Physicochemical, functionality and storage stability of hog plum (*Spondia pinnata*) juice powder produced by spray drying

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Abstract Hog plum juice powder was obtained from its juice under optimized condition by spray drying with juice: maltodextrin ratio at 2:1, 4:1 and 6:1 (v/w) basis. The inlet temperature and feed rate were varied between 120 to 175 °C and 8 to 14 mL/min. The effect of variables i.e. maltodextrin level, temperature and feed rate on the physicochemical properties and total phenolic content were studied. Moisture content, hygroscopicity, bulk density, water activity and total phenolic content of the powder were significantly affected by inlet temperature and maltodextrin level. However feed rate showed no any significant effect on the bulk density of the powder. An increase in inlet temperature and maltodextrin level reduced the total phenolic content in the spray dried powder. Morphological study showed that at high inlet temperature the spray dried powder were of smooth surfaces however, at low inlet temperature majority of the particles were of shrivelled surfaces. Spray dried hog plum juice powder made with 3.9:1 juice: maltodextrin, processed at 171 °C inlet temperature and at 8 mL/min feed rate had less hygroscopicity, water activity, moisture content and potent TPC content. Storage temperature significantly affected the TPC and DPPH free radical scavenging activity of the powder. Refrigeration temperature was found to be more effective to reduce the losses of TPC and DPPH free radical scavenging activity during storage. Colour acceptability of the refrigerated sample was comparatively more than to the sample stored at room temperature.

Keywords Hog plum · Spray drying · *Spondia pinnata* · Total phenolic content

Introduction

In the present scenario the higher consumption of fruits and vegetables proven to reduce the several chronic diseases such as cancer, cataract, brain and immune dysfunction etc. (Ames et al. 1993). Several researches reported that the tissue of various plants grown in tropical and subtropical region is rich in nutrients, phytochemicals, polyphenols and flavonoids (Adewuyi et al. 2010). It is generally assumed that frequent consumption of plant derived phytochemical from fruits, vegetables, tea, and herbs may contribute to shift the balance toward an adequate antioxidant status.

Hog plum (*Spondias pinnata* L. f. kurz) is a wild edible fruit which belongs to the family of *Anacardiaceae* and found in India, Sri Lanka, Bangladesh, China, and other South-East Asian countries. The fruit is aromatic astringent, refrigerants and is used for treatments of articular and muscular pain (Kritikar and Basu 1975). The hog plum plant has been used intensively in many traditional herbal medicines across the world. The ripe fruits are eaten as pickles, chutneys, jams and sherbet and are also taken for sour and slightly bitter taste, which is a valuable source of vitamin C. The leaves and pulp extracts of hog plum fruit have anti-tumor and antibacterial activity (Murakamia et al. 1995; Mahanta et al. 2006). The young leaves, fruit and flower of this plant is used for edible purposes.

Hog plum is a seasonal fruit, so its availability as a fresh fruit is limited only for a specific period. Hence spray-drying of the fruit juice may be a good alternative to make its health promoting components available throughout the

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season. Spray-drying has been widely utilized for commercial production of fruit powder and also in the production of milk powders (Kim and Chen, 2009). Fruit juice powder have number of benefits over the liquid counterparts such as easier handling, reduced weight or volume, easy transportation and longer shelf life (Kha et al. 2010). Spray-dried powders have good reconstititional characteristics (Yousefi et al. 2011), low water activity and are most suitable for transport and storage. Spray drying protects the active material against undesirable reactions and it is highly suitable process for heat sensitive components (Sagar and Kumar 2010). Maltodextrin is one of the most commonly used drying aids for spray drying of juices owing to its useful role as a carrier or an encapsulating agent. Dib-Taxi et al. (2003) used carrier agents to protect vitamin C in camu–camu powder and Righetto and Netto (2005) used carrier agent to increase stability of products in acerola powder.

As per the best of our knowledge there are no studies reported on optimization of spray drying of hog plum juice powder and its stability during storage. In the present investigation processing condition for the development of spray dried hog plum juice were optimized by using response surface methodology and effect of storage temperature on functional properties of the optimized hog plum juice powder were also evaluated.

Materials and methods

Raw materials

The fresh fruit hog plum (*Spondia spinnata* L. f. kurz) were collected from the campus of Tezpur University, India. The fruit was properly washed under running water to remove the adhering dust. The washed fruits were used for extraction of juice and the development of spray dried hog plum juice powder.

Moisture content, fat, ash content and vitamin C

Moisture content, ash content, fat (%) and vitamin C of hog plum juice and pomace (left after extraction of juice) was estimated as per the method of Ranganna (1986) and % carbohydrate (by Anthrone method) was calculated as per the method of Thimmaiah (2012).

Process standardization for development of spray dried hog plum juice powder

The seeds of the fruit were separated with the help of stainless steel knife and the fruit part was converted into the pulp using a laboratory grinder. Hog plum juice was

separated by squeezing the pulp through double folded muslin cloth and the filtered juice was concentrated up to 50% in rotary evaporator at 70 °C temperature. As carrier agent maltodextrin was added into the juice and was homogenized on magnetic stirrer for 20 min. The juice was fed into spray dryer and dried at predetermined inlet temperature. The spray dried powder was packed into laminates and stored at 4 °C temperature for further analysis.

Preliminary trial showed that when the ratio of juice: maltodextrin (v/w basis) was greater than 6:1 than most of the material stuck on chamber wall while at the ratio below 2:1 a significant reduction in total phenolic content of powder was observed. Hence the ratio of juice: maltodextrin in the present study was varied between 2:1 and 6:1 (Juice: maltodextrin (v/w basis)).

Spray drying

The feed comprising of maltodextrin and juice powder was spray dried in Lab plant LU 20 lab sprayer (Labultima, Mumbai, India). The processing condition of spray drying was optimized by using Box–Behnken design (BBD). The processing variable i.e. juice: maltodextrin ratio were varied from 2:1 to 6:1 (v/w basis of fresh juice), temperature were varied from 120 to 175 °C and feed rate were varied from 8 to 14 mL/min. Experiment design for the optimization of spray dried hog plum juice powder is given in Table 1.

Drying parameters were normalized as coded variables so they can affect the response more evenly and so the units of parameters became irrelevant for the investigation (Bas and Boyaci 2007). Variables were coded as per the formula given below:

$$X = \frac{(x_i - x_o)}{\Delta x}$$

where X is the coded value, x_i is the actual value and x_o is the actual value in the centre of domain and Δx is the increment of x_i corresponding to variation in one unit of x. Response variables were fitted on polynomial model equation (given below) which is generally able to describe the relationship between the responses and the independent variables.

$$Y = \beta_0 + \sum_{i=1}^2 \beta_i X_i + \sum_{i=1}^2 \beta_{ii} X_i^2 + \sum_{i < j=1}^2 \beta_{ij} X_i X_j$$

where Y represents the response variables, X_i and X_j represents independent variables and β_0 , β_i , β_{ii} and β_{ij} represents the regression coefficient for intercept, linear, quadratic and interaction terms. Analysis of variance (ANOVA) was used in order to evaluate model adequacy, regression coefficients and statistical significance.

Table 1 Chemical composition of hog plum juice and pomace

Properties	Juice	Pomace
Moisture content (%)	94.27 ± 0.65 ^a	73.73 ± 2.26 ^b
Ash content (%)	0.81 ± 0.25 ^a	1.17 ± 0.25 ^b
Carbohydrate (%) (Anthrone method)	4.35 ± 0.11 ^a	2.91 ± 0.21 ^b
Vitamin C (g/100 mL)	28.21 ± 3.75 ^a	12.98 ± 1.24 ^b
TSS	4.6 ± 0.11	–

Value = mean ± SD. Value in the same row with different superscript differ significantly at 5% probability level

Statistical analysis was performed using RSM software Design matrix version 7.0.0 trial (Stat-Ease, Minneapolis, MN, USA). The results were reported at $p = 0.05$. The model adequacy were tested by coefficient of determination (R^2), model p value and lack of fit testing.

Optimum processing condition was selected on the basis of final moisture content, hygroscopicity, water activity, bulk density, and total phenolic content of the finished spray dried hog plum juice powder.

Moisture content

Moisture content, fat and carbohydrate was estimated as per the method of AOAC official methods (18th edition).

Determination of total phenolic content (TPC)

Estimation of TPC was performed by using Folin–Ciocalteu reagent (FCR) method as described by Luo et al. (2012). For determination of TPC of spray dried hog plum juice powder, 50 mg of extracted powder was mixed with 5 mL of methanol and the mixture was stirred at 25 °C for 30 min. The stirred mixture was centrifuged at 5000 rpm for 10 min, supernatant was analysed for its TPC in terms of gallic acid equivalents (GAE)/mg of spray dried hog plum juice powder.

Hygroscopicity

The spray dried powder (1 g) was placed in an airtight container containing saturated solution of sodium carbonate. Sample was weighed after 1 week and hygroscopicity was expressed in terms of g of adsorbed moisture per 100 g of powder (Cai and Corke 2000).

Bulk density and tapped density

For bulk density (ρ_B) 2.0 g of hog plum juice powder was added into 10 mL of graduated measuring cylinder and the occupied volume was recorded and then bulk density was observed in terms of mg/mL.

Water activity

Water activity of the spray dried hog plum juice powder was estimated using an electronic dew point water activity meter (4 TE Aqualab, Decagon, USA).

Color characteristics of spray dried hog plum juice powder

The color values was analysed by using Hunter Color Lab (Ultra scan VIS, USA) calibrated with white tiles. Obtained values were expressed in terms of L , a and b where L represents lightness and darkness, a redness and greenness and b represents yellowness and blueness. All the samples were analysed in duplicates. Color intensity in terms of chroma was calculated by the formula $(a^2 + b^2)^{1/2}$, hue angle (H°) was calculated by using the formula $H^\circ = \arctan(b/a)$ (Duangmal et al. 2008; Mishra et al. 2014).

Scanning electron microscopy (SEM) analysis

Particle morphology of spray dried hog plum juice powder was evaluated by scanning electron microscope (SEM). Powders were attached to a double sided adhesive tape on SEM stubs, coated with 3–5 mA palladium under vacuum and was examined with a JEOL scanning electron microscope (JSM-6390 LV, Japan, PN junction type, semiconducting detector). SEM was operated with 20 kV at two different magnification i.e. $\times 1000$ and $\times 3000$ (Quek et al. 2007).

Storage study

The spray dried hog plum juice powder was stored at constant RH (75%) but two different temperatures i.e. ambient temperature (25 ± 2 °C) and refrigeration temperature (4 ± 1.5 °C). The stored samples were withdrawn at the interval of 10 days and were evaluated for DPPH free radical scavenging activity, total phenolic content and colour values. The storage studies were carried out up to 30 days for all the stored samples.

Statistical analysis

All the experiments were carried out in duplicate and obtained mean values were analysed by using one way ANOVA. The graph of mean value and error bar was calculated by using excel version of 2010.

Results and discussion

Chemical composition of hog plum fruit juice, and pomace

The hog plum juice and the pomace were analysed for moisture content, ash and vitamin C. Moisture content of the juice and pomace was 94.27 and 73.73% respectively. Moisture content, carbohydrates, vitamin C and fat % of fruit juice was significantly higher than the pomace of the fruit at 5% probability level. Comparatively higher vitamin C was extracted in the juice than the pomace. Fresh fruit juice had 4.6% of total dissolved solids and so before spray drying maltodextrin was added into the juice to protect the vital nutrient of juice during drying and also to increase the total solids in the juice.

Experimental design for the development of spray dried hog plum juice powder

The processing condition of the spray dried juice was optimized by using response surface methodology using

Box–Behnken design. Preliminary study was conducted to decide the inlet temperature, feed rate and maltodextrin level. A Box–Behnken design with three numeric factors on five levels was used for designing the experimental conditions. Results of different run of the experiments are given in Table 2. Process variables i.e. temperature, maltodextrin level and feed rate were found to be statistically significant for moisture content, TPC, hygroscopicity and bulk density. ANOVA was performed to estimate the level of significance.

Response surface methodology

The interactive effect of feed rate and temperature on the moisture content of the spray dried powder is presented in Fig. 1a. Feed rate showed negative effect on the moisture content, higher feed rate in shorter contact time making the heat transfer less efficient and hence reduced the rate of water evaporation. As the inlet temperature was increased from 120 to 175 °C the moisture content of finished powder was decreased from 9.58 to 4.56% (Table 2). Due to the increased rate of heat transfer at high inlet temperature there was a greater driving force for moisture evaporation (Solvol et al. 2012; Grabowski et al. 2006) and so a significant reduction in moisture content in the spray dried powder was observed. Figure 1b presents the interactive effect of maltodextrin and temperature on moisture content of the finished spray dried powder. Both maltodextrin and temperature showed statistically significant effect on

Table 2 Box–Behnken design with experimental values of response variables of hog plum fruit juice powder

Expt no.	Real process variable			Experimental response				
	Temperature (°C)	Feed rate (mL/min)	Malto-dextrin	Moisture content (%)	Bulk density	Total phenolic content (mg/100 g GAE)	Water activity	Hygroscopicity (g/100 of powder)
1	120	11	2	9.58	0.47	213.12	0.314	17.89
2	175	11	6	4.56	0.54	473.39	0.259	20.11
3	120	8	4	7.72	0.52	404.68	0.276	20.36
4	147.5	8	2	7.65	0.49	327.76	0.22	19.65
5	175	14	4	5.19	0.54	279.65	0.24	18.00
6	147.5	11	4	7.55	0.50	546.78	0.25	24.99
7	120	11	6	8.5	0.46	475.56	0.29	21.54
8	147.5	11	4	7.17	0.51	543.76	0.26	26.07
9	147.5	11	4	7.67	0.49	542.99	0.258	23.94
10	147.5	8	6	5.68	0.56	584.77	0.256	26.54
11	147.5	11	4	7.36	0.49	541.76	0.242	24.89
12	147.5	14	2	9.21	0.54	198.89	0.279	22.40
13	175	8	4	5.58	0.50	474.89	0.210	22.00
14	175	11	2	8.45	0.47	193.65	0.20	20.98
15	120	14	4	8.05	0.47	371.88	0.31	18.23
16	147.5	14	6	6.14	0.53	485.54	0.27	18.98
17	147.5	11	4	7.25	0.51	545.54	0.25	25.00

Fig. 1 Response surfaces and contour plots for the effects of variables on moisture content: **a** feed rate and temperature, **b** juice: maltodextrin ratio and temperature, and **c** juice: maltodextrin ratio and feed rate

Table 3 Solutions for optimum condition (at temperature 171 °C, feed rate 8 mL/min and juice: maltodextrin 3.9:1) for spray dried hog plum juice powder

Particular	Predicted response	Optimum response
Moisture content (%)	5.40 ± 0.21 ^a	5.30 ± 0.11 ^a
TPC (mg/100 g GAE)	465.78 ± 5.21 ^b	468.35 ± 6.34 ^b
Hygroscopicity (g/100g of powder)	21.71 ± 0.98 ^c	21.98 ± 1.04 ^c
Water activity	0.21 ± 0.01 ^d	0.22 ± 0.04 ^d
Bulk Density (g/mL)	0.50 ± 0.06 ^e	0.52 ± 0.03 ^e

Value = mean ± SD. Value in the same row with different superscript differ significantly at 5% probability level

moisture content of the sample. Increase in the maltodextrin level resulted in the decreased moisture content, as the ratio of maltodextrin was increased from 6:1 to 2:1 (juice: maltodextrin (v/w)) the moisture content of spray dried hog plum juice powder was decreased significantly at $p < 0.5$. As per the Grabowski et al. (2006) and Kha et al. (2010) on increasing the maltodextrin level the level of feed solids were increased and so reduced the total level of moisture for evaporation. The feed rate and maltodextrin collectively had no statistically significant effect on the finished moisture content of the spray dried powder however feed rate showed an obvious effect on the moisture content of powder. As the feed rate was increased the moisture content was also increased in the powder (Fig. 1c; Table 3).

Figure 1b represents the effect of variables on the total phenolic content of the spray dried hog plum juice powder. The effects of maltodextrin and temperature on phenolic content are shown in Fig. 2a. Both the maltodextrin level and temperature showed statistically significant effect on the TPC of spray dried juice powder. TPC was significantly increased with increase in the ratio of juice: to maltodextrin from 2:1 to 5:1 and on further increase in the ratio of juice:

maltodextrin, TPC content was slightly decreased. On increasing the level of maltodextrin a decreasing trend in the phenolic content were observed this is due to the concentration effect of maltodextrin (Mishra et al. 2014). When the temperature was increased from 120 to 161.5 °C the TPC of the spray dried powder was increased and above 161.5 °C temperature a reverse trend was observed. Figure 2b showed the interactive effect of maltodextrin and feed rate on the TPC of the powder. Maltodextrin and feed rate showed significant effect on the TPC of spray dried powder. As the feed rate was increased the TPC was decreased. Increased level of maltodextrin effectively encapsulate the phytonutrients of the juice and so protect it against thermal degradation during drying (Mishra et al. 2015).

Figure 3 presents the effect of variables on the hygroscopicity of the powder. The interactive effect of maltodextrin and temperature on the hygroscopicity of powder are presented in Fig. 3a. Maltodextrin showed significant effect ($p < 0.05$) on the hygroscopicity of the spray dried hog plum juice powder. Hygroscopicity was lowest when 2: 1(juice: maltodextrin v/w) ratio was used for spray drying of the juice. Mishra et al. (2014), Rodriguez-Hernandez et al. (2005) and Cai and Corke (2000) also observed the same finding while spray drying of amla juice powder, cactus pear juice powder and betacyanin pigments, respectively. Maltodextrin is a material of having low hygroscopicity property and it's utility as a carrier material for spray drying is well established (Goula and Adamopoulos 2008). The lowest hygroscopicity values were obtained when powder produced at 6:1 ratio of juice: maltodextrin and at 120 °C temperature. Tonon et al. (2008) explained that lower the particle moisture content, the higher their hygroscopicity because due to greater moisture gradient at low moisture content, powder have greater tendency to absorb the moisture content. Feed rate

Fig. 2 Response surfaces and contour plots for the effects of variables on total phenolic content: **a** maltodextrin and temperature, **b** feed rate and maltodextrin, and **c** temperature and feed rate

was also one of the important parameter which affected the hygroscopicity of the powder (Fig. 3b).

The water activity of the powder was varied from 0.20 to 0.32. According to Fig. 4 temperature, maltodextrin and feed rate were significantly affected the water activity of the spray dried powder. At higher inlet temperature, there is greater temperature difference between the drying air and atomized feed and so greater driving force for moisture removal reduced the water activity of the powder significantly (Fig. 4a). Increased in the solid content due to increased level of maltodextrin reduced the amount of moisture content for the evaporation and so reduced the finished moisture content and water activity of the powder. Addition of maltodextrin also reduced the amount of free water available, resulted in the low water activity of the hog plum juice powder (Fig. 4b). Higher feed rate negatively affected the water activity of spray dried hog plum

juice powder (Fig. 4c). At higher feed rate the moisture content of the powder was comparatively high, which directly affected the water activity of the powder too. Figure 5 presents the effect of variables on the bulk density of spray dried hog plum juice powder. Temperature and maltodextrin level significantly affected the bulk density of the powder, however feed rate showed no any significant effect on the bulk density of the powder. At low inlet temperature, the reduced rate of drying favours the high retention of water in the sample and so increased the bulk density of the powder, however at high inlet temperature rapid rate of drying produced particle with porous structure and smooth surface which reduced the bulk density of the powder (Fig. 5b). Walton (2000) explained that when the evaporation rate is fast the product dry more to a porous structure. When drying temperature increased there is a greater tendency that the particles to be hollow which

Fig. 3 Response surfaces and contour plots for the effects of variables on hygroscopicity: **a** maltodextrin and temperature, **b** feed rate and maltodextrin, and **c** feed rate and temperature

Fig. 4 Response surfaces and contour plots for the effects of variables on water activity: **a** feed rate and temperature, **b** temperature and maltodextrin, and **c** maltodextrin and feed rate

Fig. 5 Response surfaces and contour plots for the effects of variables on bulk density: **a** feed rate versus temperature, **b** juice: maltodextrin versus temperature, and **c** juice: maltodextrin versus feed rate

resulted in a lower bulk density and particle density (Walton, 2000; Goula and Adamopoulos 2005). As shown in Fig. 5c an increase in the concentration of carrier agent i.e. maltodextrin leads to a decrease in bulk density. This might be due to the addition of maltodextrin which minimizes the thermoplastic particles from sticking and the sticky or less free flowing particles are involved with high bulk density (Kwapinska and Zbicinski 2005). As per the Kwapinska and Zbicinski (2005) skin forming particles like maltodextrin often contain air bubbles and so reduced the bulk density. All the obtained results were fitted to a second-order polynomial model and multiple regression coefficients were generated for all responses, using method of least square approach (MLS). Model adequacy was estimated by calculating the F value for model, F value for lack of fit test and by R^2 . Particularly high R^2 for moisture content (MC), bulk density, TPC, water activity and

hygroscopicity confirmed that the applied polynomial models were in accordance with the experimental results. Considering all the responses obtained simultaneously, RSM was used to compromise the optimum conditions. Optimized conditions of variables were obtained by numerical optimization techniques. Temperature 171 °C, feed rate 8 mL/min, juice: maltodextrin ratio 3.9 was found to be optimum. Duplicate samples were prepared and were analysed for moisture content, TPC, hygroscopicity and water activity; the corresponding values for moisture content, TPC, hygroscopicity, water activity and bulk density were 5.3%, 468.35 mg/100 GAE, 21.98 g/100g of powder, 0.22 and 0.50g/mL respectively which showed an excellent agreement with the predicated responses and actual responses. There were no any significant difference were observed in predicted and actual responses at $p < 0.5$ and hence the model was found satisfactory.

Fig. 6 Micrographs of particles at different inlet temperature and at constant juice: maltodextrin ratio (6:1 v/w basis) at magnification of **a** 120 °C, 1000 × ; **b** 120 °C, 3000 × ; **c** 147.5 °C, 1000 × ; **d** 147.5 °C, 3000 × ; **e** 175 °C, 1000 × ; **f** 175 °C, 3000 ×

Particle morphology of spray dried hog plum juice powder

Figure 6 shows the particle morphology of hog plum juice powder produced at different temperature and at constant juice: maltodextrin ratio i.e. 6:1. The particle showed spherical shapes and of different sizes which is a characteristics of spray drying. When the inlet temperature of the spray dried powder was low the majority of the particle showed withered surfaces while increasing the inlet temperature resulted in the larger number of particles of smooth surfaces. Present findings support the findings of Allamila-Beltran et al. (2005), Nijdam and Langrish (2006) and Tonon et al. (2008). As per the Tonon et al. (2008) faster rate of drying at higher temperature, causing faster water evaporation and resulting in formation of smooth surface and hard crust. Nijdam and Langrish (2006) explained that vacuole forms within the particle soon after a skin develops on the surface which inflate when particle

temperature exceed the local ambient boiling point and the vapour pressure within the vacuoles rises above the ambient pressure. In the case of high drying temperature the rate of evaporation of moisture is very high which favours the formation of dry and hard skin and so that the hollow particles cannot deflate when vapour condenses within the vacuole as the particles moves in the cooler region of spray drier, however when the drying temperature is not sufficiently high the skin of the particle is moist and supple for longer which may collapse on cooling (Nijdam and Langrish, 2006).

Effect of storage on TPC and DPPH free radical scavenging activity of spray dried hog plum juice powder

The spray dried powder was stored at constant RH (75%) and at two different temperatures i.e. ambient temperature (25 ± 2 °C) and refrigeration temperature (4 ± 1.5 °C)

separately for the analysis of TPC the powder was withdrawn at interval of 10 days. The significant effect of storage temperature was seen on the retention of TPC in the spray dried powder. The loss of total phenolic content was significantly less ($p < 0.5$) in sample stored at refrigeration temperature (14.52%) than to the sample stored at room temperature (33.33%) for the same duration of the storage. The rate of oxidation of TPC may be increased at room temperature and so reduced the retention of overall TPC in the stored sample (Quek et al. 2007). According to the Gil-Izquierdo et al. (2004) and Gonzalez-Molina et al. (2008) precipitation of flavonoids at refrigeration temperature may be one of the probable reason for lowering of TPC at refrigeration temperature (Gil-Izquierdo et al. 2004; Gonzalez-Molina et al. 2008).

The sample stored at ambient temperature lost its DPPH free radical scavenging activity at faster rate than the sample stored at refrigeration temperature (17.33%) which may be correlated with the loss of total phenolic content of the powder. Degradation rate of DPPH free radical scavenging activity was comparatively higher than to the rate of degradation of total phenolic content which supports the findings of Mishra et al. (2015). Mishra et al. (2015) reported that being secondary metabolites phenolics groups may be broken down or synthesized in new components which may or may not be having DPPH free radical scavenging activity. Mutual degradation of DPPH free radical scavenging activity and total phenolic contents are well reported by several scientists.

Effect of storage on colour characteristics of spray dried hog plum juice powder

Generally colour is an important attribute of any food sample, is significantly affected by storage temperature. Room temperature adversely affected the lightness of the stored product however refrigerated sample showed better stability of the colour during the same period of storage. There was no any significant difference observed in the lightness of the sample during the 30 days of storage when stored at refrigeration temperature at 5% probability level however the lightness of room temperature sample was decreased from 77.41 to 21.65 during the 30 days of storage. Increased rate of darkness in sample at room temperature may be due to the increased rate of oxidation within the sample, causes an increased redness and subsequently darkness of the sample (Mishra et al. 2014). Redness of the sample increased with decrease in the hue angle. The redness of the room temperature stored sample was increased with the progress of storage time as the hue angle of the stored powder was decreased from 87.58° to 60.11°; however sample stored at refrigeration temperature showed no any significant change in the hue value during

the same period of storage. The reason of the increased in the redness of the sample stored at room temperature is due to the increased rate of oxidation at room temperature than to the refrigeration temperature which can be easily correlated with *L* value of stored powder.

Conclusion

The processing condition for the spray drying of hog plum juice powder was optimized by Response surface methodology with Box–Behnken design. Juice: maltodextrin ratio (from 2:1 to 6:1), inlet temperature (120 to 175 °C) and feed rate (8–11 mL/min) significantly affected moisture content, hygroscopicity, water activity and total phenolic content. Bulk density was not significantly affected by feed rate however temperature and maltodextrin affected the bulk density significantly. Temperature 171 °C, feed rate 8 mL/min, juice: maltodextrin ratio 3.9 was found to be optimum and produced the powder of having low hygroscopicity, water activity, moisture content and good amount of TPC. The corresponding values for moisture content, TPC, hygroscopicity, water activity and bulk density of optimum powder were 5.30%, 468.35 mg/100 GAE, 21.98 g/100 g, 0.22 and 0.50 mg/mL respectively. The spray dried hog plum juice powder produced under optimum condition and stored at refrigeration temperature, was adequately effective to preserve the TPC, DPPH free radical scavenging activity and colour of the hog plum juice powder. A strong correlation between TPC and DPPH free radical scavenging was also observed.

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