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Spouted bed as an efficient processing for probiotic orange juice drying

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ABSTRACT

This study evaluated the influence of spouted bed drying temperature and maltodextrin dextrose equivalent on the probiotic microbial survival during drying and storage period and on physicochemical properties of fermented probiotic orange juice in powder. Probiotic orange juice was spouted bed dried at 60, 70, 80 and 90 °C using maltodextrin with a different dextrose equivalent (10, 20, 30 and 39). After drying, the microbial was higher when lower drying temperatures were applied. During the storage, the highest drying temperatures (80 and 90 °C) negatively affected the microorganism survival. On the other hand, at the lowest drying temperature (60 °C), the product presented higher Aw, what negatively affected the microbial survival during storage. The temperature of 70 °C was the best to preserve the microbial viability during storage. Physicochemical parameters were improved when temperature increased and dextrose equivalent decreased.

1. Introduction

Most probiotic foods available in the market are dairy-based. This kind of products are not suitable for people with galactosemia, restrictions on the consumption of cholesterol and allergy to milk proteins (Mestry, Mujumdar, & Thorat, 2011; Perricone, Bevilacqua, Altieri, Sinigaglia, & Corbo, 2015). As a consequence, there is a tendency in the development of non-dairy based probiotic products. Some food matrices such as fruits and vegetable juices have been successfully used to produce probiotic beverages (Alves, Messaoud, Desobry, Costa, & Rodrigues, 2016; Costa, Fonteles, De Jesus, & Rodrigues, 2013; Fonteles, Costa, Jesus, & Rodrigues, 2011; Pereira et al., 2017; Pereira, Maciel, & Rodrigues, 2011). Orange juice is the most widely popular and consumed juice (Leite, Augusto, & Cristianini, 2016). Thereby, this is the predominantly processed juice, contributing with > 50% of the international juice trade (Guerrouj, Sánchez-Rubio, Taboada-Rodríguez, Cava-Roda, & Marín-Iniesta, 2016). Thus, orange juice is a suitable non-dairy matrix for a probiotic beverage.

Associated to the claim for health and well-being, there has been also a great interest in convenience and practice. In this way, a suitable drying method can be an interesting alternative not only to increase convenience, but also to decrease the product transportation and storage costs, besides to provide storage under ambient conditions (Krishnaiah, Nithyanandam, & Sarbatly, 2014; Mestry et al., 2011; Rocha, Souza, Alsina, & Medeiros, 2011). Among the drying techniques, spray drying is widely known as a feasible technology. However, when this technique is used to dry probiotic products high microbial viability losses have been observed during processing due to the high temperatures usually applied in this process (Alves et al., 2016; Anekella & Orsat, 2013). Spouted bed dryer is a low cost equipment that has been pointed out as an alternative to spray drying (Costa, Andreola, de Andrade Mattietto, de Faria, & Taranto, 2015). In spouted bed drying, a paste or suspension is inserted into a drying chamber by atomization meeting inert particles in motion and covering them as a fine film, which is dried by the contact with the hot air. Due to the friction between the inert particles, the dried product is removed from the particle surfaces and recovered by a cyclone (Oliveira et al., 2007). This technique is suitable for drying heat-sensitive materials, preserving bioactive compounds and microorganism cells since it uses lower temperatures compared to the conventional spray drying (Alves et al., 2016; Costa et al., 2015).

Fruit juices contains high amounts of components, such as sugars and short-chain organic acids, with low glass transition temperature (*Tg*) which is associated with low yield, operating problems, and powder-handling difficulties (Cano-Chauca, Stringheta, & Ramos, a. M., & Cal-Vidal, J., 2005; Igual, Ramires, Mosquera, & Martínez-Navarrete, 2014). Thus, fruit juice drying requires the use of drying adjuvants. Drying agents such as maltodextrin, gum Arabic, whey protein, gelatin and modified starch have been used to increase the *Tg* producing a free flowing powder with improved handling and

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physicochemical properties (Krishnaiah et al., 2014). Among the known and commercially available drying agents, maltodextrin is the most applied in food industry due to its competitive price, versatility and availability.

To guarantee beneficial effects of the probiotics in the host organism, it is necessary that the microorganisms reach the gastrointestinal tract in sufficient quantities. Therefore, high levels of probiotic cells should be found in the product after drying and during storage (Vesterlund, Salminen, & Salminen, 2012), Aside from the viable cell counts, probiotic juice in powder form also needs to be properly characterized regarding the powder properties. Food powders characterization does not relies only on their composition and microstructure, but also on the particle size, size distribution, chemical, and physical properties, among other parameters (Barbosa-Canovas, Ortega-Rivas, Juliano, & Yan, 2005). The particle properties are used for qualitative assessment of the behavior of suspensions and powders, for example, as an equipment selection guide. The proper powder characterization is important due to their effects on many food processes and unit operations dealing with powders and particulates (Ortega-Rivas, 2009).

In a previous study, our group concluded that spouted bed dryer was the best equipment for probiotic orange juice drying (Alves et al., 2016). Thus, the aim of this study was to evaluate the influence of the drying temperature and the use of maltodextrin with a different dextrose equivalent (DE) on the probiotic microorganism viability and on the physicochemical properties of fermented probiotic orange juice spouted bed dried and stored at room temperature.

2. Material and methods

2.1. Probiotic juice preparation

2.1.1. Microorganism and inoculum preparation

The probiotic strain *Lactobacillus casei* NRRL B-442, donated by the United States Department of Agriculture (NRRL *Culture Collection,* Peoria Illinois, USA) was used to prepare the probiotic juice. Freeze-dried cells of *L. casei* were grown in the Man Rogosa & Sharpe (MRS) broth (Himedia, India) at 37 °C for approximately 12 h. The culture was stored at − 20 °C in sterile screw cap tubes containing glycerol at 50% *w*/w (Vetec Química Fina Ltd., Brazil). Then, the stock culture of *L. casei* was propagated in 100 mL of MRS broth at 37 °C until reaching an absorbance of 0.600, corresponding to a cell concentration of 8.0 log of colony forming units per milliliter (log CFU mL^{-1}) (Alves et al., 2016). The cell concentration was determined by optical in a spectrophotometer (Spectrum® SP200UV) at 590 nm. The MacFarland scale was used to determine the cell concentration in the inoculum (Costa et al., 2013; Fonteles et al., 2011; Pereira et al., 2011).

2.1.2. Fermentation of orange juice

Frozen concentrated orange juice (FCOJ) without sugar and additives (LANJAL®, Brazil) obtained from a local market, was diluted with potable water (1:7 v:v). Sodium hydroxide (NaOH 12 N) (Vetec Química Fina Ltda, Brazil) was used to adjust the juice pH to 6.0. The juice was inoculated with 2% (*w*/w) of the inoculum and was incubated at 30 °C for 20 h in a BOD incubator (MA 415, Marconi) (Alves et al., 2016).

2.2. Drying of the probiotic juice

The probiotic orange juice drying was carried out using a mini spouted bed model FBD 3.0 (Labmaq do Brasil, Ribeirão Preto SP, Brazil), equipped with a conical stainless steel drying chamber (h = 881 mm, D1 = 350 mm; D2 = 102 mm). Maltodextrins (Cargill-Maltogill, Brazil) with different dextrose equivalents (DE) (10, 20, 30 and 39), were used as drying agent at 15% (*w*/w). In all experiments the atomizer nozzle air rate, the air drying flow rate, the feed flow rate and the air pressure in the atomizer nozzle were kept at 30 L/min, 1.7 m^3/min, 3.0 mL/min and 80 psi, respectively. Tested inlet air temperatures were 60, 70, 80 and 90 °C. As inert, 400 g of polystyrene spheres with 3 mm of diameter were used.

2.3. Microbial viability

Viability was measured in the fermented juice before drying and in the powder obtained after the spouted bed drying. Viability was also measured during a storage period of 5 weeks. Before drying, serial dilutions of the probiotic orange juice were done using sterile peptone water. Plates containing MRS agar were seeded with 0.1 mL of the appropriate dilution (*spread plate* method) and incubated at 37 °C for 72 h in a BOD incubator (MA 415, Marconi) (Burns et al., 2015; Vinderola & Reinheimer, 2000). Plates containing between 25 and 250 typical colonies of *L. casei* were counted and the results were expressed as log of colony forming units per grams of solids (log CFU/g).

After drying, 1 g of the powder was reconstituted in 10 mL of peptone water. The suspension was kept at 25 °C for 30 min to release the cells. Then, the quantity of *L. casei* cell was analyzed as previously described in this section to the fermented juice before drying. The log reduction was calculated according to the follow equation:

$$\text{Log reduction} = N_0 - N \quad (1)$$

where N_0 is the amount of microbial cell before the drying and N is the amount of microbial cell after the drying, both in Log CFU/g.

Probiotic orange juice powder samples were stored during 5 weeks in hermetically sealed polypropylene bags at 25 °C ± 2.

2.4. Physicochemical analyses

2.4.1. Water activity

The water activity of the powder samples was determined using a water activity meter (HygroPalm, Rotronic, Bassersdorf) at 20 ± 1.5 °C.

2.4.2. Moisture content

Moisture content was determined gravimetrically in a closed system with silica gel placed in an oven (Memmert A 2000) at 40 °C. The sample weight was measured for 5 days, until constant weight was achieved. Samples of 1 g were used (Alves et al., 2016).

2.4.3. Isotherms

Isotherms were obtained from a Dynamic Vapor Sorption equipment – DVS (Surface Measurement Systems, London, UK) at 25 ± 2 °C. After the equipment stabilization, a small amount of sample was inserted in the equipment capsule. The relative humidity was adjusted from 0 to 80% automatically. The sample stayed at each relative humidity until mass stabilization.

2.4.4. Glass transition temperature (Tg)

Glass Transition Temperature was determined by Differential Scanning Calorimetry using a Netzsch DSC equipment (Netzsch, Germany) fitted with a nitrogen-based cooling system. An amount of 16 mg of the powder sample was placed in aluminum pans which were hermetically sealed. The aluminum pans containing the samples were heated from 0 to 100 °C at a heating rate of 10 °C/min. An empty pan was used as the equipment baseline.

2.4.5. Particle size

The light scattering method was used to determine particle size, by using a laser diffraction particle size analyzer Mastersizer 3000 (Malvern Instruments, Malvern, UK) equipped with wet sample unit. A small quantity of sample (15% of obscuration) was suspended in ethanol under stirring and the particle size was measured 10 times for each sample. Particle size was expressed as the volume mean diameter