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Effect of spray-dryer operating variables on the fermented beetroot juice powder quality

Priti Jain and Mohan Singh

Abstract
Present work was carried out to study the effect of inlet air temperature (140, 142, 144, 146 & 148 °C) and maltodextrin concentration (4, 5, 6, 7 and 8%) on the quality attributes such as moisture content, solubility, hygroscopicity, bulk density, betalain content and product recovery of the spray dried fermented beetroot juice powder. The results of experimental data show that increase in the inlet air temperature led to higher powder solubility and hygroscopicity. The moisture content, bulk density, betalain content and product recovery of the beetroot powder decreases with increase in the inlet air temperature. The increase in maltodextrin concentration caused a reduction in moisture content and betalain content. The optimized parameters for spray dried fermented beetroot juice powder have been obtained with inlet air temperature of 144 ^{0}C and maltodextrin of 6% at constant feed flow rate of 150 ml/h.

Keywords: Spray drying, beetroot, maltodextrin, betalain content, fermentation

Introduction
Beta vulgaris, commonly named beetroot, is botanically classified as an herbaceous biennial from the Chenopodiaceae family. There are several varieties and bulb colour ranges from yellow to red. Deep red-colored beetroots are most popular for human consumption, both cooked and raw as salad or juice. Red beetroots contain a large concentration of betanin, 300-600 mg/kg (Kanner *et al*. 2001) [20]. Red betanin represents 75-90% of total colour present in beetroot (Koul *et al*. 2002) [22]. Due to betalain pigments, beetroot powder has good antioxidant capacity (Kaur and Kapoor 2002) [21]. Beetroot powder or extracted pigments are used industrially. Beetroot powder as a colorant (betalain) has several applications in foods, such as ice cream, cake, mixes, yogurt, desserts, fruit chews, gravies, sauces, confectioneries, dry mixes and dairy products (Roy *et al*. 2004; Koul *et al*. 2002) [30, 22].
Beetroot is reported to have medicinal properties, particularly to improve digestion and blood quality (Stintzing and Carle 2004; Delgado-Vargas *et al.* 2000) [33, 10]. *B. vulgaris* has water soluble betalain pigments that mainly comprise betacyanins (betanin, iso-betanin, pro-betanin and neo-betanin) and betaxanthins (Alard *et al*. 1985) [2]. Red colour is due to betacyanins, whereas betaxanthins have a yellow shade.
Spray drying is a process of transformation of a liquid system (solutions, dispersions, emulsions) into a dry particulate powder. The liquid system is atomized into droplets, which are dried through contact with a drying medium, usually air, at a high temperature. During the spray drying process, the droplets are produced and the solvent (often water) is evaporated. Spray drying is commonly used in the food industry to ensure the microbiological stability of the products, reducing biological degradation, storage and transportation costs, obtaining a product with appropriate properties in terms of moisture content, solubility, hygroscopicity, nutritional composition, glass transition temperature, color and fluidity, etc. (Fazaeli *et al*. 2012a; Chen and Patel 2008) [14, 9].
The processing conditions of the spray drying can produce sticky products, especially when the composition of the feed is rich in sugars and acids. This could generate an adherence of particles to the internal wall of the drying chamber, creating agglomeration and a lower product yield (Hennigs *et al*. 2001; Bhandari and Howes 2005) [18, 5].
The use of maltodextrins, gums, pectins, vegetable fibers, and starches as an encapsulation agent in spray drying has been widely studied (Adhikari *et al*. 2003; Ersus and Yurdagel 2007; Tonon *et al*. 2008; Osorio *et al*. 2011; Wang and Zhou, 2012) [1, 13, 34].

These additives improve the properties of the finished product because they increase of the glass transition temperature (Tg) and more stability during storage (Bhandari *et al*. 1997; Fazaeli *et al*. 2012a) [4, 14].

Good quality fruit and vegetable powders required by the commercial sector can be obtained by using spray drying technology. This can be achieved through experimental optimizations, evaluating the effects of independent variables (formulation and processing) on response variables. The response surface methodology (RSM) is a successful tool using mathematical and statistical techniques for developing, improving and optimizing processes that describes the relationship between a response and the independent variables (Myers and Montgomery 2009). In recent years, the RSM has been used to optimize the processing conditions of spray drying for starch derivatives (Drusch and Schwarz 2006) [11], insulin (Stahl *et al*. 2002) [32], acai extract (Tonon *et al*. 2008) [34], acerola extract (Germano *et al*. 2009) [23], pomegranate juice (Youssefi *et al*. 2009) [39] and mandarin oil (Bringas *et al*. 2011) [6].

The objective of this study was to evaluate the effect of air temperature and maltodextrin concentration on the quality attributes of fermented beetroot powder by using spray drying.

Materials and Methods

Fresh and matured beetroots were procured. Maize based maltodextrin (National starch, Singapore) was used as carrier agent. Yeast strains namely *Saccharomyces cerevisiae* (MTCC 178) was procured from Institute of Microbial Technology, Chandigarh.

Extraction and fermentation of beetroot juice

The fresh and matured beetroots were selected and were washed thoroughly in lukewarm water to remove adhered foreign materials. The skin of beetroot was peeled with the help of a hand peeler. The peeled beetroots were then sliced and crushed with the help of a small capacity laboratory electrical juicer. The obtained beetroot juice was filtered with the help of a 11 µm nylon mesh and transferred into glass beaker. The recovery of juice was around 55% of the fresh weight of beetroots.

The freshly prepared juice was then thoroughly mixed with selected percentages of maltodextrin with the help of a magnetic stirrer. The beetroot juice was filtered by 150 micron filter to remove fibers. For fermentation the filtered beetroot juice was inoculated with 10% (v/v) S*acchromyces cerevisiae* (MTCC 178) and incubated at 25 ^{0}C for 24 h.

Spray drying of fermented beetroot juice and Statistical analysis

The beetroot juice powder was produced by using a Lab scale twin cyclone spray dryer Labultima LU-222 Advanced model (Plate 1). The study was conducted to optimize the process parameters i.e. inlet air temperature (140, 142, 144, 146 and 148 ˚C) and maltodextrin concentration (4, 5, 6, 7 and 8%) at a constant air and feed flow rate of 57.92 m3/h and 150 ml/h, respectively. Central composite rotatable design (CCRD) of response surface methodology was used to optimize the operational parameters on the basis of various responses such as moisture content, solubility, hygroscopicity, bulk density, betalain content and product recovery. The criteria for optimization were to have low moisture content, highest solubility, low hygroscopicity, maximum retention of betalain content and highest product recovery. Each experimental observation was recorded and response surfaces were generated by statistical analysis software namely Design expert 8.0.7.1.

Plate 1: Lab scale twin cyclone spray dryer Labultima LU-222

Determination of physicochemical parameters of beetroot powder

Moisture content

Moisture content was determined by the digital moisture meter. One gram of each powder was placed in digital moisture meter at 100 ˚C for 10 min.

Solubility

The solubility of powder was determined by the procedure recommended by Eastman and Moore (1984) [12].

Hygrscopicity

About 1 g of beetroot powder was spread evenly on Petri dishes (9 cm diameter) to allow for a high surface area between humid air and powder. Samples of each powder were placed in respective seprate dishes in disiccator at 23 ˚C and 76% relative humidity using HNO_3 solution. Ten minutes interval was selected to get the kinetics of moisture sorption (Al-Kahtani and Hassan 1990) [3].

Bulk density

Bulk density (g/mL) was determined by gently adding 2 g of powder into an empty 10 mL graduated cylinder. The ratio mass and the volume of powder occupied in the cylinder determine the bulk density value (Goula *et al*. 2004) [15].

Betalain Content

Betalain content of beetroot juice were estimated by a spectrophotometric method (Wyter and Dreiding, 1957; Platteelli and Minale 1964) [38, 27].

Product Recovery

The product recovery was measured as the mass ratio of the dried powder collected at the end of spray drying process to the initial solid content in the feed.

The product recovery was calculated with following equation:

$$\text{Product Recovery, \%} = \frac{\text{The weight of obtained spray dried powder}}{\text{The total solid weight in initial feed}} \text{X } 100$$

Results and discussion

Effect of inlet air temperature and maltodextrin concentration on the quality attributes of fermented beetroot powder

Moisture content

The influence of inlet air temperature and maltodextrin concentration on the moisture content of fermented beetroot powder is shown in fig. 1. An increase in the inlet air temperature from 140 to 148 °C reduces the residual moisture content of beetroot powder from 5.8 to 1.6% (w.b) for any constant maltodextrin concentration within the range of 4 to 8%. It may be inferred that greater the temperature difference between the drying air and the juice particles, the greater will be the rate of heat transfer into the particles providing the driving force for moisture removal. By using spray drying similar observations were obtained during the preparation of different fruit juice powders such as watermelon juice powder (Quek *et al*. 2007) [28], tomato juice (Goula and Adamopoulos 2008) [16] and acai juice (Tonon *et al*. 2008; Tonon *et al*. 2011) [34, 35].

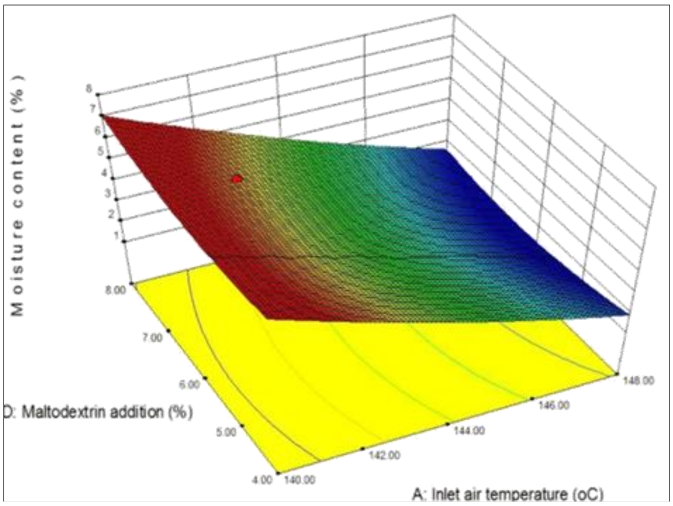

Fig 1: Effect of inlet air temperature and maltodextrin addition on the moisture content of fermented beet root powder

Whereas, an increase in maltodextrin concentration from 4 to 8%, decreased moisture content from 4.5 to 3.4% (w.b) for any constant inlet air temperature within the range of 140 to 148 °C. Similar observations were recorded by Quek *et al.* (2007) [28]. This can be attributed to the fact that the concentration of the drying additive increased the total solids content of the feed and reduced the amount of water for evaporation i.e. resulting in low moisture content of the end product.

Solubility

The solubility of fermented beetroot powder increased from 78.3 to 96.8% with an increase in inlet air temperature from 140 to 148 °C for any constant maltodextrin concentration within the range of 4 to 8% (Fig. 2). It can be inferred that the moisture content of the beetroot powder decreases with an increment in inlet air temperature which results in an increment in the solubility of obtained beetroot powder. Increase in drying air temperature generally produces the particles of larger size requiring lesser time to dissolve. Goula *et al*. (2004) [15] also found that the powders with lower moisture content are more soluble.

Whereas, an increase in maltodextrin concentration from 4 to 8% increases the solubility of the beetroot powder from 96.5 to 98.9% for any constant inlet air temperature within the range of 140 to 148 °C. This variation may be attributed to the fact that maltodextrin has superior water solubility. According to Chauca *et al*. (2005) [7] maltodextrin is a carrier agent which is mainly used in the spray drying process due to its physical properties, such as high solubility in water. Grabowski *et al*. (2008) [17] also reported that the water solubility index of sweet potato powder increases as the amount of maltodextrin increases.

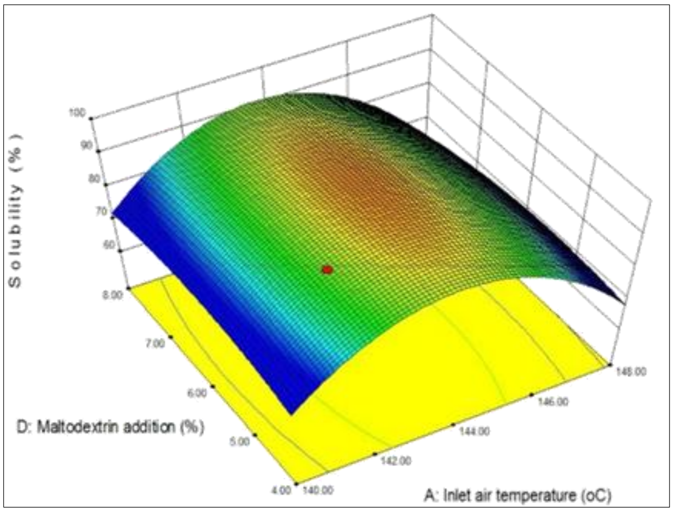

Fig 2: Effect of inlet air temperature and maltodextrin addition on the solubility of fermented beet root powder

Hygroscopicity

For any maltodextrin concentration within the range of 4 to 8%, an increase in inlet air temperature from 140 to 148 °C leads to an increase in the hygroscopicity of the beetroot powder from 0.15 to 0.29 g/g. This may be due to the fact that with an increase in the inlet air temperature there is a reduction in the residual moisture content in obtained powder which results in an increase in the hygroscopicity. Goula *et al*. (2004) [15] and Tonon *et al*. (2008) [34] also reported that the hygroscopicity of the powder is inversely related with its moisture content.

From fig. 3, it can be seen that for any constant inlet air temperature within the range of 140 to 148 °C, with an increase in maltodextrin concentration from 4 to 8%, there is slight reduction in the hygroscopicity of the obtained beetroot powder. This can be attributed to the fact that maltodextrin absorbs less water. Jaya and Das (2004) [19] also reported that hygroscopicity of mango powder decreases by increasing the amount of added maltodextrin. Phanindra *et al*. (2005) [26] mentioned that the pineapple juice powder containing high-molecular weight additives absorbs less water during exposure to 53% relative humidity for 12 h and Rodriguez-Hernandez *et al*. (2005) [29] found that the least hygroscopic cactus pear powder was obtained at the highest maltodextrin concentration.

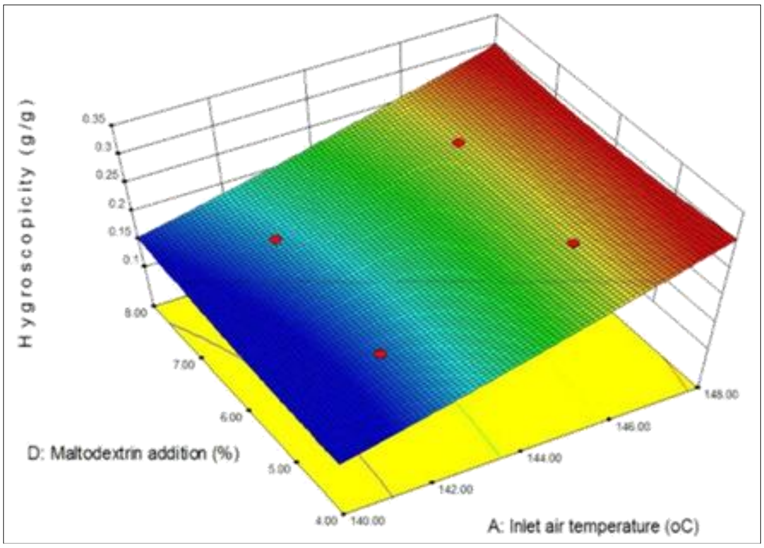

Fig 3: Effect of inlet air temperature and maltodextrin addition on the hygroscopicity of fermented beet root powder

Bulk Density

The bulk density of the beetroot powder decreases with an increase in the inlet air temperature (Fig. 4). An increase in inlet air temperature from 140 to 148 °C leads to a decrease in bulk density from 0.43 to 0.22 g/ml for any constant maltodextrin concentration within the range of 4 to 8%. Whereas an increase in maltodextrin concentration from 4 to 8% increases the bulk density from 0.37 to 0.42 g/ml for any constant inlet air temperature within the range of 140 to 148 °C.

Evaporation rates are higher at elevated inlet air temperature, which result in a more porous or fragmented structure of the spray dried powder with lower bulk density. An increase in the inlet air temperature often results in a rapid formation of dried layer on the droplet surface and particle size and it causes the skinning over or casehardening on the droplets at the higher temperatures. This leads to the formation of vapor-impermeable films on the droplet surface, followed by the formation of vapor bubbles and, consequently the droplet expansion (Chegini and Ghobadian, 2007; Tonon *et al*. 2011) [8, 35]. Walton (2000) [36] also reported, the increase of drying air temperature generally causes the decrease in bulk, particle density and provides the greater tendency to the particles to hollow.

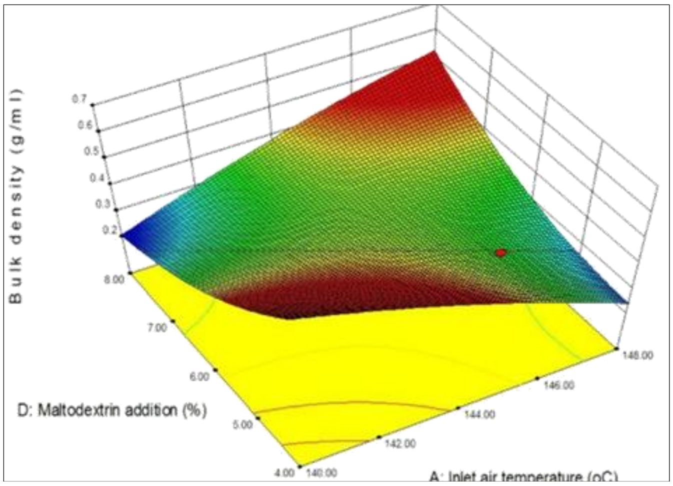

Fig 4: Effect of inlet air temperature and maltodextrin addition on the bulk density of fermented beet root powder

Product recovery

Increase in inlet air temperature from 140 to 148 °C leads to a decrease in powder recovery of the fermented beetroot powder from 13.7 to 13.3% for any constant maltodextrin concentration within the range of 4 to 8% (Fig. 5). It may be due to stickiness of powder. Whereas, an increase in maltodextrin concentration from 4 to 8% increases the powder recovery from 11.3 to 17.9% for any constant inlet air temperature within the range of 140 to 148 °C. This is also in agreement with the results of Shrestha *et al*. (2007) [31]; Papadakis *et al*. (1998) [25] and Quek *et al*. (2007) [28].

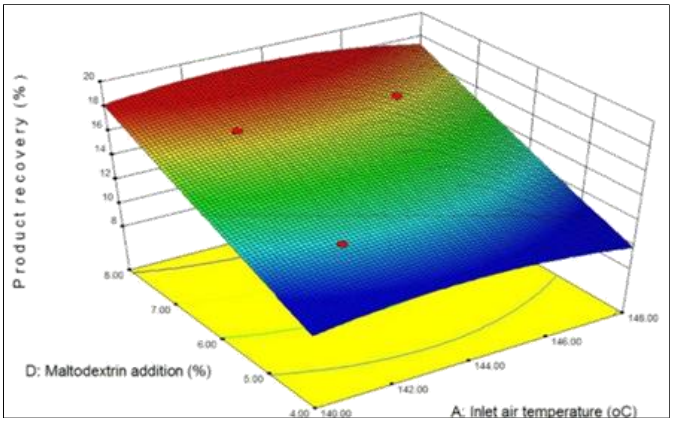

Fig 5: Effect of inlet air temperature and maltodextrin addition on the product recovery of fermented beet root powder

Betalain content

The betalain content of the fermented beetroot powder reduced from 17.1 to 16.4% with an increase in inlet air temperature from 140 to 148 °C for any constant maltodextrin concentration within the range of 4 to 8% (Fig. 6). This may be due to be the degradation of betalain pigment at higher temperature. Whereas, an increase in maltodextrin concentration from 4 to 8% decreases betalain content from 18.28 to 13.7% for any constant inlet air temperature within the range of 140 to 148ºC. During mixing of the juice with maltodextrin the betalain and other solids get adsorbed on the surface of carrier agent evenly. When the maltodextrin is present in excess the dilution of colour is more in the mixture as the particles of maltodextrin are relatively lighter in colour.

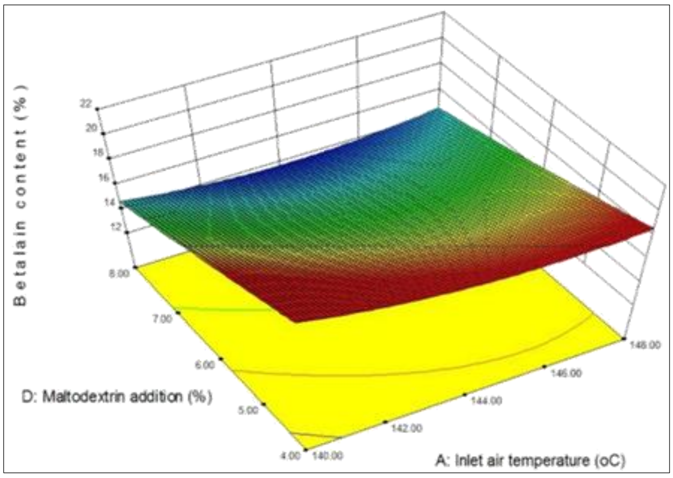

Fig 6: Effect of inlet air temperature and maltodextrin addition on the betalain content of fermented beet root powder

Conclusions

This study was concluded that increase on maltodextrin concentration caused a reduction in moisture content and betalain content. Inlet air temperature also showed significant effect on all the responses studied. Increasing temperature led to higher powder solubility and hygroscopicity, and to lower moisture content, bulk density, betalain content and product recovery. The better quality of spray dried fermented beetroot powder was obtained at inlet air temperature of 144 ^{0}C and maltodextrin of 6% with feed flow rate of 150 ml/h.

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