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Effect of inlet temperature on physicochemical properties of spray-dried jamun fruit juice powder

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ABSTRACT

The aim of the present investigation is to study the effect of inlet temperatures on the physicochemical properties of spray-dried jamun juice powder. The inlet temperatures varied from 140 to 160 °C, whereas other parameters like outlet temperature (80 °C), maltodextrin concentration (25%) and feed flow rate (10 mL/min) were kept constant. Moisture content, water activity, bulk density, solubility, hygroscopicity, colour, powder morphology, particle size and glass transition temperatures were analyzed for the powder samples. Higher inlet temperature increased the moisture content of the powder, and led to the formation of larger particles. Powder samples showed water activity values below 0.3, which is good for powder stability. The colour of the jamun juice powder was mainly affected by inlet temperature, leading to the formation of powders that were significantly brighter and less purple as the inlet temperature increased. Glass transition temperature ranged from 55.85 to 71.78 °C. Powders produced at lower inlet temperatures showed smoother particle surfaces, whereas higher inlet temperature showed spherical particles with some shrinkage as analyzed by scanning electron microscope.

1. Introduction

Jamun (*Syzygium cumini*) commonly known as Indian blackberry, is an underutilized fruit from the Indian subcontinent and it belongs to the Myrtaceae family. The jamun fruits are available abundantly during the summer season for a short period. Jamun fruit attracted the attention of researchers and food processors as a potential source of food ingredients. The fruits are deep purple or bluish in colour with pinkish pulp and are widely consumed as a fruit and also used for the treatment of various diseases as an astringent, antiscorbutic, diuretic, antidiabetic, and in chronic diarrhea and enlargement of the spleen [1,2]. Its fruit is a rich source of anthocyanins whose content is equivalent to that of blueberries and black currants and higher than that of blackberries, all widely acclaimed anthocyanin-rich edible fruits. The fruits are edible and are reported to contain vitamin C, gallic acid, tannins and anthocyanins including delphinidin, cyanidin, petunidin, malvidin-glucoside and other components, which are responsible for the deep purple colour [3]. These beneficial effects are mostly due to the presence of bioactive compounds, such as pigments and phenolic compounds.

Spray drying is not only a useful method of changing liquids into solids for increasing shelf-life and stability of the product but reduced volume also helps in easy handling. Spray drying is one of the common methods for encapsulating sensitive ingredients by using carrier agents that will act as a coating material or 'wall' to isolate them from the outside environment and to protect against oxidation [4]. The most commonly used microencapsulating agents are maltodextrin, gum arabic or a combination of both. The addition of carrier agents into the feed solution influences the properties and stability of powder. The addition of high molecular weight additives to the product before atomizing is a widely used alternative that increases glass transition temperature [5]. Tonon et al. [6] reported the significant effect of inlet air temperature on the physicochemical properties of the spray-dried powder. The quality of reconstituted spray-dried powder is good because the product temperature is rarely elevated above 100 °C [7]. Spray-dried jamun juice powders can be added to food systems for a variety of functional benefits. Ideally, spray-dried jamun juice powder should reconstitute instantly or serve as an anthocyanin-rich additive. There are numerous reports on antioxidant activity of jamun fruit and their stabilities. However, there is limited information of how encapsulating agents and drying conditions may influence the physicochemical properties of jamun fruit powder.

The present study investigates the effect of inlet temperature on spray drying of jamun juice and evaluates the physical properties of the powder produced. The influence of temperature on the microstructure of the powder is analyzed.

2. Materials and methods

2.1. Sample preparation

Fresh jamun (*S. cumini*) fruit was purchased from a local market in Puducherry, India. It was immediately processed without further

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storage. Jamun fruit was washed, deseeded and extracted by using a fruit juicer (Philips HL1631/J; Amsterdam, Netherlands) and the juice was filtered using 3 layers of cheese cloth. The carrier agent—maltodextrin (MD) (Himedia, Mumbai) with 20 DE (1:4 w\v)—was added to the juice at different concentrations of 15, 20, 25 and 30%. Then, the juice and carrier agent were mixed together until complete dissolution. About 2 kg of jamun fruit was used for each experiment. The pH, total soluble solids and moisture content of the jamun juice was determined by the method described by Ranganna [8].

2.2. Spray drying process

Experiments were performed using a pilot plant spray dryer at a drying rate of 0.6 kg of water h^{-1} under various combinations of operating parameters. The spray-drying assembly used in the present study consists of a two-fluid nozzle to atomize liquid feed into fine droplets, and a drying chamber where the atomized liquid comes in contact with the hot air. This is followed by two cyclone separators. The first cyclone separator collects coarser particles and the second traps the fine and ultrafine particles. The chamber diameter is 32 cm and the height of the chamber is 55 cm. The diameter of two-fluid nozzle is 1.4 mm. The feed flow rate was controlled through the speed of the peristaltic pump. The spray dryer can be operated at an inlet temperature ranging from 130 to 170 °C and outlet temperature (OT) ranging from 75 to 95 °C. For each spray-drying experiment, 100 mL of feed was pumped over a wider period of time which varied depending on the feed flow rate. In this work, the feed flow rate was fixed as 10 mL/min. Pressure ranged from 0.8 to 1.2 kg/cm^2. The temperature of the feed mixture was 25 °C. Dried powder samples were collected in the glass bottle at the base of the cyclone and stored in airtight containers in a desiccator containing silica gel until further analysis. The samples were labeled as A, B, C, D and E for IT 140, 145, 150, 155 and 160 °C, respectively.

2.3. Powder analysis

2.3.1. Product yield

The product yield of samples after spray drying were calculated according to the following formula [9].

$$\text{Product yield}(\%) = \frac{\text{Obtained spray dried powder}(g)}{\text{Jamun juice}(g) + \text{carrier agent}(g)} \times 100$$

2.3.2. Moisture content

The moisture content of the powders was analyzed using the AOAC [10].

2.3.3. Water activity (a_w)

The water activity of the powders was measured using an electronic dew point water activity meter (Aqualab Series 4TE, Decagon Devices, Inc., Pullman, Washington, USA).

2.3.4. Total acidity

The total acidity of the fresh jamun juice and reconstituted powders was determined by titration method [11]. Each of the samples (10 mL) was titrated against 0.1 N NaOH (standardized using standard oxalic acid) using phenolphthalein indicator. The end point was noted (the colour changed from colourless to pale pink). Total acidity was calculated in terms of citric acid using the formula:

$$\text{Acidity}(\%) = \frac{\text{Titre value} \times \text{Normality of NaOH} \times \text{Equivalent weight of citric acid} \times 100 \times 50}{\text{Weight of the sample} \times 10 \times 1000}$$

2.3.5. Turbidity

The turbidity of jamun juice and reconstituted powder samples was measured by a UV spectrophotometer (UV-1800, Shimadzu, Japan) at 900 nm using distilled water as a blank [12].

2.3.6. Bulk and tapped density

A known quantity of spray-dried jamun juice powder was loaded into a 10 mL graduated cylinder and the volume occupied was recorded and then used to calculate the bulk density (ρ_B) (weight per volume) The tapped density (ρ_T) was calculated by tapping the cylinder for 5 min (32 taps per minute) using a densitometer (M/s Shah Brothers, Mumbai, India) with displacement amplitude of 6.5 cm. The final volume was then read and used to calculate the tapped density [13].

2.3.7. Particle density

The particle density (ρ_P) was measured using the method suggested by Jinapong et al. [14]. Briefly, 1 g of dried powder sample was transferred into a 10 mL measuring cylinder with a glass stopper. A total of 5 mL of petroleum ether was then added to this sample and shaken for some time so that all the particles were suspended. Finally, the wall of the cylinder was rinsed with 1 mL of petroleum ether and the total volume of the petroleum ether and suspended particles were read. The powder density was calculated as follows:

$$\rho_P = \frac{\text{Weight of the powder (g)}}{\text{Total volume of petroleum ether and suspended particles (mL)} - 6}$$

2.3.8. Porosity and flowability

The porosity (ε) of the powdered sample was calculated using particle density (ρ_P) and tapped density (ρ_T). The flowability of powder was expressed as Carr index (CI) (Table 1) in terms of tapped density (ρ_T) and bulk density (ρ_B) as described by Jinapong et al. [14]

$$\varepsilon = \frac{\rho_P - \rho_T}{\rho_P} \times 100$$

$$CI = \frac{\rho_T - \rho_B}{\rho_T} \times 100$$

2.3.9. Cohesiveness (Hausner ratio)

The cohesiveness of the powders was evaluated in terms of Hausner ratio (HR) (Table 2), calculated from the bulk density (ρ_B) and tapped density (ρ_T) [14].

$$HR = \frac{\rho_T}{\rho_B}$$

2.3.10. Wettability

The wettability was evaluated according to the method described by Vissotto et al. [15], considering the time required for 1 g of powder deposited on the liquid surface to become completely submersed in 400 mL of distilled water at 25 °C.

2.3.11. Solubility

The solubility of the powder was determined by Eastman and Moore's [16] method with some modifications. A total of 1 g of powder sample was mixed into 100 mL of distilled water in a blender at high velocity (1550 rpm for 5 min). The moisture content of the powder was about 3.2%; as a result, 1 g of powder was added to 100 mL of distilled

Table 1
Classification of powder flowability based on Carr index (CI).

CI (%)	Flowability
<15	Very good
15–20	Good
20–35	Fair
35–45	Bad
>45	Very bad