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# Production and spouted bed drying of acerola juice containing oligosaccharides

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ABSTRACT

In the present study, acerola (*Malpighiae marginata*) juice was used as substrate for oligosaccharides synthesis by the dextransucrase acceptor reaction. Due to the low sugar content of acerola, external sugars (sucrose, glucose and fructose) were added to the juice and the oligosaccharides synthesis was carried out using a central composite rotated design. High oligosaccharide and low dextran yields were obtained indicating that the acceptor reaction had occurred. The sugar conversion into oligosaccharides was also high (>60%) and oligosaccharides with a degree of polymerization up to 12 were obtained. The prebiotic juice was dried in a spouted bed using maltodextrin as carrier. The powder dried at 60 °C showed low hygroscopicity (7.90%), low moisture (1.91%) and low water activity (0.18).



*Keywords:* Dextransucrase acceptor reaction; Prebiotic oligosaccharides; Acerola juice; Spouted bed; Fruit juices; Functional foods

## 1. Introduction

The human intestine is a complex ecosystem colonized by more than 500 hundred strains, which makes the human gut the most active metabolic organ in the human body. The gut function might affect the body health in several ways. Because of that, an intense attempt to control and understand the intestinal microorganisms has been undertaken lately (García-Peris et al., 2012). Prebiotic oligosaccharides are non-digestible food ingredients that positively affect the healthy due to the selective stimulation of beneficial bacteria growth in the colon, contributing to the functional equilibrium (Calderón et al., 2012; Fernando et al., 2011). The selective growth of *lactobacillus* and *bifidobacterium* promoted by the prebiotic oligosaccharides results in intestinal acidification due to the production of short chain fatty acids, which contributes to the calcium absorption. The intestinal transit is also improved and a decrease of pathogen counts has been reported in response to the increased beneficial strain counts (Roberfroid et al., 2010).

Nowadays, dairy products are the main source of prebiotic oligosaccharides in the food industry. However, some consumers avoid dairy products due to milk allergy, lactose intolerance or vegetarianism. On the other hand, the consumption of fruit juices has increasing due to their nutritional value and exotic taste (Silva et al., 2012). Prebiotic oligosaccharides might be extracted from vegetables such as chicory but the industrial production is carried out using microbial enzymes such as hydrolases and glucosyltransferases (Boler and Fahey, 2012). The enzyme dextransucrase from *Leuconostoc mesenteroides* B-512 is a glucosyltransferase traditionally applied to produce dextran in a medium containing only sucrose as the carbon source. When, besides sucrose, another carbohydrate is also present in the reaction medium, the glucose units deviate from the dextran chain. This reaction is called an acceptor reaction and the main acceptor studied for dextransucrase is maltose, which forms isomalto-oligosaccharides with a degree of polymerization from 1 to 10 (Rabelo et al., 2006; Rodrigues et al., 2005; Heincke et al., 1999). The use of fruit juices as a vehicle for prebiotic

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oligosaccharides is an interesting alternative to dairy products.

The recent studies on vegetable food matrices as a vehicle for prebiotic oligosaccharides target the incorporation of the oligosaccharides in the food matrix. In the present study, acerola juice was chosen as food matrix to develop a prebiotic juice due to its exotic taste and high vitamin C content. Instead of adding oligosaccharides to the juice, they were synthesized directly in the juice by the dextransucrase acceptor reaction, where glucose and fructose were the acceptors.

Despite the increasing interest in fruit juice consumption, their storage and transportation is a concern. Dried foods are an interesting alternative because drying is a process able to increase the shelf life and decrease the transport and storage costs of foodstuffs. Powdered juices present several advances over the ready to drink product such as low weight and volume, easy preparation, longer shelf life and storage at room temperature. The dehydration of fruit juices is not an easy task due to their high content of sugars and low weight organic acids, which results in powders with a low glass transition temperature. The use of proper carriers is an alternative to improve the drying process (Goula and Adamopoulos, 2010). The most studied equipment for drying liquids is the spray dryer.

The spouted bed dryer is a useful alternative. It features excellent heat transfer coefficients and a uniform drying temperature distribution, which might result in better quality powders compared to other dryers (Bacelos et al., 2008). This equipment has been used for the drying of pastes and suspensions, producing a powder of high quality and low cost (Bezerra et al., 2013). Drying of pastes in a spouted bed occurs in the presence of inert particles, which act as a support for the paste and as a heat source for drying. The paste might be atomized through a nozzle atomizer or dripped onto the moving bed of particles. During the process, the bed becomes wet and a thin layer of material is gradually formed around the inert particles. The film on the particle surface is dried and the liquid bridges disappear gradually, resulting in a fragile, crumbly coating layer. Due to friction between individual particles and the particles and the column wall, the film is removed as a powder (Braga and Rocha, 2013). Spouted bed drying is often considered to be a good option for the drying of granular products that are too coarse to be readily fluidized (Chua and Chou, 2003), which makes this equipment suitable for drying fruit pieces (Cardoso and Pena, 2014; Contreras et al., 2012; Huang et al., 2009).

Few works have been published on the spouted bed drying of fruit pastes and liquids (Medeiros et al., 2002; Cabral et al., 2007; Rocha et al., 2011; Fujita et al., 2013). Thus, the prebiotic acerola juice was dehydrated in a spouted bed and a preliminary characterization of the powder produced was undertaken.

## 2. Materials and methods

### 2.1. Acerola juice preparation

The juice was prepared by diluting the commercial acerola pulps stored frozen (−20 °C) before the use. The dilution was carried out using potable water at 1:2 (100 g of acerola pulp to 200 mL of water) according to the manufacturer's instructions. The sugar content (glucose, fructose and sucrose) was determined by HPLC as described further, and the juice pH was determined by direct measurement with a Marconi PA 200 potentiometer (Marconi, Piracicaba—SP, Brazil).

### 2.2. Oligosaccharides synthesis

A $2^2$ central composite rotated design (CCRD) with 3 central points was carried out to evaluate the effect of the initial sugar concentration on the oligosaccharides production by the dextransucrase acceptor reaction (Table 1). Due to the low sugar content, sucrose and reducing sugars (fructose and glucose) were added to the juice to reach the desired concentration. The acceptors (glucose and fructose) were adjusted to reach equimolar proportions (1:1); the independent variables were sucrose and reducing sugar concentrations. The pH of the juice was adjusted to 5.2 (optimum for enzyme synthesis) with NaOH. The syntheses were carried out batchwise in 250 mL Erlenmeyer flasks containing 25 mL of juice at 30 °C for 24 h. The enzyme activity was 1 IU/mL. The enzyme was synthesized in-house as described by Rabelo et al. (2006). After the synthesis, the dextran was precipitated by adding three volumes of ethanol 96% (v/v). The desired responses were oligosaccharides formation, dextran and residual sugars (sugars not consumed during the synthesis).

### 2.3. Analytical determinations

#### 2.3.1. Sugar quantification by HPLC

Sugars were quantified by HPLC in a Varian Pro Star system (Varian Inc, Palo Alto, California, USA) composed of two high-pressure pumps, Pro-Star model 210, a refractive index (RI) detector, Pro Star model 355, an auto sampler, Pro Star model 410, and a Timberline column oven. Separation was achieved in an Aminex 87C (7.8 mm × 30 cm) column at 85 °C. Ultrapure water (Milli-Q) at 0.6 mL/min was used as eluent. The samples were filtered with a 0.45 μm cellulose acetate membrane; the injection volume was 20 μL. The detector temperature was 35 °C and the software Star Chromatography WS 6.0 was used to acquire and handle the data. Quantification was undertaken against a calibration curve built with external standards. All samples were analyzed in triplicate.

#### 2.3.2. Dextran determination

The dextran precipitated with ethanol was re-suspended in distilled water and quantified by phenol–sulfuric miniaturized method as described by Fox and Robyt (1991).

#### 2.3.3. Oligosaccharide determination

The oligosaccharides and dextran formed during the synthesis, as well as the residual sugar (non-consumed sugars) were determined by mass balances according to the following equations:

$$\text{Oligosaccharides}\ \ (\text{g/L}) = \text{TS}_{\text{cons}} - \text{DXT} \tag{1}$$

$$Y_{\text{OLIGO}}(\%) = \frac{\text{Oligosaccharides}\ \ (\text{g/L})}{\text{TS}_{\text{consumed}}\ \ (\text{g/L})} \times 100 \tag{2}$$

$$Y_{\text{DXT}}(\%) = \frac{\text{DXT}\ \ (\text{g/L})}{\text{TS}_{\text{consumed}}\ \ (\text{g/L})} \times 100 \tag{3}$$

$$Y_{\text{RS}}(\%) = \frac{\text{Non consumed sugars}\ \ (\text{g/L})}{\text{Total sugar}\ \ (\text{g/L})} \times 100 \tag{4}$$

where $\text{TS}_{\text{cons}}$ total sugar consumed in the enzyme reaction (g/L), DXT dextran formed during the enzyme synthesis (g/L),