Production of spray-dried honey jackfruit (*Artocarpus heterophyllus*) powder from enzymatic liquefied puree

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Abstract This paper presents the enzymatic liquefaction process for honey jackfruit optimized with Pectinex[®] Ultra SP-L and Celluclast[®] 1.5 L individually or in combinations at different concentrations (0–2.5% v/w) and incubation time (0–2.5 h). Treatment with combinations of enzymes showed a greater effect in the reduction of viscosity (83.9–98.8%) as compared to single enzyme treatment (64.8–87.3%). The best parameter for enzymatic liquefaction was obtained with 1.0% (v/w) Pectinex[®] Ultra SP-L and 0.5% (v/w) Celluclast[®] 1.5 L for 1.5 h. Spray drying process was carried out using different inlet temperatures (140–180 °C) and maltodextrin concentrations (10–30% w/w). Results indicated that the spray-dried honey jackfruit powder produced at 160 °C with 30% w/w maltodextrin gave the highest product yield (66.90%) with good powder qualities in terms of water activity, solubility, moisture content, hygroscopicity, color and bulk density. The spray-dried honey jackfruit powder could potentially be incorporated into various food products.

Keywords Honey jackfruit · Enzymatic liquefaction · Spray drying

Introduction

Asia and the Pacific region are the largest tropical fruits producing region, which accounts for nearly 60% of the total global production (80 million tons) in 2014 (FAO 2016). The intakes of tropical fruits have a lot of benefit for health, whereby the fruits possessed antioxidant and antimicrobial properties (Ble-Castillo et al. 2010). However, fruits usually have very short shelf-life due to their high sugar and moisture content (Phisut 2012). Many fruits are wasted especially during the peak harvesting seasons. Thus, fruit preservation method is important to solve this problem.

Dehydration method is widely used to preserve fruits as it reduces moisture in fruits, which inhibit the growth of microbe and enzymatic activity. Spray-drying can be used for drying of heat-sensitive fruit materials. It has the advantages of low cost and equipment readily available. The resulting powder has a much longer shelf life than the fresh fruits, easier transportation and storage (Kha et al. 2010). Drying agent is used to reduce the stickiness of powder by encapsulating the juice particle during the spray drying process. It will reduce the deposition of powder onto the drying chamber wall which improves the drying process and leads to a higher yield of product (Tan et al. 2011). Maltodextrin is commonly used as a drying agent due to its advantages of high solubility, colourless, bland flavor and commercially available (Caliskan and Dirim 2013). According to Wong et al. (2015), the highest yield of spray-dried pineapple powder was obtained with 15% (w/w) maltodextrin. Fang and Bhandari (2012) reported that at least 50% (w/v) maltodextrin was needed for spray-dried of immature bayberry juice.

The enzymatic liquefaction process increases fluidity by breaking down the fruit structure such as pectin, cellulose

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and hemicelluloses into smaller particles, which eases the separation process. It also improves the quality of fruit juice in term of clarity, flavor, filterability and colour (Tochi et al. 2009). Chong and Wong (2015) reported that there was a 90.0% viscosity reduction when only 0.5% (v/w) of both pectinase and cellulase were added together into the Sapodilla puree. Meanwhile, 68.4% reduction in viscosity was found by Wong et al. (2015) for pineapple puree produced with 1.5% (v/w) pectinase and 0.5% (v/w) cellulase.

Jackfruit (*Artocarpus heterophyllus* Lam.) also known as *jak-fruit*, *jak* and *jaca* in Malaysia; *nangka* in the Philippines; *khanun* in Thailand; *khnor* in Cambodia; *mak mi* or *may mi* in Laos; and *mit* in Vietnam, which belongs to Family Moraceae. It is believed to be originated from Western Ghats of India and Malaysia, but also found in central and eastern Africa, Southeast Asia, Florida, Brazil, Australia and many Pacific Islands (Shanmugapriya et al. 2011). The weight of jackfruit ranging from 20 to 40 kg, 35 inches in length and 20 inches in diameter. The yellow bulbs constituting the perianth portion of the fruit are fleshy, fibrous and rich in sugars as well as carotenoids. Ripe jackfruit can be eaten raw, or used in many desserts throughout Southeast Asia (Swami et al. 2012). However, it has very short shelf life and needs to be consumed within a few days.

Research on the preservation of honey jackfruit into spray-dried powder is yet to be established. There is limited scientific information on how the encapsulating agent and drying conditions may influence the physiochemical properties for the spray-dried honey jackfruit powder. Therefore, spray drying was used in this study to preserve the honey jackfruit into readily available fruit powder and also to reduce the wastage of the fruit during its fruiting season.

Thus, the objectives of this study were to optimise the parameters of enzymatic liquefaction in terms of enzyme concentrations and incubation time for the production of honey jackfruit puree; to evaluate the optimum spray drying parameters by using different inlet temperatures and maltodextrin concentrations in the production of honey jackfruit powder; and to characterise the physicochemical properties of spray-dried honey jackfruit powder.

Materials and methods

Raw materials and chemicals

Honey jackfruit (*A. heterophyllus*) used in this study was purchased from a local company in Kepong, Kuala Lumpur, Malaysia. Maltodextrin (DE 10–12) was obtained from Bronson and Jacobs, Australia. Pectinex[®] Ultra SP-L and

Celluclast[®] 1.5 L were obtained from Novozymes, Denmark.

Preparation of honey jackfruit puree

The honey jackfruits (*A. heterophyllus*) were cleaned and washed. Bulbs were separated from the fruit. The seed were removed from the bulbs and the honey jackfruits were cut into small pieces (1 cm × 1 cm × 0.5 cm) prior to blending using a Waring[®] blender (Osaka Chemical, Osaka, Japan) at the maximum speed (22,000 rpm) for 30 s until a homogenous puree was obtained. The puree was kept at 4 °C until further processing.

Enzymatic liquefaction

For enzymatic liquefaction, 500 g of homogenised jackfruit puree was individually treated with different concentrations (0–2.5% v/w, at an interval of 0.5% v/w) of Pectinex[®] Ultra SP-L (Novozymes, Denmark). The enzyme-added purees were incubated at 50 °C using a water bath, (Mettler Lab Companion, Jeio Tech, Selangor, Malaysia). The viscosity and colour were measured at an interval of 30 min for 2.5 h. The enzyme in the treated puree was deactivated at 90 °C for 5 min. Combined enzymes treatment was then performed by adding the optimised Pectinex[®] Ultra SP-L concentration with Celluclast[®] 1.5 L at different concentrations (0–2.5% v/w). Viscosity was chosen as the key evaluation to determine the best parameter for enzymatic liquefaction. Liquefied puree with the highest percentage of viscosity reduction was more favourable as it will maximize the yield of juice and prevent the clogging of spray dryer (Phisut 2012).

Spray drying conditions of honey jackfruit powder

The best combination of enzyme concentration and incubation time determined from enzymatic liquefaction was used to produce the feed solution for spray drying. The aqueous extract of honey jackfruit puree was mixed with 20% w/w maltodextrin at 1:1 ratio. The 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 100, 20%, 40 and 6 mm, respectively. The spray drying process was first optimized using different inlet temperatures from 140 to 180 °C at an interval of 10 °C. The procedure was then repeated by using different concentrations of maltodextrin, 10–30% w/w (at an interval of 5% w/w) with the fixed optimized inlet temperature.

The powders obtained from the collecting vessel after each spray drying process were immediately weighed and

vacuum packed. The mass of the spray-dried powder which showed the highest yield was chosen as the optimised spray-dried powder. The product yield was calculated based on the relationship between the total solid (TS) content of the resulting powder and the TS in the feed mixture (Fang and Bhandari 2012). All the spray-dried powders produced were then subjected to physicochemical analyses.

Analytical methods

Moisture content and water activity

The moisture content of the spray-dried powder was determined based on AOAC method (1984). The water activity of the samples was measured by using a water activity meter (Novasina, Labmaster, Switzerland) at 25 ± 1.0 °C.

Viscosity

The viscosity of the enzymatic liquefied honey jackfruit puree was measured by using a viscometer (Model DV-II + Pro, Brookfield Engineering Laboratory, Inc., Middleboro, MA). The unit of measurement used was centipoises (cP) and was carried out at 25 ± 1.0 °C. The viscosity reduction was expressed in percentage based on the following calculation:

$$\text{Viscosity reduction (\%)} = \frac{\text{Viscosity of control} - \text{Viscosity of sample}}{\text{Viscosity of control}}$$

Hygroscopicity

Hygroscopicity was determined according to the method of Cai and Corke (2000), with slight modifications. 2 g of spray-dried powder produced were placed in a glass desiccator at 25 ± 1.0 °C containing saturated solution of ammonium chloride, NH_4Cl . Sample was weighed after 1 week and hygroscopicity was expressed as gram of adsorbed moisture per 100 g of powder (g/100 g).

Bulk density

Bulk density of the samples was determined based on Tonon et al. (2011) method with slight modifications. A total of 5 g of spray-dried honey jackfruit powder was added into 50 ml glass measuring cylinder and the cylinder was repeatedly tapped manually until non-significant volume change was observed. The ratio between the mass of the spray-dried powder and the volume occupied in the cylinder determines the bulk density value.

Solubility

The solubility of spray-dried honey jackfruit powder was determined using the method by Anderson (1982). 2.5 g spray-dried honey jackfruit powder was dissolved in 5 ml of distilled water. It was then placed in a 30 °C water bath for 30 min. The mixture was then centrifuged at $3000 \times g$ for 10 min. The supernatant obtained was placed in a preheated oven at 105 °C until a constant weight was obtained. The powder solubility (%) was expressed as percentage of dry solids in 2.5 g of sample.

Colour characteristics

The colour characteristics of the spray-dried honey jackfruit powder were analyzed by using Hunter Laboratory Colorimeter (Model SN 7877, Ultra-scan, Hunter Associates Laboratory, Virginia) calibrated with white tiles. Obtained results were expressed as Hunter colour values L, a and b where L denotes lightness and darkness, a redness and greenness and b yellowness and blueness.

Statistical analysis

All experiments were conducted in triplicates ($n = 3$) and an analysis of variance (ANOVA) was performed. Statistical analyses were performed using Minitab software version 17.0 (Minitab 17, Pennsylvania, USA). Data were statistically analyzed using one-way ANOVA and Tukey HSD tests. The data were expressed as mean $\pm$ standard deviations. The confidence level was set at 95% ($p < 0.05$) for statistical significance.

Results and discussion

Enzymatic liquefaction

Viscosity is useful to identify the optimum enzymatic liquefaction parameter because low viscosity can maximize the yield of fruit juice and prevent the clogging of spray dryer (Phisut 2012). From Tables 1 and 2, percentage of viscosity reduction was significantly ($p < 0.05$) increased after enzymatic liquefaction although no significant differences were observed from 1.5 to 2.5 h (Table 2). The highest percentage in viscosity reduction was 87.3 ± 1.0 when Pectinex[®] Ultra SP-L was added individually (Table 1). However, there was $94.1 \pm 2.1\%$ viscosity reduction when 1.0% (v/w) Pectinex[®] Ultra SP-L and 0.5% (v/w) Celluclast[®] 1.5 L were added together into the honey jackfruit puree and incubated for 1.5 h (Table 2). The addition of higher concentrations of enzymes did not show any significant ($p < 0.05$) differences in the reduction of

Table 1 Viscosity reduction (%) in honey jackfruit purees treated with 0.0–2.5% (v/w) Pectinex® Ultra SP-L for 0.0–2.5 h

Pectinex® Ultra SP-L concentration (% v/w)	Incubation time (h)					
	0.0	0.5	1.0	1.5	2.0	2.5
0.0	Control	$-17.4 \pm 0.8^{D,d}$	$-17.1 \pm 1.0^{D,d}$	$-23.6 \pm 1.3^{D,c}$	$-31.3 \pm 1.1^{C,b}$	$-42.0 \pm 0.9^{C,a}$
0.5		$5.2 \pm 1.1^{B,e}$	$64.8 \pm 1.2^{C,d}$	$66.2 \pm 1.4^{C,d}$	$74.0 \pm 0.8^{C,c}$	$77.3 \pm 1.2^{B,b}$
1.0		$6.9 \pm 0.9^{A,e}$	$72.5 \pm 2.0^{B,d}$	$77.9 \pm 0.6^{B,c}$	$79.0 \pm 0.9^{B,b}$	$85.8 \pm 0.5^{A,a}$
1.5		$8.0 \pm 1.6^{A,e}$	$74.6 \pm 1.3^{A,d}$	$79.2 \pm 1.2^{B,c}$	$82.4 \pm 1.0^{A,b}$	$84.4 \pm 1.5^{A,a}$
2.0		$8.4 \pm 1.2^{A,d}$	$75.8 \pm 0.9^{A,c}$	$76.2 \pm 1.1^{B,c}$	$82.0 \pm 0.8^{A,b}$	$85.2 \pm 0.8^{A,a}$
2.5		$9.5 \pm 1.5^{A,e}$	$73.5 \pm 1.7^{A,d}$	$80.6 \pm 0.8^{A,c}$	$83.0 \pm 1.1^{A,b}$	$86.0 \pm 1.3^{A,a}$

Values are means $\pm$ standard deviations of triplicate analysis (n = 3)

Different letters (A–D) in the same column are significantly different at $p < 0.05$

Different letters (a–d) in the same row are significantly different at $p < 0.05$

Table 2 Viscosity reduction (%) in honey jackfruit purees treated with 1.0% (v/w) Pectinex® Ultra SP-L and 0.0–2.5% (v/w) Celluclast® 1.5L for 0.0–2.5 h

(% v/w)		Incubation time (h)					
Pectinex® Ultra SP-L	Celluclast® 1.5 L	0.0	0.5	1.0	1.5	2.0	2.5
1.0	0.0	Control	$-25.7 \pm 1.2^{D,b}$	$-40.6 \pm 2.2^{C,a}$	$-40.5 \pm 1.4^{B,a}$	$-42.3 \pm 0.9^{B,a}$	$-40.0 \pm 1.3^{B,a}$
	0.5		10.2 ± 2.0^{Ad}	$83.9 \pm 0.9^{C,c}$	90.1 ± 1.1^{Bb}	$94.1 \pm 2.1^{A,a}$	$96.3 \pm 1.5^{A,a}$
	1.0		10.5 ± 1.5^{Ad}	$86.4 \pm 1.1^{B,c}$	$93.3 \pm 0.6^{A,b}$	$95.6 \pm 0.7^{A,a}$	$97.2 \pm 2.0^{A,a}$
	1.5		12.2 ± 1.3^{Ad}	88.7 ± 1.3^{Ac}	$94.3 \pm 1.4^{A,b}$	$96.4 \pm 1.2^{A,a}$	$97.9 \pm 1.4^{A,a}$
	2.0		13.0 ± 0.9^{Ad}	$89.5 \pm 0.8^{A,c}$	$94.8 \pm 1.3^{A,b}$	$96.8 \pm 1.5^{A,a}$	$98.3 \pm 1.2^{A,a}$
	2.5		13.6 ± 1.5^{Ad}	$91.4 \pm 1.0^{A,c}$	$94.8 \pm 2.1^{A,b}$	$97.0 \pm 1.1^{A,a}$	$98.3 \pm 0.7^{A,a}$

Values are means $\pm$ standard deviations of triplicate analysis (n = 3)

Different letters (A–D) in the same column are significantly different at $p < 0.05$

Different letters (a–d) in the same row are significantly different at $p < 0.05$

viscosity (Table 2). Therefore, the combined enzymes, 1.0% (v/w) Pectinex® Ultra SP-L and 0.5% (v/w) Celluclast® 1.5 L were chosen as the desired enzyme concentration. The usage of enzyme should be minimal for the enzymatic liquefaction as it could cause higher production cost (Chong and Wong 2015). The viscosity of honey jackfruit puree reduced with increased of incubation period due to the more prominent hydrolysis effect by the enzymes.

The greater viscosity reduction of enzymes in combination was due to the synergistic effect of cellulolytic and pectolytic enzymes. The combination usage of enzymes improves the degradation of both cellulose and pectin found in the cell wall of jackfruit (Nahar and Pryor 2013). The breakdown of pectin and cellulose fibrils led to structural breakdown and loss of wall strength. Thus, water holding capacity was reduced and releasing the free water into the system. According to Norjana and Noor Aziah (2011), the presence of unbound water is responsible for

the overall reduction in viscosity. Similar findings were also obtained by other researchers on carambola juice (Abdullah et al. 2007), banana juice (Tapre and Jain 2012), Sarawak pineapple (Wong et al. 2015) and Sapodilla (Chong and Wong 2015).

Honey jackfruit puree without the addition of enzyme exhibited a significant increase of viscosity from 0 to 2.5 h incubation period (Tables 1, 2). This was most probably due to the present of heat and water that causes the swelling of starch molecules that were present in the jackfruit puree and this phenomenon is commonly known as gelatinization (Tester and Morrison 1990). The water loss during the incubation period also played a minor role for the increased viscosity of puree. However, the increased of viscosity for control samples was higher for honey jackfruit purees treated with combination of enzymes (Table 2) than those treated with Pectinex® Ultra SP-L (Table 1). This could be explained by puree with more damaged granules will swell faster and increased the viscosity.

Table 3 Yield and physicochemical analysis of honey jackfruit powder spray-dried under different inlet temperatures (140–180 °C) at 20% (w/w) maltodextrin

	Inlet temperature (°C)				
	140	150	160	170	180
Product yield (%)	44.30 ± 1.32 ^d	50.72 ± 1.10 ^c	60.67 ± 0.92 ^a	54.60 ± 0.73 ^b	53.93 ± 1.02 ^b
Water activity (A_w)	0.21 ± 0.04 ^a	0.23 ± 0.04 ^a	0.20 ± 0.01 ^a	0.20 ± 0.02 ^a	0.19 ± 0.01 ^a
Hygroscopicity (%)	37.75 ± 0.68 ^a	39.02 ± 1.63 ^a	39.00 ± 1.12 ^a	40.05 ± 1.85 ^a	39.58 ± 1.52 ^a
Moisture content (%)	7.30 ± 0.42 ^a	7.52 ± 0.29 ^a	6.68 ± 0.32 ^{a,b}	6.60 ± 0.50 ^{a,b}	6.13 ± 0.47 ^b
Solubility (%)	97.80 ± 1.22 ^a	97.91 ± 0.85 ^a	98.71 ± 1.06 ^a	95.79 ± 1.63 ^a	97.84 ± 1.48 ^a
Bulk density (g/ml)	1.75 ± 0.08 ^a	1.59 ± 0.05 ^a	1.73 ± 0.06 ^a	1.71 ± 0.10 ^a	1.64 ± 0.01 ^a
L*	87.33 ± 1.82 ^a	85.98 ± 1.29 ^a	86.49 ± 0.76 ^a	85.59 ± 1.76 ^a	86.02 ± 0.29 ^a
a*	0.87 ± 0.63 ^a	0.86 ± 0.63 ^a	0.90 ± 0.13 ^a	0.83 ± 0.59 ^a	0.87 ± 0.14 ^a
b*	37.95 ± 5.78 ^a	41.26 ± 3.00 ^a	38.89 ± 0.33 ^a	40.81 ± 2.84 ^a	40.56 ± 0.56 ^a

Values are means ± standard deviations of triplicate analysis (n = 3)

Different letters (a–c) in the same row are significantly different at $p < 0.05$

Spray drying

Effect of inlet temperature

From Table 3, different inlet temperatures used significantly ($p < 0.05$) affected the yield of powders. The results indicated that the highest powder yield was obtained when inlet temperature used was 160 °C and the outlet temperature was above 100 °C (106.3 °C). Thus, inlet temperature of 160 °C was selected as the best parameter for spray drying of honey jackfruit puree. According to Patel et al. (2009), the powder with the lowest moisture content was obtained when the outlet temperature was in the range of 100–110 °C. A significant ($p < 0.05$) decreased in powder yield was then observed at 170 °C (54.60 ± 0.73%) and 180 °C (53.93 ± 1.02%). According to LeÓN-Martínez et al. (2010), cohesion and melting of powder onto the chamber wall of spray dryer at higher temperature can results in lower powder yield.

The moisture contents of the spray-dried honey jackfruit powders were reduced from 7.30% (140 °C) to 6.13% (180 °C) when the inlet temperature was increased in this study (Table 3). The similar observation was obtained in different spray-dried fruit powders such as acai and watermelon (Tonon et al. 2009; Quek et al. 2007). This is due to rapid heat transfer between particles and drying air causing faster water removal (Solvol et al. 2012).

Moisture content is an effective factor in determining the powder quality as high moisture content would limits the shelf-life and impairs flowability of powder (Moreira et al. 2009). Low moisture content in powder could also solve the problem of stickiness and reduce caking during storage. The moisture contents were below 10% from this study (Table 3) and could be categorized as microbiologically safe (Ng et al.

2012). The moisture contents were also below 10% (2.93–4.47%) for spray-dried Sarawak pineapple powders with the inlet temperatures (150–180 °C) at 30% w/w maltodextrin as reported by Wong et al. (2015).

There was no significant difference ($p < 0.05$) for water activity as the inlet temperature increased. As seen from Table 3, water activity was ranged from 0.19 to 0.23 A_w and was considered to be stable (<0.6) against browning, microbial, auto-oxidation, hydrolytic reactions and enzymatic activity (Marques et al. 2007). The water activity of honey jackfruit powders was found to be lower than the spray-dried mountain tea extract powders (0.28–0.33) which were spray-dried at three different temperatures (145, 155 and 165 °C) (Nadeem et al. 2011). Inlet temperature did not influenced the hygroscopicity and bulk density of the powder significantly ($p < 0.05$).

Drying temperature did not show any significant ($p < 0.05$) effect on solubility of the honey jackfruit powder (Table 3). Mishra et al. (2014) and Sousa et al. (2008) also observed that inlet drying temperature had no significant effect on solubility of amla and tomato powders. Solubility of honey jackfruit powder ranged from 95.79 to 98.71% in the present study. These values were higher when compared with 85.91–90.00% in spray-dried sapodilla (Chong and Wong 2015), 91.43–94.98% in spray-dried amla powder (Mishra et al. 2014), 17.65–26.30% in spray-dried tomato powder (Sousa et al. 2008) and 36.91–38.25% in gac powder (Kha et al. 2010). The high solubility observed in spray-dried honey jackfruit powder makes it suitable for reconstitution.

These results concluded that the powder being spray-dried at 160 °C showed the highest product yield (60.67%) with acceptable qualities in terms of moisture content, water activity, hygroscopicity, solubility and bulk density.

Table 4 Yield and physicochemical analysis of honey jackfruit powder spray-dried under different maltodextrin concentrations (10–30% w/w) at 160 °C

	Maltodextrin concentration (% w/w)				
	10	15	20	25	30
Product yield (%)	30.90 ± 2.00 ^c	50.20 ± 1.05 ^d	61.40 ± 1.08 ^c	63.80 ± 1.31 ^b	66.90 ± 0.90 ^a
Water activity (A_w)	0.21 ± 0.01 ^a	0.17 ± 0.01 ^{b,c}	0.18 ± 0.01 ^b	0.15 ± 0.01 ^d	0.16 ± 0.00 ^{c,d}
Hygroscopicity (%)	43.32 ± 0.02 ^a	41.16 ± 0.01 ^b	40.07 ± 0.02 ^c	38.77 ± 0.01 ^d	38.43 ± 0.01 ^e
Moisture content (%)	8.81 ± 0.04 ^a	7.27 ± 0.01 ^b	6.73 ± 0.02 ^c	5.64 ± 0.02 ^d	5.72 ± 0.04 ^e
Solubility (%)	96.84 ± 0.04 ^b	98.78 ± 0.02 ^a	98.50 ± 0.05 ^a	98.90 ± 0.05 ^a	99.04 ± 0.11 ^a
Bulk density (g/ml)	0.63 ± 0.01 ^a	0.52 ± 0.01 ^b	0.44 ± 0.03 ^c	0.44 ± 0.02 ^c	0.46 ± 0.03 ^c
L*	85.11 ± 2.24 ^a	85.98 ± 1.29 ^a	86.49 ± 0.76 ^a	85.59 ± 1.76 ^a	86.02 ± 0.29 ^a
a*	0.87 ± 0.63 ^a	0.88 ± 0.51 ^a	0.82 ± 0.12 ^a	0.83 ± 0.59 ^a	0.87 ± 0.14 ^a
b*	37.95 ± 5.78 ^a	41.26 ± 2.99 ^a	38.88 ± 0.33 ^a	40.81 ± 2.84 ^a	40.56 ± 0.56 ^a

Values are means ± standard deviations of triplicate analysis (n = 3)

Different letters (a–e) in the same row are significantly different at $p < 0.05$

Effect of maltodextrin concentration

According to Table 4, there was a significant ($p < 0.05$) increase of powder yield from 30.90 ± 2.00 to $66.90 \pm 0.90\%$ as the concentration of maltodextrin increased from 10 to 30% (w/w). Honey jackfruit pulp is high in sugar content in nature, thus carrier agent could help to solve the stickiness problem (Caliskan and Dirim 2013). The present study showed that spray drying with 30% (w/w) of maltodextrin gave the highest powder yield ($66.90 \pm 0.90\%$). The addition of maltodextrin increased the product yield by preventing adhesion of honey jackfruit on the dryer walls (Caliskan and Dirim 2013). Similar results were found by Nadeem et al. (2011) whereby an increase of 21.7% and 36.0% was observed in product yield for mountain tea by increasing the carrier concentration from 0 to 3% and to 5% (w/w). However, Wong et al. (2015) and Tonon et al. (2009) reported that increasing the maltodextrin concentration decreased the powder yield of Sarawak pineapple and acai, respectively due to increasing of mixture viscosity.

Moisture content and water activity of the spray-dried honey jackfruit powders decreased significantly ($p < 0.05$) with the increase of maltodextrin concentration (Table 4). It is in agreement with results reported by Fazaeli et al. (2012), Mishra et al. (2014), and Kha et al. (2010) in black mulberry juice powder, amla juice powder and Gac fruit aril powder. These findings could be explained by the fact that additional concentration of drying aid resulted in an increase of feed solids and reduced the level of total moisture for evaporation (Fazaeli et al. 2012). The average water activity of powders in this study ranged from 0.15 to $0.21A_w$ (<0.6) and thus can be considered quite microbiologically stable. These results were within the range of

those reported by Fazaeli et al. (2012) for the spray-dried black mulberry juice powder.

Hygroscopicity decreased significant ($p < 0.05$) from an initial of 43.32–38.43% as the maltodextrin concentration increased from 10 to 30% (w/w) for honey jackfruit powder in the present study. Chong and Wong (2015), Wong et al. (2015) and Mishra et al. (2014) also observed a reduction in hygroscopicity with increasing of maltodextrin concentrations in spray-dried sapodilla powder, Sarawak pineapple powder and amla juice powder, respectively. Maltodextrin is a material having the property of low hygroscopicity in nature and therefore, would lower the overall hygroscopicity of the powder (Phisut 2012). Maltodextrin also has superior water solubility. The results indicated that all powders had high solubility ($>96\%$) (Table 4).

Increasing of maltodextrin concentration from 10 to 20% (w/w) causes a significant ($p < 0.05$) decrease in powder bulk density. This was due to the increased in maltodextrin concentration is more likely to produce a more porous powder products which will minimized the stickiness nature. Thus, eventually leads to the reduction in bulk density as total volume occupied by each particles increases. Goula and Adamopoulos (2010) also reported that the reduction of bulk density occurred for tomato juice powder and orange juice powder as the maltodextrin concentration increased.

Colour characteristics of powder

Colour measurements is also an important indicator for manufacturing plant as it will eventually determines the attractiveness and acceptability of consumers (Quek et al. 2007). As seen from Tables 3 and 4, colorimetric results

showed that the spray-dried honey jackfruit powder were not significantly ($p < 0.05$) influenced by the inlet temperature and maltodextrin concentration. No significant difference for all 3 scales namely L^* , a^* and b^* . The L^* values were higher than 85.0, which indicates that all the powders obtained were having very light shade. This could be due to the addition of maltodextrin powder into the feed which have a pure white colour in nature. Values of a^* and b^* scales clearly indicate that the powders have a vibrance yellow colour due to the higher positive b^* scale and less than 1.0 value for a^* .

Conclusion

The present study describes the possibility of producing spray-dried honey jackfruit powder with the aid of enzymatic liquefaction. The combination usage of enzymes, 1.0% v/w Pectinex® Ultra SP-L and 0.5% v/w Celluclast® 1.5 L at 50 °C for 1.5 h showed the highest efficiency in reducing the viscosity of the honey jackfruit puree. Spray-dried honey jackfruit powder produced under the inlet temperature of 160 °C and 30% w/w of maltodextrin gave a higher powder yield as compared to the other inlet temperatures (140, 150, 170 and 180 °C). Physicochemical properties of the spray-dried honey jackfruit powder were successfully determined. The results obtained indicate that good quality of honey jackfruit powders can be produced by spray drying, which demonstrate a great potential for the uses of such powders in the food industry. The storage potential should be carried out in future projects.

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