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FULL LENGTH ARTICLE

Influence of process conditions on the physicochemical properties of pomegranate juice in spray drying process: Modelling and optimization

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Abstract In this study an attempt was made to investigate the efficiency of spray drying process of pomegranate juice using response surface methodology (RSM). Different drying conditions such as inlet air temperature (*A*), feed flow rate (*B*) and aspirator rate (*C*) were varied in order to study the changes in quality parameters of spray drying process including moisture content (Y_1), hygroscopicity (Y_2), powder yield (Y_3). Three factors three level Box–Behnken response surface design (BBD) was used to evaluate the effect of process variables on spray drying process. 3D Response surface contour plots were used to study the interactive effects of the process conditions and optimal spray drying conditions were determined as follows: inlet air temperature of 130 °C, feed flow rate of 6 rpm and aspirator rate of 100%. Under these conditions, moisture content, hygroscopicity and powder yield are found to be 6.85%, 19.85 g/100 g and 14.95 g respectively.

1. Introduction

The growing properties of fruits and vegetables are limited in many Asian countries to certain seasons and localities, especially in India (Shruthi et al., 2013). In order to meet the demand of the market throughout the year in all areas, the commodities are preserved using different techniques such as spray drying, freeze drying and drum drying (Gomez and Lajolo, 2008). High moisture content of the fresh food products will lead to the drop of quality and, indirectly, to a decrease in their quantity. The drying of fruits controls the moisture content by either removing moisture or binding it so that the fruits become stable to both microbial and chemical degradation (Jagtiani et al., 1988). Drying is a common and economical preservation method for many fruits in countries such as India. Although most of the drying methods are conventional and primitive, there is an critical need to apply advanced techniques such as spray drying, with the objectives of increasing productivity and obtaining closer control of the process to achieve a better product quality (Thirugnanasambandham et al., 2014d). This requires basic data on spray drying together with knowledge of the basic principles involved. Hence, it is

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important today to develop new nutritional food, maximize their nutrient content in both processing and storage and extend the shelf life, and thus to meet the requirement of the market (Goula and Adamopoulos, 2010).

Spray drying involves atomization of feed into a spray and contact between the spray and drying medium resulting in moisture loss (Chemical Engineers' Handbook, 2007). Spray drying has been used extensively in pharmaceutical and food industries in dehydration of fluid foods such as coffee and fruit juices (Vander-lijn, 1976). Spray drying will result in powders with low water activity and ease in transportation and storage. Therefore, it is crucial to optimize the spray drying process to obtain powders with better yield, nutritional and physicochemical properties (Goula and Adamopoulos, 2008). Moreover, spray drying process can be significantly affected by parameters such as inlet air temperature, feed flow rate and aspirator rate. In conventional optimization technique, a single factor is varied while all other factors are kept constant for a particular set of experiments (Lim and Khoo, 1990). Similarly, other variables would be individually optimized through the single dimensional searches which show the long processing time and incapable of reaching the true optimum without consideration of interaction among the drying process variables (Crowe, 1971). The technique of defining and investigating all possible conditions in a complex nature experiment involving multiple process variables is known as response surface methodology (RSM). RSM is a technique for designing experiment, which helps the researchers to build models, evaluate the effects of several factors and achieve the optimum conditions for desirable responses in addition to reducing the number of experiments (Huntington, 2004).

Pomegranate fruit (Punica granatum L.) is a popular edible fruit native to India. The total production of pomegranate was approximately about 980,000 tons in 2013 (Sharma et al., 2000). Epidemiological studies show that the consumption of pomegranate fruits with high phenolic content is correlated with reduced cardio diseases and cancer mortality (Masters, 1997). Thus, pomegranate fruit juices have received attention due to their high anthocyanin content and antioxidant activity. Pomegranate is a tropical and seasonal fruit, and its production occurs during August and September (Gupta, 1978). Therefore, many processes such as cold storage, concentration, reducing to paste, and drying are used to conserve pomegranates or their juice. But, these techniques are not sufficient to preserve the pomegranate juice for the better nutritional quality and pomegranate juice processing industries are forced to develop a technically and economically viable technique to enhance the shelf life the pomegranate juice and their products (Murugesan and Orsat, 2011).

However, from the extensive literature survey, it was found that no research reports are available there for the efficiency of spray drying process of pomegranate juice using response surface methodology (RSM). Hence the primary objective of the present study was to investigate the individual and interactive effect of drying process variables such as inlet air temperature (A), feed flow rate (B) and aspirator rate (C) on moisture content (Y_1), hygroscopicity (Y_2), and powder yield (Y_3). Three factors three level Box–Behnken response surface design (BBD) was used to evaluate the effect of process variables on spray drying process. The obtained result will create novel opportunities to exploit the in-depth knowledge regarding the spray drying process of pomegranate juice.

2. Materials and methods

2.1. Raw materials and chemicals

Pomegranate fruits of the same age were purchased from the local market in Erode, India. They were washed in cold tap water to remove dirt and foreign materials and only mature fruits were selected for the experiments. The skin of the pomegranate fruits was then removed, and the fruit juice was extracted from the fleshy sacs using a hand-operated domestic press. The obtained juice was stored at 4 °C overnight. Finally, the cold sterile single-strength clarified juice with 15.2% TSS was rapidly cooled and frozen at 25 °C and used for further experiments.

2.2. Spray drying procedure

A mini spray dryer (Model L-251, Spark Laboratoriums, Chennai) equipped with two fluid atomizers was used in the spray-drying process. Spray drying was carried out at an various inlet air temperature, feed flow rate and aspirator rate with constant pressure of 4.5 bar. Once the total juice solids were adjusted (12% $w = w$), the following substances were added: maltodextrin, Arabic gum and waxy starch at concentration levels of 9% ($w = w$). The solution was also treated with microcrystalline cellulose (Merck, Darmstadt, Germany), which was used at concentration of 4% ($w = w$). The dryer was washed with water at the desired setting for 10 min before and after the spray-drying process. All spray-dried powders were collected, weighed, sealed in bottle, and stored at 4 °C in clean water activity container of known weight.

2.3. Physico-chemical properties

The physico-chemical properties of pomegranate powder such as moisture content, hygroscopicity and powder yield were determined as per the standard procedure described in elsewhere (Obon et al., 2009).

2.4. BBD response surface design

In this present study, response surface methodology (RSM) coupled with three factors three level Box–Behnken response surface experimental design (BBD) was employed to investigate the individual and interactive effects of drying process variables such as inlet air temperature (A), feed flow rate (B) and aspirator rate (C) on moisture content (Y_1), hygroscopicity (Y_2), and powder yield (Y_3) via Design- Expert 8.0.7.1 (State-Ease Inc., Minneapolis, MN, USA) statistical package. For statistical calculations, the process variables were coded at three levels (−1, 0 and +1) and the coding was done by the following equation (Chegini and Ghobadian, 2007):

$$x_i = \frac{X_i - X_z}{\Delta X_i} \qquad i = 1, 2, 3 \ldots k \tag{1}$$

where x_i, is the dimensionless value of an independent variable; X_i, the real value of an independent variable; X_z, the real value of an independent variable at the centre point; and ΔX_i, step change of the real value of the variable i. The range of independent variables and their levels are presented in Table 1.