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Effect of Spray Drying Conditions on the Physical Properties of Sugarcane (*Saccharum officinarum*) Powder

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Abstract: Sugarcane juice is obtained by grinding the stems of the sugarcane plant (Saccharum officinarum) to create a liquid extract. However, sugarcane juice can soon deteriorate due to the presence of simple sugar after extraction causes enzymatic browning and microbial decay.The purpose of this study was to determine the effect of spray drying conditions on sugarcane powder's physical properties. Tthe effect of maltodextrin concentrations (6% and 12% (w/v)) and inlet air temperatures (150 °C, 160 °C, and 170 °C) on the physical properties of spray-dried sugarcane powder were investigated. A constant feed flow rate of 3Lh-1 and a regulated air pressure rate were used. The investigation for this study was conducted using a mini spray dryer. For all inlet air temperatures used, a significant decrease in the moisture content, water activity, bulk density, and solubility of the spray-dried products was observed. At 150°C, 160°C, and 170°C, the inlet air temperature significantly reduced the moisture content, water activity, bulk density, and solubility of the spray-dried products. The increased temperature of the incoming air improved the flowability or wetability of the products, thereby increasing the product yield of the operation. Additionally, increasing the maltodextrin concentration improved the bulk density (0.57 ± 0.04 to 0.80g/ml ± 0.12) and flowability (41.94 ° ± 0.58 to 52.10 ° ± 0.04) of the spray-dried products, while decreasing the solubility time (165.33 - 273.33 sec) and wettability time (5.23 - 115.33 sec). However, for all maltodextrin concentrations, there were no significant changes in the sugarcane powder's moisture content (0.72 ± 0.44% - 4.18 ± 0.67%) or water activity (0.20 ± 0.02 - 0.31 ± 0.01). This study demonstrates that an inlet air temperature of 150 °C and a maltodextrin content of 12% (w/v) are the optimal conditions for producing sugarcane powder due to its favourable look and solubility. Additionally, this research discovery can be applied to the production of instant sugarcane beverages and other related commodities.

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1. Introduction

Sugarcane (*Saccharum* species hybrids) is a grass family plant that was predominantly grown for sugar production. Sugarcane juices contain approximately 10-15% natural sugar and are considered nutritious and refreshing beverages [1] due to their high vitamin and mineral content, organic acids, amino acids, starches, gums, and phosphatides [2]. Additionally, sugarcane juice is widely suggested for recovering patients with jaundice, cancer, and cardiovascular disease, making it an ideal healthy beverage [3].

Additionally, consumers value the nutritional benefits of pure sugarcane juices. However, because sugarcane juice is naturally sweet, it is susceptible to bacterial activity that could lead in the fermentation of sugar to ethanol. Improper handling of fresh sugarcane juices or improper treatment of fresh sugarcane juices increases the likelihood that the products will be highly contaminated with microorganisms [4]. As a result, it is frequently produced on a small scale by roadside vendors throughout the long and hot humid months.

Drying methods could be used to preserve the powdered food's quality. Powdered foods have a longer shelf life, are lighter in weight, have an easier flow, and are compatible with other food items. [5].During the spray drying process, the feed is supplied in a fluid state through a nozzle into a chamber that contains a stream of hot air. Spray drying parameters such as inlet temperature and wall material concentration also affect the physical properties of sugarcane powders. These properties include product yield, moisture content, water activity (aw), wettability, solubility, bulk density, flowability, colour, and soluble solids. Therefore, due to its speed, economy, and adaptability, spray drying could be used to produce sugarcane juice powders. This study investigated the process of producing powdered sugarcane juice using a spray dryer. It is as an alternative to increase the shelf life of sugarcane juice.

2. Materials and Methods

2.1 Sugarcane juices preparation

The newly extracted sugarcane juices were immediately transported to an icebox in order to keep the freshness [5]. The sugarcane juices were thoroughly blended with the carrier agent using a homogenizer (MOTOLOGY; model MEAF 71A-2). Maltodextrin at various quantities was added to sugarcane juices and kept at -20 °C until further usage [5].

2.2 Spray drying method

The spray drying procedure was carried out with the aid of a laboratory small spray dryer (SOLTEQ; model FD 20) fitted with a 0.7 mm diameter spray nozzle. The factors that were altered during the study were the input temperature and feed concentration. According to Rodrguez & Velásquez [6] the input and output air temperature ranges will be 150 °C-170 °C and 95 °C - 112 °C, respectively. At room temperature (25 °C), the solutions were supplied into the drying chamber via a peristaltic pump with a feed flow rate of 3.0 L h^{-1} and an air spray pressure control range of 0.7 to 1.4 kg cm^{-2}.

2.3 Determination of physical attributes

2.3.1 Productivity of the process

The yield of the process was defined as the ratio of the total solid content of the feed mixture to the total solid content of the resultant powder [7]. The powder yield was calculated using the powder (dry base) collected by weight of the dry matter taken for drying from the spray dryer collection chamber, as modified by Maltini, Nani & Bertolo [8]. The yield of the procedure is estimated using Eq.1:

$$Py(\%) \quad = \frac{Dry\ mass\ of\ microparticles\ (g)}{Dry\ mass\ of\ raw\ material\ (g)} \times 100 \qquad \text{Eq. 1}$$

2.3.2 The amount of moisture in the air

A moisture analyser was used to determine the moisture content of powders (model A&D MX-50 Company Limited, Tokyo Japan). A 5 g sample was weighed and placed on an aluminium pan using a digital balance. The heating temperature was standardised at 160 °C based on the user's manual. Moisture content was expressed as a percentage (%), and samples were generated in triplicate at a temperature of 25 °C.

2.3.3 Hydraulic action

The water activity was determined using a water activity metre (model Aqua Lab, DECAGON, Meter Group Inc., Pullman, WA), and a 1 g powder sample was prepared and placed in the water activity meter according to the manufacturer's instructions. The sample chamber lid was closed over the sample, awaiting vapour equilibrium. For this experiment, duplicate samples were produced at a room temperature of 25 °C.

2.3.4 Wettability

The wettability test was calculated using the following approach, which was slightly modified from that proposed by Dacanal & Menegalli [9]. It was determined by measuring the time required for 2 g of powder to completely dissolve in 40 mL of distilled water with a height of approximately 10 cm from the starting point to the surface of the water. The samples were produced in triplicate at room temperature (25°C).

2.3.5 Solubility

Solubility was determined in accordance with Da-Silva [10] with certain modifications. To determine the solubility, the powder's whole weight will be introduced to water for sediment formation, which serves as the indicating factor for the solubility test. In this test, 5 g of powder was introduced to a 25 mL beaker of room temperature distilled water. After placing the beaker on the magnetic stirrer, another 50 ml of distilled water was added to the powder and the stirrer was set to 200 rpm.

2.3.6 Density of the Bulk

The bulk density was determined using the ratio of the powder's weight to the volume occupied after 50 taps in the measuring cylinder [11]. A 2 g of powder (2 g) was tapped 50 times by hand in the 10 mL measuring cylinder. This experiment was conducted in triplicate at 0 °C. The bulk density was determined using Eq. 2.

$$Bulk\ density \quad = \frac{The\ mass\ of\ powder\ (g)}{Volume\ of\ the\ cylinder\ (mL)} \qquad \text{Eq. 2}$$

2.3.7 Flowability

The static angle of the rest process was used to determine flowability [7]. A total of approximately 50.0 g of the powder was dropped from a height of 25 cm using a funnel attached to a graft paper. The radius of the conical pile was determined using the formula tan á = H/R, where á represents the angle of repose in degrees (°), H represents the height from which the powder is thrown, and R represents the radius of the conical pile. The repose angle was determined, and powder with an angle of repose of 35 ° was considered free-flowing, 35-45 ° was considered very cohesive, 45-55 ° was considered highly cohesive, and 55 ° was considered extremely cohesive.

2.3.8 Colorimetry

The colour test was conducted by filling a petri dish with 2 g powder and measuring it using a Hunter Laboratory Calorimeter (HUNTERLAB; model SN 7877) calibrated with white and black tile. The outcome was expressed in terms of the values L, an, and b, where L denotes lightness and darkness, a denotes redness, and b denotes yellowness and blueness. The following equation was used to calculate the colour analysis: tan-1 (b* / a*) = hue (1)

2.3.9 Soluble Solid

The soluble solid concentration was evaluated using a refractometer (ATAGO; model Pal-1) and a sample was made by diluting 0.5 g of powder in 2.5 mL of distilled water. A small aliquot of the mixture was placed on the refractometer's glass lens to determine the Brix° result (hue = tan-1 (b* / a*). At room temperature (25 °C), the experiment was repeated three times.

3. Results and Discussion

According to the summary in Table 1, the yield of sugarcane powders rises as the carrier agent concentration is raised. Low carrier agent concentrations may result in the formation of sticky powder. The product yield at a 6 % maltodextrin concentration (8.36 % -10.73 %) is lower than at a 12 % maltodextrin concentration (12.09 % - 15.35 %).

Table 1: Effects of different maltodextrin concentration and inlet temperature on physical properties of sugarcane powders

Means value ± standard deviation. PY (Process yield); MC (Moisture content); aW (Water activity); Wet (Wettability); Sol (Solubility); BD (Bulk density; Flow (Flowability); SS (Soluble solid)

Concentration of wall material (%,wt/v)	**Inlet temperature (^{0}C)**	**Physical properties determination**								
		PY (%)	MC (%)	aW	Wet (sec)	Sol (sec)	BD (g/ml)	Flow (^{0})	Colour	SS (Brix ^{0}) (%)
6%	150	8.36	4.18 ± 0.67	0.28 ± 0.01	5.23 ± 1.04	248.33 ± 34.93	0.57 ± 0.04	52.7 ± 0.52	88.52	18.31 ± 0.08
	160	10.02	2.62 ± 0.08	0.27 ± 0.02	6.93 ± 0.91	269.33 ± 34.08	0.55 ± 0.07	48.28 ± 0.05	86.96	16.53 ± 0.35
	170	10.73	2.57 ± 0.72	0.25 ± 0.02	25.74 ± 1.31	273.33 ± 5.77	0.52 ± 0.03	52.10 ± 0.04	85.93	16.06 ± 0.71
12%	150	12.09	1.63 ± 0.47	0.31 ± 0.01	74.00 ± 5.29	175.33 ± 36.56	0.80 ± 0.12	45.72 ± 0.01	86.60	16.74 ± 0.08
	160	14.29	1.30 ± 0.07	0.26 ± 3.21	81.33 ± 3.21	165.33 ± 45.29	0.75 ± 0.03	52.3 ± 0.17	85.61	17.70 ± 0.05
	170	15.35	0.72 ± 0.44	0.24 ± 0.02	115.33 ± 3.01	221.67 ± 8.50	0.65 ± 0.02	41.94 ± 0.58	85.53	16.77 ± 0.02

It can be demonstrated by the same results reported on a research of the impact of maltodextrin concentrations (0, 3, and 5%) on the qualities of watermelon juice powder. The results indicated that any particles collected in the collector were robust in the absence of maltodextrin in the feed [12].

Additionally, the effect of inlet temperature on acai juice powder process production revealed that the highest process yield was observed when the inlet temperature was increased, correlating with Tonon's findings [7]. The findings of this study indicate that when the inlet temperature increases, the process yield of sugarcane powders increases as well, ranging from 8.36 per cent to 15.35 per cent. Additionally, when the temperature of the inlet air increases, the moisture content of the product falls due to the faster heat transfer between the product and the drying air. At higher inlet air temperatures, there is a bigger temperature difference between the atomized feed and the drying air, which results in the largest driving power for water evaporation [13].

According to Table 1, the bulk density increased in the range of 0.52 g/mL to 0.80 g/mL as the maltodextrin concentration was raised. This is accomplished by raising the maltodextrin concentrations, which results in an increase in the powder's bulk density. This component will result in a decrease in the amount of air trapped in particles trapped in a less porous and dense structure. The inclusion of maltodextrin may have decreased the adhesion of thermoplastic particles, and a powder's sticky or less free-flowing state has been associated with a high bulk density [11]. This could be because the dry powder or fragmented structure evaporates more quickly and has a more porous structure, which results in less droplet shrinkage and a lower powder density [14].

Moreover, increasing the maltodextrin concentration in the feed solution increases the flowability of the powder (41.94 °- 52.10 °). This can be explained by the quick absorption of moisture by the greater sugar content in the feed solution, which can result in a decrease in powder flowability [8]. Additionally, the flowability of all powder samples ranged between 41.94 ° and 52.10 °, demonstrating a transition from somewhat cohesive to cohesive particles as the inlet air temperature increased. This is because the inlet air's high temperature has an effect on the residual moisture in the powder, which has a greater angle of repose than powder obtained by Chauhan and Patil [15].

When the intake air temperature is increased, the powder becomes darker and exhibits increased redness and yellowness in comparison to the powder generated at a low inlet air temperature. This is explained by the caramelization process occurring at higher inlet air temperatures during spray drying. Soluble solid is the term used to describe the process of measuring the sugar content of sugar-containing liquids (honey, juices, and syrup) using a refractometer. The refractive index is used to determine the total soluble solid content of a solution. This is determined with a refractometer, and the result is expressed in Brix degrees. Sucrose is the primary sugar found in sugarcane powders. Table 1 illustrates the link between total soluble solid (TSS), inlet air temperature, and maltodextrin concentrations. It was discovered that adding maltodextrin increases the total solid content of the feed [16] and thus decreases the moisture content of the product, which decreases as the inlet temperature increases.

Figure 1 shows the moisture content of spray-dried sugarcane powder ranging from 0.72% - 4.18% (dry basis). The moisture content of sugarcane powder was lowered by increasing the maltodextrin concentration (6–12%) (wt/v). This is because a high concentration of maltodextrin lowers sugarcane powder's hygroscopicity [7]. As a result, adding maltodextrin to low molecular weight sugars such as glucose, sucrose, fructose, and organic acids may affect their surface stickiness. Due to the intrinsic cohesiveness of powder with low flowability, it is difficult for it to sink when put on a liquid surface [16]. Apart from the moisture level, it has been demonstrated that the particle size and chemical makeup of the powder are connected to its flowability. Additionally, when the air inlet temperature rises, the moisture content falls due to the faster transmission of heat between the product and the drying air. There is a bigger temperature difference between the atomized supply and the drying air at higher inlet temperatures, which provides the greatest driving force for water evaporation [17].

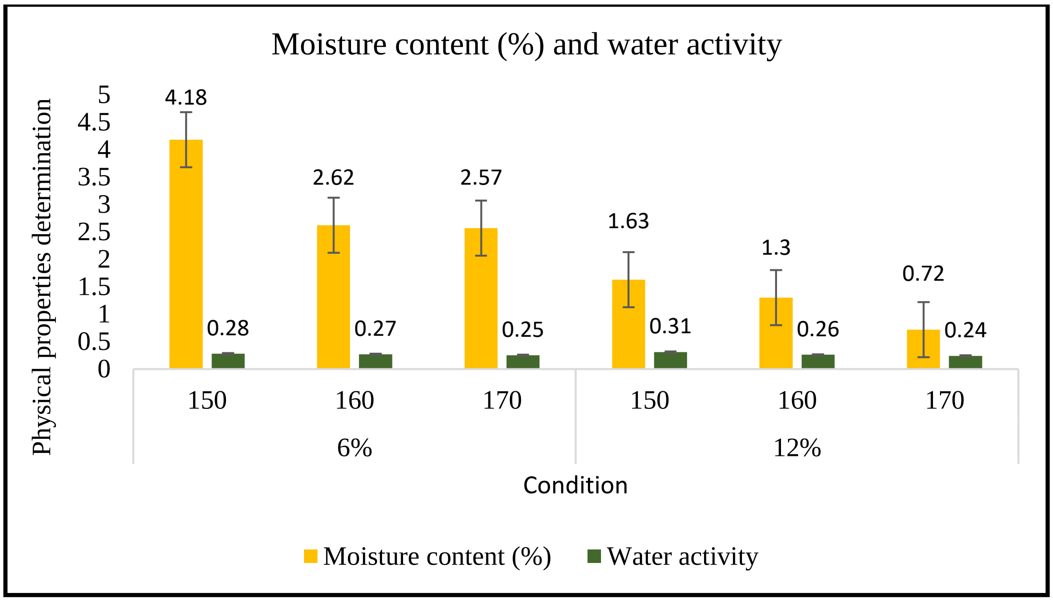

Figure 1: Effect of different inlet temperature and concentrations of maltodextrin on moisture content and water activity

Water activity (aw) is the most critical component in determining the quality and safety of food. Apart from temperature and pH, water activity has an effect on the shelf life, protection, texture, flavour, and odour of foods [18]. However, it is the most critical aspect in preventing rotting. Because bacteria generally do not develop (when the value of water activity is) less than 0.91, the majority of moulds frequently cease to proliferate when aw is less than 0.80. According to Figure 1, the water activity of sugarcane powder is less than 0.40, ranging between 0.25-0.31, which is very stable for powder stability due to the lack of available free water. This demonstrated that these powders were safe to store for an extended period without microbiological deterioration or metabolic breakdown [19].

On the other hand, as observed in Figure 2, the wettability time of sugarcane powders reduced as maltodextrin concentrations increased. This observation is directly related to the fact that maltodextrin functions as a bulking agent due to its less porous powder composition, low porosity, and high bulk density. The powder obtained has a wettability of 5.23 sec – 115.33 sec, as shown in Figure 2. The wettability of the powder rose as the inlet air temperature increased. This can be attributable to a variety of variables, including a decrease in the residual moisture content, the porous structure's porosity, and the powder's particle size.

Sugarcane powder has a solubility time of 165.33 sec to 273.33 sec. The solubility time of sugarcane powder ranged between 165.33 and 273.33 seconds, indicating that the powder should dissolve quickly in room temperature water. Additionally, these studies indicated that when maltodextrin concentrations increased, the powder's solubility time decreased. This circumstance can be described as increased maltodextrin concentrations contributing to a high bulk density of the powder and the powder being less porous, which can and directly affect the lower water absorption. Additionally, the high input temperatures applied to the spray-dried sugarcane powders shortened the time required for solubility. As illustrated in Figure 2, the solubility decreased as the inlet air temperature increased.

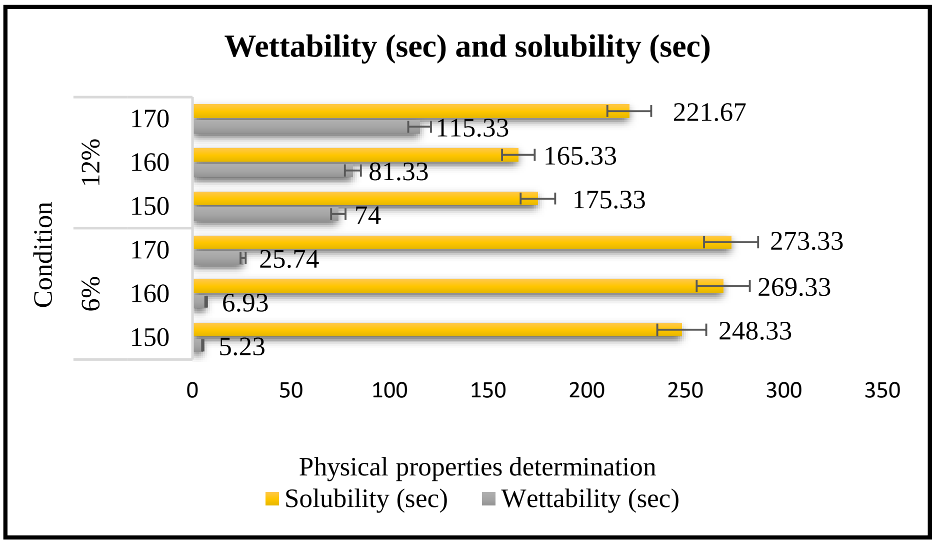

Figure 2: Effect of different inlet temperature and concentration of maltodextrin on solubility and wettability

3. Conclusion

In conclusion, the inlet temperatures (150 °C, 160 °C, and 170 °C) and maltodextrin concentrations (6% and 12%) have a significant effect on the physical qualities of spray-dried sugarcane powders. Increased inlet air temperature results in the development of powder with a high degree of blackness, redness, and yellowness, as well as a decrease in moisture content, water activity, bulk density, and solubility, except for wettability. Additionally, large quantities of maltodextrin improved the powder's lightness, volume density, and flowability, while decreasing its solubility and wettability resistance. The use of maltodextrin reduces the powder's adherence, which is a major issue when sugarcane powder or other sugar-rich food is dried or other sugar-rich food is dried. This study demonstrates that an inlet air temperature of 150 °C and a maltodextrin content of 12% (w/v) are the optimal conditions for producing sugarcane powder due to its attractive look and solubility. Additionally, this research discovery can be applied to the production of instant sugarcane beverages and other related commodities.

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