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Feasibility Study for Production of Green Banana Flour in a Spray Dryer

Ricardo K. Oi[a, b], José C. C. Santana[c], Elias. B. Tambourgi*[b], Moraes Júnior[b]

[a] Catholic University of Santos, Industrial Engineering Graduation Program, Av. Conselheiro Nébias, 300, Zip Code 11015-002 – Santos-SP, Brazil
[b] UNICAMP, School of Chemical Engineering, Av. Albert Einstein, 500, Post Code: 6066, Zip Code: 13083 – 970, Barão Geraldo, Campinas-SP, Brazil
[c]UNINOVE, Industrial Engineering Post-Graduation Program, Av. Francisco Matarazzo, 612, Água Branca, Zip Code: 05001-100, São Paulo, SP, Brazil
eliastam@feq.unicamp.br

The green banana biomass is a component that can be industrially applied to a wide variety of foods because don’t interfere in the sensory attributes of others ingredients and has functional properties, especially the presence of resistant starch. This use can be expanded if this product be produced in powder form. This research presents a feasibility study for production of green banana flour in spray dryer with rotary atomizer. The variables selected in the experimental procedure were: type of atomizer, biomass’s concentration, atomizer’s rotation, biomass’s temperature and biomass’s flow rate. It was defined as response the mass and the moisture content of the product. These variables had two levels of variation, which corresponded to the completion of 32 tests. In this study it was proved the feasibility to produce green banana flour in spray drying process.

1. Introduction

The need for improved health leads the consumers to seek out specific foods or physiologically active food components, also called the functional food. In recent years, the term functional, applied to food, has taken different connotation that is to provide an additional physiological benefit, beyond the basic nutritional needs (Oi et al., 2012).

Lately, appeared different functional foods, including the biomass of green banana (green banana cooked and processed, lacking taste and odorless), that’s a option for the consumers and can be used in place of traditional thickeners such as wheat, soy, starch cassava and corn starch, improving the nutritional value and assuming the taste of the foods. In addition to vitamins A, C and B complex (B1, B2 and niacin) this biomass has the minerals essential for the proper functioning of the human body (Freitas and Tavares, 2005).

Several researches have been published about these properties of green banana, which revealed the beneficial effects on some diseases such as colorectal cancer, diarrhea, glycemic index, insulin response, dyslipidemia, cardiovascular disease and celiac disease (Bello-Pérez et al., 2011; Englyst and Cummings, 1986; Langkilde et al., 2002; Lee et al., 2006; Topping et al., 2003; Zandonadi, 2009).

The drying process is utilized for several countries with the aims to keep the nutritional quality of agricultural products. It is defined as been the withdrawal of volatile substances (commonly, but not exclusively, the water) of a solid product, or it is the operation in where the water activity of a product is decreased for the withdrawal of water by vaporization. The water into solid is called of moisture. Thus, the drying process is the conjunct of science and technology that need of experimental look through on several phenomenon’s that occurs in this process (Benvenga et al., 2011; Curvelo Santana et al., 2010).

Due to importance of drying process to industries, several techniques have been applied to organic and inorganic products, main agricultural products, from the simplest ones such as solar dryer (Chavan et al., 2008) to the most sophisticated, like: microwave dryer to dry of carrot and apple chips (Cui et al., 2008) and of plaster of Paris (Ganespillai et al., 2008), ultrasound dryer to dry the fruit pulps of banana, genipap, jamb, melon, papaya, pineapple, pine and sapota (Fernandes and Rodrigues, 2008) and pulse-combustion dryer to dry aluminum, calcium, iron, ferrite, cupper, iron, nickel, silicates, starch and hazardous waste (Kudra et al., 2008).

Several drying methods have been applied to fruits and vegetables, from the simplest ones as solar and sun drying to the most expensive, like microwave and freeze drying. In order to get dried products with high nutritional and sensorial attributes, non-conventional drying methods have also been used, like those with modified atmosphere, microwave, osmotic dehydration, sun/solar, freezer drying, foam mat drying and others (Santos et al., 2008).

The spray dryer works through spraying, defined as the process of dividing the liquid in millions of micro-droplets forming a spray, and 1 m^3 of liquid form about 2 x 10^{12} droplets with a diameter around 100 μm (Masters, 1985).

The spray dryer accepts the input of feeding flow of the particulate fluids by the end of the process to produce dry particles, being the best option among many drying operations due to its flexibility, thus it's widely used in industrial drying of various products, including food (Masters, 1985). The physicochemical properties of the products obtained by this process are preserved (Foust et al., 1980).

Currently, the biomass of green banana is produced in low production scale by semi-industrial process. This biomass is obtained in the pasty form, and even the processing is aseptic, there remains a constant concern with the microbiological issue as well as the perish-ability of the material. One option for industrial scale is the drying process by spray dryer to obtain flour (Oi, 2011; Oi et al., 2012, 2010).

This paper had as general objective to study the drying of green banana biomass in an experimental spray dryer with rotary atomizer to produce flour. The specific objective of this study was to determine the best operating conditions in the spray dryer with the following variables: type of atomizer, atomizer's rotation, biomass's concentration, biomass's temperature and biomass's flow rate. There are several variables involved in spray drying process, thus it becomes important to analyze them to a better understanding this phenomenon to apply in industrial scale, justifying the development of this research.

2. Experimental

The tests to study the drying of the green banana biomass were carried out in an experimental spray dryer, built for the development of this research, which is represented in the Figure 1. This equipment consists of drying chamber with volume of 0.2 m^3, diameter of 0.63 m and height of 0.91 m, made of carbon steel and inside lined with polymer resin.

In the experimental spray dryer were used two rotary atomizers with 30.25 mm of diameter, made of aluminum. The atomizer which is called type A has shape like rectangular holes with two semicircles at the ends and area of 162.88 mm^2. The atomizer type B has shape like circular holes and area of 254.47 mm^2. The atomizers were moved by an electric motor with rotation control and cooled by a cooler.

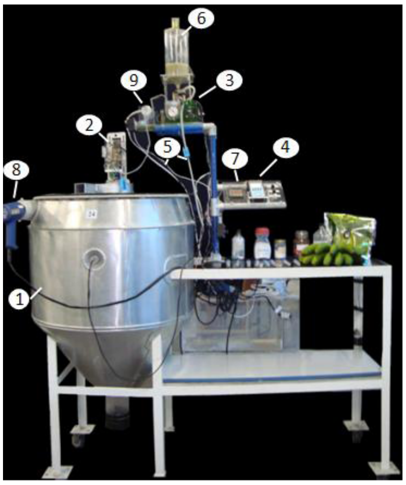
The biomass was injected into the atomizer by a peristaltic pump that consists of an aluminum rotor with four rollers, and driven by an electric motor with rotation control. The biomass was stored in a cylindrical tank made of acrylic. In the top cover was installed an agitator for mixing the feed. The biomass was heated before being atomized in a heat exchanger, which is compound of double tube, electrical resistance, thermal insulation and protection of aluminum. The air was heated by two heaters with electrical resistance of 2,000 W each, installed on opposite sides of the chamber (Oi, 2011; Oi et al., 2012, 2010).

In the green banana biomass, that has viscous shape, it was added water to prevent clogging in the atomizer and pipelines. Thus, in the tests it was used a suspension of pulp's banana and water at concentration of 50 % or 60 % (Oi, 2011; Oi et al., 2012, 2010).

To the end of each drying process assay, the drying samples were collected for measuring its drying mass ($\boldsymbol{M_i}$) and; its moisture content ($\boldsymbol{H_i}$) withdrawal from corn malt was obtained by weight difference (on percent form). The initial moisture content was measured at 103-105 °C of drying temperature, during 40 at 50 h in convective dryer according to Ascar (1985). The initial mass was called of $\boldsymbol{M_0}$ and the moisture content was calculated of according to Equation 1 (Benvenga et al., 2011; Curvelo Santana et al., 2010).

$$H_i = \left(\frac{M_0 - M_i}{M_0} \right) \cdot 100 \qquad (1)$$

In the experiment were used five variables at two levels of variation, which corresponded to the achievement of 32 tests of a 2^5 experimental planning (Benvenga et al., 2011; Curvelo Santana et al., 2010; Lee et al., 2006). The responses were the mass and the moisture content. To ensure the reliability of the experiment, each test was performed three times.



1) Drying chamber
2) Electric motor
3) Peristaltic pump
4) Temperature indicator
5) Silicone hoses to transport the biomass
6) Feed tank with agitation of the biomass
7) Controller of flow rate
8) Air heater
9) Heat exchanger for preheating of the biomass

Figure 1 – Photo of experimental spray dryer.

Table 1 presents the variables used in this work. From the adjustment of the spray dryer under the conditions of each test, the dry product was collected for 15 min. Then the samples were weighed, recording the mass, and placed in an oven, and it was measured until to achieve constant weight, and thus it was obtained the moisture content. The values of variables and responses were entered into the MINITAB 15 to make the statistical analysis.

Table 1 - Variables used in the experiment

Variables	Level	
	-1	+1
Atomizer type, D	A	B
Biomass's concentration, C (%)	50	60
Atomizer's rotation, S (rpm)	23000	27000
Biomass's temperature, T (ºC)	30	40
Biomass's flow rate, F (mL/min)	40	60

3. Results and Discussions

Intending an industrial application, the goal is to obtain a product with low moisture content, because levels more than 13 % can provide microbial growth and deterioration in short time. There isn't a regulation establishing a maximum level of moisture content for the green banana flour (Oi, 2011).

Seventeen samples of the 32 showed moisture content below 13 %, and are represented in the Table 2. The variables were: type of atomizer (D), biomass's concentration (C), atomizer's rotation (S), biomass's temperature (T) and biomass's flow rate (F). The responses were mass (M) and moisture content (H).

Among the samples with moisture content below 13 %, the test number 13 was the one with the larger mass (12.656 g) and recorded moisture content of 9.17 %. It was obtained with variables: atomizer type B, biomass's concentration of 50 %, atomizer's rotation of 27,000 rpm, biomass's temperature of 30 °C and biomass's flow rate of 40 mL/min.

Figure 2.a shows the mass variation with the variables, the horizontal line in all five graphs represents the average mass in the experiment (6.522 g) and Figure 2.b represents a Pareto chart with the five variables used for the mass. The vertical line refers to the level of statistic significance for $\alpha = 0.2$. In the tests that produced samples with larger mass showed the following variables: a) Atomizer type B; b) Biomass's concentration of 50 %; c) Atomizer's rotation of 27,000 rpm; d) Biomass's temperature of 30 °C; e) Biomass's flow rate of 40 mL/min.

The biomass's concentration of 50 % produced samples with larger mass. It can be explained by the fact this level has greater amount of water present in the biomass in comparison with the other level of concentration analyzed, and thus the mass of these samples showed the higher value.

Table 2 - Samples with lower moisture content

Assays	D	C (%)	S (rpm)	T (ºC)	F (mL/min)	M (g)	H (%)
27	B	60	23,000	40	40	0.695	0.14
26	B	60	23,000	30	60	0.385	0.52
28	B	60	23,000	40	60	0.315	0.64
5	A	50	27,000	30	40	2.170	0.93
2	A	50	23,000	30	60	3.720	3.91
32	B	60	27,000	40	60	0.120	4.35
1	A	50	23,000	30	40	2.840	4.41
4	A	50	23,000	40	60	3.660	6.18
24	A	60	27,000	40	60	0.400	7.53
3	A	50	23,000	40	40	3.580	8.81
11	B	50	23,000	40	40	2.016	8.97
13	B	50	27,000	30	40	12.656	9.17
29	B	60	27,000	30	40	0.368	9.52
31	B	60	27,000	40	40	0.355	10.25
30	B	60	27,000	30	60	0.125	10.62
20	A	60	23,000	40	60	0.118	11.32
21	A	60	27,000	30	40	0.270	12.97

The atomizer type B produced samples with higher mass, this phenomenon is explained by the area of holes 56 % larger than the atomizer type A, which favored a better spraying of the biomass in the chamber.
In the flow rate of 40 mL/min, there is lower amount green banana biomass through the atomizer relative to another level tested, that allowed a more efficient drying, and thus obtaining samples with higher amount of mass.
The atomizer's rotation of 27,000 rpm provided a better spraying of the biomass in the chamber. A higher speed of particles allowed greater efficiency in the drying process, and thus a greater amount of material could be collected from the collector, compared to the rotation of 23,000 rpm.
Both levels of biomass's temperature showed similar amount of mass, so this variable had a small influence on the variation of mass. This situation can be explained by the effect of chamber temperature be more significant in the drying process than the feed temperature.
From the five variables used in the experiment, the biomass's concentration was the one that most influenced the response of mass. The concentration and rotation were the only that presented statistical significance in the phenomenon.

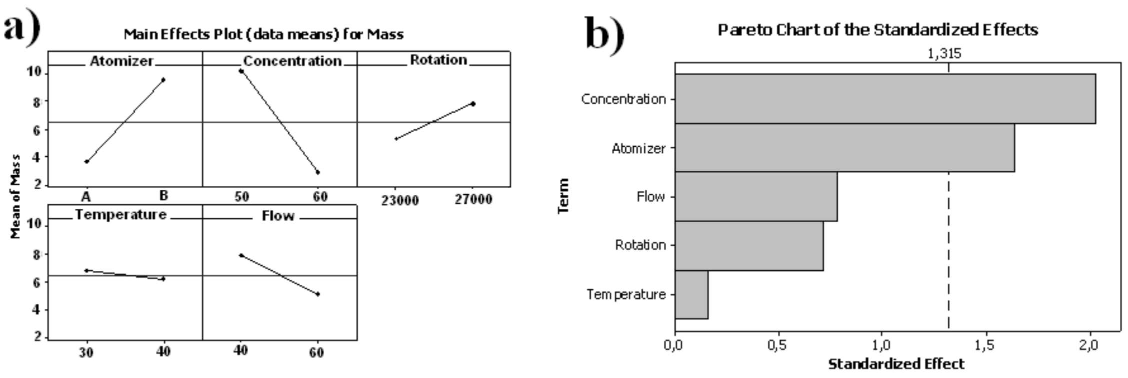


Figure 2. Influence of the variables effect on the mass. a) Evaluations of effects. b) Pareto chart

The variation of moisture content in relation to the variables is illustrated in Figure 3.a. The horizontal line represents the average moisture content (31.5 %) and Figure 3.b illustrates a Pareto chart with the five variables used in the experiment for the moisture content. The levels of variables that produced samples with low moisture content were: a) Atomizer type B; b) Biomass's concentration of 60 %; c) Atomizer's rotation of 23,000 rpm; d) Biomass's temperature at 40 °C; e) Biomass's flow rate of 60 mL/min.

The biomass's concentration of 60 % was the one that produced samples with lower rates of moisture content. It can be explained by the fact that level of concentration shows lower amount of water present in the biomass compared to level of 50 %.
The variable type of atomizer didn't have a significant effect on the moisture content. The atomizer B produced samples with the lowest moisture content, because its circular shape allows a better spraying of the biomass in the chamber, in addition it has the area of the holes 56 % higher than the atomizer type A.
The biomass's temperature of 40°C provided samples with lower moisture content. A higher temperature allows greater power efficiency and thus the spray drying process is favored, generating the driest samples.
The biomass's flow rate and the atomizer's rotation, in both levels, showed similar amount of moisture content in the samples, so these variables had a small influence on the variation of this response. The concentration was more significant in the drying process than the flow rate. The type of atomizer had more influence on the spraying the biomass than rotation to produce samples with low moisture content.
As in the mass, the concentration was also the variable with the greatest influence on the variation of moisture content. Among the five variables, it was the single statistically significant in the experiment.

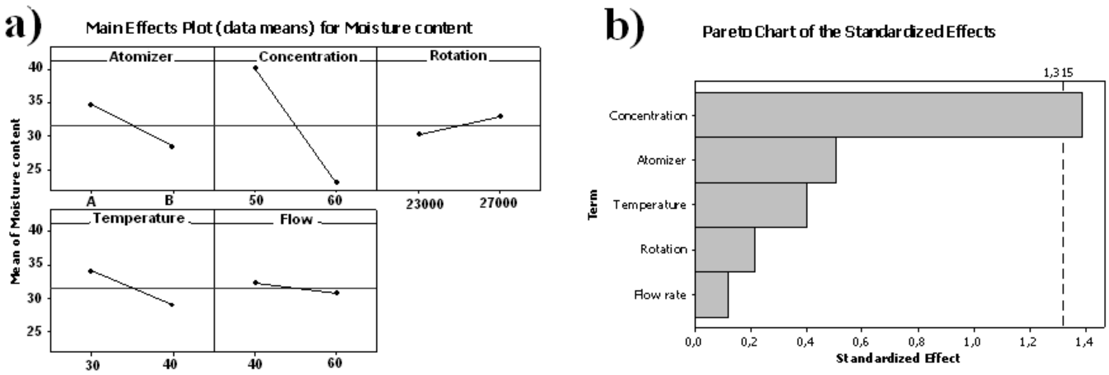


Figure 3. Influence of the variable effects on the moisture content. a) Evaluations of effects. b) Pareto chart

The test number 13 presented the best conditions of moisture content and mass, respectively, 9.17 % and 12.656 g. From the sample obtained in this experiment it was performed a microscopic analysis, and the size of the granules didn't exceed 500 µm as shown in the Figure 4.

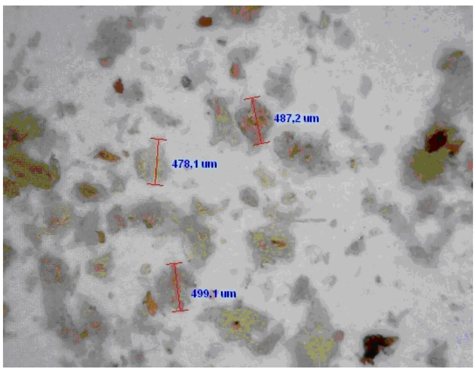


Figure 4 - Particles dry of green banana

Oi (2011), Oi et al. (2010) and Oi et al. (2009) obtained similar results. Therefore, this study concluded that in addition to the best conditions of moisture content and mass, the test number 13 also presented results of granule size in the patterns previously studied. For reference, the granules size of wheat flour is around 250 µm, while the value for the wheat bran is about 600 µm. Within these values, is possible to use the green banana biomass in the powder form to produce pasta, bread, biscuit, cake and others types of industrials foods.

4. Conclusions

This study carried out following conclusions:

The best conditions of mass and moisture content ware, respectively, 12.656 g and 9.17 %, with the following variables: atomizer type B, biomass's concentration of 50 %, atomizer's rotation of 27,000 rpm, biomass's temperature of 30 °C and biomass's flow rate of 40 mL/min. Seventeen of 32 samples showed moisture content below 13 %, reference value for food particles, so that 53.13 % of the samples are within the standard. Among the five variables used in the experiment, the biomass's concentration was the one that most influenced in the two responses, and showed statistic significance. Other variable statistically significant for the mass was the atomizer's rotation, while others variables produced low effects in the responses. The biomass's concentration of 50 % produced samples with higher mass, because there is more water present in the biomass, compared with the other concentration level analyzed. The biomass's concentration of 60 % provided samples with low moisture content, because there is less water in the biomass, in relation to another level, thus it produces samples with higher amount of solids. In the sample obtained in test number 13, the size of the granules didn't exceed 500 μm, so that can be applied in several industrials foods. In all tests it was possible to collect samples containing green banana in powder form, thus it was able to prove the feasibility of drying the green banana biomass in spray dryer with rotary atomizer to produce flour.

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