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Original article

Investigation of suitable spray drying conditions for sugarcane juice powder production with an energy consumption study

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ABSTRACT

Sugarcane juice was spray-dried under various conditions to determine the most suitable drying conditions for the manufacture of sugarcane juice powder. Initially, fresh, 30°Brix and 50°Brix sugarcane juice samples were dried in a laboratory-scale spray dryer at an air-drying temperature between 130 °C and 170 °C using maltodextrin, Arabic gum and dietary fiber as drying aids. It appeared that sugarcane juice should be concentrated under vacuum to 30°Brix and added with at least 15% maltodextrin before drying at 170 °C in order to obtain dried powder product with a low drying cost. After conducting the experiments in the laboratory, sugarcane juice powders were produced in a factory using an industrial-scale spray dryer under five drying conditions. It was found that the energy cost of industrial-scale production of sugarcane juice powder ranged between 0.77 USD and 2.06 USD per kg of powder. According to the results of the industrial-scale experiments, the sugarcane juice powder should be produced using vacuum evaporation of the sugarcane juice to 30°Brix prior to adding maltodextrin at 30% by weight and then spray drying at 190 °C.

Introduction

Sugarcane (*Saccharum officinarum* L.) is a vital crop in the world particularly for the tropical countries, with the majority of sugarcane being used for sugar and alcohol production (Sachs, 1980; Verheye, 2010). Sugarcane juice is popular in many countries due to its taste and low price (Songsermpong and Jittanit, 2010). Additionally, in Indian medicinal practice, it has been used to cure jaundice and liver-related disorders (Kadam et al., 2008). Hudson et al. (2000) and Hollman (2001) claimed that the flavonoids existing in sugarcane juice have abilities to protect cells from degenerative processes and to reduce the development of health problems such as cancer and cardiovascular diseases. Nevertheless, the marketing of sugarcane juice is limited due to its rapid deterioration in quality (Mao et al., 2007).

Processing sugarcane juice to powder is an interesting method to lengthen the product shelf life at ambient temperature and to reduce logistical expenditure. In addition, the powder is easy to use compared with squeezing the juice from the fresh sugarcane stem. Sugarcane juice powder can be consumed as an instant juice powder or as a flavoring agent. Sugarcane juice powder is dissimilar to the crystallized sugar generally available in the market in aspects of flavor, pigments, nutrients and physical properties due to different manufacturing techniques (Oliveira et al., 2007).

Although, to date there has been no published research on the production of sugarcane juice powder, a number of studies on fruit juice drying were found. Gabas et al. (2007) claimed that drying the fruit juice could produce a powder that reconstituted quickly to a product resembling the original juice. According to previous works, there are some difficulties in drying fruit juices that have a high sugar content due to thermoplasticity and hygroscopicity at high temperatures and humidities causing difficulties in packaging and utilization (Bhandari et al., 1997; Adhikari et al., 2004; Cano-Chauca et al., 2005). These characteristics are attributed to low molecular weight sugars such as fructose, glucose and sucrose and organic acids that are the major solids in fruit juices (Bhandari et al., 1997; Cheuyglintase and Morison, 2009). The low glass transition temperature (T_g), high hydroscopy, low melting point and high water solubility of these solids cause a highly sticky or rubbery product when dried (Adhikari et al., 2003; Cheuyglintase and Morison, 2009).

Adding some drying carriers such as maltodextrin (MD) and Arabic gum (AG) into the feed usually overcomes the thermoplasticity and hygroscopicity troubles (Bhandari et al., 1993; Cano-

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Chauca et al., 2005; Gabas et al., 2007). These drying adjuncts are high molecular weight compounds that have high T_g; accordingly, they can raise the T_g value of the feed and the subsequent powder (Shrestha et al., 2007). According to Cano-Chauca et al. (2005) and Langrish et al. (2007), MD is the most popular adjunct in spray drying due to its physical properties such as high water solubility; AG is recommended for fruit juice drying due to its emulsification properties and because it dissolves easily in water.

Spray drying is a technique commonly used in the food industry to make food powder due to its effectiveness under optimum conditions (Cano-Chauca et al., 2005). Spray drying parameters such as the drying air temperature and the feed rate are influential regarding the attributes of spray-dried food such as color, particle size, bulk density, moisture content, nutrient retention, average time of wettability and the amount of insoluble solids (Greenwald and King, 1981; Welti and Lafuente, 1983; Chegini and Ghobadian, 2005; Fazaeli et al., 2012).

Due to the lack of research on the spray drying of sugarcane juice, this study was carried out with the following objectives: 1) to study the feasibility of producing spray-dried sugarcane juice powder; 2) to determine suitable drying conditions for spray drying sugarcane juice; and 3) to compare the product quality between various drying carriers and to estimate the energy cost of industrial-scale production of sugarcane juice powder.

Materials and methods

Raw materials

Fresh sugarcane juice squeezed from freshly harvested sugarcane of the "Suphanburi 50" variety was obtained at the local market nearby Kasetsart University, Bangkok, Thailand. The fresh sugarcane juice was used for preparing concentrated sugarcane juice of 30°Brix. The concentrated juice samples were produced using a laboratory-scale vacuum evaporator (model REV-T; Hisaka Works Co. Ltd.; Osaka, Japan). The sugarcane juice was heated using hot water as a heating medium at a temperature of 70 °C and evaporated in the chamber under vacuum of 70 cm Hg. The system was operated until the juice concentration reached the level of 30°Brix.

Two sorts of drying adjunct (MD and AG) were primarily applied in this study. The MD had a dextrose equivalent (DE) 10–12, pH 4.7 and a moisture content of 5.2%. It was made by Zhucheng Dongxiao Biotechnology Co., Ltd. (Zhucheng city, Shandong, China). The AG used in this work was KB-120 (food grade), which had a pH (25% solution in water) of 4.4 and a moisture content of 11.8%. It was supplied by Lab Valley Limited Partnership (Bangkok, Thailand).

Drying experiments

The feed materials were prepared by adding the specified amount of drying carriers into the concentrated sugarcane juice samples of 30°Brix and then stirring. The ratios by weight of juices (30°Brix) and MD at 1:0.1 and 1:0.15 were applied whereas those of juices (30°Brix) and AG were 1:0.05, 1:0.1 and 1:0.15. These figures can be converted to ratios between the weight of total soluble solid in sugarcane juice and the dry weight of drying aid as shown in Table 1.

The feed materials were dried in a small-scale spray dryer (Mobile Minor 2000, GEA Process Engineering; Soeborg, Denmark). The schematic diagram of the dryer is shown in Fig. 1.

The drying conditions applied in this study are summarized in Table 2. The feed rate was maintained at 0.022 L/min for all drying runs. At the end of drying, the sugarcane juice powders were collected, weighed and kept in sealed containers for quality determination.

Quality determination

The color and pH of the fresh sugarcane juice after standardization to 12°Brix were measured using a colorimeter (model CM-3500d; Konica Minolta Sensing, Inc.; Osaka, Japan), and a pH meter. The sugarcane juice powder samples collected from the drying runs were measured for their bulk density, moisture content, water activity and solubility. In addition, the reconstituted samples of sugarcane juice powder were determined for color, pH and the percentage of insoluble solid. All quality attributes were determined in three replications.

Bulk density determination

The procedure described by Al-Kahtani and Hassan (1990) was applied. Samples of 20 g of powder were put into a 100 mL graduated cylinder which was mounted on the shaker compartment of a water bath (model Stuart Scientific SBS 30; Bibby Scientific Ltd.; Stone, UK). The shaker was operated at 100 revolutions/min for 5 min. The bulk density was calculated by dividing the weight of the powder by the volume occupied in the cylinder.

Moisture content determination

The moisture content of powder was determined using the oven method with 2 g of powder and drying at 105 °C for 2 h. Subsequently, each sample was cooled in a desiccator, weighed and redried for 2 h. The process was repeated until the change in weight between successive drying cycles at 2 h intervals was not more than 2 mg (Jittanit et al., 2010). The weight loss after drying in the oven was used to calculate the moisture content of the powder and was expressed on a wet basis (wb).

Water activity measurement

The water activity of sugarcane juice powder was measured using a thermoconstanter (model TH2/RTD33; Novasina AG; Lachen, Switzerland).

Determination of solubility

To determine the solubility of powder, the method of Al-Kahtani and Hassan (1990) was applied. Each powder sample (10 g) and distilled water (100 mL) were put into a 500 mL beaker. Then, a magnetic bar was added and the beaker was placed on a stirrer (model 210T; Fisher Scientific (M) Sdn Bhd; Selangor Darul Ehsan, Malaysia) at a speed level setting of 5. Measurement was conducted at room temperature (25 °C). The time for the powder in the beaker to be completely dissolved was recorded in seconds and then converted into decimal minutes.

Color and pH measurement for reconstituted samples

The powder samples were dissolved in distilled water to prepare reconstituted samples that had a soluble solid content of 12°Brix. The color of reconstituted samples was measured and expressed as L^*, a^* and b^* values in the CIE system (Francis, 1998). The color and pH of the reconstituted samples were measured and then compared to those of the fresh sugarcane juice.