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Physicochemical Characteristics of Microencapsulated Red-Fleshed Dragon Fruit Juice Powder Through Spray Drying

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ABSTRACT: Dragon fruits are seasonal and likely perishable in ambient condition, but they have great near future in the food industry as a functional food and natural food colorant, which can be exploited through spray drying technology. In this context, the present investigation was aimed to standardize the operation parameters to produce spray dried dragon fruit powder. In this study, three levels of inlet air temperature (140, 150 and 160°C) and maltodextrin (MD) concentration (15, 17.5 and 20%) were carried out, whereas other parameters were kept constant. The result revealed that, the dragon fruit juice powder obtained at an inlet temperature of 150°C with 20% MD had highest powder recovery (15.78%), whereas the treatment with 150°C with 15% MD was founded to be excellent in maintaining superior physicochemical properties (Moisture content: 4.12%, A_w: 0.29, Hygroscopicity: 19.59%, Solubility: 95.53%, Wettability: 10.16%, Bulk density: 0.68 g/ml, Betacyanin: 8.68 mg/100g, TSS: 41.60 °B, Total sugar: 8.84%, Titratable acidity: 0.51%, Ascorbic acid: 6.43% and Iron: 2.10 mg/100g) and colour characteristics (*L : 56.13, *a** : 32.13 and *b** : –16.43) which demonstrated the potentiality of its uses in functional food industries.**

Keywords: Water activity, Solubility, Hygroscopicity, Bulk density, Particle size, Ascorbic acid, Betacyanin,

INTRODUCTION

Dragon fruit, *Hylocereus polyrhizus* (Weber) Britton & Rose is a tropical vine belongs to Cactaceae family. It is originated from the tropical and subtropical forests of Latin America and Mexico. Dragon fruit drew the attention of the academic researchers and food processors because of its potential source of dietary ingredients. The fruits are very attractive for its red skin, mouth-melting deep purple-red colour pulp with edible black seeds (Vinod *et al*., 2020). Red-flesh dragon fruit is rich in pigment betalains consisting of water soluble betacyanins and betaxanthin. The fruit is rich in antioxidants, polyphenols, vitamin C, B vitamins, polyunsaturated fatty acids, fibre, protein and minerals like calcium, iron, potassium, sodium, etc. It is widely consumed as it controls various diseases such as breast cancer, colon cancer, diabetics, high cholesterol, anaemia, etc.

Dragon fruits are seasonal and likely perishable in ambient condition, but they have great future in the food industry as a functional food, flavouring agent, natural food colourant, etc. which can be exploited by various processing techniques. One of the technique is to convert them into microencapsulated powder through spray drying. Encapsulation is a process to entrap active agents within a carrier material and it is a useful tool to improve the delivery of bioactive molecules into foods (Fang and Bhandari, 2010). Spray drying is one of the popular and comparatively most affordable system used to produce the microencapsulated powder. Dragon fruit can be powdered to have a longer shelf life, therefore could be easily and readily available during the off-season and also served as a good source of betalains rich functional food ingredient for addition into food products as natural colour and having instant properties such as food ingredient, pharmaceutical or nutraceutical composition and cosmetics.

Spray drying is a process of altering the liquid state feed into a dried powder form. This is accomplished by atomizing the liquid into a drying chamber, where the liquid droplets are passed through a hot air stream (Quek *et al*., 2007). Fruit powder is hygroscopic and requires drying agents such as starch, gum arabica and maltodextrin for making spray-dried powders (Jaya and Das, 2004). Maltodextrins are the most common additives used for drying of fruit powder (Singh *et al*., 2019). The addition of carrier agents into the feed solution determines the properties and stability of powder. Crystalline and amorphous forms of the powder shows difference in particle size, bulk density, physicochemical properties, chemical stability, water-solubility, hygroscopicity, flow properties, etc. There are various reports on pigment content, antioxidant properties, their stabilities and powdering of dragon fruit (Phebe *et al*., 2009). However, there is limited scientific information about how encapsulating agents and drying conditions may influence the physicochemical properties of dragon fruit juice powder.

Therefore, the present study was carried out to standardize the process parameters for preparation of spray dried dragon fruit juice powder and assess the physicochemical characteristics of the produced powder with emphasis on the water activity, hygroscopicity, solubility, wettability, bulk density, particle size, betacyanin and colour by varying inlet air temperatures and maltodextrin concentration of spray drying.

MATERIALS AND METHODS

Materials: Dragon fruits were procured from Mr. Mahadev Kolekar's farm located at Kagwad in Belagavi district of Karnataka. Fruits of uniform size, shape and fully ripened were selected and harvested manually, packed in corrugated fibre board boxes and brought to the laboratory for further experiment. Maltodextrin was purchased from HiMedia Laboratories, India.

Sample preparation: Fresh dragon fruits were washed, peeled manually and the juice was extracted through laboratory fruit juice extractor machine under hygienic condition. The juice was stored at -20 ± 0.5 °C before spray drying. Frozen juice was thawed and filtered using a hand-held kitchen strainer to remove mucilage content and seeds (Herbach *et al*., 2006). The filtrate was then centrifuged at 3,000 × g for 10 min with a bench-top centrifuge (Remi R-8C DX, India) to reduce the viscosity of the fruit juice to ease the drying process.

Spray drying process: Maltodextrin was added to the clarified juice and diluted it with water at a ratio of 1:0.5 and homogenised for 10 min with a basic lab homogenizer (Bajaj Majesty: HB04, India). Then the mixture was spray-dried in a laboratory spray dryer (Technosearch instruments, Thane, India) at different maltodextrin concentration (15, 17.5 and 20%) and inlet air temperatures (140, 150 and 160°C) with outlet air temperature and feed flow rate pre-set at 70°C and 2 ml/min respectively. Spray dried powder was collected and transferred into laminated aluminium pouches and stored in a desiccator at room temperature for further studies.

Analysis of physicochemical properties

Powder recovery (%): The recovery percentage of dragon fruit powder was calculated according to the following formula as mentioned by Fang and Bhandari, (2012).

Recovery (%)

$$= \frac{\text{Weight of powder obtained}}{\text{Weight of juice + Weight of carrier agent}} \times 100$$

Moisture content (%) and Water activity (A_w): The moisture content of dragon fruit powder was estimated by using moisture analyser (Model: P1019319, A&D company limited, Japan). Water activity was quantified by digital water activity meter (Novasia AG: ms-1 aw, Switzerland).

Hygroscopicity (%): Hygroscopicity of dragon fruit powder was evaluated based on the method described by Cai and Corke (2000). At least 2 g of powder was placed in a desiccator containing saturated NaCl solution (75.29% relatively humidity). After one week, the moisture gained by the powder was measured and hygroscopicity was expressed as gram of adsorbed moisture per 100 grams of dry matter.

Solubility (%): The solubility of dragon fruit powder was determined as recommended by Cano-Chauca *et al*. (2005). 100 ml of distilled water and 1 g of dragon fruit powder were homogenized in a blender for 5 minutes. The solution was then centrifuged at 3000 g for 5 min. An aliquot of 25 ml of the supernatant was transferred to a pre-weighed petri dish and immediately dried in an oven at 90°C for 10 hr. The solubility (%) was calculated based on the dry weight of the supernatant compared to its expected dry matter.

Wettability (s): The wettability of dragon fruit powder was evaluated according to the method described by Vissotto *et al*., (2010) considering the time required for one gram of powder deposited on the liquid surface to become completely submerged in 400 ml of distilled water at 25 °C.

Bulk density (g/ml): The bulk density of dragon fruit powder was measured using the method suggested by Jinapong *et al*., (2008). The powder was tightly loaded into a 10 ml tared graduated cylinder to the 10 ml mark and weighed. The volume read directly from the graduated cylinder was then used to calculate the bulk density (ρ_{bulk}) according to the relationship: mass/volume.

Particle size (d.nm): The zetasizer nano range (ZETA sizer, nano 383 issue 5.0, Malvern, England) is used to measure the particle size of particles or molecules in a liquid medium. The equipment requires the sample to be diluted. The computer system uses the Malvern software for control of the equipment and for showing the results (Tze *et al.*, 2012).

Betacyanin (mg/100g): Total betacyanin content of spray dried dragon fruit powder was quantified by the procedure mentioned by Tze *et al.*, (2012) and expressed as mg/100g.

Total betacyanin content (mg/100g)

$$= \frac{A \times MW \times DF \times V \times 100}{\varepsilon \times LC \times W}$$

Where, A = Absorbance value at a wavelength of 538 nm, MW = Molecular weight of betanin (550 g/mol), DF = Dilution factor, LC = Path length of the cuvette (1 cm), Ɛ = Molar extinction coefficient of betanin in water (60,000 l/mol), V = pigment solution volume (ml), W = weight of spray dried powder (g).

Colour (*L*a*b) values:** The colour of the dragon fruit powder was measured by using a Lovibond colour meter (Lovibond RT300, The Tintometer Limited, Salisbury, UK) fitted with 8mm aperture. The instrument was calibrated against black and white tiles provided. Colour was expressed in Lovibond units *L** (lightness/darkness), *a** (redness/greenness) and *b** (yellow/blueness). To obtain these values, the lens of the colour reader was placed over the powder taken in sample boxes. The colour difference between the treatments was observed, three measurements were performed and the values were averaged to get the final value.

Total soluble solids (°B): Total soluble solids (TSS) of spray dried dragon fruit powder was quantified by reconstituting the powder in equal amounts of water (1 g/ml) using a hand refractometer (Erma, Tokyo, Japan) of range 28-62 °B. The percentage of dry substance in it is read directly at 20 °C as degree Brix.

Titratable acidity (%); The titratable acidity was quantified according to Jamilah *et al.* (2011) by homogenizing 10 g of the spray dried powder in 100 ml distilled water, titrated with 0.1 N NaOH to pH 8.1 and expressed in terms of citric acid as per cent acidity of the sample**.**

Ascorbic acid content (mg/100g): The ascorbic acid content of spray dried dragon fruit powder was quantified using iodine titration method by the procedure mentioned by Lee *et al*., (2013).

One milligram of powder was transferred to the conical flask with 4.0 ml of distilled water and 5.0 ml of 0.1 M of sulphuric acid. Two milliliters of 1% of the starch indicator solution was added to the mixture and swirled to blend. The mixture was titrated immediately with 0.001 N standardised iodine solution and the endpoint was assessed when a faint purple solution was obtained. One ml of 0.001 N iodine was equivalent to 88.06 µg ascorbic acid and was expressed as mg/100 g.

Total sugars (%)

The per cent total sugar present in dragon fruit pulp were estimated using the Anthrone method. The values obtained are expressed as per cent.

Total sugar (%)

$$= \frac{\text{Value from graph} \times \text{total volume of extract}}{\text{Aliquot sample used} \times \text{weight of sample}} \times 100$$

Iron (mg/100g): Iron content was estimated as per the procedure given in AOAC (2000) official method 999.11.

Statistical analysis: The research work was conducted in triplicate and subjected to statistical analysis in a completely randomized block design (CRD). The data was analysed using Web Agri Stat Package 2.0 (WASP) developed by ICAR research complex, Goa. The level of significance used in 'F' test was $p \leq 0.01$. Critical difference values were calculated wherever 'F' test was significant.

RESULT AND DISCUSSION

Dragon fruit pulp composition: Table 1 shows the physicochemical properties of dragon fruit pulp. It can be noted that the dragon fruit pulp has a pH of 4.62 which is slightly acidic which influence the organoleptic properties and microbial safety. It has a low total soluble solid (TSS) of 11.5 °B and total sugar of 8.17% which is an important parameter for reduced stickiness and free flowability of spray dried powder.

Effect of spray drying conditions on powder recovery (%): There was a significant difference ($P \leq 0.01$) in the yield of red-flesh dragon fruit juice powder. The recovery percentage of spray dried powder varied from 9.41 to 15.78 per cent.

Table 1: Physicochemical properties of dragon fruit pulp.

Analysis	Values*
TSS (°brix)	11.5
pH	4.62
Titratable acidity (%)	0.43
Ascorbic acid (%)	8.21
Total sugar (%)	8.17
Iron (mg/100g)	0.74
Betacyanin (mg/100g)	16.64
Moisture content (%)	84.26

* Mean ± standard deviation of triplicate analysis.

Powder recovery could be affected by the inlet temperatures were, higher the inlet temperature, higher will be the process yield. Process yield is associated with the efficiency of heat and mass transfer processes occur during the spray drying process. But here, the maximum recovery was recorded in the treatment T_4 with 150 °C inlet temperatures (Fig. 1) and this is because sometimes there will be a reduction in the yield as inlet temperature increases due to the melting of the powder and cohesion wall.

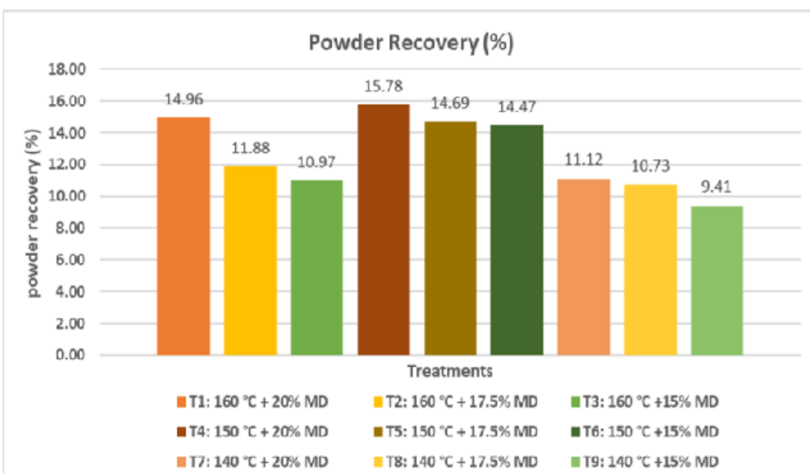

Fig. 1. Influence of inlet temperature and maltodextrin levels on powdery recovery of the microencapsulated dragon fruit powder

It is also recorded that, as the maltodextrin concentration increases the recovery of the powder increased irrespective of inlet air temperatures. This high recovery of the powder might be due to increase in the addition of maltodextrin (MD) that results in non-sticky powder. The low recovery at low MD concentration is due to the more amount of powder adhered to the drying chamber and cyclone as decreasing of MD concentration leads to increasing of hygroscopicity of powder. This was in accordance with Lee *et al*., (2013) in dragon fruit powder and Santhalakshmy *et al.*, (2015) in jamun juice powder.

Moisture content (%): Moisture content is an important feature of powder, which is related to the drying efficiency. The moisture content of spray dried product plays an important role in determining its free flowability and storage stability due to its effect on glass transition and crystallization behavior (Shrestha *et al*., 2007). The moisture content of spray dried dragon fruit powder was in the range of 3.75 to 5.97 per cent, which was sufficient to make food powder biologically safe (Table 2).

Generally, increasing the inlet temperature decrease the moisture content of the powder. This may be due to the greater loss of water from powder because of the higher rate of heat transfer into sprayed small particles, which provides a great driving force for moisture evaporation and also due to crust formation on the droplet surface (Pombo *et al*., 2020). Increase in maltodextrin concentration resulted in the lower moisture content of the powder. This might be due to the addition of maltodextrin into feed before spray drying increase the total solid content in feed and reduced the amount of free water for evaporation. Consequently, the hygroscopicity of the final powder was reduced, thus resulting in lower powder moisture content. This results were similar to those of Bakar *et al*. (2013) in pitaya peel powder, Kamtekar *et al*., (2017) in jamun juice powder and Pombo *et al*., (2020) in cupuassu fruit powder.

Water activity (a_w): Water activity is indeed an important factor for spray dried powder because it can have a substantial effect on the shelf life of powder produced. Water activity is a greater measure of shelf life than of moisture content. High water activity indicates more free water available for biochemical reactions and hence, shorter shelf life. The data recorded that water activity was slightly affected by both inlet temperature and MD concentration (Table 2). The water activity of dragon fruit powder was in the range of 0.25 to 0.42 which was microbiologically and chemically quite stable. Generally, food with water activity less than 0.6 is stable both from microbiologically and chemically.

Results showed that water activity decreased with increasing maltodextrin concentration and higher inlet air temperature. This might be due to higher level of MD concentration; a rapid drying was occurred hence powder with low moisture content and water activity was obtained. This was in agreement with Tze *et al.* (2012) in dragon fruit powder, Santhalakshmy *et al*. (2015) in jamun juice powder and Pombo *et al*. (2020) in cupuassu powder.

Hygroscopicity (%): Hygroscopicity of the analysed powders were low and ranged from 18.21 to 20.62 per cent (Table 2). The rapid removal of moisture during spray-drying resulted in an amorphous and highly hygroscopic powder, which absorbs moisture when exposed.

Hygroscopicity values increased with an increase of moisture content as well as lower powder moisture contents indicated lower hygroscopicity (capability to adsorb moisture content up to equilibrium). The samples produced at higher temperatures had less hygroscopicity value, which could be related to the powder's moisture content. Maltodextrin percentage has the highest effect on hygroscopicity so the increasing maltodextrin, hygroscopicity decreased. Tonon *et al*. (2008) observed that "the lower hygroscopicity values are obtained when the highest concentrations of MD were used and this was evident from the fact that MD is a low hygroscopicity material". The inlet air temperature has a role in the hygroscopicity of the powder. It showed that higher inlet air temperature, decreases the hygroscopicity of the powder thereby it maintains free-flowing of the powder. Similar results were recorded by Santhalakshmy *et al*. (2015) in jamun juice powder, Bazaria and Kumar (2018) in beetroot juice powder and Sasikumar *et al*. (2020) in blood fruit powder.

Solubility (%): Solubility is the most dependable criteria to evaluate the behaviour of powder in aqueous solution (Caparino *et al*., 2012). The solubility of dragon fruit powder ranged from 90.25 to 96.53 per cent (Table 2). Generally, solubility increased with increase of inlet temperature because of the production of large particle size at high inlet air temperature and required less time for the powder to dissolve.

Further higher concentrations of maltodextrin resulted in high solubility relative to low concentrations of maltodextrin. This difference may be attributed to the fact that maltodextrin, which is an amorphous and non-crystalline substance, contribute to superior water solubility (Cano-Chauca *et al*., 2005). These results corroborate with Santhalakshmy *et al*., (2015) and Singh *et al*., (2019) in jamun juice powder, Aswathy *et al*., (2019) in cherry tomato powder and Sasikumar *et al*., (2020) in blood fruit powder.

Wettability (s): Wettability seems to be very important physical characteristics of the powder. It can be characterised as the ability of the powder to penetrate into the liquid due to the capillary forces (Hogekamp and Schubert, 2003). The wettability of dragon fruit powder ranged from 8.52 to 14.33 s (Table 2).

Table 2: Moisture content (%), water activity (Aw), hygroscopicity (%), solubility (%) and wettability (s) of dragon fruit juice powder.

Treatments	Moisture content (%)	Water activity (A_w)	Hygroscopicity (%)	Solubility (%)	Wettability (s)
T_1: 160 °C + 20% MD	3.75	0.25	18.21	96.53	8.52
T_2: 160 °C + 17.5% MD	3.84	0.26	18.94	96.14	8.66
T_3: 160 °C +15% MD	4.14	0.29	19.42	95.68	9.72
T_4: 150 °C + 20% MD	3.86	0.26	18.26	96.08	12.89
T_5: 150 °C + 17.5% MD	3.94	0.28	19.38	95.59	13.21
T_6: 150 °C +15% MD	4.12	0.29	19.59	95.53	10.16
T_7: 140 °C + 20% MD	4.03	0.29	19.14	94.13	13.49
T_8: 140 °C + 17.5% MD	5.13	0.35	20.52	92.59	14.21
T_9: 140 °C +15% MD	5.97	0.42	20.62	90.25	14.33
S.Em±	0.05	0.01	0.24	0.61	0.33
C.D. @ 1%	0.2	0.04	0.96	2.48	1.36

The result indicated that the rise in inlet temperature had shortened, the duration of wettability. It was inversely related to the size of the particles since larger particles showed more space between them hence more readily penetrated by water. In other side, smaller particles were less porous, make it more difficult for the solvent to enter the food matrix, resulting in low powder reconstitution properties. This view was the same as that of Ferrari *et al.* (2012) in blackberry juice powder and Santhalashmy *et al.*, (2015) in jamun juice powder.

Bulk density (g/ml): Bulk density of spray-dried dragon fruit powder was observed in a range from 0.66 to 0.71 g/ml (Table 3). Generally, the increase of inlet air temperature causes a decrease in bulk and particle density, it also provides a greater tendency to the hollowness of the particle. The concentration of maltodextrin greatly influenced the bulk density of the powder obtained. Here, increase of the concentration of maltodextrin resulted in a decrease in the density of powder. This result may be attributed to the addition of maltodextrin, which minimized the thermoplastic particles from sticking each other or less free-flowing nature of powder was associated with a high bulk density. The effect of maltodextrin on the increase of bulk density was due to its skin forming ability which induced in increasing the volume of air trapped in the particles as increased with the maltodextrin concentration (Kwapinska and Zbicinski, 2005). This result was similar to Yusof *et al.*, (2013) in white-flesh dragon fruit powder, Mendez *et al.*, (2013) in red-flesh dragon fruit and Tan *et al* (2015) in bitter melon powder.

Particle size (d.nm): The impacts of the operating parameters on the particle size were analysed by the Zetasizer system, which provided the average size of the microencapsulated dragon fruit powder. The size of the particles in dragon fruit powder was beyond the nanoscale spectrum. The particles produced in this study were ranged from 331.1 to 714.3 d.nm (Fig. 2).

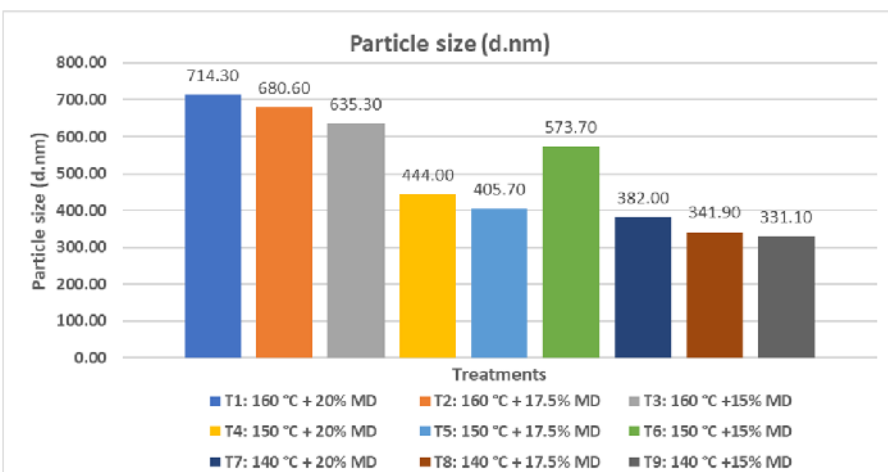

Fig. 2. Influence of inlet temperature and maltodextrin levels on particle size (d.nm) of the microencapsulated dragon fruit powder

The higher particle size (714.30 d.nm) was registered in treatment T_1 (160 °C inlet temperature + 20% MD). The rise in inlet air temperature contributed to the development of larger particle sizes as high temperature induced higher swelling. According to Reineccius (2001), drying at elevated temperatures had resulted in quicker drying rate, which had contributed to the early forming of a structure and had not caused the particles to shrink while drying. When the inlet air temperature was lowered, the particle had remained more shrunk and smaller. Here, increased inlet air temperature also resulted in the rapid formation of a dry layer on the surface of the droplet. This hardened surface did not cause the moisture to be removed from the droplet and it contributed to a rise in the particle size. Higher concentration of maltodextrin also resulted in the development of larger particles, which may be attributed to feed viscosity, which increased exponentially with maltodextrin concentration. The mean liquid droplet size varies directly from the feed viscosity at steady atomizer speed. The greater the viscosity of the liquid, the greater will be the size of the droplets produce during the atomization, hence the larger particles are produced by spray drying.

In Figure 2, the sample T_6 (150 °C inlet temperature + 15% MD) showed deviation against other treatments and earlier findings. The presence of larger particles might be attributed to an incipient agglomeration process, where the formation of irreversible link bridges lead to the production of particles of greater size (Tonon *et al*., 2009).

Instrumental colour analysis: The colour of powder is an important quality attribute concerning the powder as a natural food colorant. Colour changes are determined by the values of L^*, a^* and b^* (Table 3).

***L** value:** The L^* value measures the lightness of the sample; thus, it indicates the lightness of the dragon fruit powder in different treatments. Significantly highest L^* value was noticed in treatment T_1 (160 °C inlet temperature + 20% MD). As the inlet temperature increased the lightness value of the powder also increased. Maltodextrin concentration significantly affected the L^* value which was evident from Table 3, where an increase in the lightness of the powder was obtained by increasing the maltodextrin concentration. Similar results had also been observed in Bakar *et al.*, (2013) in pitaya peel powder, Santhalakshmy *et al*., (2015) in jamun juice powder and Aswathy *et al*. (2019) in cherry tomato powder.

Table 3: Bulk density (g/ml), betacyanin (mg/100g) and colour values of dragon fruit juice powder.

Treatments	Bulk density (g/ml)	Betacyanin (mg/100g)	Colour values		
			L*	***a****	***b****
T_1: 160 °C + 20% MD	0.61	7.78	59.29	30.50	-15.38
T_2: 160 °C + 17.5% MD	0.62	7.95	59.08	30.56	-15.61
T_3: 160 °C +15% MD	0.64	8.19	58.62	31.64	-15.88
T_4: 150 °C + 20% MD	0.65	8.31	57.77	31.37	-16.05
T_5: 150 °C + 17.5% MD	0.67	8.53	56.65	31.56	-16.24
T_6: 150 °C +15% MD	0.68	8.68	56.13	32.13	-16.43
T_7: 140 °C + 20% MD	0.68	8.25	58.12	31.92	-17.37
T_8: 140 °C + 17.5% MD	0.69	8.42	57.16	32.21	-17.45
T_9: 140 °C +15% MD	0.71	8.55	56.60	32.47	-17.75
S.Em±	0.01	0.04	0.15	0.23	0.28
C.D. @ 1%	0.04	0.15	0.63	0.93	1.00

***a** value:** The a^* value measures the redness of the spray-dried dragon fruit powder, that showed all values located in the positive quadrant (+a^*) which indicated towards red colour. An increase of inlet air temperature resulted in reduction of red colour, which might be due to the major deterioration of betacyanins at higher temperatures. According to Herbach *et al*., (2006), "After sustained heating at high temperature, betacyanin has been found to decompose into yellow degradation products (Cyclo-dopa5-O-b-glucoside and Betalamic acid), resulting in a loss of red colour". Similar results have also been observed in Santhalakshmy *et al*., (2015) in jamun juice powder and Jafari *et al*., (2017) in pomegranate juice powder. The concentration of maltodextrin greatly influenced the a^* value. From Table 3 it was also observed that there was a decrease in redness of the powder by increasing the maltodextrin concentration. The colour of the dragon fruit is red whereas the colour of maltodextrin is white, that is why the addition of a high volume of maltodextrin had resulted in a powder of light purple colour. The similar results had also been observed in Quek *et al*., (2007) in watermelon powder, Bakar *et al*., (2013) in pitaya peel powder, Kamtekar *et al*., (2017) in jamun juice powder and Bazaria and Kumar (2018) in beetroot juice powder.

***b** value:** The b^* value measures the blueness of the spray-dried dragon fruit powder, that showed all values located in the negative quadrant (-b^*) which indicated towards blue colour. The b^* values increased as the inlet air temperature increased in different treatments, similarly as the maltodextrin concentration increased, the b^* values show an increasing trend. The result was in accordance with Quek *et al*., (2007) in watermelon powder, Jafari *et al*., (2017) in pomegranate juice powder, Kamtekar *et al*., (2017) in jamun juice powder and Aswathy *et al*., (2019) in cherry tomato powder.

Betacyanin (mg/100g): Dragon fruit pulp showed betacyanin content about 16.58 mg/100g. Spray drying of the dragon fruit juice caused a significant loss of betacyanin content in the resultant powder. It was founded to be in the range from 7.78 to 8.68 mg/100g (Table 3).

Increase of inlet air temperature reduced the betacyanin content because betacyanin compounds were heat sensitive so it would be degraded easily at high temperatures of above 60°C due to the instability of pigment structure (Herbach *et al*., 2006).

The similar findings were reported by Lee *et al*., (2013) in dragon fruit powder and Bakar *et al*., (2013) in pitaya peel powder.

Total soluble solids (°Brix) and Total sugars (%): The total soluble solids and total sugar increased after spray drying process which indicated that TSS and sugar value was significantly greater in powder than in pulp of dragon fruit juice. This might be due to the evaporation of moisture from the juice and retention of soluble solids or increasing TSS content of powder might be due to the hydrolysis of complex carbohydrates. In the present investigation, highest TSS and sugar was recorded in treatment T_1 (160 °C inlet temperature + 20% MD) and lowest was observed for treatment T_9 (140 °C inlet temperature + 15% MD), it was also recorded that as the temperature and MD concentration increase the TSS and sugar was found to be increased (Table 4). The similar findings were reported by Santhalakshmy *et al.*, (2015) and Kamtekar *et al*., (2017) in jamun juice powder.

Table 4: TSS (°B), Total sugar (%), Titratable acidity (%), Ascorbic acid (%) and Iron (mg/100g) of dragon fruit juice powder.

Treatments	TSS (°B)	Total sugar (%)	Titratable acidity (%)	Ascorbic acid (%)	Iron (mg/100g)
T_1: 160 °C + 20% MD	44.55	10.84	0.32	3.84	1.80
T_2: 160 °C + 17.5% MD	43.67	10.23	0.38	4.38	1.87
T_3: 160 °C +15% MD	42.75	9.56	0.44	4.97	1.93
T_4: 150 °C + 20% MD	43.24	9.82	0.32	5.09	1.97
T_5: 150 °C + 17.5% MD	42.93	9.66	0.45	5.36	2.03
T_6: 150 °C +15% MD	41.60	8.84	0.51	6.43	2.10
T_7: 140 °C + 20% MD	42.53	9.37	0.38	5.58	1.93
T_8: 140 °C + 17.5% MD	39.86	8.61	0.51	6.06	2.00
T_9: 140 °C +15% MD	38.90	8.24	0.58	7.25	2.03
S.Em±	0.023	0.064	0.05	0.14	0.04
C.D. @ 1%	0.09	0.26	0.22	0.57	0.12

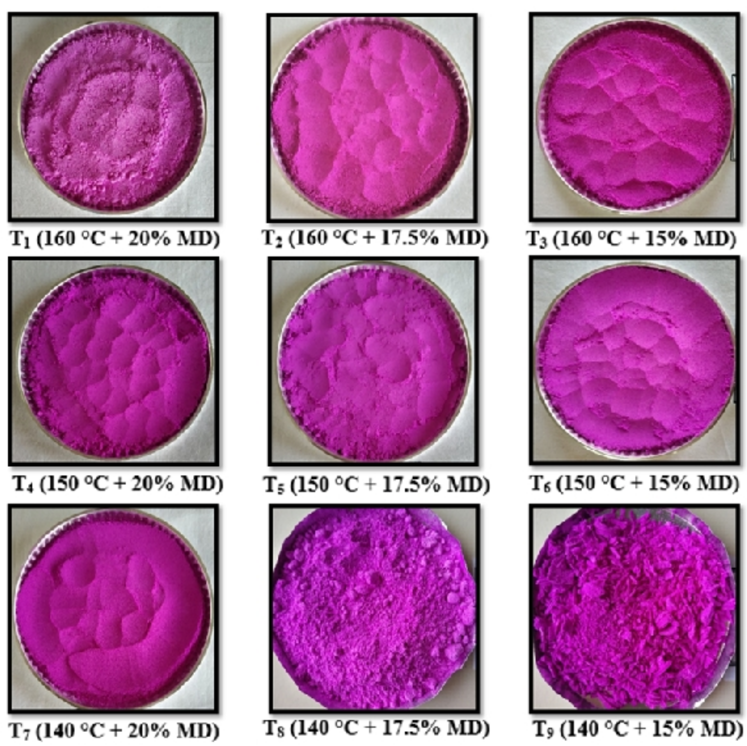

Plate 1. Dragon fruit powder obtained from different treatments through spray drying

Titratable acidity (%): In the present investigation, titratable acidity measured in terms of citric acid ranges from 0.32 to 0.58 per cent and highest titratable acidity was found for the treatment with low temperature and low MD (140°C inlet temperature + 15% maltodextrin). From table 4, it is clear that as the inlet temperature and MD concentration increased, acidity was found to be decreased. This might be due to the conversion of organic acid to sugars through gluconeogenesis at a lower temperature. Similar findings were reported by Santhalakshmy *et al.* (2015) and Kamtekar *et al.* (2017) in jamun juice powder.

Ascorbic acid (mg/100g): Ascorbic acid is one of the antioxidant agents present in food products which contribute towards the antioxidant activity. As ascorbic acid is heat liable and water soluble, their retention can be seen only 25-30 per cent after spray drying. In the present investigation, the ascorbic acid content of dragon fruit powder ranged from 3.84 to 7.25 mg/100g (Table 4). Ascorbic acid retention was highest in treatment T_9 (140 °C inlet temperature + 15% MD) and lowest in T_1 (160 °C inlet temperature + 20% MD). It was found that increase in inlet temperature decreased the ascorbic acid content in microencapsulated dragon fruit powder. This might be due to the oxidation of ascorbic acid under high temperature as it is a heat liable vitamin. These results were in accordance with Lee *et al*., (2013) in dragon fruit powder and Pombo *et al*. (2020) in cupuassu powder.

Iron (mg/100g): The data on iron content of dragon fruit powder as influenced by inlet temperature and MD concentration is presented in Table 4. Iron content differed significantly among the treatments. The iron content in spray dried dragon fruit powder ranged from 1.80 to 2.10 mg/100g.

Significantly maximum iron content was associated with treatment T_6 (150 °C inlet temperature + 15% MD) whereas lowest iron content was noticed in treatment T_1 (160 °C inlet temperature + 20% MD). There was no particular trend for iron content in dragon fruit powder concerning inlet temperature, however lowest degree of iron content was due to maximum maltodextrin concentration. These results are in accordance with Aswathy *et al*. (2019) in cherry tomato powder.

CONCLUSION

The present investigation drew the inference that the treatment with 150 °C inlet temperature with 20% MD concentration gave highest powder yield. Inlet air temperatures and MD concentrations had significant impact on physicochemical characteristics of the spray-dried dragon fruit powder. The most suitable processing conditions for the powder production with superior physicochemical and colour characteristics received at an inlet air temperature of 150 °C with 15% maltodextrin. The outcomes obtained during the present investigation indicated that good quality powders with optimum moisture content and water activity can be produced by spray drying, which demonstrates the substantial potentiality for the use of such powders in the functional food ingredients and food colouring agent in the various food processing industry.

FUTURE SCOPE

Further investigations are still required to assess the use of anticaking agent for better flowability and microbial stability of the powder and to know the versatility of red-flesh dragon fruit powder as a natural food colorant by incorporating it into other food models such as yogurt, pizza, pastille, cocktails etc.

Conflict of interest. The authors declare no conflict of interest.

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