the color reader was placed on the powder (Tze *et al.*, 2012). Total color change between the sample before drying and the final product was determined by the following equation:

$$\Delta E = \sqrt{(L_0^* - L^*)^2 + (a_0^* - a^*)^2 + (b_0^* - b^*)^2} \qquad (3)$$

where L_0^*, a_0^*, b_0^* and L^*, a^*, b^* are the values of the sample before drying and the values of the powdersafter drying, respectively (Kha *et al.*, 2010).

Chemical properties

Lycopene was determined according to spectrophotometer method developed by Fish *et al.* (2002)and modified by Kong and Ismail (2011). The pink guava powder of 0.6 g was taken into 50ml conical flask and 5 ml of pure acetone containing 0.05% butylatedhydroxytoluene (BHT), 5 ml of 95% ethanol and 10 ml of hexane were added and stirred. The mixture was shaken using WiseCube Shaking Incubator (WIS-20R, Daihan Scientific Co. Ltd., Korea) at 200 rpm for 20 min. Then, 3 ml of distilled water was added and shaken again at 200 rpm for another 5 min. Finally, the mixture was left for 5 min for phase separation, and the hexane layer was read in 1 cm path length quartz cuvette 503 nm using UV-vis spectrophotometer (Ultrospec 3100 pro, Biochrom Ltd., England) with hexane as the blank. The lycopene content was estimated as mg/100g pink guava based on the equation. Molar extinction coefficient for lycopene in hexane is 17.2×10^4 M^{-1} cm (Kong and Ismail, 2011).

$$Lycopene\ content\ \left(\frac{mg}{100}g\right)$$
$$= \frac{A_{503}}{17.2 \times 10^4 M^{-1}cm} \times \frac{536.9g}{mol} \times \frac{10^3 mg}{1g} \times \frac{10ml}{kg\ sample} \times \frac{11}{10^3 ml}$$
$$= \frac{(A_{503} \times 0.0312)}{kg\ sample} = \frac{(A_{503} \times 0.312)}{100g\ sample} \qquad (4)$$

The Vitamin C content was measured using DCIP titration method (AOAC, 2007). The chemicals used for solvent preparation were acetic acid, ascorbic acid, 2.6-dichloroindophenol (DCIP), metaphosphoric acid (HPO_3) and sodium bicarbonate ($NaHCO_3$). The powder of 2 gm was taken and dissolved in metaphosphoric acid solution and made up the volume to 20 ml and filtered. Four ml of the filtered sample was titrated with indophenol dye solution until a light but distinct rose-pink color persists around 15 seconds. For the standardization of dye, 5 ml of standard ascorbic acid solution and 5 ml of metaphosphoric-acetic acid solution were mixed together and titrated with dye solution until light pink color persists around 15 seconds. The following formulas were used to determine dye factor and ascorbic acid.

$$Dye\ factor,\ DF = 0.5\ /\ titre \qquad (5)$$

$$Ascorbic\ acid\ (mg/100\ g) = \frac{Titre\ value\ for\ sample \times DF \times Volume\ made\ up \times 100}{Sample\ taken\ for\ titration \times Wt.\ of\ powder\ taken} \qquad (6)$$

Statistical analysis

The data was analyzed by analysis of variance (ANOVA) and Duncan's multiple range test using SAS 9.3 TS L1M2. All the measurements were conducted in triplicate and evaluated as mean value with standard deviations. The diagrams of mean value and error bars were generated by using Microsoft excel version of 2010.

Results and Discussion

Effect of drying techniques at different MDC on physical properties of powder

In spray-dried pink guava powder, the final moisture content significantly (p<0.01) decreased (Table 1) from 3.51% to 2.17% with the increase of 10% MDC from 10% to 20% MDC, while it increased in freeze-dried powder from 4.43% to 5.4% (Figure 1.a). Maltodextrin has hydrophilic glucose chain, which can easily hold more water molecules (Chronakis, 1998). This could be the reason to the retention or increase of moisture content with higher MDC in freeze-dried (FD) powder. The spray drying due to high temperature (170ºC), might be retarded

Table 1. ANOVA result for SD and FD powder

Powder properties	MDC significance (p-value)		Method significance (p-value)	Interaction significance (p-value)	Mean	
	SD	FD	DM	MDC×DM	SD	FD
Moisture content (%)	0.01	0.01	0.01	0.01	2.86	4.89
Water activity	0.01	0.01	0.01	0.01	0.37	0.39
Particle size (μm)	0.01	0.01	0.01	0.01	9.07	42.01
Glass-transition tempt. (°C)	0.01	0.01	0.01	0.01	183.30	168.59
Powder yield (%)	0.01	0.05	0.01	0.01	39.69	94.35
Lycopene (mg/100g)	0.05	0.05	0.01	0.01	27.48	33.29
Vitamin C	0.01	0.01	0.01	0.01	649.33	728.22

N.B: MDC = Maltodextrin concentration, SD = Spray drying, FD = Freeze drying, DM = Drying method, MDC×DM = Interaction between maltodextrinconcentration and drying method;p<0.01 and 0.05 indicates the statistical significant level at 1% and 5%, respectively
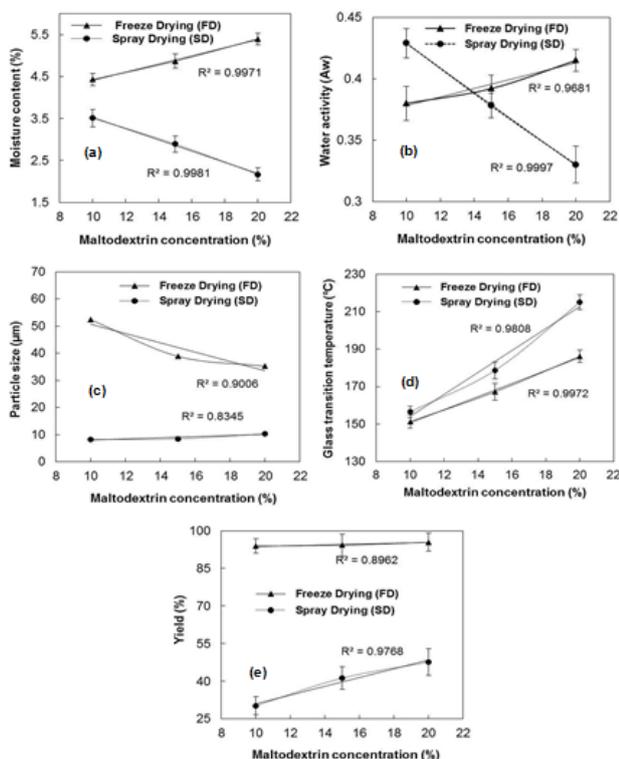

Figure 1.Effect of drying techniques on (a) moisture content, (b) water activity, (c) particle size, (d) glass transition temperature and (e) powder yield of freeze-dried (FD) and spray-dried (SD) powder at different maltodextrin concentrations (MDC)

the water holding capacity of glucose chain and higher MDC increased the solid content of the feed, which reduced the total water evaporation and resulting in reduced moisture content (Kha *et al.*, 2010).

The water activity of spray-dried (SD) powder sharply decreased from 0.429 to 0.330 with the increase of 10% MDC from 10% to 20% MDC, whereas, the FD powder increased from 0.380 to 0.415 with the increase of 10% MDC (Figure 1.b). The trend of the powder moisture content showed almost proportional relationship with the water

activity of powder. Moisture content indicates the amount of available water in a substance and the water activity shows how much available water reacts with biological reaction or affects the substance. Thus, increase of available water might have the possibility to increase the water activity level (Intipunya and Bhandari, 2010). Similar observation was observed by several researches (Harnkarnsujarit and Charoenrein, 2011; Dak *et al.*, 2014). The SD powder had smaller particle size and ranged from 8.24 to10.34 μm, while, the FD powder varied from 35.23 to 52.38 μm (Figure 1.c). The SD powder is 4 to 5 times smaller than the FD powder. This is because of the spray nozzle (0.5 mm), which produces very small droplets in the drying chamber. In contrast, the FD juice was found in crystalized form, which was grinded into powder. Thus, the FD powder had higher particle size. In commercial aspect, SD powder is more in demand due to the production of smaller and regular shape particles, which reduces the volume, packaging and transportation cost and enhances the stability (Intipunya and Bhandari, 2010; Caparino *et al*., 2012). However, higher MDC causes higher feed viscosity and resulted in higher particle size in SD powder (Tonon *et al*., 2008).

The glass transition temperature (Tg) significantly (p <0.01) increased from 156 to 215°C and from 151 to 186°C in SD and FD powders, respectively, with the increase of 10% MDC from 10% MDC to 20% MDC, which was around double in SD powder than that of FD powder (Figure 1.d). Tze *et al.* (2012) reported that the glass transition temperature increased with the increase of MDC. Furthermore, Caparino *et al.* (2012) observed the higher Tg in spray-dried powder than freeze-dried powder. The SD powder produced at 20% MDC had highest Tg (215°C) (Figure 1.d). A higher Tg is considered for better stability, since Tg affects the powder's shelf life during storage

and transportation (Intipunya and Bhandari, 2010). Higher MDC significantly (p<0.01) increased the yield of SD powder from 30.25 to 47.63%by the increase of 10% MDC in spray drying feed sample (Figure 1.e). However, the yield increased by 11% from 10% to 15% MDC and then by 6% from 15% to 20%MDC (Figure 1.e). TheSD yield reduction at 15% to 20% MDC compared to 10% to 15% MDC is due to a higher feed concentration, which increases the viscosity and produces larger feed droplets. Some of these droplets dripped directly inside the chamber and stucked on the chamber wall and few of them deposited on residue collection tube, therefore resulted in a loss on powder yield(Shrestha *et al.*, 2007). However, the increase of 11% spray drying yield from 10% to 15% MDC indicates that the increase of around 5% MDC drying matterfrom 10% to 15% MDC reduced the loss of 6% of juice dry matter during spray drying. In contrast, the yields in FD are almost nearer around 93.4 to 95.3%. However, the maximum yield (95.38%) was found in freeze drying, which was almost double than that of spray drying (47.57%), as shown in Figure 1.e. This is because of the wall deposition problem during spray drying, which reduced the yield percentage in SD (Bhandari *et al.*, 1997), while freeze drying does not have wall deposition problem. The powder loss in FD depends on how carefully the grinding of freeze-dried juice crystals is performed and the sieving performance after grinding. According to Man *et al.*(1999), freeze drying yield was higher (83.9%) than the yield of spray drying (58.7%).

Effect of drying techniques at different MDC on chemical properties of powder

Both of the contents of lycopene and vitamin C significantly decreased by 3.28 mg and 186 mg, respectively, in FD powder with the increase of 10% MDC, and increased by 4.4 mg and 103 mg, respectively, in SD powder with the increase of 10% MDC. The lycopene content and vitamin C were higher in FD powder than that of SD powder (Figure 2). This is because, freeze drying process is able to avoid the negative effect of high temperature on thermal sensitive compounds, such as lycopene and vitamin C, and allow a higher concentration of lycopene and vitamin C (Laokuldilok and Kanha, 2015). Asmaltodextrin is a good binder for heat sensitive nutrient, a higher MDC increased the retention of vitamin C and lycopene content in SD powder as shown in Figure 2 (Tonon *et al.*, 2008). In contrast, as freeze drying is maintained at a very low temperature and high pressure, the loss of vitamin C and lycopene content due to thermal effect
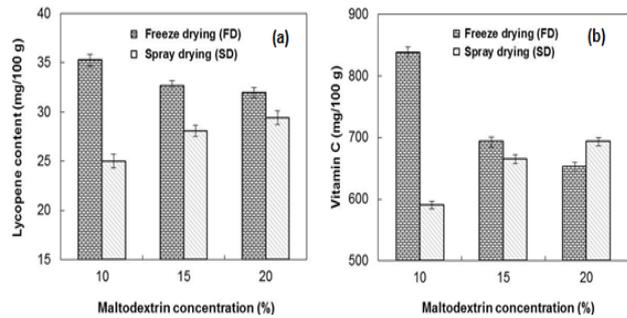

Figure 2. Effect of drying techniques on (a) lycopene content and (b) vitamin C of pink guava powder at different maltodextrin concentrations (MDC)

is comparatively very less than spray drying. This is corroborated by Laokuldilok and Kanha (2015). Hence, the retention of vitamin C and lycopene content were higher at low MDC in FD powder. A higher MDC increased the content of maltodextrin in FD powder, which resulted in lower values of vitamin C and lycopene content in whole powder content.

Statistical observation on drying methods

The effects of drying methods were significant (p<0.01) on the pink guava powder properties. The interaction between MDC and drying method (MDC×DM) is also found as highly significant (Table 1). SD method was more significant to reduce the moisture content to around 2.18-3.51% and had low water activity around 0.326-0.429, which shows satisfactory range for better stability of powdered product (Marques *et al.*, 2007). Furthermore, SD is comparatively better in the production of smaller powdered particles, which showed five times smaller powdered particles than the FD particles (Table 1). In addition, the statistical mean of Tg was 15ºC higher in SD powder than in FD powder. In contrast, FD was more effective in retention of lycopene and vitamin C. Although, the mean difference of lycopene between SD and FD powders was quite small (5.81 mg), the vitamin C showed quite high mean difference between them is around 78 mg (Table 1).

Cost analysis of SD and FD powder

The production cost of FD powder was more than 2.5 times higher than that of SD powder. FD process consumed more than 5 times higher in electricity (Table 2). An industrial scale comparison observed that the freeze drying process is around 4-5 times more expensive than spray drying (Hammami and René, 1997). Furthermore, FD is quite lengthy process, in which, FD required 960 hr to produce 1 kg pink guava powder and SD took only 35 hr. to produce 1 kg powder. However, the feed sample cost is comparatively higher in spray drying than

Table 3. Color analysis of freeze-dried and spray-dried pink guava powder

Drying method	MDC (%)	Lightness L*	Color ratio a*/b*	Chroma c	Hue angle h	Color change ΔE
FD	10	61.86±1.95[b]	0.387±0.003[a]	21.98±0.82[a]	68.82±0.19[b]	21.23±1.97[b]
	15	64.66±0.81[ab]	0.356±0.003[b]	23.12±1.19[a]	70.77±0.53[a]	24.01±0.78[ab]
	20	67.30±0.79[a]	0.351±0.003[c]	22.36±0.37[a]	70.58±0.16[a]	26.42±0.65[a]
p-value	MDC	<0.05	<0.01	>0.05	<0.01	<0.05
SD	10	75.43±0.12[c]	0.330±0.001[a]	24.43±0.08[b]	72.03±0.08[c]	35.03±0.08[c]
	15	76.63±0.12[b]	0.295±0.001[b]	24.73±0.08[b]	73.60±0.05[b]	36.11±0.08[b]
	20	77.76±0.08[a]	0.242±0.001[c]	25.30±0.05[a]	76.26±0.14[a]	37.79±0.20[a]
p-value	MDC	<0.01	<0.01	<0.01	<0.01	<0.01

N.B: MDC = Maltodextrin concentration, FD = Freeze drying, SD = Spray drying; p- value = significant level at p<0.01, p<0.05, [a] Values are mean ± standard error; Superscript (a,b,c,…) = Treatment significant in order to column

Table 2. Cost analysis of drying performance for the production of 1 kg pink guava powder

Drying method	Drying cost affecting factors				
	Raw material (Ringgit)	Electricity (Kwh)	Electricity cost (Ringgit)	Drying time (hr.)	Total expense (Ringgit)
SD	36.00	105.00	26.30	35.00	62.30
FD	16.33	576.00	144.00	960.00	160.33

that of freeze drying (Table 2). This is because of the production loss, caused by wall deposition, which is higher in SD than that of FD.

Effect of drying techniques at different MDC on color properties of powder

In case of color properties, the MDC was highly significant (p<0.01) on the SD powder properties than the FD powder properties (Table 3). The lightness significantly increased from 75.43 to 77.76 degree in SD powder and 61.86 to 67.30 degree in FD powder with increase of MDC from 10% to 20%, which indicates that the color undergone pigment oxidation or thermal degradation(De Sousa *et al.*, 2008). Furthermore, MDC is white in color and a good encapsulating agent, which encapsulated the pink color of SD and FD powders and increasingly revealed the white color of maltodextrin with the increased MDC (Mahendran, 2010). However, the mean value of lightness is 64.60 degree in FD powder and 76.60 degree in SD powder reveals that FD powder carries more pink color than SD powder (Table 3).

The color ratio *(a*/b*)* indicates the pink color concentration of SD and FD powders. The color ratio, chroma and hue angle are closely related with lightness. Since, the increase of lightness refers to the color loss, it reduces the color, *a** (red) and affects to the color ratio. From Table 3, the color ratio of SD and FD powders significantly (p<0.01) reduced with higher MDC. All of the values of color ratio

were higher in FD powder. In case of SD powder, chroma increased by 0.87 and hue angle increased by 4.23º with the increase of 10% MDC to 20% MDC, but there was no specific trend in FD powder (Table 3). Since the region of pure red color is 0º and yellow color is 90º, the increase of hue angle indicates that the conversion of red color to yellow color happened due to the loss of red color affected by drying conditions (Quek *et al.*, 2007). The color change varied from 21.23 to 26.42 in FD powder and from 35.03 to 37.79 in SD powder, which shows that the color change is around 12.5 degree less in FD power than that of SD powder (Table 3). This is due to the thermal effect and pigment oxidation on large volume of feed sample at spray drying chamber (De Sousa *et al.*, 2008;Caparino *et al.*, 2012).

Conclusion

The drying methods had significant (p<0.01) effects on physicochemical characteristics of pink guava powder. A higher MDC significantly reduced the moisture content and water activity, increased the glass transition temperature, powder yield and retention of vitamin C and lycopene in SD powder. It also significantly increased the moisture content, water activity and glass transition temperature and reduced the retention of vitamin C and lycopene in FD powder. In the aspect of powder stability, SD powder had the lowest moisture content (2.18%), lowest water activity (0.326) and highest glass transition temperature (215ºC), which refers high stability. In contrast, the retention of lycopene, vitamin C and color compounds were better at 10% MDC of FD powder than that of SD powder. Therefore, the powder produced by spray drying can be considered more satisfactory in terms of better physical properties, satisfactory retention of color and chemical compounds and economic process. In addition, the quality of SD powder might also be

affected by different operating conditions, which could be investigated in further study in order to commercial production.

Acknowledgments

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