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Effect of spray dryer inlet temperature and maltodextrin concentration on colour profile and total phenolic content of Sapodilla *(Manilkara zapota)* powder

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Abstract

The effects of inlet temperatures of 140, 160, 180, 200 and 220ºC and maltodextrin (DE10-12) concentrations at 10, 20, 30, 40 and 50% (w/v) on the total phenolic content (TPC) and colour profile of spray dried Sapodilla powders were studied. The colour profiles and TPC of the sapodilla powder produced were measured using a Hunter Laboratory Calorimeter (L^*, a^* and b^*) and Folin-Ciocalteu method, respectively. TPC of powders were significantly affected by the inlet temperature. However, an increase in the concentration of maltodextrin from 20 to 50% (w/v) did not significantly affect the adjusted TPC. A slight decreased in adjusted TPC when maltodextrin concentration increased from 10 to 20% (w/v). An increase in drying temperature did not significantly affect the a^* (greenness to redness) and b^* (blueness to yellowness) values. Spray dried Sapodilla powder slightly lost its L^* (lightness) when inlet temperature increased from 200 to 220ºC. Higher concentrations of maltodextrin resulted in lower a^* and b^* values. L^* increased significantly when the addition of maltodextrion increased from 10 to 20% (w/v). Spray dried Sapodilla powder added with 20 or 30% (w/v) maltodextrin and processed at 200ºC inlet temperature shows acceptable colour and TPC.

Introduction

Sapodilla *(Manilkara zapota)*, a fruit comes from the family of Sapotaceae. It is believed to be originated from Central and South America (Sin *et al.,* 2006). It is also well established that Sapodilla fruit is a good source of total phenolic content and antioxidants (Leong and Shui, 2002). The ripe flesh of Sapodilla is yellowish brown in colour. It is caramel-like, soft, sweet and juicy with mild pleasant aroma. However, being a seasonal fruit its availability as a fresh fruit is for limited period. Spray drying of the fruit juice may be a good alternative to make its health promoting components available throughout the season.

Spray drying is a well-known technique used extensively in food processing industries. It converts liquid material into powder continuously in just one single step (Moreira *et al*., 2009; Ahmed *et al*., 2010). During the process, the feed is atomized into the drying chamber, where the resulting spray mixes with hot gas and turns into dried particles (Caparino *et al*., 2012). Spray drying is also one of the encapsulation methods suitable for encapsulating highly heat sensitive or volatile substances found in fruits and vegetables (Fang and Bhandari, 2011). The resulting spray dried fruit powders have number of benefits such as easier handling and packaging, reduced weight or volume, storage space and transportation cost (Goula and Adamopoulos, 2010; Fazaeli *et al*., 2012). Coupled with longer shelf life, fruit powder present great potential to be served as a source of functional food additive, such as flavouring and colouring agents (Caliskan and Dirim, 2013). In addition, it will also increase the health benefits of the incorporated food products due to their high antioxidative ability (Zin *et al*., 2002).

Stickiness due to the high amount of sugars in fruit juices is the major limitation that causes operational problems during spray drying (Obon *et al*., 2009; Tan *et al*., 2011). Therefore, drying agent is used to prevent the deposition of powder onto the drying chamber, which improves the drying process and leads to higher yield of product (Tan *et al*., 2011; Souza *et al*., 2015). Maltodextrin is widely used drying agent due to its advantages of high solubility, bland flavor, colourless, cheap and commercially available (Phisut, 2012).

Phenolic compounds are the major antioxidant in plants and fruits (Kalt *et al*., 2000; Win *et al*., 2011). The consumption of this secondary metabolites is health beneficial and safe from adverse side effects (Fang and Bhanndari, 2011; Kanlayavattanakul and Lourith, 2011). They possess a variety of biological activities, which includes the protection

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against a variety of degenerative diseases such as ageing, cancer, diabetes, inflammation, arthritis and cardiovascular diseases (Zin *et al.*, 2002). However, the valuable TPC in fruits are easily degraded during processing, resulting in getting powder with poor quality (Gallegos-Infante *et al.*, 2013). For instance, TPC in bayberry is destroyed due to the heat exposure at high operating temperatures (Fang and Bhanndari, 2011).

Colour plays an important role in assessing the quality of food product. It is an important sensory attributes for product acceptance evaluated by consumers (Abadio *et al.*, 2004). It allows detection of anomalies or defects that food items may present (Quek *et al.*, 2007). A dark product may indicate deterioration for certain product, and is usually less appealing to consumers. It is more desirable to have fresh-like products with high closeness to its original colour (Keenan *et al.*, 2011). Many factors are responsible for the degradation of colour, such as heat and browning. It is thus a challenge in maintaining the naturally coloured pigments in food processing industry (Dutta *et al.*, 2006). The conditions used during processing need to be adjusted in order to obtain a best possible product quality.

Use of spray drying to produce Sapodilla powder after enzyme liquefaction and characterization of powder in terms of hygroscopicity, bulk density, solubility, water activity and moisture content have been reported (Chong and Wong, 2015). However, information on the changes in TPC and colour profile of spray dried Sapodilla powder is unknown. Thus, the present study investigated the effect of spray dryer inlet temperature and maltodextrin concentration on colour profile and TPC of Sapodilla powder. Information gained regarding the best conditions in preserving the Sapodilla fruit into a more stable form of fruit powder with acceptable TPC and color could enhance its marketability.

Materials and Methods

Preparation of feed solutions

Three kilograms of Sapodilla *(Manilkara zapota)* fruits were purchased from a supermarket in Cheras, Selangor, Malaysia. The fruits were cleaned with tap water, peeled, deseeded and cut into small pieces prior to blending using a Waring blender (Osaka Chemical, Osaka, Japan) for 30-60 s until a homogenous puree was obtained. 2000 g of puree was subjected to enzymatic liquefaction with 0.5% (v/w) Pectinex® Ultra SP-L and 0.5% Celluclast® 1.5 L at 40°C for 1.5 hours. The enzyme-liquefied Sapodilla puree was made into juice using a muslin cloth through filtration process. The obtained juice with high clarification was then added with different maltodextrin (DE 10-12) concentrations (10-50% w/v) at 1:1 ratio (Chong and Wong, 2015).

Spray drying

The feed solution (1000 ml) was spray-dried using a laboratory-scale mini spray dryer (Buchi, B-290, Flawil, Switzerland). The inlet /outlet temperature measured were 140°C/82.3°C, 160°C/94.0°C, 180°C/104.3°C, 200°C/118.7°C and 220°C/128°C. The aspirator rate, air flow rotameter, pump rate and the pneumatic nozzle cleaner speed during drying was kept constant, which was at 90%, 40 mm, 20% and 5, respectively. Maltodextrin concentration was kept constant at 30% (w/v) during the study on the effect of different inlet temperatures, whereas inlet temperature was fixed at 180°C for the study on the effect of different maltodextrin concentrations. After the spray drying process (about 30 mins), the Sapodilla powder was collected in a glass collection vessel. All formulations were carried out in triplicate.

Colour measurement

The colour profile of powder was measured using Hunter Laboratory Calorimeter (Model SN 7877, Ultra-scan, Hunter Associates Laboratory, Virginia, United States). The results were expressed in accordance with the CIE Lab. System. The L^* value signifies "lightness", which ranges between 0 and 100. a^* value represents changes from "greenness to redness" (-80 for green and 100 for red) and b^* from "blueness to yellowness" (-80 for blue and 70 for yellow) (Ahmed *et al.*, 2000). The instrument was calibrated against a standard black and white reference tiles. All measurements were taken in triplicates.

TPC measurement

The TPC of powder was determined using Folin-Ciocalteu method described by Win *et al*. (2011) with slight modifications. Samples (0.4 ml, triplicate) were introduced into test tubes followed by 2.0 ml of Folin-Ciocalteu's reagent (10 times dilution) and 1.60 ml of Na_2CO_3 (7.5% w/v). The test tubes were vortexed, covered with parafilm and allowed to stand for 30 min in the dark before absorbance at 765 nm was measured using a PRIM Light spectrophotometer (Secomam, Champigny-Marne, France). The total phenolic content (TPC) was expressed as milligram of gallic acid equivalents (GAE)/100g material. The calibration equation for gallic acid was y = 0.0111x - 0.0148 (R^2=0.9998), where y is the absorbance and x is the gallic acid concentration in mg/L.

Statistical analysis

All experiments were carried out in triplicate as mean ± standard deviation Statistical analyses were performed using SPSS software (SPSS, Inc., Chicago, IL). Data were statistically analyzed using one-way ANOVA and Tukey HSD tests. Differences were considered significant at 95% ($p<0.05$).

Results and Discussion

Effect of inlet temperature

Table 1 shows the effect of different inlet temperatures on the colour and TPC of the spray dried Sapodilla powders. The lightness *(L^*)* of powders produced with different inlet temperatures (140°C-220°C) were in the range of 92.77±0.61 to 94.08±0.55. A significant effect on L^* of the spray dried Sapodilla powder was observed when inlet temperature was increased from 200ºC to 220ºC (Table 1). An increase in inlet temperature produced significantly ($p<0.05$) darker product than powders produced at lower inlet temperatures (140-200°C). Sapodilla powders may exposed to some browning reactions or caramelization of sugars in the spray dryer due to high temperature. Therefore, spray dried Sapodilla powders may lost their brightness. This phenomenon was also observed by Quek *et al.* (2007), Phoungchandang and Sertwasana (2010), Caliskan and Dirim (2013) for the spray dried watermelon, ginger and sumac extract powders, respectively.

However, previous studies also reported that the lightness *(L^*)* of Gac fruit powder (Kha *et al.*, 2011) and Amla juice powder (Mishra *et al*., 2014) increased with the increase of inlet temperature. The higher degree of L^* of powders at higher inlet temperature indicates that some pigments had undergone oxidation. Probably, reduction in the rate of oxidation of tannins would lessen the powder color.

The greenness to redness *(a^*)* and the blueness and yellowness *(b^*)* of spray dried Sapodilla powders obtained with different inlet temperatures (140°C-220°C) were found in the ranged of -0.04±0.23 to 0.15±0.14 and 6.80±0.93 to 8.93±1.48, respectively. No significant difference ($p<0.05$) were observed as indicated from Table 1, which implies that changing of inlet temperatures did not significantly ($p<0.05$) affect on the a^* and b^* colour profile of Sapodilla powders. Samples dried at 140°C and 160°C showed low positives a^* values, indicating a slight tendency to a reddish color; while negatives a^* values were obtained for samples dried at 180°C to 220°C, indicating a slight tendency to green.

From Table 1, the TPC of spray dried Sapodilla powder produced at different inlet temperatures ranged from 1071.22±50.06 to 1268.44±108.20 mg GAE/100g. The TPC was significantly ($p<0.05$) increased when inlet temperature increased from 140ºC to 220ºC. The present findings are in agreement with Madrau *et al.* (2009) and Ahmed *et al.* (2010) in their work on spray drying of apricot juice and purple sweet potato pulp, respectively. The reason was due to the faster drying process at higher temperatures, which caused shorter exposure time and thus lesser degradation on the heat-sensitive phenolic compounds (Demarchi *et al.*, 2013). In addition, it may be caused by the polymerization as well as synthesis of polyphenols at higher drying temperatures, which increases the TPC of the powder (Mishra *et al*., 2014).

Table 1. Effect of inlet temperature on the colour profile (L^*, a^* and b^*) and TPC of sapodilla powder

Inlet temperature (°C)	Colour L^*	a^*	b^*	Total Phenolic Content (mg GAE/100g)
140	93.93 ±0.28^a	0.15 ±0.14^a	6.80 ±0.93^a	1071.22±50.06^c
160	94.08 ±0.55^a	0.07 ±0.20^a	7.02 ±0.93^a	1120.74±22.95^b
180	93.97 ±0.74^a	-0.05 ±0.17^a	7.62 ±1.11^a	1157.00± 60.00^b
200	93.78 ±0.55^{ab}	-0.14 ±0.20^a	8.20 ±1.02^a	1268.44±108.20^a
220	92.77 ±0.61^b	-0.04 ±0.23^a	8.93 ±1.48^a	1266.78±150.39^a

Data were expressed as mean ± standard deviation (n=3).
$^{a-b}$ Values in each column with different superscripts are significantly different (P<0.05).

Sapodilla powders produced with high inlet temperature (200ºC and 220ºC) were preferable as it could preserve higher phenolic compounds. However, the obtained results contradicted the result of Quek *et al.* (2007), who found that there was an adverse effect on the TPC of watermelon juice powder when different inlet temperatures were used.

Effect of maltodextrin concentration

Table 2 indicates the effect of different maltodextrin concentrations (w/v) on the colour and TPC of the spray dried Sapodilla powders. Powder produced with the additional of 10% (w/v) maltodextrin showed the lowest value of L^*, which is the darkest of all powders. The L^* value of spray dried Sapodilla powder significantly ($p<0.05$) increased with change in maltodextrin concentration from 10% (w/v) to 20% (w/v), which was 87.31±2.71 and 92.52±1.37 (Table 2), respectively. The higher

Table 2. Effect of maltodextrin concentrations on the colour profile (L^*, a^* and b^*) and TPC of sapodilla powder

Maltodextrin concentration (% (w/v)	Colour			TPC (mg GAE/100g)	Adjusted TPC (mg GAE/100g)
	L^*	a^*	b^*		
10	87.31 ± 2.71^b	0.95 ± 0.29^a	12.94 ± 0.77^a	293.20 ±18.30^a	1588.40 ±86.17^a
20	92.52 ± 1.37^a	0.30 ± 0.33^b	8.19 ± 1.50^b	251.20 ±19.90^b	1481.46 ±47.16^b
30	91.60 ± 1.19^a	0.28 ± 0.17^b	7.26 ± 0.17^b	205.50 ± 3.70^c	1477.46 ±22.39^b
40	92.59 ± 0.22^a	0.25 ± 0.19^b	5.96 ± 1.02^c	167.20 ± 7.00^d	1436.66 ±49.48^b
50	92.56 ± 1.00^a	0.09 ± 0.15^c	5.06 ± 0.73^c	146.60 ±10.60^e	1476.67 ±16.44^b

Data were expressed as mean ± standard deviation (n=3).

[a-e] Values in each column with different superscripts are significantly different (P<0.05).

Adjusted TPC of Sapodilla powder was calculated by TPC minus the weight of addition of maltodextrin.

luminosity at higher concentration of maltodextrin was probably due to the white colour effect from maltodextrin and resulted in whiteness of the powder. However, no significant differences were found from 20% to 50% (w/v) addition of maltodextrin.

The value of a^*, which is an indication of greenness or redness and the value b^*, which is an indication of blueness or yellowness of the spray dried Sapodilla powder decreased with the increasing of maltodextrin concentration (Table 2). The lowest a^* was found at the highest concentration of maltodextrin. Similar results were obtained for watermelon powders using maltodextrin (Quek *et al.*, 2007). Higher concentrations of drying agent will generally resulted in lower a^* and b^* values because an increase in the ratio of drying agent to sample would led to a dilution of material. All powders showed low positives values for a^*, indicating a slight tendency to a reddish colour. Meanwhile, all powders displayed positives b^* values, indicating tendency to yellow colour. It is advisable not to add too much of maltodextrin into the feed solution prior to drying as it would cause significant discoloration, which might affect the product marketability (Dutta *et al.*, 2006).

According to Table 2, TPC of spray dried Sapodilla powders was significantly ($p<0.05$) reduced when the concentration of maltodextrin was increased from 10% to 50% (w/v). The reason was due to the concentration effect of maltodextrin as seen from the adjusted TPC (Table 2). A significant ($p<0.05$) decreased in the adjusted TPC of the spray dried powder was only observed with an increase in the maltodextrin concentration from 10% to 20% (w/v), which is equals to 6.7% decreased in adjusted TPC. However, there was no significant ($p<0.05$) difference for the adjusted TPC from 20% to 50% (w/v). It was not preferable to add in maltodextrin at high concentration as it would increase the total solid content and caused the nutrients from the product to be diluted (Quek *et al.*, 2007).

Ten percent (w/v) of maltodextrin cannot be recommended for the production of spray dried Sapodilla powder although it gives the highest value of adjusted TPC (1588.40±86.17), as the product yield was only 20.87±5.41% due to excessive stickiness as reported by Chong and Wong (2015). However, the powder yields at 20% to 30% (w/v) maltodextrin concentrations were above 50% (50.78±3.79% and 57.42±8.25%) (Chong and Wong, 2015), which could be considered as efficient drying (Fang and Bhandari, 2011). Furthermore, powders produced at these concentrations of maltodextrin showed better retention of TPC (ranging from 1477.46±22.39 mg GAE/100g to 1481.46±47.16 mg GAE/100g) and colour. Thus, 20% or 30% (w/v) maltodextrin were chosen as the best parameters for drying agent to be used.

Conclusion

The effect of spray dryer inlet temperatures and maltodextrin concentrations on the colour and TPC of Sapodilla powder were evaluated. It was desirable to preserve the original colour and TPC in Sapodilla powder in order to enhance it marketability. The Sapodilla powder dried at 200°C with additional of 20% or 30% (w/v) maltodextrin was adequately effective to produce powder with potent antioxidant (TPC) and acceptable color in terms L^*, ^{a*} and b^*. The produced Sapodilla powder presents great potential as a source of natural functional food additive. The storage potential should be investigated in future research.

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