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Effect of drying technique and feed flow rate on bacterial survival and physicochemical properties of a non-dairy fermented probiotic juice powder

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ABSTRACT

Drying of probiotic fruit juice can be a good alternative for new probiotic foodstuff production since most probiotic foods are dairy-based products, which are not suitable for people with galactosemia, lactose intolerance or allergy to milk protein. Thus, the aim of this study was to evaluate the influence of spray and spouted bed drying and feed flow rate on the microorganism survival and physicochemical properties of probiotic orange juice powder. Fermented probiotic orange juice containing *Lactobacillus casei* NRRL B-442 was spray-dried at 140 °C and spouted bed dried at 60 °C, respectively. Three different feed flow rates were studied for each equipment. Maltodextrin and gum Arabic were used as drying agents at 15% (w/w). The low temperature used in the spouted bed drying resulted in better probiotic bacteria viability compared to the product obtained by spray drying. Moisture and glass transition temperature were improved at the lowest feed flow rate (0.2 L/h), and faster rehydration time was achieved using maltodextrin. Thus, the spouted bed drying at low feed flow rates using maltodextrin as drying agent were the best parameters to produce powder fermented probiotic orange juice with high viability levels after drying and with good physicochemical parameters.

1. Introduction

Nowadays a great claim for health, well-being, and practical food consumption, leads the food industry and the researchers to the development of functional foods such as probiotics (Martins et al., 2013). Despite the growing demand for new products, the inclusion of probiotics in food matrices is still a challenging area of research in food technology (Martín et al., 2015).

A large number of probiotic products available in the marketing comprises mainly dairy products. However, a great part of the world population is affected by lactose-intolerance and cannot consume dairy-based products (Perricone et al., 2015). In addition, many people suffer from milk allergy, galactosemia and hypercholesterolemia, which also imparts restrictions to dairy products consumption (Martins et al., 2013; Mestry et al., 2011). Thus, there is a great interest in the development of probiotic products using non-dairy sources (Antunes et al., 2013). Several types of non-dairy food matrices such as fruits and vegetable juice have been successfully used to produce probiotic beverages, such as cashew juice (Pereira et al., 2011), cantaloupe melon juice (Fonteles et al., 2011) and pineapple juice (Costa et al., 2013). However, fruit juices present a high amount of water, which increases their transport cost. Non-sterile fruit juices should be stored under refrigerate temperatures. Drying is a way to decrease the product transportation and storage cost (Krishnaiah et al., 2014), besides providing storage under ambient conditions (Rocha et al., 2011).

Fruit juices atomization is not an easy process due to the presence of a high proportion of low molecular weight sugars and short-chain organic acids in their composition (Cano-Chauca et al., 2005; Igual et al., 2014). Low molecular weight components impart low glass transition temperature (*Tg*) to the product that is associated with the powders tendency to forming agglomerates and become sticky (stickiness) (Cano-Chauca et al., 2005). Stickiness phenomenon occurs when particles insufficiently dried collide with another particle or with the drier wall and become stuck.

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Stickiness is related to low yield, operating problems, and powder-handling difficulties (Downton et al., 1982). Thus, fruit juice atomization requires proper adjustment of the drying parameters, such as drying temperature, outlet air temperature, feed flow rate, air drying speed, atomization pressure and the use of drying agents to ensure the physicochemical quality of the powder product (Chegini et al., 2008). Different high molecular weight substances as maltodextrins and gum Arabic have been reported as good alternatives to be used as drying agents in fruit juice (Fazaeli et al., 2012; Phisut, 2012). They act by increasing the glass transition temperature and reducing the stickiness and caking, producing free flowing powder with improved handling and physicochemical properties (Krishnaiah et al., 2014).

When the drying is performed in a product containing living cells, as probiotic juices, the viability of these microorganisms becomes one of the most important parameter to be observed (Mestry et al., 2011). Spray drying is commonly used as microencapsulation method in the food industry since it is economical and flexible (Martín et al., 2015). However, the high temperature used in spray drying might cause injuries to microbial cells (Golowczyc et al., 2011). The drying of pastes and suspensions in spouted bed is a lower cost alternative to the spray drying. Spouted bed is able to produce powders with the same quality level of the spray-drying (Bezerra, Amante, de Oliveira, Rodrigues, & da Silva, 2013; Costa et al., 2015; Medeiros et al., 2002). In addition, the spouted bed drying uses lower temperatures than the spray drying, which can help to preserve the microorganisms and bioactive compounds of interest. To our knowledge, no studies have been performed on spouted bed drying of probiotic fruit juices containing probiotics.

Thus, the goal of this work was to evaluate the influence of spouted bed and spray drying techniques on the viability of the probiotic microorganism and on the physicochemical properties of fermented probiotic orange juice.

2. Materials and methods

2.1. Raw material

Frozen concentrate orange juice without added sugars and preservatives (LANJAL®) was obtained from a local market. *Lactobacillus casei* NRRL B-442 was donated by the United States Department of Agriculture (NRRL *Culture Collection*, Peoria Illinois, USA).

2.2. Microorganism and inoculum preparation

Lactobacillus casei lyophilized cells were activated in MRS (Man Rogosa and Sharpe) broth (Himedia, Mumbai, India) at 37 °C for 12 h. Glycerol 50% (v/v) (Vetec Química, Brazil) was then added to the culture before storage at −20 °C in sterile screw cap tubes. For inoculum preparation, the stock culture of *L. casei* was inoculated in 100 mL of MRS broth at 37 °C until a cell concentration of approximately 8.0 log colony forming units per milliliter (log CFU/mL) was achieved.

2.3. Orange juice fermentation

Frozen concentrate orange juice was diluted with water (1:7) and the juice pH was adjusted to 6.0 with NaOH 12 N. The diluted juice was inoculated with 2% (v/v) of the inoculum and incubated at 30 °C for 20 h in a BOD incubator (MA 415, Marconi).

2.4. Probiotic juice drying

Before drying, the fermented orange juice was mixed separately with each one of the following drying agents: maltodextrin dextrose equivalent (DE) 20 (Cargill, Brazil) or gum Arabic (Willy Benecke, Germany), both at 15% (w/w). A stirrer (BestCook, China) was used to homogenize the mixture, which stayed at 25 °C for 30 min before drying.

The drying of fermented probiotic orange juice was carried out using a mini spray dryer (MSD 1.0, LU-228, Labmaq do Brasil Ltd, SP, Brazil) and a mini spouted bed dryer (FBD 3.0, Labmaq do Brasil Ltd, SP, Brazil) equipped with a conical stainless steel drying chamber (h = 881 mm; D1 = 350 mm; D2 = 102 mm). During spray drying, inlet air temperature, nozzle air flow rate and hot drying air flow rate were kept at 140 °C, 30 L/min and 3.5 m^3/min, respectively. In the spouted bed drying, inlet air temperature, fluidizing air flow rate and nozzle air flow rate were kept at 60 °C, 1.7 m^3/min and 30 L/min, respectively. Polystyrene spheres (400 g) with 3 mm of diameter were used as inert particles. Feed flow rates of 0.2, 0.5 and 0.7 L/h were used in the spray drying and 0.2, 0.3 and 0.4 L/h in the spouted bed drying. These values were chosen according to the minimum and maximum limits for each equipment. Both equipments were allowed to reach uniform process temperature for 15 min before drying.

2.5. Microbial viability

Before drying, dilutions (up to 10^6) of the fermented probiotic orange juice were done in sterile peptone water. The diluted samples were spread on MRS agar (aliquots of 0.1 mL), using spread plate method. The plates were then incubated at 37 °C for 72 h in a BOD incubator (MA 415, Marconi). After this, plates containing between 25 and 250 typical colonies of *L. casei* were counted.

After drying, the powder was reconstituted in peptone water (1:10 w/v) and the suspension was kept at 25 °C for 30 min to release the cells. Then, the amount of *L. casei* cell was counted as described above in this section. The colony counts were expressed as log of colony forming units per gram of solid (log CFU/g).

2.6. Physicochemical analyses

2.6.1. Moisture content

Moisture content was determined gravimetrically in a closed system with silica gel placed in an oven (model UM 200, Memmert, Germany) at 40 °C. The sample weight was measured for 5 days, until constant weight. Samples of 1 g were used.

2.6.2. Water activity (Aw)

The Aw was determined using a water activity meter (Hygro-Palm HP 23, Rotronic, Bassersdorf, Switzerland) at 20 ± 1.5 °C.

2.6.3. Glass transition temperature (Tg)

The *Tg* was determined by differential scanning calorimetry using a Netzsch DSC 200 calorimeter (Netzsch, Germany) with a nitrogen-based cooling system. Aluminum pans were filled with 16 mg of the powder product and hermetically sealed. An empty pan was used as reference. Each sample was heated at a temperature rate of 10 °C/min in a temperature range from 0 to 100 °C. The *Tg* was determined using the Netzsch Proteus Thermal Analysis software.

2.6.4. Particle size

Particle mean diameter was measured using a laser diffraction particle size analyzer, Mastersizer 3000 (Malvern Instruments, Malvern, UK) equipped with a wet sample unit. A small sample amount was suspended in ethanol under agitation, and the particle size was measured successive times. Particle size was expressed as the volume mean diameter (d_{50}).