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ORIGINAL ARTICLE

Production of spray-dried enzyme-liquefied papaya (*Carica papaya* L.) powder

Produção por atomização de mamão (*Carica papaya* L.) em pó liquefeito por enzima

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Abstract

Water removal during drying process consumes energy and lead to high production cost. Hence, enzymatic mash treatment was proposed to reduce the usage of water to produce feed concentration that is suitable for drying. In this study, papaya powder was prepared from papaya puree treated with 1.0% v/w of Pectinex® Ultra SP-L, a pectinase enzyme, with incubation under 50 °C up to 2 hours. The liquefied papaya puree was spray-dried at selected maltodextrin concentrations (10% to 50% w/w of papaya puree) and inlet temperatures (140 °C to 180 °C). The physico-chemical properties of papaya puree, spray-dried powder, and reconstituted powder were assessed. Results showed that an increase in maltodextrin concentration led to lower process yield, lower moisture content and hygroscopicity, and better solubility. The powder produced was brighter in colour (L*) and less yellowish (b*). The papaya puree added with 20% maltodextrin achieved the highest process yield (74.91% ± 9.15%) and better solubility (69.60 ± 0.48 s/g) with optimal moisture content (5.21% ± 0.15% dry basis) and hygroscopicity (24.79% ± 0.58%) which was selected as optimal concentration. Meanwhile, increasing spray drying inlet temperatures led to a reduction in moisture content (26%) but did not significantly affect (p > 0.05) water activity, hygroscopicity, bulk density and colour of spray-dried papaya powders. The inlet temperature of 150 °C achieved the highest solubility (48.17 ± 4.51 s/g) with moderate process yield (74.01% ± 7.69%) and moisture content (5.91% ± 0.70% dry basis) which was considered as optimal drying temperature. The reconstituted powder showed no significant effect in viscosity, pH, and colour regardless of the different maltodextrin concentrations and inlet temperatures used. The optimized spray powder showed no significant difference with initial spray drying feed in total soluble solids, pH, and b* value.

Keywords: Hygroscopicity; Maltodextrin; Pectinase; Reconstituted powder; Solubility; Yield.

Resumo

A remoção da água durante o processo de secagem consome energia e gera altos custos de produção. Nesse sentido, o tratamento enzimático é uma alternativa para a redução do consumo de água na concentração adequada da alimentação no processo de secagem por atomização. Neste estudo, o mamão em pó foi produzido a partir de um purê de mamão tratado com 1,0% v/w de Pectinex® Ultra SP-L, uma enzima pectinase, com incubação a 50 °C por até 2 horas. O purê liquefeito foi seco por atomização com concentrações selecionadas de maltodextrina (10% a 50% w/w) e diferentes temperaturas de entrada (140 °C a 180 °C). Foram avaliadas as propriedades físico-químicas do purê de mamão, do pó seco e do pó reconstituído. Os resultados mostraram que o aumento na concentração de maltodextrina levou a um menor rendimento de processo, menor teor de umidade e menor higroscopicidade, e uma maior solubilidade. O pó produzido tinha uma cor mais brilhante (L*) e menos amarelada (b*). O purê de mamão adicionado com 20% de maltodextrina alcançou o maior rendimento do processo (74,91% ± 9,15%) e melhor solubilidade (69,60 ± 0,48 s/g), com ótimo teor de umidade (5,21% ± 0,15% em base seca) e higroscopicidade (24,79% ± 0,58%), sendo essa concentração considerada como ideal. O aumento da temperatura de entrada no atomizador levou à redução do teor de umidade (26%), mas não afetou significativamente ($p > 0,05$) a atividade da água, a higroscopicidade, a densidade aparente e a cor dos pós de mamão secos. A temperatura de entrada de 150 °C alcançou a maior solubilidade (48,17 ± 4,51 s/g), com rendimento moderado de processo (74,01% ± 7,69%) e teor de umidade (5,91% ± 0,70% de base seca), tendo sido considerada a temperatura ideal de secagem. A reconstituição do pó obtido mostrou não haver efeito significativo das diferentes concentrações de maltodextrina e temperaturas de entrada utilizadas na viscosidade, pH e cor. O pó obtido no processo otimizado não mostrou diferença significativa em termos de sólidos solúveis totais, pH e valor b* com relação à alimentação inicial empregada no atomizador.

Palavras-chave: Higroscopicidade; Maltodextrina; Pectinase; Pó reconstituído; Solubilidade; Rendimento.

1 Introduction

Papaya (*Carica papaya* L.) is a very wholesome and inexpensive fruit that is available all the time regardless of the weather and season (Ahmad et al., 2013). It is highly appreciated around the world for its flavour, nutritional quality and digestive properties (Aravind et al., 2013). Regular consumption of papaya is able to ensure sufficient amount of vitamins (A, B_2 and C) and minerals (folate, calcium, thiamine, iron, niacin, and potassium) intake (Krishna et al., 2008; Ahmad et al., 2013; Aravind et al., 2013). Most of the literature showed limited work on the production of papaya powder. Drying studies of papaya were carried out by using foam-mat drying (Kandasamy et al., 2014), freeze-drying (Athmaselvi et al., 2014), and hot air oven and solar drying (Padmapriya, 2013). Studies on the production of spray-dried papaya powder are rather rare and the production of papaya powder also broadens its potential applications in the food industry.

Spray drying is a technique widely used in the food industry to produce fruit powders such as soursop (Chang et al., 2018a), pineapple (Wong et al., 2015), tamarind (Muzaffar & Kumar, 2015), and beetroot (Bazaria & Kumar, 2018). In addition, spray drying has been successfully applied for carotenoid stability in plant foods such as carrots, tomato pulp, and sweet potato (Wagner & Warthesen, 1995; Goula & Adamopoulos, 2005a; Grabowski et al., 2006). The physico-chemical properties of the powders mainly depend on the operating conditions, usage of carrier agents, and respective concentrations (Chew et al., 2019; Chegini & Ghobadian, 2005, 2007; Muzaffar & Kumar, 2015; Phisut, 2012). Feed that has low viscosity and smooth consistency prevents clogging issue during the drying process and improve the spray drying efficiency (Chang et al., 2018a; Grabowski et al., 2006). Hence, incorporation of the enzyme during the pre-treatment step can be an alternative to produce spray drying feed.

Application of enzyme in juice and beverage industry is mainly to increase extraction yield, increase operation efficiency (pressing and solid removal), liquefy the fruit before processing, to improve colour and aroma, juice clarification, and hydrolyze insoluble substances (Schols et al., 2009; Bhat, 2000). The common enzymes used for liquefaction are pectinases and cellulases. Most of the researchers including

Chang et al. (2018b), Liew Abdullah et al. (2007) and Tran et al. (2008) used pectinase enzymes with different enzyme concentrations to liquefy soursop fruits, carambola fruit, and gac fruit, respectively. Pectinase speeds up the extraction of pectin-rich fruit juices by degrading the gel structure of fruit pulp. According to Chaudhri & Suneetha (2012), pectinases hydrolyze the methyl esterified α-(1,4) linked homogalacturonic acid backbone and branched neutral sugar side chains of pectin. The enzyme-liquefied puree has the lower viscosity, easier to be pumped into the spray dryer and the problem of clogging can be prevented (Bazaria & Kumar, 2018; Chegini & Ghobadian, 2007; Phisut, 2012).

The fruit powders obtained by spray drying may have some problems in their properties such as stickiness, high hygroscopicity, and low solubility (Fazaeli et al., 2012). Hence, additives such as maltodextrin may serve as drying aid to facilitate drying as well as to reduce the stickiness and hygroscopicity of powder (Phoungchandang & Sertwasana, 2010; Fazaeli et al., 2012; Fang & Bhandari, 2012; Phisut, 2012). This research work aimed to study the feasibility of enzyme pectinase in pre-treatment steps in preparation of spray drying feed and the effects of maltodextrin and inlet temperatures on the spray-dried papaya powders. Apart from that, the Physico-chemical properties of papaya fruit puree, spray-dried papaya powder, and reconstituted powders were carried out.

2 Materials and methods

2.1 Materials

The fruit used was “Sekaki” papaya purchased from a local fruit store in Puchong, Selangor at the maturity stage of 5 in which yellowish-orange colour covered 75% of the skin’s surface. The selected fruits were uniform in size and free from external defects. The fruits were rinsed with running water to remove dirt and dust. The skins were peeled using the fruit peeler, the fruit was cut into half and the seeds were removed. A total of 10 kg of fruit pulps were collected and cut into small cubes (20 mm × 20 mm × 20 mm).

2.2 Liquefaction of papaya pulp

Enzymatic liquefaction of papaya pulp was performed by following the method which was optimized previously by Saw (2013). The papaya pulps were homogenised using a blender (Panasonic, Japan) at high speed for 1 min without the addition of water. Approximately 250 g of blended pulps were placed into 500 mL beakers and added with 1.0% v/w of Pectinex ® Ultra SP-L (Novozyme, Denmark). The mixture of the enzyme and blended pulps were stirred using a spatula for 30 seconds and placed into the water bath (Memmert, Germany) at 50 °C for an incubation time of two hours and shaken at 100 rpm. After two hours, the mixture was placed into a water bath at 95 °C for five minutes to inactivate the enzyme. The enzyme liquefied papaya purees were then sieved by using cloth strainer filter with handle (25 cm length × 30 cm depth × 12 cm diameter) for three times to ensure a smooth consistency. Physico-chemical properties of sieved papaya puree were examined and compared with the spray-dried reconstituted powders.

2.3 Spray drying of papaya powder

The spray drying process was conducted in two separate parts. Firstly, 200 g of enzyme-treated papaya puree was weighed in 500 mL beaker and added with maltodextrin solution. Maltodextrin DE-10 (Bronson and Jacobs, Australia) solution was prepared at different concentrations of 10%, 20%, 30%, 40% and 50% w/w of papaya puree by dissolving into 200 g of warm water (Fang & Bhandari, 2011). Then, the mixture was stirred for 30 seconds using the spatula and ready for spray drying. A mini spray dryer (Büchi Labortechnik AG, B-290, Switzerland) was used and the aspirator rate was set to 90%. The nozzle speed was adjusted to 5 and the air compressor was set to 40nm. The inlet temperature was set to 160 °C to make sure that inlet temperature is an independent parameter in this part. Initially, distilled water was sprayed for

5 minutes to warm up the spray dryer then only the feed of the sample was pumped. The spray-dried papaya powder was recovered at the collection vessel of the spray dryer.

The second part of spray drying was conducted after selecting the optimum maltodextrin concentration obtained from the first part. Five different inlet temperatures were selected ranged of 140 °C, 150 °C, 160 °C, 170 °C, to 180 °C for each spray drying. The spray-dried papaya powder was immediately weighed and vacuum-packed using polyethylene-polyamide vacuum pouch (15 cm length × 15 cm width) as soon as possible. The weight of the spray-dried powders, total times were taken and powder conditions were recorded for each spray drying process.

2.4 Analysis of spray-dried powder

2.4.1 Process yield

The process yield of powder was calculated according to the following Formula 1, based on dry matter measurements (Fang & Bhandari, 2012; Fazaeli et al., 2012).

$$\text{Process yield } \% = \frac{\text{Weight of spray-dried powder (g)}}{\text{Dried weight of papaya juice (g) x Weight of maltrodextrin (g)}} \text{ x } 100\% \quad (1)$$

2.4.2 Moisture content

The moisture content of the papaya powder was determined using AOAC 935.29 standard method (Association of Official Analytical Chemists, 2000; Jittanit et al., 2010). Two grams of the powder were weighed in the pre-dried and pre-weighed aluminum plates and then dried in the oven (UNB 500, Memmert, Germany) at 105 °C for 24 hours. The dried powder samples were cooled and weighed to obtain constant weight. The moisture content was calculated using the Equation 2 below and expressed as a dry basis.

$$\text{Percent of moisture content (w / w)} = \frac{\text{Weight of wet sample (g) - Weight of dry sample (g)}}{\text{Weight of dried sample (g)}} \text{x} 100\% \quad (2)$$

2.4.3 Water Activity (Aw)

The LabMaster water activity meter (Novasina, Switzerland) was used to determine the water activity (Aw) of the powders. The device was switched on an hour before to warm up. Two grams of powder were weighed into a container and placed in the sample port of the water activity meter and read at room temperature (Chang et al., 2018a).

2.4.4 Hygroscopicity

The hygroscopicity of the papaya powder was determined according to the method described by Cai & Corke (2000). Saturated ammonium chloride solution with 78% of RH was prepared in the glass desiccator at 25 ± 1.0 °C. Two grams of spray-dried papaya powder were weighed in the pre-dried and pre-weighed containers and placed into the desiccator. The powder was removed and weighed after 7 days. The hygroscopicity of the powder was calculated using the Equation 3 below.

$$\text{\% of hygroscopicity} = \frac{\text{Weight of sample after a week (g) - Initial weight of sample (g)}}{\text{Initial weight of sample (g)}} \text{ x } 100\% \quad (3)$$

2.4.5 Bulk density

Five grams of the papaya powder were transferred to a 50 mL measuring cylinder. Bulk density was calculated from the weight of powder contained in the cylinder after being repeatedly tapped manually by

rubber tap on a bench 20 times and the volume was recorded. Bulk density was calculated using the Equation 4 and expressed as grams per millilitre (g/mL) (Tonon et al., 2011).

$$\text{Bulk density (BD)} = \frac{\text{Weight of powder (g)}}{\text{Volume of powder (mL)}} \quad (4)$$

2.4.6 Solubility

The solubility of the powder was analysed according to the method proposed by Phoungchandang & Sertwasana (2010). Approximately 400 mL of distilled water was heated to 70 °C. Approximately 0.5 g of spray-dried papaya powders were added into a beaker containing hot water and stirred. The time taken to completely dissolve the powder was recorded by using a stopwatch (Model 505, Diamond, China). The solubility was was calculated using the Equation 5 and expressed as a second per gram (s/g).

$$\text{Solubility} = \frac{\text{Time required to dissolve the dry powder (s)}}{\text{Weight of powder (g)}} \quad (5)$$

2.4.7 Colour

The colour of the papaya puree, papaya powder, and reconstituted powder were analysed using HunterLab's ColorFlex Ez Colorimeter (Hunter Associates Laboratory Inc., USA). EasyMatch QC-ER software was used to create the fruit job template file connecting this instrument to the computer for electronic records. The colorimeter was firstly standardized against a black tile and then followed by a white tile. The sample was poured into the Quartz sample cup and placed on top of the sample port. The colour data was expressed in terms of L*, a* and b* values where L* represents luminosity or lightness, a* represents the degree of redness or greenness and b* represents the degree of yellowness or blueness (Phoungchandang & Sertwasana, 2010).

2.5 Analysis of reconstituted powder

The spray-dried papaya powder was rehydrated with distilled water to a similar total soluble solid content as the initial fruit puree before undergoing spray drying (Jittanit et al., 2010). Around 5.5 g of papaya powders were added with 50 mL warm water. The mixture was stirred to form a light orange-yellowish solution and the TSS content was examined. The papaya powder was added continuously until the total soluble solid obtained 9.8 ± 0.1 °Brix. Then, viscosity, pH, and colour test were carried out on reconstituted powders.

2.5.1 Total Soluble Solid (TSS)

Total soluble solid (TSS) was obtained by using a digital refractometer MA 871 (0 to 85 °Brix) (Milwakee, Romania). Distilled water was used to calibrate the digital refractometer. A drop of the sample was placed on the refractometer's sample port and read (Chang et al., 2018b).

2.5.2 Viscosity

A Brookfield viscometer (DV-II+ Pro, Brookfield, US) equipped with Rheocalc software program was used to measure the viscosity. The spindle of Ultra Lower Adapter (ULA) was selected and the viscometer was auto-zero before conducting the analysis. The rotational speed was set to 200 rpm. Approximately 15 mL of the samples was placed in the sample tube and read at room temperature (Wong et al., 2015).

2.5.3 pH value

The pH values were measured using a digital pH meter (Jenway, UK). The calibration of the pH meter was done using a pH buffer 7.0 followed by pH buffer 4.0. The probe of the pH meter was inserted into the sample and read at room temperature.

2.6 Statistical analysis

All the statistical analysis of the data collected from the experiment was analysed using IBM SPSS software (IBM SPSS Statistics 22). The data collected was expressed in terms of mean ± standard deviations. The Tukey's Honestly Significant Difference (HSD) One-way ANOVA was performed to determine the significant differences between the means of data collected ($p \leq 0.05$).

3 Results and discussion

3.1 Physico-chemical properties of enzyme-treated papaya puree

The physico-chemical properties of the enzyme-treated papaya puree used for the spray drying process were investigated. TSS of the papaya puree was 9.8 ± 0.1 °Brix which is close to the TSS (10 °Brix) reported in fully ripened 'Sekaki' papaya fruit (Chan, 2001; International Tropical Fruits Network, 2011). Besides, the average pH is 4.09 ± 0.05, indicating it as low acid fruit which is less susceptible to microbial growth (Chukwuka et al., 2010). The reported pH value of ripened papaya was 5.7 (Zuhair et al., 2013). The difference in pH might due to the difference in the variety and geographical conditions (Sanudo et al., 2008). The enzyme-treated papaya puree had the viscosity of 2.35 ± 0.04 cP. The value is low due to the ability of pectinase to digest the pectin matrix of the plant cell, lead to a smooth consistency that facilitates the feed to be pumped into the spray dryer and prevent clogging (Chang et al., 2018b; Chegini & Ghobadian, 2007; Phisut, 2012). Furthermore, the L*, a*, and b* value of the puree were 24.00 ± 1.05, 13.72 ± 1.13, and 26.23 ± 0.81, respectively that exhibited a bright orange-yellow in colour.

3.2 Spray-dried papaya powder with different maltodextrin concentration

3.2.1 Process yield, feed flow rate and outlet temperature

Table 1 describes the process yield, feed flow rate and outlet temperature of spray-dried papaya powder over different maltodextrin concentration. The process yield was ranged between 53.07% ± 8.53% and 74.91% ± 9.15%. From the result, 20% maltodextrin is reported to provide the highest process yield while the lowest process yield was obtained by the addition of 50% maltodextrin. The process yield decreases when higher concentrations of maltodextrin were added (> 30%). Tonon et al. (2008) and Jittanit et al. (2010) reported that higher solid contents in the feed increased the number of solid particles available in the drying system as well as increased the deposition of material on the chamber wall. This study also agreed with Bazaria & Kumar (2018) that the higher maltodextrin concentration promoted higher powder yield. Thus, the process yield obtained is low with the increase of solid content due to higher maltodextrin concentrations.

Table 1. Process yield, feed flow rate and outlet temperature of the spray drying process over different maltodextrin concentration.

Maltodextrin concentration (% w/w papaya puree)	Process yield (%)	Feed flow rate (g/min)	Outlet temperature (°C)
10	63.09 ± 7.38^{ab}	2.87 ± 0.17^{ab}	92-95
20	74.91 ± 9.15^{b}	2.71 ± 0.23^{a}	95-99
30	60.48 ± 6.55^{ab}	3.00 ± 0.17^{abc}	94-99
40	59.61 ± 4.61^{ab}	3.15 ± 0.04^{ab}	94-97
50	53.07 ± 8.53^{a}	3.30 ± 0.04^{a}	94-98

Values are means ± standard deviations of triplicate determination. Within the same column, different superscripts are significantly different at $p < 0.05$, as measured by the Tukey's HSD Test.

The feed flow rates varied with different concentration of maltodextrin (Table 1). Higher feed flow rate implied in shorter contact time between the feed and drying air caused the feed was not fully atomised (Chegini & Ghobadian, 2007). As a result, it increased the feed wall deposition and reduced the collection of process yield (Phisut, 2012). This agreement with the process yield result as a higher concentration of maltodextrin has the lowest process yield which might be caused by the high feed flow rate. Meanwhile, the outlet temperatures were ranged from 92 °C to 99 °C which is within the range suggested by Kim et al. (2009) of 80 °C to 110 °C to prevent the loss of heat-sensitive material.

Visually, papaya powder produced by 10% maltodextrin exhibited hard, coarse and sticky powder with bright orange colour (data not shown) which deposited on the chamber wall. Meanwhile, the papaya powders produced with > 20% maltodextrin are appeared to be soft and fine with pale orange colour seen. Chang et al. (2018a) suggested that the addition of maltodextrin could contribute to an increasein the total solid contents and alter the surface stickiness of the powder. Therefore, the addition of drying aid is necessary but the concentration should not be too high that lost the attractive colour of the fruit powder (Kha et al., 2010).

3.2.2 Physico-chemical analyses of spray-dried papaya powder

Table 2 describes the physico-chemical analyses of spray-dried papaya powder produced from different concentrations of maltodextrin. The moisture content was ranged between 3.91% ± 0.26% dry basis to 7.38% ± 0.91% dry basis. The moisture content of powder was significantly reduced ($p \leq 0.05$) by up to 29% when maltodextrin concentration increased from 10% to 20%. However, no significant difference ($p > 0.05$) of moisture content of powder added with 20% to 50% of maltodextrin. Reduction of moisture content was observed in spray drying of pineapple powder (-12%), gac fruit powder (-17%) and bayberry powder (-21%) with an increase in maltodextrin concentration (Jittanit et al., 2010; Kha et al., 2010; Fang & Bhandari, 2012). This may be due to the addition of maltodextrin increased the total solids in the feed and reduced the total moisture for evaporation (Quek et al., 2007). However, there was no significant difference ($p > 0.05$) observed in Aw of the spray-dried papaya powders ($p > 0.05$) regardless of the concentration of maltodextrin used (Table 2). The Aw was ranged from 0.22 ± 0.05 to 0.28 ± 0.04 aw. A similar range of powder Aw (0.20 to 0.23 aw) was reported from Fang & Bhandari (2012) in the production of bayberry juice powder under the same maltodextrin concentrations (10% to 50%). Since the Aw of spray-dried papaya powder was lower than 0.6 aw, the papaya powder was considered microbiological stable and prevented from the deterioration (Tang & Yang, 2004; Quek et al., 2007).

Table 2. Physico-chemical properties of spray-dried papaya powder over different maltodextrin concentrations.

Maltodextrin concentration (% w/w papaya puree)	Moisture content (% dry basis)	Water activity (aw)	Hygroscopicity (%)	Bulk density (g/mL)	Solubility (s/g)	Colour parameters		
						L*	a*	b*
10	7.38 ± 0.91^{a}	0.28 ± 0.04^{a}	28.95 ± 1.79^{a}	0.65 ± 0.09^{a}	165.32 ± 0.69^{a}	89.71 ± 1.06^{b}	4.55 ± 0.89^{a}	15.81 ± 0.50^{a}
20	5.21 ± 0.15^{b}	0.25 ± 0.04^{a}	24.79 ± 0.58^{b}	0.53 ± 0.05^{a}	69.60 ± 0.48^{c}	91.43 ± 1.26^{ab}	3.28 ± 0.62^{a}	13.44 ± 1.15^{ab}
30	5.01 ± 0.37^{b}	0.22 ± 0.05^{a}	24.64 ± 0.52^{b}	0.58 ± 0.07^{a}	70.30 ± 0.25^{c}	91.35 ± 1.39^{ab}	3.41 ± 0.51^{a}	13.19 ± 1.95^{ab}
40	3.96 ± 0.50^{b}	0.23 ± 0.04^{a}	21.65 ± 1.03^{c}	0.61 ± 0.03^{a}	70.48 ± 0.27^{c}	92.35 ± 1.36^{ab}	2.96 ± 0.69^{a}	10.72 ± 2.15^{b}

Values are means ± standard deviations of triplicate determination. Within the same column, different superscripts are significantly different at $p < 0.05$, as measured by the Tukey's HSD Test.

Meanwhile, an increase in maltodextrin concentration results in the reduction of hygroscopicity for spray-dried papaya powder. The hygroscopicity of spray-dried powders decreased by up to 26% when maltodextrin concentration increased from 10% to 50%. A similar trend was reported by Tonon et al. (2008) that the hygroscopicity of acai powders decreased from 15.79 to 12.45 g/100 g when maltodextrin concentration increased from 10% to 30%. According to GEA's (2005) analytical method, the powder was considered very hygroscopic when hygroscopicity between 20.1% and 25% and extremely hygroscopic if > 25%. From Table 2, the powder produced at 10% of maltodextrin was referred to as extremely hygroscopic (28.95% ± 1.79%) while the remaining powders were referred to as very hygroscopic (21.45% ± 0.64% to 24.79% ± 0.58%).

There was no significant difference ($p > 0.05$) in the bulk density of the spray-dried papaya powder regardless of the concentration of maltodextrin used. The bulk density varies from 0.53 ± 0.05 g/mL to 0.65 ± 0.09 g/mL. On the other hand, the solubility of spray-dried powders ranged from 69.60 ± 0.48 s/g to 165.32 ± 0.69 s/g. Spray-dried powder using 10% maltodextrin had the poorest solubility which needs the longest time to be dissolved in water. Meanwhile, powder with 20% maltodextrin had the lowest solubility value of 69.60 ± 0.48 s/g, indicating the powder dissolves easily in water. According to Cano-Chauca et al. (2005), maltodextrin has a high degree of solubility which facilitates the dissolution of powder in water. Overall, the papaya powder produced in this study has high solubility which may be reconstituted into a drink.

The colour measurements (L*, a* and b*) of the spray-dried papaya powder are presented in Table 2. The lightness (L*), redness (a*) and yellowness (b*) ranged from 89.71 ± 1.06 to 92.74 ± 0.53, 2.84 ± 0.66 to 4.55 ± 0.89 and 10.72 ± 2.15 to 15.81 ± 0.50, respectively. The L* value was increased when the concentration of maltodextrin used was higher. This might be due to the masking effect of the white colour of maltodextrin (Chang et al., 2018a). There was no significant difference ($p > 0.05$) observed in a* value, indicating the addition of maltodextrin did not affect the redness of powder. However, increasing maltodextrin concentration resulted in a reduction of b* values (Table 2). The b* value decreased by up to 32% when maltodextrin increased from 10 to 40%. Grabowski et al. (2006) and Kha et al. (2010) mentioned that increasing maltodextrin concentration caused the loss of the colour intensity in some spray-dried powders. Hence, the optimal concentration of maltodextrin must be used which retained the colour of the fruit powder.

Overall, the papaya puree added with 20% maltodextrin achieved the highest process yield (74.91 ± 9.15%) and better solubility (69.60 ± 0.48 s/g) with optimal moisture content and hygroscopicity. The powder produced was orange in colour and had soft and fine texture as well as non-sticky characteristics. Hence, this level of maltodextrin was selected as an optimal concentration in the spray drying of papaya juice and proceed to the second part of the experiment. This was in accordance with the finding from Mohd Taufik (2009) who had optimized 20% of maltodextrin in the production of dragon fruit powder.

3.3 Spray-dried papaya powder with different inlet temperatures

3.3.1 Process yield, feed flow rate and outlet temperature

Table 3 presents the process yield, feed flow rate and outlet temperature of spray-dried papaya powder over different inlet temperatures. The process yield was ranged from 34.32% ± 7.88% to 80.67% ± 3.74%. The range of process yield in papaya powder was lower as compared to pineapple powder that varied from 73.2% to 81.3% at inlet temperatures from 130 °C to 170 °C (Jittanit et al., 2010). The highest process yield was achieved when spray drying inlet temperature at 160 °C. Meanwhile, papaya powder formed at inlet temperatures of 140 °C and 180 °C exhibited low process yields. This might be due to high inlet temperatures led to the rapid formation of the dried layer at the droplet surface (Chegini & Ghobadian, 2007; Phisut, 2012). However, when the temperature was too high (180 °C), it caused the melting of powder which led to

stickiness problems and low process yield (Bhandari et al., 1993; Papadakis et al., 2006). This study is different from the result reported by Bazaria & Kumar (2018) that higher inlet temperature led to higher powder yield.

Table 3. Process yield, feed flow rate and outlet temperature of the spray drying process over different inlet temperatures.

Inlet Temperature (°C)	Process yield (%)	Feed flow rate (g/min)	Outlet temperature (°C)
140	42.28 ± 4.72^{b}	2.93 ± 0.07^{a}	84-87
150	74.01 ± 7.69^{a}	2.78 ± 0.15^{a}	89-91
160	80.67 ± 3.74^{a}	2.78 ± 0.10^{a}	96-98
170	72.60 ± 9.64^{a}	2.91 ± 0.81^{a}	100-102
180	34.32 ± 7.88^{b}	2.93 ± 0.07^{a}	106-114

Values are means ± standard deviations of triplicate determination. Within the same column, different superscripts are significantly different at $p < 0.05$, as measured by the Tukey's HSD Test.

There was no significant difference ($p > 0.05$) in the feed flow rate for all different inlet temperatures. The feed flow rates vary from 2.78 ± 0.10 g/min to 2.93 ± 0.07 g/min (Table 3). Meanwhile, the outlet temperatures were ranged from 84 °C to 114 °C. The outlet temperatures increased as the inlet temperatures increased. The outlet temperatures were within the range of 80 °C to 110 °C which ensures good retention of heat-sensitive food components (Kim et al., 2009). Apart from that, the spray-dried papaya powders produced at 140 °C and 180 °C were coarse and sticky (data not shown). In contrast, the spray-dried powders produced at inlet temperatures of 150 °C to 170 °C appeared to be soft and fine with non-sticky textures. Visually, an increased in drying temperatures resulted in pale orange-yellow colour in spray-dried papaya powder. This might be due to the high temperature that caused the loss of retention of the colour pigment (Goula & Adamopoulos, 2005b; Quek et al., 2007; Kha et al., 2010).

3.3.2 Physico-chemical analyses of spray-dried papaya powder

Table 4 displays the physicochemical analyses of spray-dried papaya powder at different inlet temperatures. The moisture content was ranged from 4.72% ± 0.25% to 6.35% ± 0.32% dry basis. The highest moisture content was achieved when spray drying at an inlet temperature of 140 °C. It decreases gradually and up to 26% when the inlet temperature increased from 140 °C to 180 °C. Moisture contents of powders sprayed at 170 °C and 180 °C showed no significant difference ($p > 0.05$). This result is in agreement with the works of Muzaffar & Kumar (2015) and Jittanit et al. (2010) whereby reduction of the moisture contents of tamarind powder and pineapple powder (-17%) were observed when inlet temperature used was increased. This might be due to a greater rate of heat transfer into the particles at higher inlet temperatures (Quek et al., 2007; Kha et al., 2010; Phisut, 2012), improved moisture removal efficiency and caused the reduction of moisture content in spray-dried powder. On the other hand, the Aw showed no significant difference ($p > 0.05$) when subjected to different inlet temperatures. The Aw was ranged from 0.16 to 0.20 aw, which was lower as compared to watermelon powder (0.20 to 0.29 aw) and acai fruit powder (0.20 to 0.26 aw) (Quek et al., 2007; Tonon et al., 2011). This range of Aw was < 0.60 aw, indicating the spray-dried papaya powder was microbiologically stable (Quek et al., 2007).

Table 4. Physico-chemical properties of spray-dried papaya powder over different inlet temperatures.

Inlet Temperature (°C)	Moisture content (% dry basis)	Water activity (aw)	Hygroscopicity (%)	Bulk density (g/mL)	Solubility (s/g)	Colour parameters		
						L*	a*	b*
140	6.35 ± 0.32^{a}	0.20 ± 0.01^{a}	22.57 ± 0.46^{a}	0.51 ± 0.01^{a}	65.72 ± 2.31^{a}	87.95 ± 0.72^{a}	6.78 ± 0.83^{a}	15.94 ± 1.70^{a}
150	5.91 ± 0.70^{ab}	0.19 ± 0.01^{a}	22.47 ± 0.23^{a}	0.50 ± 0.01^{a}	48.17 ± 4.51^{b}	87.89 ± 0.53^{a}	6.82 ± 0.56^{a}	16.16 ± 1.11^{a}
160	5.69 ± 0.46^{ab}	0.18 ± 0.02^{a}	22.12 ± 0.99^{a}	0.47 ± 0.03^{a}	55.72 ± 3.06^{ab}	87.39 ± 0.90^{a}	6.91 ± 0.79^{a}	16.17 ± 1.44^{a}
170	4.99 ± 0.60^{b}	0.16 ± 0.01^{a}	21.80 ± 1.09^{a}	0.50 ± 0.01^{a}	0.53 ± 0.05^{a}	86.48 ± 1.34^{a}	7.22 ± 0.51^{a}	16.94 ± 0.99^{a}
180	4.72 ± 0.25^{b}	0.20 ± 0.04^{a}	21.36 ± 0.93^{a}	0.53 ± 0.05^{a}	62.74 ± 2.76^{a}	86.86 ± 0.27^{a}	7.23 ± 0.33^{a}	17.32 ± 0.97^{a}

Values are means ± standard deviations of triplicate determination. Within the same column, different superscripts are significantly different at $p < 0.05$, as measured by the Tukey's HSD Test.

The hygroscopicity of spray-dried papaya powders varies from 21.36% ± 0.93% to 22.57% ± 0.46%, with no significant difference ($p > 0.05$) observed among all powders regardless of the inlet temperatures. These powders were considered "very hygroscopic" in accordance with GEA's (2005) analytical method. Goula & Adamopoulos (2008) had reported that spray-dried sugar-rich particles absorb moisture from the surrounding air easily which is very hygroscopic, inducing powder caking. At the same time, the bulk density of the spray-dried papaya powders had no significant difference ($p > 0.05$) regardless of the inlet temperatures used. It is ranged from 0.47 ± 0.03 g/mL to 0.53 ± 0.05 g/mL, lower as compared to spray-dried gac powder (0.66 to 0.78 g/mL) and spray-dried ginger powder (0.48 to 0.83 g/mL) (Kha et al., 2010; Phoungchandang & Sertwasana, 2010).

The solubility of spray-dried powders ranged from 48.17 ± 4.51 s/g to 65.72 ± 2.31 s/g. The powder produced from an inlet temperature of 140 °C had the lowest solubility (65.72 ± 2.31 s/g), indicating more time to dissolve in water. The solubility value of spray-dried powder increased by up to 30% to 62.74 ± 2.76 s/g when inlet temperature increased from 140 °C to 180 °C, indicating poorer solubility when temperature used to spray dry is higher. Increasing inlet temperature caused by a decrease in solubility was also reported in orange and watermelon juice powders (Chegini & Ghobadian, 2005; Quek et al., 2007). This might be due to the formation of a hard surface layer over the powder particle at a very high inlet temperature that prevented the diffusion of the water molecules through the particle. As a result, the wettability of the particle decreased and solubility of the powder reduced at high temperatures (Chegini & Ghobadian, 2005; Quek et al., 2007).

The colour parameters (L*, a* and b*) of the spray-dried papaya powders produced under different inlet temperatures are shown in Table 4. The lightness (L*), redness (a*) and yellowness (b*) ranged from 86.86 ± 0.27 to 87.95 ± 0.72, 6.78 ± 0.83 to 7.23 ± 0.33 and 15.94 ± 1.70 to 17.32 ± 0.97, respectively. No significant differences ($p > 0.05$) were observed in L*, a*, and b* values regardless of the inlet temperatures used. Kha et al. (2010) also reported that the lightness of gac fruit powder was not significantly influenced ($p > 0.05$) by the drying temperature. The loss of pigment in the fruit powder happened when the inlet temperature used more than 180 °C (Kha et al., 2010).

Overall, the papaya puree spray-dried at 150 °C with the feed flow rate of 2.78 ± 0.15 g/min had the highest solubility (48.17 ± 4.51 s/g) and moderate process yield (74.01% ± 7.69%) and moisture content (5.91% ± 0.70% dry basis) which was considered as optimal drying temperature. The papaya powder produced was soft and fine texture as well as a non-sticky characteristic with pale orange in colour. Hence, drying at 150 °C was selected as optimum inlet temperature used for spray drying of papaya powder. This was in accordance with the findings of Quek et al. (2007) and Jittanit et al. (2010) in the production of watermelon powder and pineapple powder, respectively.

3.4 Physico-chemical analyses of reconstituted powder

3.4.1 Viscosity

The viscosity of the reconstituted powders produced from various maltodextrin concentrations was ranged from 2.57 ± 0.04 cP to 2.64 ± 0.07 cP. There was no significant difference in all viscosities values under all concentrations of maltodextrin ($p > 0.05$), indicating the maltodextrin concentration did not influence the viscosity of the reconstituted powder. Meanwhile, the viscosity of reconstituted powder produced under different inlet temperatures was ranged from 2.52 ± 0.03 cP to 2.60 ± 0.03 cP. Similarly, the viscosities of reconstituted powders showed no statistical difference under all inlet temperatures used. This viscosity was low before, because the heats applied during spray drying might alter the structure of pectins (Goula & Adamopoulos, 2008). As a result, lower viscosity of reconstituted powder obtained.

3.4.2 pH value

The pH values of the reconstituted powders produced over different maltodextrin concentration and inlet temperatures were ranged from 4.12 ± 0.24 to 4.16 ± 0.19 and 4.11 ± 0.05 to 4.16 ± 0.04, respectively. The pH values of the reconstituted powders showed no significant difference ($p > 0.05$) regardless of the maltodextrin concentrations and inlet temperatures used. The pH values of reconstituted papaya powders were higher as compared to the pH values of reconstituted pineapple powder which varied from 3.4 to 3.7 in the study conducted by Jittanit et al. (2010).

3.4.3 Colour

The colour parameters (L*, a* and b*) of the reconstituted powders produced with the addition of different maltodextrin concentrations and inlet temperatures were measured. The lightness (L*), redness (a*) and yellowness (b*) were ranged from 12.21 ± 0.78 to 17.46 ± 0.82, 2.78 ± 0.15 to 3.47 ± 0.49 and 14.93 ± 1.45 to 20.21 ± 2.14 over different maltodextrin levels. An increase in the maltodextrin concentrations from 10% to 50% caused an increase in L* of reconstituted powders by up to 43%. The effect of a high amount of maltodextrin contributed greater in the lightness of gac powder was also reported (Kha et al., 2010). Meanwhile, a* and b* values were not significantly affected ($p > 0.05$) by maltodextrin concentrations.

The L*, a* and b* values of reconstituted papaya powders were from 17.00 ± 1.48 to 17.88 ± 0.80, 3.12 ± 0.30 to 4.09 ± 0.15 and 18.79 ± 1.99 to 20.62 ± 3.80, respectively. There was no significant effect ($p > 0.05$) in terms of L* and b* values of the reconstituted powders produced under all inlet temperatures. The reduction of a* value by up to 24% was recorded when the inlet temperature increased from 160 to 180 °C, indicating that the reconstituted papaya powders were less reddish. This was in agreement with the works of Sousa et al. (2008) and Kha et al. (2010) whereby the reduced redness in tomato powders and gac fruit powders were caused by increasing drying inlet temperatures.

3.5 Reconstitution of optimized powder

Table 5 describes the physico-chemical analyses of initial papaya puree and optimized reconstituted powder (20% maltodextrin and spray-dried at 150 °C). Reconstituted powders showed no significant difference ($p > 0.05$) in terms of TSS, pH, and b* value when compared to the initial papaya puree before undergoing a spray drying process. However, significant ($p \leq 0.05$) higher viscosity (10%) and lower L* (26%) and a* (73%) values when reconstituted. These differences might be due to the heat treatment during the spray drying process as well as the addition of carrier agents. Hence, we concluded that the optimized reconstituted powder is similar to the initial papaya puree in terms of TSS, pH, and b* value.

Table 5. Physico-chemical analyses of initial papaya juice and optimised reconstituted powder.

Analyses	Papaya puree	Optimised reconstituted powder
TSS (°Brix)	9.83 ± 0.06[a]	9.90 ± 0.17[a]
Viscosity (cP)	2.35 ± 0.04[a]	2.60 ± 0.03[b]
pH	4.09 ± 0.05[a]	4.13 ± 0.03[a]
Colour L*	24.00 ± 1.05[a]	17.88 ± 0.80[b]
a*	13.72 ± 1.13[a]	3.67 ± 0.36[b]
b*	26.23 ± 0.81[a]	20.54 ± 2.94[a]

Values are mean ± standard deviation of triplicate determination. Within the same row, different superscripts are significantly different at $p \leq 0.05$ as measured by the Paired T-test.

4 Conclusion

This research study showed the feasibility to produce papaya powder pre-treated with enzyme pectinase by using a spray drying process. The spray-dried papaya powder produced was appeared in soft and fine texture as well as a non-sticky characteristic with pale orange in colour. The results indicated that 20% maltodextrin concentration as the optimum concentration as it achieved the highest in process yield (74.91% ± 9.15%) and solubility (69.60 ± 0.48 s/g) with the feed flow rate of 2.71 ± 0.23 g/min. Meanwhile, at the inlet temperature of 150 °C, the powder recovery was high (74.01% ± 7.69%) at the feed flow rate of 2.78 ± 0.15 g/min with the highest solubility (48.17 ± 4.51 s/g). The spray-dried papaya powder under the parameter of 20% of maltodextrin and inlet temperature of 150 °C presented different characteristics in terms of viscosity and colour measurements. The optimised reconstituted powder was slightly different from the initial papaya puree. Further studies on the sensory evaluation of the fresh papaya fruit and reconstituted powder are suggested to be carried out.

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