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FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Determination of production efficiency, color, glass transition, and sticky point temperature of spray-dried pomegranate juice powder

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Abstract: The aim of the study was to determine the powder recovery, color characteristics, glass transition temperature (T_g), and sticky point (T_s) temperature of spray-dried pomegranate juice powder as affected by different concentrations of maltodextrin (DE 20). Five different combinations of pomegranate juice and maltodextrin (95:5, 90:10, 85:15, 80:20 and 75:25 v/w) were prepared and spray dried in a laboratory-type spray dryer. Increase in concentration of maltodextrin significantly increased the powder recovery and 20% of maltodextrin was required for successful spray drying of pomegranate juice (powder recovery > 50%). Color values of pomegranate juice powder were significantly influenced by concentration of maltodextrin. With increase in concentration of maltodextrin powder, lightness (L^* value) increased from 45.54 to 74.46, a^* value decreased from 20.43 to 11.45 and b^* value decreased from 2.16 to -3.83. Results showed that with increase in maltodextrin concentration from 5% to 25%, T_g increased from 38.23°C to 71.61°C. Sticky point temperature also showed an increase from 56.86 to 89.43°C with increase in concentration of maltodextrin.

Subjects: Food Additives & Ingredients; Food Chemistry; Food Engineering; Food Science & Technology

Keywords: pomegranate juice powder; maltodextrin; powder recovery; glass transition temperature; sticky point temperature

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PUBLIC INTEREST STATEMENT

For spray drying of pomegranate juice, requirement of drying aid is necessary to minimize the stickiness problem. Thus, the aim of the present study was to find out the required concentration of drying aid (maltodextrin) which would provide optimum glass transition temperature for successful spray drying of pomegranate juice. The results can be helpful for food companies looking for production of quality pomegranate juice powder and to minimize the stickiness problem during spray drying of pomegranate juice.

1. Introduction

Pomegranate (*Punica granatum* L.), native fruit of Iran is widely cultivated in parts of Asia, North Africa, the Mediterranean, and the Middle East (Sarkhosh, Zamani, Fatahi, & Ebadi, 2006). The juice obtained from pomegranate fruit contains higher levels of antioxidants than most other fruit juices (Gil, Tomas-Barberan, Hess-Pierce, Holcroft & Kader, 2000; Hong, Seeram, & Heber, 2008). Consumption of pomegranate juice reduces the risk of coronary heart disease, stroke, certain types of cancers, and aging (Sumner et al., 2005). The disease preventing ability of pomegranate juice is due to number of compounds such as ellagic acid, pedunculagin, punicalagin, and punicalin. These compounds are potent antioxidants which promote health by destroying cell damaging free radicals. (Negi, Jayaprakasha, & Jena, 2003; Rosenblat & Aviram, 2006).

The pomegranate is a seasonal fruit and not available round the year. However its high nutritional and antioxidant value makes it desirable to have a pomegranate product available throughout the year. Pomegranate juice in powder form can be a suitable option for this case and it has many benefits and economic potentials such as reduced volume or weight, reduced packaging, easier handling and transportation and much longer shelf life. Spray drying is a common technique used in industries for production of powders from wide range of products (Quek, Chok, & Swedlund, 2007). Spray drying results in powders with good quality, low water activity, and longer shelf life. However, the dehydration of fruit juice by spray drying is not a simple task.

Fruit juices contain low molecular weight sugars (such as glucose and fructose) and organic acids (such as citric, malic, and tartaric acid.) which have low glass transition temperature and thus lead to problems like stickiness of powder particles to dryer wall during spray drying of these juices at temperatures normally prevailing in spray dryer (Bhandari, Senoussi, Dumoulin, & Lebert, 1993; Shrestha, Howes, Adhikari, & Bhandari, 2007). The problem can be resolved by addition of high molecular weight drying aids (maltodextrin, gum Arabic and protein isolate), which have higher glass transition temperature (T_g) values, to the juice before spray drying (Muzaffar & Kumar, 2015; Bhusari, Muzaffar & Kumar, 2014).

Considering the difficulty in production of spray-dried pomegranate juice powder, the major objective of this study was to study the effect of maltodextrin concentration on powder recovery, glass transition temperature, and sticky point temperature, which would provide information about the minimum concentration of maltodextrin needed for successful spray drying of pomegranate juice. Color characteristics of the resulting powder as affected by different concentrations of maltodextrin were also determined.

2. Materials and methods

2.1. Raw materials

Fully ripened pomegranate (*Punica granatum*), variety Kandhari were purchased from Sangrur (Punjab, India). Maltodextrin (DE 20) manufactured by Himedia, India was used as a drying aid.

2.2. Preparation of juice and its analysis

The skin of the pomegranate fruit was removed and juice was extracted from the fleshy sacs with the help of hydraulic juice presser at a pressure of 5–6 kg/cm². The juice was filtered through three layers of muslin cloth to remove any suspended particles. The juice was then analyzed for color, total soluble solids, acidity, pH, reducing sugars, total sugar, ascorbic acid, and Anthocyanin content.

2.3. Spray drying

Feed solutions containing different proportions of pomegranate juice and maltodextrin (95:5, 90:10, 85:15, 80:20 and 75:25 v/w) were prepared. The solutions were then fed into a tall type laboratory-scale spray dryer (S.M. Scientech, Calcutta, India) with cocurrent regime and a two-fluid nozzle atomizer. Feed was metered into the spray dryer by means of a peristaltic pump. As per our previous study in all the experimental runs, inlet air temperature, feed flow rate, feed temperature,

compressor air pressure, and blower speed were kept at 171°C, 30 ml/min, 25.0 ± 0.5°C, 0.06 MPa, and 2,400 rpm, respectively (Muzaffar, Dinkarrao, & Kumar, 2015). After the completion of the every experimental run, the powder was collected from cyclone and cylindrical parts of dryer chamber by lightly sweeping the chamber wall as proposed by Bhandari et al. (1993). The powders were then immediately packed in polyethylene bags to prevent subsequent moisture uptake, and stored in a desiccator containing calcium carbonate for further analysis.

2.4. Powder Recovery

The powder recovery of the powder samples after spray drying was determined according to the following formula, based on dry matter measurements:

$$\text{Powder recovery(\%)} = \frac{\text{Spray dried powder obtained(g)}}{\text{Total pomegranate juice solids(g) + Maltodextrin(g)}} \times 100\%$$

2.5. Color measurement

The color of pomegranate juice powder samples was determined, using a color spectrophotometer (CM-3600d, Konica Minolta). The results were determined in terms of Hunter color values of L*, a*, and b*, where L* denotes lightness and darkness, a* redness and greenness, and b* yellowness and blueness.

2.6. Determination of glass Transition Temperature (T_g)

Differential scanning calorimeter (DSC, Netzsch—Germany) was used to measure the glass transition temperature. The instrument was calibrated with indium kept in a closed aluminum pan. After the calibration, about 20 mg of the powder sample was taken in the sample pan. An empty aluminum pan was used as a reference. All the scans were taken at the same heating rate of 10°C/60 s from 10 to 130°C. Thermograms thus obtained were analyzed for the onset, mid, and end points of glass transition. Most researchers consider the midpoint temperature of a thermogram as the T_g.

2.7. Determination of sticky point temperature (T_s)

The measurement of T_s of the powder samples was determined as per the procedure given by Jaya and Das (2004, 2005).

2.8. Statistical analysis

All the analyses were carried out in triplicate and the results were expressed as mean ± standard deviation. Statistical analysis was performed, employing Duncan's Multiple Range Test (DMRT) at 95% confidence level (p < 0.05).

3. Result and discussion

3.1. Physicochemical analysis of pomegranate juice

Results of physicochemical analysis of pomegranate juice are presented in Table 1. Color analysis of pomegranate juice revealed 41.10 L* value, 25.97 a* value, and 2.87 b* value. TSS, acidity, and pH of pomegranate juice were 14.67° Brix, 0.639%, and 4.237, respectively. The juice contained about

Table 1. Physicochemical properties of pomegranate juice

Color	L* = 41.10 ± 0.29, a* = 25.97 ± 0.34, b* = 2.87 ± 0.05
TSS (°Brix)	14.67 ± 0.23
Acidity (% as citric acid of juice)	0.639 ± 0.15
Reducing sugars (%)	7.392 ± 1.56
Total sugar (%)	10.321 ± 0.91
Ascorbic acid (mg/100 g Juice)	11.088 ± 2.39
Anthocyanin (mg/100 g Juice)	20.87 ± 1.17
pH	4.237 ± 0.46

Notes: L* defines lightness, a* denotes the red/green value and b* the yellow/blue value.

7.392% reducing sugar and 10.321% total sugar. Ascorbic acid and Anthocyanin contents of the juice were 11.088 and 20.87 mg/100 g juice, respectively.

3.2. Powder recovery

Process yield is one of the major concerns for spray drying process as it is closely related to the production cost and efficiency. According to Bhandari, Datta, Crooks, Howes, and Rigby (1997) powder recovery of more than 50% is the criteria for successful spray drying in laboratory-type spray driers. Table 2 shows the influence of maltodextrin concentration on powder recovery during spray drying pomegranate juice. Without the use of drying aid no powder was recovered during spray drying of pomegranate juice and all the juice solids stick to the wall of dryer chamber. When 5% of maltodextrin was added to pomegranate juice, the powder recovery rose only to about 9.48%. Further addition of maltodextrin (10–25%) significantly increased the powder recovery to about 62.59%. Addition of 20% maltodextrin was regarded as the necessary amount for successful spray drying (powder recovery > 50%) of pomegranate juice. The increase in powder recovery with the addition of maltodextrin is due to the increase in overall T_g of pomegranate juice solids, overcoming the stickiness problem during spray drying.

3.3. Color

The color of the juice powder is an important quality attribute as it determines the consumer acceptance. Color values for pomegranate juice powders are presented in Table 2. Concentration of maltodextrin significantly affected the color values of pomegranate juice powder. It was found that, with increase in concentration of maltodextrin, L* value significantly increased; however, significant decrease was observed in a* and b* values. The change in color values is due to the concentration effect of the maltodextrin having the inherent whitish color. Similar results were also found by Muzaffar and Kumar (2015) during spray drying of tamarind pulp.

3.4. Glass transition temperature

The glass transition temperature (T_g) of spray-dried powders is a very important factor to assess if a droplet/particle is likely to stick with the walls of drying chamber during spray drying. All the amorphous materials change from the glassy to rubbery state at a glass transition temperature (T_g) which is specific for each material. The glass transition temperature of pomegranate juice powders ranged from 38.23 to 71.61°C (Table 2). With increase in concentration of maltodextrin, the T_g values of pomegranate juice powder increased significantly which may be due to high molecular weight of maltodextrin, resulting in increase in overall T_g at every concentration level. These results are in agreement with the findings of Muzaffar and Kumar (2015) and Fang and Bhandari (2012) observed during spray drying of tamarind pulp and bayberry juice.

Table 2. Powder recovery, color, glass transition, and sticky point temperature of spray-dried pomegranate juice powder

Pomegranate juice: maltodextrin (v/w)	Powder recovery	Color			Glass transition temperature (°C)	Sticky point temperature (°C)
		L*	a*	b*		
95:5	9.48 ± 2.43 ^e	45.54 ± 0.05 ^e	20.43 ± 0.32 ^a	2.16 ± 0.06 ^a	38.23 ± 0.34 ^e	56.86 ± 1.54 ^e
90:10	22.67 ± 1.97 ^d	48.27 ± 0.13 ^d	18.65 ± 0.05 ^b	1.81 ± 0.45 ^a	42.15 ± 0.79 ^d	60.12 ± 0.45 ^d
85:15	35.78 ± 2.63 ^c	62.22 ± 0.05 ^c	16.70 ± 0.14 ^c	0.13 ± 0.05 ^b	51.62 ± 1.05 ^c	68.21 ± 0.98 ^c
80:20	54.67 ± 2.35 ^b	68.37 ± 0.11 ^b	15.57 ± 0.04 ^d	-0.81 ± 0.02 ^c	66.84 ± 0.85 ^b	84.64 ± 1.32 ^b
75:25	62.59 ± 1.64 ^a	75.46 ± 0.62 ^a	11.45 ± 0.23 ^e	-3.83 ± 0.23 ^d	71.61 ± 0.76 ^a	89.43 ± 0.56 ^a

Values were expressed as the average of triplicates ± standard deviation.

Different letters (a–e) in the same column indicate a significant difference between powders produced with different concentrations of maltodextrin.

L* defines lightness, a* denotes the red/green value and b* the yellow/blue value.

3.5. Sticky point temperature (T_s)

Sticky point temperature (T_s) is defined as the temperature at which a powdery material will start caking. Sticky point temperature is always higher than the glass transition temperature. Generally, it is accepted that the sticky point temperature lies about 20°C above the glass transition temperature (Bhandari et al., 1997). Using 5% of maltodextrin, the sticky point temperature of the powder was only about 56.86°C and so most of the powder particles stick to the drying chamber wall (Table 2). Further addition of maltodextrin significantly increased the sticky point temperature at every concentration level. Twenty percent maltodextrin was required for successful spray drying of pomegranate juice with powder recovery greater than 50%.

4. Conclusion

Relationship between concentration of drying aid (maltodextrin DE 20) with glass transition temperature (T_g) and Sticky Point temperature of pomegranate juice powder during spray drying of pomegranate juice was established. Addition of maltodextrin (5–25%) significantly increased the glass transition temperature from 56.86 to 89.43. This will give the information about the stability of powder and the minimum concentration of drying aid necessary for successful spray drying of pomegranate juice. The study revealed that use of 20% maltodextrin is required for successful spray drying (powder recovery > 50%) of pomegranate juice. With the addition of maltodextrin, L^* value (powder lightness) increased from 45.54 to 75.46 due to inherent whitish color of maltodextrin. Further addition of maltodextrin decreased the powder redness and yellowness at every concentration level.

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Competing interests

The authors declare no competing interest.

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