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Physico-chemical and sensory properties of yogurt from ultrafiltreted soy milk concentrate added with inulin

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The total solids required for yogurt preparation were obtained by soy milk microfiltration and ultrafiltration. Inulin was incorporated at the level of 20–70 g/L, and the soy milk containing inulin was fermented using conventional microorganisms. The chemical, physical and sensory properties of the products were evaluated. The membrane concentration of soy proteins leads to yogurts with an increase of 59 g/L of proteins and 15 g/L of vegetable fats, reducing ash and anti-nutrients content. The clot had high stability and protein concentration generated a buffer effect smoothing the acidity and the flavor obtained is more agreeable. In addition, the proteins were concentrated without thermal treatment. As the inulin content increased, creaminess and viscosity increased as well. The products prepared presented nice smell, flavor and color, being the sample with higher global acceptability the yogurt with 50 g/L of inulin ($P < 0.05$).

1. Introduction

The incorporation of soy milk and its by-products in human diets is arousing an increasing interest due to its important nutritional properties such as calcium, high quality proteins, polyunsaturated fatty acids; and an accurate content of isoflavones which inhibit the process of bone destruction and have anticancer effects (Donkor, Henriksson, Vasiljevic, & Shah, 2007; Genovese & Lajolo, 2002; Tang & Mab, 2009). Furthermore, Canabady-Rochelle and Mellema (2010) had concluded by a thermodynamic study that soy protein could be a possible protein vector for further Ca supplementation, since the nature of Ca-protein interaction is similar in cow's milk. Therefore, foods derived from soy, such as soy milk, become an alternative since they are lactose free (Mattos et al., 2009).

The preparation of yogurt requires a content of 12–15 g/100 g in total solids to obtain a fermented final product with the adequate texture and viscosity. A way proposed for soy milk concentration is by membrane technology such as microfiltration (MF) and ultrafiltration (UF) (Chove, Grandison, & Lewis, 2007; Liu, Nie, & Shen, 1989). By this process, a soy concentrate with special characteristics is obtained, because of the increase of high-class proteins and fats which are essential polyunsaturated fatty acids. Furthermore, the membrane does not retain oligosaccharides and anti-nutrients, as phytic acid which binds to the minerals preventing its absorption (especially zinc, calcium and magnesium) and decreasing protein solubility. Even though small amounts of these anti-nutrients remain in the concentrate, they are then, deactivated by fermentation creating a product with better nutritional properties (Ali, Ippersiel, Lamarche, & Mondor, 2010; Alibhai, Mondor, Moresoli, Ippersiel, & Lamarche, 2005; Krishna Kumar, Yea, & Cheryan, 2004). One of the advantages of the ultrafiltration is that products present higher functional characteristics than those obtained by conventional methods, principally due to the non-use of chemical products and thermal treatments (Mondor, Ippersiel, & Lamarche, 2010; Rinaldoni, Campderrós, Menéndez, & Pérez Padilla, 2009).

Soy milk concentrate fermented to produce yogurt, combines the beneficial properties of soy with a product usually more digestible as yogurt. Sugars are necessary for the fermentative process but due to their low molecular weight they are not concentrated by the UF process. Therefore, as soy milk is low in sugar, the addition of saccharides was required. Inulin is a non-digestible carbohydrate present in many vegetables, fruits and cereals, and as an ingredient for applications in the food industry, where it is used in a large variety of food products (dairy products, bread and other bakery products, confectionery, ice cream, beverages and spreads), due to its technological and nutritional benefits (Cardarelli, Buriti, Castro, & Saad, 2008; Farnworth et al., 2007; Kip, Meyer, & Jellema, 2006). Inulin effects on food formulations include fat and sugar replacement, low-

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calorie agent, dietary fiber, thickener, emulsifier, humectants, gelling capacity with water and lyoprotectant upon food proteins (Franck, 2002; Hennelly, Dunne, O'Sullivan & O'Riordan, 2006; Rodríguez Furlán, Pérez Padilla, & Campderrós, 2010; Rosell, Santos, & Collar, 2009). It is a functional food additive due to its prebiotic properties which is not digested in the small intestine, but it is fermented in the colon by lactic acid bacteria such as yogurt starter cultures. Consequently, this compound promotes the growth of healthy bacteria and enhances calcium and magnesium absorption and immune functions, as well as it reduces the level of cholesterol and serum lipids (Dello Staffolo, Bertola, Martino, & Bevilacqua, 2004; Guven, Yasar, Karaca, & Hayaloglu, 2005; O'Brein, Mueller, Scannell & Arendt, 2003).

The objective of this study was to investigate the effect of the addition of inulin on chemical, physical and sensory properties of the soy yogurt manufactured from ultrafiltered concentrate.

2. Material and methods

2.1. Raw materials

Commercial soy milk (ADES®, Argentine) was used as raw material for yogurt preparation. Its composition was: 15 g/L fat, 26 g/L protein, 30 g/L sugar, 8.9 g/100 g total solids and 0.6 g/100 g ash.

Starter cultures (Yo-Flex, YF-L702, Argentine) constituted by *Lactobacillus delbruckii* subspecies *bulgaricus* and *Streptococcus salivarius* subspecies *termophilus*.

The inulin was provided by Orafti Chile S. A. The commercial inulin employed was mainly constituted of linear chains of fructose, with a glucose terminal unit and had a molecular weight of 2400 g/mol.

2.2. Analysis

Raw material, concentrate and fermented products were analyzed in duplicate according to standard methods replication. Density (ρ) was measured with a digital densimeter (Metter, USA), pH was measured using a digital pH-meter (Orion, USA), titratable acidity was determined with 0.1 mol equi/L NaOH (AOAC 947.05). The total protein content was calculated by determination of total nitrogen by the Kjeldahl method using a Digestion Blocks and a semiautomatic Kjeldahl Distiller (Selecta, Spain), the conversion factor used to express the results was 5.71 (AOAC 991.22). The fat content was measured by the Rosse–Gottlieb method (AOAC 905.02). Total solids were determined by weight difference, drying in an oven at 70 ± 1 °C (AOAC 925.23), during 24 h. For ash determination, samples were weighted into porcelain crucibles and incinerated in a muffle furnace (Indef, Argentina) with a temperature programmer to reach 520 °C (AOAC 945.46).

The determination of yogurt syneresis was carried out, after 24 h of cold storage at 4 °C. The gels were stirred for 60 s on a platform and centrifuged for 20 min at 12,075 g in an ultracentrifuge (Beckman USA) at 4° C (Rinaldoni, Campderrós et al., 2009). Syneresis, S (g/100 g) was calculated as mass of serum *m (serum)* that had separated from the gel due to centrifugation, related to the total mass of gel *m (gel)* that was centrifuged:

$$S\% = \frac{m(serum)}{m(gel)} \times 100\%$$

The apparent viscosity was measured with a rotational viscometer Haake (with a rotor 1 which has a shear rate of 3750 s^{-1} at 10 °C).

Rheological behavior of the yogurts was measured at 10 ± 1 °C, using a stress controlled rheometer RheoStress 80 (Haake, Germany), with a cone-plate geometry cell. The diameter and angle of the cone were 60 mm and 1°, respectively. The samples were covered with a thin film of silicone oil to prevent water evaporation during measurements. Ascending and descending flow curves of shear stress versus shear rate were carried out in the range of 1–200 (s^{-1}) during 5 s.

Sensory analysis was performed of yogurts by comparison technique for classifying each global preference (Lawless, 1998). The samples were tested at 25 °C, in an uniformly illuminated room, by three groups of 30 untrained judges. The analysis consisted of testing four samples with different inulin content, which presented similar sensory characteristics such as odor, color, texture, over which should say what was the most pleasant, at its discretion. Water was provided for rinsing between samples.

2.3. Statistical analysis

The obtained data were statistically evaluated by test of variance (ANOVA) on the three groups and their corresponding responses, whereas a statistically significant $P < 0.05$.

2.4. Soy milk concentration: microfiltration – ultrafiltration steps

The experimental equipment for ultrafiltration of skim-milk was one commonly used: a Pellicon cassette module (Millipore, USA) with modified polysulfone membranes with a cut-off of 10 kDa (Rinaldoni, Tarazaga, Campderrós, & Pérez Padilla, 2009). Total membrane area was 0.5 m^2. The feed (soy milk) was thermostated at 20 ± 2 °C in a water bath and was impulsed with a centrifugal pump. Temperature, recirculation rate, transmembrane pressure, pH and permeate flux rate were continuously recorded. The auxiliary elements are an analytic balance connected with an electronic interface and the PC, with acquisition data (ADQ12-B Converter A/D 12 bits Micro Axial).

Soy milk concentration by UF was carried out in batch mode, by continuously removing the permeate stream. The solids content was measured in the concentrate stream and the process was stopped when the desired concentration was achieved. The volume concentration ratio (VCR) was determined as reported by Cheryan (1986).

At different VCR, concentrate samples were taken and refrigerated for subsequent analysis. When the UF process was stopped, concentrates were stored at 4 °C.

After each filtration the membrane was cleaned in-line according to instructions provided by the manufacturer. The membrane hydraulic permeability recuperation was always tested to verify that the cleaning procedure was correctly done.

2.5. Yogurt manufacture

Two replicate trials were conducted in the manufacture of yogurt with the soy milk. Manufacturing stages for the production of soy yogurt with inulin is shown in Fig. 1. Experimental groups were divided into five parts, one was reserved as control and inulin was added to the others in different ratio: 20, 30, 50 and 70 g/100 g. The samples were pasteurized at 90 ± 1 °C for 30 s, then they were cooled to 38 ± 1 °C and inoculated with 20 mL of the microorganisms and kept at 41 ± 2 °C. During the fermentation stage the acidity development was studied, and the process was stopped cooling to 4 ± 2 °C when the product reached a pH = 4.65 ± 0.05.