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Production of Spray-dried "Terung Asam" (*Solanum lasiocarpum* Dunal) Powder

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Abstract

Easily perishable and highly seasonal "Terung Asam" (*Solanum lasiocarpum* Dunal) fruit, a geographical indication plant of Sarawak, was converted into powder for shelf life extension. Spray drying was employed with a range of inlet temperature (140 - 180 °C) and the slurry was cooperated with food graded maltodextrin (5 - 25 % w/w) as food processing aid. The spray-dried "Terung Asam" powders were analysed for process yield, moisture content (Mc), water activity (Aw), hygroscopicity (Hg), water solubility index (WSI), bulk density and colour. The reconstituted powders were assessed by determining total soluble solid (TSS), pH, viscosity and colour. The results indicated that the increase in inlet temperature had resulted in reduction in Mc, Aw, and Hg. In addition, higher concentration of maltodextrin led to reduction in Mc and Hg. At the spray drying inlet temperature of 160 °C and feed added with 25 % w/w maltodextrin, "Terung Asam" powder with the following optimal physicochemical properties was produced: Mc, 2.95±0.42 %; Aw, 0.11±0.02; Hg, 17.76±0.28 %; WSI, 98.89±1.37 %; and wettability, 621.60±119.03 s. The optimized reconstituted powder had lower L*, a* and b* values than the fresh juice, indicating it is lighter in colour, less reddish and less yellowish. Overall, the production of "Terung Asam" using spray drying is feasible with the addition of food processing aid.

Keywords: Inlet temperature, Maltodextrin, Spray drying, Terung Asam, Wettability

Introduction

"Terung Asam" is a type of eggplant which is light yellow or deep orange in colour. The scientific name of "Terung Asam" is *Solanum lasiocarpum* Dunal and it is from Solanaceae family [1]. "Terung Asam" shared some common English names such as Hairy eggplant, Hairy fruited eggplant, Thai Hairy fruited eggplant, Terong Asam, Hairy Nightshade, and Indian Nightshade [2]. It tastes pleasantly sour and therefore named "Terung Asam" which means sourish eggplant. It originally grew in the wild and was consumed by the indigenous people of Sarawak, Malaysia. Now it became a GI (geographical indication) plant of Sarawak (No. GI2010-00002), indicating it is very popular and widely grown in Sarawak [3,4]. It is planted with hill paddy by local farmers and now has been cultivated throughout the state of Sarawak. On average, the production is between 16 - 20 tonnes/hectare and the average market price of 2 USD/kg, depending on the size and quality [5].

"Terung Asam" is rich in carbohydrates and contains appreciable amounts of micronutrients and minerals [6]. The carbohydrates of "Terung Asam" consists of 5.9 g per 100 g edible portion which was the highest contributor among the other nutrients. Besides, approximately 8 mg of vitamin C can be found in "Terung Asam". Potassium is the highest mineral compound, with 188 mg per 100 g edible portion of "Terung Asam" among other minerals. "Terung Asam" has many uses whereby the people used them as sour-relish in curries, used as poultices for swellings, seeds were used for toothaches and root is used to cure fever [7,8]. In addition, it is used as a remedy in Bangladesh traditional folk medicine for coughs, asthma, fever, vomiting, sore throat and gonorrhea [8]. Hence, this reveals the benefits of "Terung Asam" which may be utilized for various purpose. However, one of the apparent features of this fruit is that it is seasonal (available from March through May) and softens easily, this makes it has a very short shelf life. Thus, prior to deterioration, raw fruit should be transformed into value-added commercial products such as fruit powder.

Drying is a method of food preservation that can inhibit the growth of bacteria, yeasts, and mold through the removal of water [9]. Among the drying techniques, spray drying is usually applied to produce the fruit juice powder [10]. It is used to prevent the food products from volatile losses, reduced volume and even increase the shelf life and product stability [9-11]. Spray-dried fruits powder product offers some advantages over the fresh fruits. In powder form, it reduced weight and volume, extended shelf life, easier transportation and handling requirements, portability, resistance to physiochemical and microbial spoilage and readily available throughout the year [9,10]. Maltodextrin is commonly used as a drying aid to overcome technical difficulties such as stickiness during the spray drying process [12,13]. It was reported that maltodextrin is able to enhance the properties of powders such as lower hygroscopicity and better flow ability [14-16] in spray dried powders.

Hence, this research was conducted to produce "Terung Asam" powder by spray drying by manipulating two parameters which are spray drying inlet temperature and maltodextrin concentration. The effect of maltodextrin level and inlet temperature on the process yield and physicochemical properties of the spray-dried "Terung Assam" powder were investigated and the optimize conditions for preparation of "Terung Asam" powder were determined. This can ensure that the seasonal "Terung Asam" powder is preserved and available all year round.

Materials and methods

Materials

"Terung Asam" (**Figure 1**) at commercial maturity stage (0.2±0.1 kg) with no bruises were purchased from a local fruit stall located in Sarawak, Malaysia. Maltodextrin DE 10 was purchased from Bronson and Jacobs (Australia). Chemicals used in analysis were purchased from Merck, Germany.

Figure 1 "Terung Asam" fruit.

Preparation of spray drying feed

The fruit was rinsed under tap water to remove surface dirt. Then, it was cut into small cubes of 1×1×1 cm^3. The cut fruits were blended for 6 to 8 min by using a juice blender (MX-377, Panasonic, Japan). Next, the juice was sieved for two times using the filter bag (mesh size of 0.1×0.1 cm^2). The sieved juice was transferred into 1 L Schott bottle for storage at chilled temperature (−4±2 °C) until needed for further experimentation. To investigate the effect of maltodextrin, different amount of maltodextrin was weighed (5, 10, 15, 20 and 25 % w/w), transferred into 500 mL beaker and followed by mixing 200 g of room temperature “Terung Asam” juice. A homogenizer was used to mix both the maltodextrin and “Terung Asam” juice to ensure all the maltodextrin dissolved completely. After that, the solution was sieved and proceeded to spray drying process.

Spray drying process

A Büchi mini spray dryer (Model B-290, Switzerland) was used in the spray drying process. The spray dryer was set at a constant aspirator rate of 100 %, pump setting 20 %, nozzle speed at 5, and compressed air flow rate of 40 mm (600 L/h). Inlet temperatures ranging between 140 to 180 °C (140, 150, 160, 170, 180 °C) at constant maltodextrin concentration (25 % w/w). The spray dryer was allowed to warm up until it reached the desired temperature. Once the set temperature was reached, it was sprayed with distilled water for 15 min. Next, 200 g of sieved “Terung Asam” juice was pumped into the spray dryer through the atomizer. The sieved juice was atomized in a hot air into small droplets. During the evaporation process, the moisture content quickly leaves the droplets. The powder was separated from the humid air through a cyclone. The powder was then accumulated in the collecting vessel. During the spray drying process, the outlet temperature and time taken for the spray drying process were taken and recorded. The spray dryer was sprayed with distilled water again for 15 min. Then, the spray dryer was switched off when the outlet temperature drops below 50 °C [17]. Lastly, the spray-dried “Terung Asam” powder obtained from the collecting vessel was immediately weighed and the mass of the powder was recorded. The powder was then vacuum-packed and stored in a dry place until the physico-chemical and the reconstituted powder analyses were conducted.

Analysis of spray-dried “Terung Asam” powder

Process yield

The amounts of the powder produced and obtained from the collecting vessel were weighed using a weighing balance (XT 220A, Precisa, Switzerland). The process yield of the powder after spray drying process was calculated based on dry basic measurement by using the following equation [17].

$$\text{Process yield (\%)} = \frac{\text{obtained spray dried powder (g)}}{\text{sieved Terung Asam juice (g) + maltodextrin (g)}} \times 100\% \qquad (1)$$

Moisture content (Mc)

The moisture content of the samples was determined based on the AOAC method [18]. Approximately 2 g of samples was weighed into pre-dried and pre-weighed empty aluminium weighing boats. Next, the samples were placed in the oven at 105 °C for 24 h. The dried samples were cooled in desiccator for 10 min and weighed until the constant weight was obtained. The Mc of the samples was determined using the following equation.

$$\text{\% Mc (w/w)} = \frac{\text{Weight of wet sample (g) – weight of dry sample (g)}}{\text{Weight of wet sample (g)}} \times 100\% \qquad (2)$$

Water activity (Aw)

The water activity of the samples was determined using a water activity meter at room temperature 25±1 °C. The water activity meter was warmed up for half an hour to ensure a stable and consistent reading. 25±1 °C. About 2 g of sample was placed into a sample container and inserted into the water activity meter. The water activity meter was closed tightly and read [14].

Hygroscopicity

The hygroscopicity of the samples was determined based on the method proposed by Cai & Corke [19]. The empty container was weighed and approximately 1 g of powder was placed on the empty container. After that, the containers were inserted in a desiccator maintaining at 80 % RH using saturated ammonium chloride solution, NH_4Cl and stored for 7 days. After storage, the powders were weighed and the hygroscopicity was calculated using the following equation.

$$\%\ \text{WI} = \frac{\text{Weight of sample after one week (g)} - \text{initial weight of sample (g)}}{\text{Initial weight of sample (g)}} \times 100\ \% \tag{3}$$

$$\text{Hygroscopicity} = \frac{\%\ \text{WI} + \%\ \text{MC}}{100 + \%\ \text{WI}} \times 100\ \% \tag{4}$$

Bulk density

The bulk density of samples was modified from the method described by Fazaeli *et al*. [17]. Five g of "Terung Asam" powder was weighed into 50 mL graduated cylinder and tapped manually for 5 times. The volume of powder occupied in the cylinder was recorded and the bulk density was calculated using the following equation.

$$\text{Bulk density (g/mL)} = \frac{\text{Weight of powder (g)}}{\text{Volume of powder occupied in the cylinder (mL)}} \tag{5}$$

Water Solubility Index (WSI)

The water solubility index (WSI) of the powders were determined according to the method described by Phoungchandang & Sertwasana [20]. Approximately 1 g of powder was mixed with 10 mL of distilled water vigorously in a 50 mL centrifuge tube. Then, the mixture was incubated in a water bath at 35 °C for 30 min, and centrifuge at 3000 rpm for 15 min. Next, the supernatant was collected in a pre-weighed aluminium boat and oven dried at 105 °C for 5 h. The dried residue was weighed and WSI was calculated by using the following equation.

$$\%\ \text{WSI} = \frac{\text{Weight of sample after five hours (g)}}{\text{Initial weight of sample (g)}} \times 100\ \% \tag{6}$$

Wettability

The wettability of the samples was determined based on methodology described by Marques *et al.* [21]. It was determined by measuring the time required to complete a timer for dissolving 1 g of sample in 100 mL of distilled water at 25 °C wrapped in a 250 mL beaker.

Colour

The colour of the samples was analysed using HunterLab's ColorFlex Ez spectrocolorimeter [22]. The spectrocolorimeter was firstly calibrated against a black tile and then followed by a white tile. Next, the powders were poured into the sample cup and three readings were taken by rotating the sample cup. The colour was expressed in terms of L* (lightness and darkness), a* (redness or greenness) and b* (yellowness or blueness).

Reconstitution and analysis of spray-dried "Terung Asam" powder

The spray-dried "Terung Asam" powder was rehydrated with water to the same total soluble solids content (TSS) as the fresh sieved "Terung Asam" juice [23]. About 2.4 g of powder was dissolved with 50 mL of diluted water. The mixture was stirred thoroughly until all the powder dissolved completely. The powder was added to the solution until the TSS reached ±6.0 °Brix.

Total soluble solid (TSS)

TSS of the samples was measured using a digital refractometer. Firstly, a drop of distilled water was placed on the surface of the digital refractometer for calibration [18]. Next, the samples were placed on the surface of the digital refractometer with a scale of 0 - 85 °Brix and read. The readings that showed on the screen were recorded.

pH

The pH values of the samples were determined using a digital pH meter [18]. Calibration of pH meter was done using two standard buffer solutions which were pH 7.0 and pH 4.0 buffer solution. The pH electrode was immersed into the beaker filled with 200 mL of samples and the readings were taken.

Viscosity

The viscosity of sieved "Terung Asam" juice was measured using a viscometer. Spindle Ultra Low Adapter (ULA) was used to measure the viscosity of the sample (15 mL). Before the measurement of viscosity, the rotational speed was set at 180 rpm and the total time taken for each sample was set to one minute. The reading that showed on the screen were taken and recorded.

Colour

Colour of the reconstituted powder was determined as described above.

Statistical analysis

All experiments were conducted in triplicate (n = 3). Statistical analysis was analysed using MINITAB v.16 (Minitab Pty. Ltd., Sydney). The Turkey's Honestly Significant Difference (HSD) one-way analysis of variance (ANOVA) was performed for the determination of differences between processes with the significant difference of $p \leq 0.05$. The data obtained was expressed as mean ± standard deviations.

Results and discussion

Effect of different maltodextrin concentrations on spray-dried "Terung Asam"

Process yield, outlet temperature, feed flow rate and powder appearance

Figure 2 shows the effect of maltodextrin level on the process yield and spray drying conditions of powder produced. Process yield was increased with the increased of maltodextrin concentration used. This shows that maltodextrin may improve the yield of product and act as a helpful drying agent in spray drying of fruit juice. Similar trend was reported by Quek *et al.* [24] in spray drying of watermelon powder. In addition, Vidović *et al.* [25] reported that the addition of <10 % w/w of maltodextrin increased the stickiness of the dried material to the spray dryer wall as well as results in a low production yield.

Outlet temperature increase with the increase of maltodextrin concentration used (**Figure 2**). The result was in accordance with finding of Quek *et al.* [24] in the spray-dried watermelon powder. The author described that outlet temperature increased from 108 to 113 °C when the maltodextrin used was increased 2 % w/w. Besides, the feed flow rate in producing "Terung Asam" powder was increased from 0.41±0.07 g/min to 1.13±0.06 g/min as the maltodextrin concentration increased. The resulted powder that was fine, soft, non-sticky with light brown colour when the maltodextrin concentration used was low (data not shown). Meanwhile, beige colour powder was observed when higher concentration (25 % w/w) of maltodextrin was used. This is in agreement with finding of Grabowski *et al.* [23], whereby an increase in maltodextrin level caused the product to be whiter and less orange coloured.

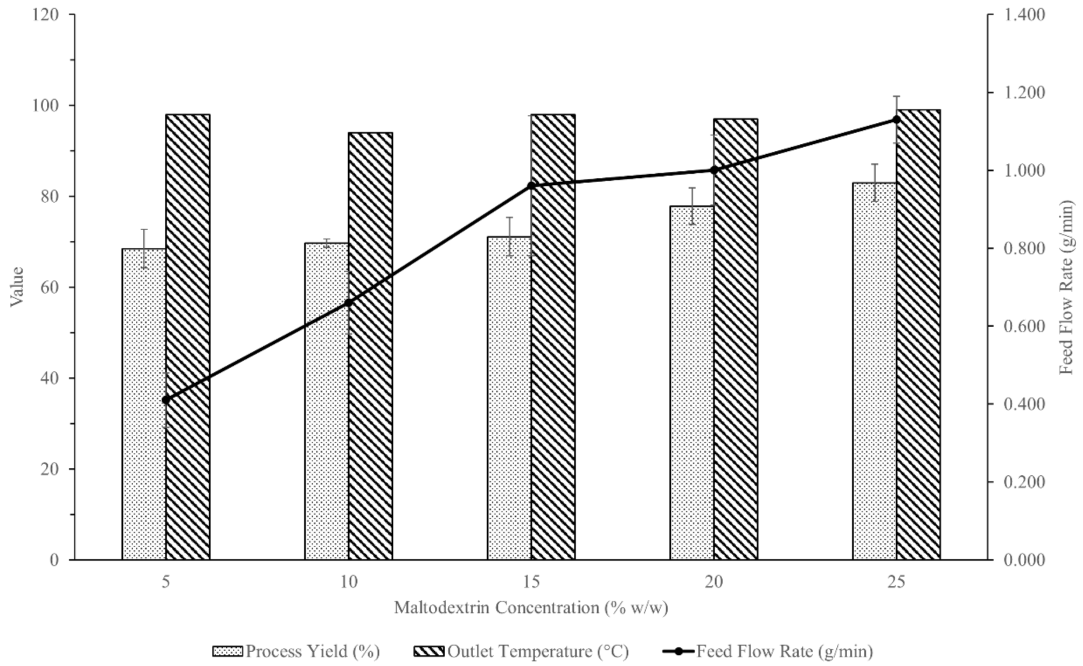

Figure 2 Process yield, outlet temperature and feed flow rate of "Terung Asam" powder at different maltodextrin level.

Physicochemical properties of powder

Table 1 presents the physicochemical properties of "Terung Asam" powder treated with different concentration of maltodextrin. With the increased of maltodextrin concentration from 5 to 25 % w/w, the Mc of "Terung Asam" powder decreased by up to 69 %. This might be due to the total solid content of the feed increased with higher maltodextrin level; and hence, reduced the amount of water for evaporation. Thus, results in lower Mc of the powder [24]. Similar trend was reported by Mishra *et al.* [26] in the production of amla juice powder.

The Aw values of "Terung Asam" powder ranged from 0.11±0.02 to 0.19±0.02, indicating the powder was considered as microbiologically stable for long term storage. This is because food product with Aw less than 0.60 was considered as microbiologically stable [24]. Furthermore, according to Marques *et al.* [21] food product with Aw ranged between 0.20 and 0.40 may protect the stability of the food product against lipid oxidation, browning and enzymatic activity.

The hygroscopicity decreased as the maltodextrin concentration increased. The lowest hygroscopicity value was 17.76±0.28 % when the highest maltodextrin concentration (25 % w/w) was used. This might be due to maltodextrin is a material with low hygroscopicity and thus it is widely used as a carrier agent for spray drying [27]. Mishra *et al.* [26] also reported that as maltodextrin level increase the hygroscopicity of amla powder decreased.

The WSI of "Terung Asam" powder increased with the increased of maltodextrin concentration. The highest WSI (98.89 ± 1.37 %) was obtained when 25 % w/w maltodextrin was added to the feed before spray drying process. Similar trend was observed by Vidović *et al.* [25] where there was an increase of WSI when the maltodextrin concentration was increased during the spray drying of *Satureja montana* extract. According to El-Samahy *et al*. [28], higher WSI value showed a higher water solubility of powder constituents. Hence, high values of WSI are favorable to give the powder a desired property.

Wetting time of "Terung Asam" powder was found to be increased when higher maltodextrin concentration (up to 25 % w/w) was used. The average times of wettability of the powder varied from 291.60 to 621.60 s. The similar trend was observed by Caliskan & Dirim [29] during the spray drying of sumac extract. In addition, increased maltodextrin concentration resulted in a partial reduction in the powder wettability, although it increased powder Mc [30]. Furthermore, caking is more easily to occur in powders with higher Mc, and this may contribute to their wetting ability because the liquid penetrates the pores more easily [21,30].

In general, the bulk density decreased when the maltodextrin concentration increased. This is probably due to the function of maltodextrin which acts as a skin-forming material and reduce the thermoplastic particles from stickiness problem [15]. Increased in maltodextrin concentration also caused lower bulk density also reported in orange juice powder [15].

Degree of lightness (L*) increased while degree of redness (a*) and degree of yellowness (b*) decreased with the increased of maltodextrin concentration. This may be explained by the white color of maltodextrin that exhibited the masking effect when the level used was increased. Grabowski *et al.* [23] reported that by increased in maltodextrin concentration level during the spray drying led to production of a lighter and less orange potato powder.

Overall, optimum maltodextrin concentration was selected based on the process yield, appearance and physicochemical properties of the powder. According to **Figure 2** and **Table 1**, 25 % w/w maltodextrin concentration is chosen as the optimum concentration due to its highest process yield (82.93±4.13 %) with the feed flow rate of 1.13±0.06 g/min. Furthermore, the powder produced was non-sticky with lower Mc (2.95±0.42 %), low the Aw (0.11±0.02), which make the powder microbiologically stable. Furthermore, it results in low hygroscopicity (17.76±0.28 %) and high WSI (98.89±1.37 %) which increased the powder ability to dissolve in water.

Table 1 Physicochemical properties of "Terung Asam" powder produced at different maltodextrin level.

Analyses	Maltodextrin Concentration (%w/w)				
	5	10	15	20	25
Moisture content (%)	9.65 ± 1.29^{a}	5.29 ± 0.21^{b}	4.39 ± 0.87^{bc}	3.01 ± 0.61^{c}	2.95 ± 0.42^{c}
Water activity (Aw)	0.19 ± 0.02^{a}	0.14 ± 0.01^{ab}	0.16 ± 0.05^{ab}	0.11 ± 0.02^{b}	0.11 ± 0.02^{b}
Hygroscopicity (%)	28.43 ± 1.53^{a}	23.59 ± 0.56^{b}	19.72 ± 1.27^{c}	18.50 ± 1.19^{c}	17.76 ± 0.28^{c}
WSI (%)	92.01 ± 1.89^{b}	96.18 ± 2.22^{ab}	96.63 ± 2.26^{ab}	98.54 ± 2.38^{a}	98.89 ± 1.37^{a}
Wettability (s)	291.60 ± 105.93^{b}	417.60 ± 42.44^{ab}	446.00 ± 40.88^{ab}	473.20 ± 83.04^{ab}	621.60 ± 119.03^{a}
Bulk density (g/mL)	0.50 ± 0.01^{ab}	0.52 ± 0.03^{a}	0.50 ± 0.01^{ab}	0.48 ± 0.02^{bc}	0.46 ± 0.01^{c}
Colour L*	82.39 ± 0.79^{b}	85.87 ± 1.67^{a}	86.96 ± 0.77^{a}	88.51 ± 1.18^{a}	88.81 ± 1.14^{a}
a*	3.74 ± 0.12^{a}	2.62 ± 0.53^{b}	2.26 ± 0.09^{bc}	1.77 ± 0.12^{c}	1.64 ± 0.26^{c}
b*	23.37 ± 1.55^{a}	18.21 ± 1.51^{b}	16.53 ± 0.34^{b}	14.25 ± 1.51^{b}	15.19 ± 2.43^{b}

Different superscripts in the same row (a-c) are significantly different at $p \leq 0.05$

Effect of different inlet temperature on spray-dried "Terung Asam"

Process yield, outlet temperature, feed flow rate and powder appearance

Figure 3 presents the effect of inlet temperature on the process yield and spray drying conditions of powder produced. Process yield was increased with increased of inlet temperature used. This may be due to a higher inlet temperature resulted in faster heat and mass transfer and increased in powder production [19]. However, the process yield increased except at drying at 170 °C (**Figure 3**). According to Dailami [31], the process yield was increased with the increased of inlet temperature until it had reached its optimum temperature and the process yield become constant even if the inlet temperature was increased gradually.

Figure 3 also shows that higher the inlet temperature led to higher outlet temperature. As the inlet temperature increased, there was an increased supply of heat energy that resulted in higher outlet temperature [10]. Similar pattern was reported by Solval *et al*. [32]. Furthermore, the feed flow rate of spray drying process was in the range between 0.91 ± 0.08 to 1.05 ± 0.03 g/min. In addition, the appearance of the powders produced at inlet temperature of 140 to 180 °C were fine, soft, non-sticky with beige colour.

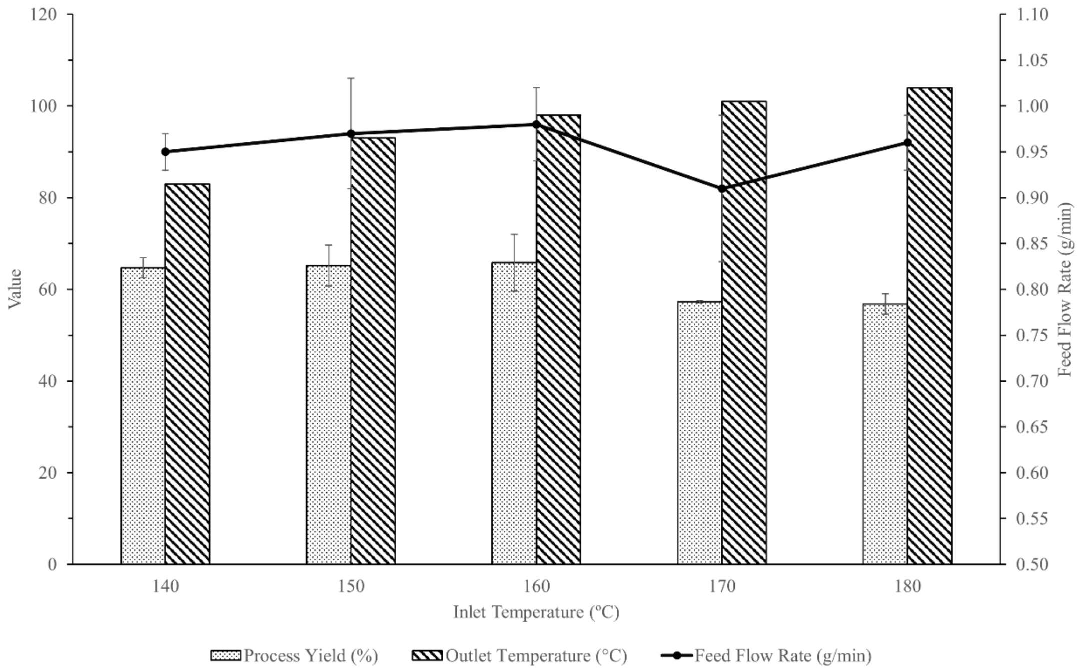

Figure 3 Process yield, outlet temperature, feed flow rate of "Terung Asam" powder at different inlet temperature.

Physicochemical properties of powder

Table 2 presents the physicochemical properties of "Terung Asam" powder produced under different inlet temperatures. Mc of spray-dried powder varied from 2.50±0.42 to 3.49±0.82 % which decreased as the inlet temperature increased. The variation was in the desired range of the quality parameters for a powder to be considered a dry product. The similar finding was obtained in the different fruit juice powders such as acai juice powder [27], soursop powder [14], and pineapple powder [16].

The Aw values of "Terung Asam" powder ranged from 0.09±0.01 to 0.13±0.02, indicating the powder was considered as microbiologically stable for long term storage. Quek *et al*. [24] reported that powder produced in this Aw range is considered as microbiologically stable whereby the Aw is less than 0.6. Similar finding was reported by Caliskan & Dirim [29] in the sumac extract powder, Wong *et al*. [16] in pineapple powder and Chang *et al*. [14] in soursop powder.

The hygroscopicity of "Terung Asam" powder varried from 17.05±0.08 to 18.61±0.34 %. As the inlet temperature increased from 140 to 180 °C, the hygroscopicity decreased from 18.61±0.34 % to 17.05±0.08 %. Similar trend was reported by Mishra et al. [26] in the production of amla juice powder. However, inlet temperature did not exhibit significant effect ($p > 0.05$) in Aw.

The inlet temperature did not show any significant effect ($p > 0.05$) on water solubility index (WSI) of the "Terung Asam" powder. The WSI of the powder varried from 96.76±0.66 % to 99.65±0.46 %. The WSI increased as the inlet temperature increased from 160 to 180 °C, except at 170 °C. The results were in accordance with Sousa *et al.* [33] that drying temperature had no significant effect ($p > 0.05$) on WSI of tomato powder.

The wettability of "Terung Asam" powder varried from 442.60±6.16 to 544.40±3.30 s. An increase in the inlet air temperature, increase the wettability time likely due to denaturation of hydrophilic constituents [21]. Furthermore, at higher operation temperatures, the formation of a hard surface layer prevents the entrance of water into the material [34].

It was found that the inlet temperature did not show any significant effect ($p > 0.05$) on the bulk density of the "Terung Asam" powder. The bulk density ranged between 0.48±0.02 and 0.49±0.02 g/mL. Mishra *et al.* [26] stated that as the inlet temperature increased, the density of the powder was decreased. When higher inlet temperature was applied during the spray drying process, the high rate of drying lead to less droplet shrinkage and thus giving lower powder density [34].

Similarly, inlet temperature did not exhibit any significant effect ($p > 0.05$) on the color of spray dried powder. The L* values of "Terung Asam" powder produced under different inlet temperature varried from 88.26±1.21 to 89.04±1.12. The highest a* value was 2.00±0.29 which produced at 170 °C. In addition, the lowest b* value was 13.40±0.59 when 180 °C was applied during the spray drying. On the other hand, the highest b* value (14.49±1.81) was obtained at 140 °C.

Overall, the inlet temperature, 160 °C was being selected as the optimised powder because of its higher process yield, 65.81±6.19 % with the average feed flow rate of 0.98±0.04 g/min. In addition, the powder condition at 160 °C are fine, soft, non-sticky powder with beige colour. Besides, the Mc of powder produced was 2.50±0.42 %, which was the lowest among the other samples. In addition, the Aw of the powder produced at 160 °C was 0.09±0.01. The value of water activity was under 0.6, therefore the powder is considered as microbiologically stable.

Table 2 Physicochemical properties of "Terung Asam" powder produced at different inlet temperature.

Analyses	**Inlet Temperature (°C)**				
	140	**150**	**160**	**170**	**180**
Moisture content (%)	3.49±0.82^a	3.05±0.46^a	2.50±0.42^a	3.19±0.40^a	3.22±0.71^a
Water activity (Aw)	0.13±0.02^a	0.11±0.0^a	0.09±0.01^a	0.11±0.03^a	0.12±0.04^a
Hygroscopicity (%)	18.61±0.34^a	17.84±0.69^a	17.21±0.58^a	17.21±0.15^a	17.05±0.08^a
WSI (%)	96.76±0.66^a	97.19±2.25^a	98.84±0.84^a	98.30±1.40^a	99.65±0.46^a
Wettability (s)	442.60±6.16^a	500.00±57.12^a	544.40±3.30^a	487.20±57.42^a	532.60±27.53^a
Bulk density (g/mL)	0.48±0.02^a	0.48±0.02^a	0.48±0.02^a	0.49±0.01^a	0.49±0.02^a
Colour L*	88.26±1.21^a	88.42±0.26^a	88.44±1.75^a	88.97±2.14^a	89.04±1.12^a
a*	1.76±0.21^a	1.72±0.03^a	1.65±0.19^a	2.00±0.29^a	1.78±0.30^a
b*	14.49±1.81^a	14.35±1.32^a	14.12±1.55^a	13.82±1.78^a	13.40±0.59^a

Different superscripts in the same row (a-c) are significantly different at $p \leq 0.05$

Comparison between the fresh juice and the optimised reconstituted "Terung Asam" powder

Table 3 shows the properties of fresh "Terung Asam" juice compared with optimized reconstituted powder solution. There is no significant difference ($p > 0.05$) for TSS, pH and viscosity measured in both fresh juice and the optimised reconstituted powder, indicating the properties of the powder was remained unchanged significantly after spray drying process. However, there is a significant difference ($p \leq 0.05$) between the color parameters for both fresh juice and the optimised reconstituted powder. The results showed that the lightness (L*), redness (a*), and yellowness (b*) of the fresh juice was higher than that of the reconstituted powder. This might be due to the non-enzymatic browning such as Maillard reaction and caramelisation occured during the spray drying process [22]. The result was similar with finding reported by Jittanit *et al.* [35] in the spray-dried of tamarind powder.

Table 3 Comparison between the fresh juice and the optimised reconstituted Terung Asam powder.

Physicochemical analysis	Fresh juice	Optimised reconstituted powder
TSS (°Brix)	5.90±0.10^a	5.90±0.06^a
pH	4.21±0.02 ^{a}	4.54±0.05^a
Viscosity (cP)	1.47±0.04^a	1.38±0.02^a
L*	14.76±0.32^a	6.22±0.02^b
a*	6.33±0.35^a	-0.63±0.09^b
b*	16.64±0.34^a	4.65±0.04^b

Different superscripts in the same row (a-b) are significantly different at $p \leq 0.05$

Conclusions

In conclusion, "Terung Asam" with short shelf life property was preserved by spray drying operation. Maltodextrin was used as drying aid and the work showed maltodextrin concentration improved the process yield and produce stable powder with lower Mc, hygroscopicity, bulk density and higher solubility. Higher inlet temperature used also promoted higher process yield, lower Mc and hygroscopicity. Overall, the "Terung Asam" powder obtained under optimized spray drying conditions, 160 °C of spray drying temperature added with 25 % w/w maltodextrin, was stable chemically and microbiologically.

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