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Development of Functional Cheeses with Fructooligosaccharides

Diana Palatnik, Noelia Rinaldoni, Diego Corrales, María L. Rolon, Haydée Montero, Germán Aranibar, María L. Castells, Noemi Zaritzky and Mercedes E. Campderrós

Abstract

Cheese is a food of great consumption in the world; however, some aspects related to its fat content and the possibility of incorporating fiber represent interesting challenges for the dairy industry. In this sense, fructooligosaccharides (FOS), as inulin and agave fructans, exhibit valuable nutritional and functional attributes that can be used as supplements as soluble fiber or as macronutrient substitutes. In this chapter, the study of the development of soft and cream cheeses was performed to determine the operating conditions that allow obtaining products with beneficial health properties taking advantage of the characteristics of this carbohydrate. The skim milk was produced by ultrafiltration, and all the products were characterized physicochemically, including determinations of color, texture, and sensory analysis. The cheeses obtained were of high moisture, >45% (w/w), and reduced fat content (10–25% w/w), including a high protein concentration. The presence of fructans did not significantly modify the texture and appearance of the developed products, but its retention in the matrix was maximal in the case of spreadable cream cheeses containing inulin. Considering the health benefits of fructans and their abundance, this development could represent an innovation for dairy industry.

Keywords: functional cheese, fructans, microfiltration membranes

1. Introduction

Cheeses are high nutritional value foods and with great market demand, outstanding among other products as it has high biological value proteins with a very favorable amino acid profile and good digestibility.

Argentina is the seventh largest producer of cheese in the world in a relatively stable market, where consumption per capita is 12 kilos per year. It is reported that half of the country's milk is destined for cheese processing. It is about 500 thousand tons and is distributed 50% to make soft cheeses, 35% for semihard, and 15% for hard. Between 70 and 75% of the production is commercialized in the domestic market: approximately 13,000 dairies supply about 870 establishments that make cheeses. In Latin America, Argentina is the country with the highest consumption of cheeses.

However, cheese has restrictions on its consumption due to its high content of calories and highly saturated fats and therefore with a potential risk to health.

Indeed, one of the market trends is the production of cheeses with reduced fat content to minimize the negative effects of lipids in the diet. With the purpose of texturally compensating the product, the addition of fructans such as inulin or agave fructans has been studied [1, 2].

Fructans are nondigestible carbohydrates present in many vegetables, fruits, and cereals. They are widely used as ingredients of functional food since they have beneficial effects on health as prebiotics. Dietary prebiotics are typically nondigestible fiber compounds that pass undigested through the upper part of the gastrointestinal tract and stimulate the growth or activity of advantageous bacteria that colonize the large bowel by acting as substrate for them. They supply dietary fiber, hypoglycemic, low calorie value, providing a better bioavailability of calcium and magnesium and improving intestinal iron absorption [3, 4]. Bosscher et al. [5] reported that the consumption of fructans in humans increases calcium absorption, improving bone mineral content and density. Besides, there are promising evidences of its performance in the regulation of lipid parameter, reduction of cancer risk, reinforcement of the immune response, and protection against bowel disorders.

According to the American Dietetic Association (ADA), it is usually understood under the name of functional food any food or potentially healthy ingredient that can provide health benefits beyond the traditional nutrients it contains.

Hippócrates, a Greek doctor more than 2000 years ago, left in his legacy a mythical phrase “That food be your medicine and medicine your food” and, although he did not use the term functional food, was implicitly referring to the consumption of certain foods that could help prevent diseases. Located in the twenty-first century, this philosophy of “food as medicine” is the basis of the paradigm of functional foods. Regarding the abovementioned, the challenge of achieving functional consumer cheeses is undoubtedly an interesting aspect for the dairy industry.

The basic technology of manufacturing a cheese is similar for almost all varieties, but it is important to mention that relatively small changes in the processing conditions give rise to important differences in the final cheese. In general these differences lie in the use of different types of ferments, in variations in cooking temperatures, curd cut, cheese grain size, brine and ripening times, and other technological conditions. Furthermore, in the case that different ingredients that provide the desired functionality are used, it also leads to really different products.

The membrane technology is increasingly employed for dairy treatment [6]. The development of membrane materials, equipment, and studies of fouling and cleaning of membranes increases their applications. These aspects are addressed in this chapter with the purpose of achieving a functional food from natural resources also using the membrane technology to perform the skimming of the raw material.

In this chapter, results about the incorporation of fructans in cheesemaking matrices are described in order to obtain reduced fat cheese-containing compounds that behave like probiotics and act as dietary fiber.

2. Materials and methods

2.1 Raw materials

The elaboration of each of the samples of cheese studied was made from 2500 ml of raw milk from a dairy farm in the province of San Luis and with milk sample of an establishment of the province of Buenos Aires. Before starting the cheese manufacturing process, a fat reduction was carried out in order to obtain a product that is low in fat and, therefore, healthier. For this purpose, a procedure using membrane technology was developed, as will be explained later.

The following compounds were added to all cheese samples per liter of milk: ferment consisting of lactic acid bacteria that allow the acidification and coagulation of milk, inhibiting, in addition, the development of other unwanted microorganisms. There are different types of ferments, and the one chosen depends on the type of cheese. In this work homofermentative mesophyll ferment, lyophilized direct inoculation composed of *Lactococcus lactis* subsp. *lactis* and *Lactococcus lactis* subsp. *cremoris* (CHR Hansen R-704), was used. Although the ferment is a direct inoculation, it is convenient to leave it pre-mature for 30 min in a little amount of milk at an optimum temperature of $34 \pm 2^\circ\text{C}$ before adding it to the rest of the milk. The working temperature was also maintained at $32\text{--}37^\circ\text{C}$ during a large part of the processing to allow the action of the ferment, rennet (CHR Hansen, Chy Max M200–0.5 ml).

FOS of different characteristics were used: (i) inulin provided by Orafit Chile SA and obtained from chicory and (ii) agave native fructans (NF), commercial products of *Agave tequilana* in powder and 72°Brix (Agaveteca Monterrey, Mexico). The commercial inulin employed is mainly constituted by linear chains of fructose, with a glucose terminal unit. Short-chain inulin GR was used in concentrations of 3 and 5% (w/w) and long-chain HP at 5% (w/v). Fructans present in Agave, particularly in *Agave tequilana*, have a polymerization degree between 3 and 29 with several β (2–6) bonds in branching fructose molecule.

The amount of fructan added was defined taking into account the conditions set by the Argentine Food Code (AFC), Chap. 17, for foods added with fibers.

For milk skimming, membrane technology was used, more precisely the microfiltration technology. Once skimmed, a physicochemical analysis was carried out, and the process of making the cheeses began.

2.2 Membrane processes for partial skim milk

As mentioned previously, current market demands healthier foods with lower health risks. Thus, it is expected that in a cheese with functional properties, its fat content will be reduced [1]. For the elaboration of the samples of cheeses, raw cow's milk was used, and the fat content was reduced by applying membrane technology.

Membrane technology is a generic term for a series of different and very distinctive separation processes. In essence, the membrane acts as a selective barrier by letting some components pass through it and retaining others depending on the molecular size, with a pressure gradient being the driving force of the process.

The feed (crude milk) was pumped through a frontal polyethylene microfiltration (MF) filter with a pore size of $5\text{--}10\ \mu\text{m}$ (Pall Corporation, USA) at room temperature ($24 \pm 1^\circ\text{C}$), which is shown in **Figure 1**. Applied transmembrane pressure and recirculation rate were controlled by a valve and by the feed rate, supplied by the variable speed pump from a feed tank. The pressure applied to the membrane was measured with a manometer, and the permeate was determined by measuring the filtrate volume collected during a certain period of time. This procedure reduced the amount of bacteria and spores and acted as cold pasteurization. The filter was cleaned and sanitized after each experiment and exchanged periodically.

The operation was carried out in three stages, taking a sample from each of them, in order to determine the degree of skimming of the milk in each step for which the fat content was determined.

2.3 Soft cheese manufacture

Partially skimmed milk was divided in different portions of 2.5 L for each batch. One of the portions was reserved to produce a low-fat cheese as a control

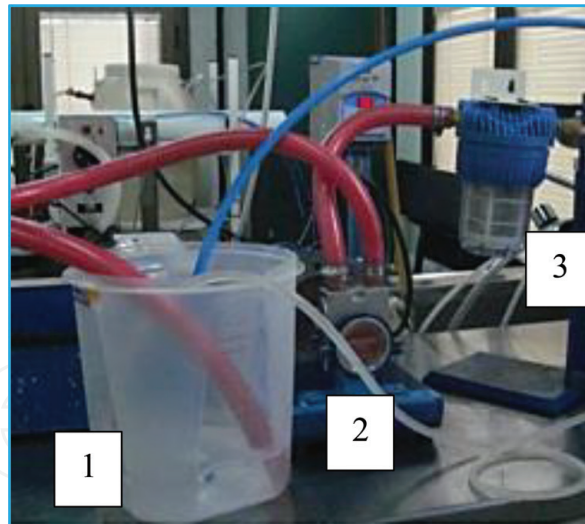


Figure 1.
Frontal MF equipment, used in the skimming of raw milk. ($T = 24 \pm 1^\circ\text{C}$): 1: feed tank; 2: pump; 3: MF filter.

(LFCC) sample, and to the rest of the portions, different fructans as inulin GR and HP (at 3 and 5% w/v) and NF [in concentrations of 0.5 and 5% (w/v)] were added. Full-fat control cheeses (FFCC), without fructans, were also produced for comparison.

Different tests were carried out in the stage of FOS aggregation, searching the way in which it would be better retained within the cheese matrix and thus obtaining a food rich in fibers. The alternatives assayed in cheeses elaboration are described as follows:

a. Preparation of samples with added inulin powder

All samples were made in duplicate. The inulin powder previously weighed according to the desired final percentage was added. The addition was done smoothly and slowly by stirring continuously to avoid the formation of lumps. Once the addition of the carbohydrate was done, the elaboration was continued according to the steps described in **Figure 2**.

The samples obtained by this process were labeled as M1 and M2:

- M1: sample with 125 g of inulin powder (5% w/v)
- M2: sample with 37.5 g of inulin powder (1.5% w/v)

b. Preparation of samples with added inulin in gel

Other forms of addition were investigated, such as the addition of carbohydrate prior to the formation of a gel [7]. Inulin shows high-level gelling properties, forming a three-dimensional network of insoluble submicron particles with a large amount of immobilized water, which ensures physical stability.

Regarding the gels made in the laboratory, it was found that the gel with 30% inulin with a heating time of 20 min was the one that exhibited the best consistency. In this way, the cheese samples were developed with incorporated inulin as gel (formed at 30% w/v) in different stages of the elaboration, resulting in samples M3 and M4 (**Figure 2**):

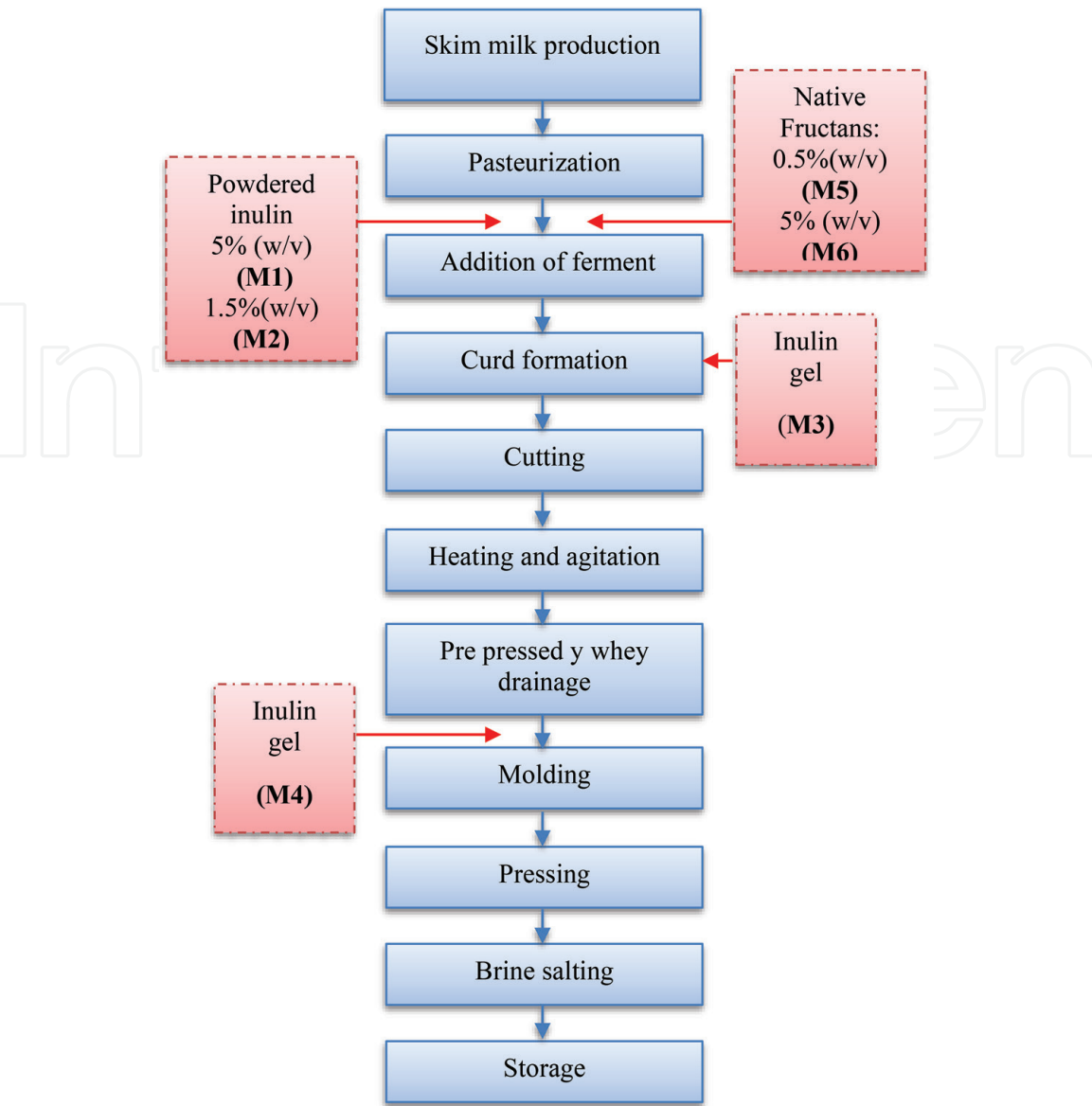


Figure 2.
Flowchart of the soft cheese making process with and without FOS.

- M3: Addition after the incorporation of the rennet and before the curd is formed
- M4: Incorporation of the gel after the syneresis stage, mixing, and molding

c. Preparation of samples with added native agave fructans powder

NF in concentrations of 0.5% and 5% (w/v) was added in powder in the same way as inulin, as is indicated in **Figure 2**.

The samples obtained were identified as:

- M5: addition of FN 0.5%
- M6: addition of FN 5%

Production was carried out in a batch process. Each formulation was replicated at least twice and analyzed independently; also each set of samples was made in the same day. The initial pH was measured (6.89 ± 0.10).

Pasteurization is an operation that is carried out to destroy the pathogenic flora and reduce the banal flora or alteration, so the milk was heated to $65 \pm 1^\circ\text{C}$ and kept at this temperature for 30 min. After that time it was quickly cooled using an ice bath. After the addition of fructans in any way, the samples were mixed. Then the temperature was brought to $34.5 \pm 2^\circ\text{C}$, and 1 g of CaCl_2 (BDH Chemicals Laboratory Reagents, United Kingdom) was added which contributes to obtain a proper floc. Then the ferment (0.1 g) was added to the batches. When the pH was at 6.5 ± 0.2 , the temperature was raised to $37.5 \pm 0.5^\circ\text{C}$, and enzymatic coagulant in powder (0.1 g) was added for coagulation, allowing acting for 40 min. To make sure that the coagulation has come to an end, a knife was placed in the dough, and it was checked that it comes out dry, without curd remains, which indicates that it has already been formed.

Cutting was done 35 ± 5 min later, the grains remained in suspension, and the dough was heated 2°C above the coagulation temperature and was gently stirred (avoiding breaking the curd cubes) and allowed to settle for 10 min. The curd was cut with a curd knife in the shape of 2-cm^3 cubes. The cut curd was allowed to settle for 10 min. Then the temperature was increased by $2 \pm 0.5^\circ\text{C}$ while gently mixing so as not to break the curd granules. After that, the samples were poured onto a sieve covered with a cheesecloth for drainage of whey, which was collected in a graduated cylinder. This process facilitates the release of the grain serum from the dough. The cheese curds were put into cylindrical plastic molds of 250 g (Vigna S.A., Argentina) and pressed during 1 h and half of each side (**Figure 3a**). A posterior mold-pressing stage was carried out in an artisanal cheese press (**Figure 3b**) and adjusted to exert pressure on the molds allowing the draining of excess serum. The pressing time was varying between the different batches according to the pH which was decreased to the desired value: 5.4 ± 0.1 . Then the samples were placed in saturated brine, calculating the dwell time in the brine according to the weight of the cheeses. The salt regulates the development of microorganisms, enhancing flavors and contributing to the formation of the product's crust. The brine was prepared at a concentration of 21°Baumé ($^\circ\text{Be}$), which is the recommended concentration for soft cheese.

The samples were remained at $6 \pm 2^\circ\text{C}$ in a refrigerator and after 24 h were packaged with a plastic film.

2.4 Preadable cream cheese manufacture with added inulin

The addition of native or short-chain inulin (GR) and high-performance (HP) inulin in cream cheeses was studied. These samples were elaborated in the National

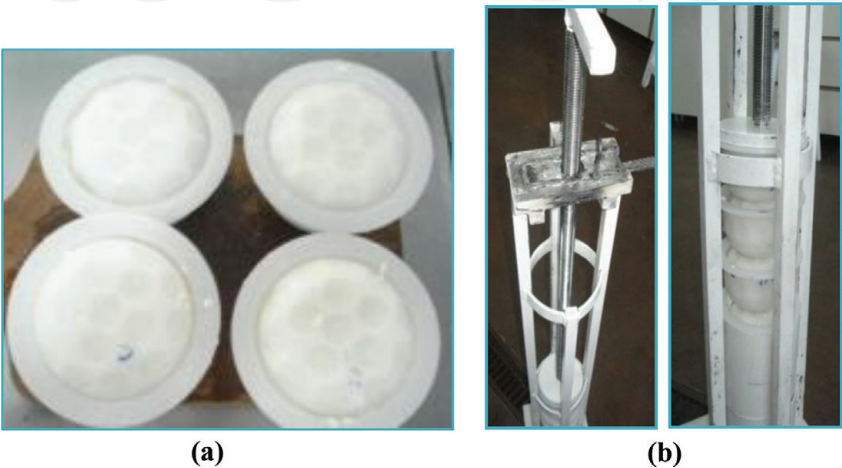


Figure 3.
(a) Plastic molds with cheese samples, (b) cheese press.

Institute of Industrial Technology (INTI of Argentina). **Figure 4** shows the general flow diagram used. In this case the raw material (milk) was provided by Mastellone S.A. (Buenos Aires, Argentina).

The elaboration process was in batch of 20 l of milk. Once the milk was received, a filtering was done to eliminate impurities, and physicochemical determinations were performed.

Pasteurization was carried out at $85 \pm 1^\circ\text{C}$ for 30 min. As in the soft cheeses with inulin, after pasteurization, the milk was quickly cooled in an ice bath until reaching

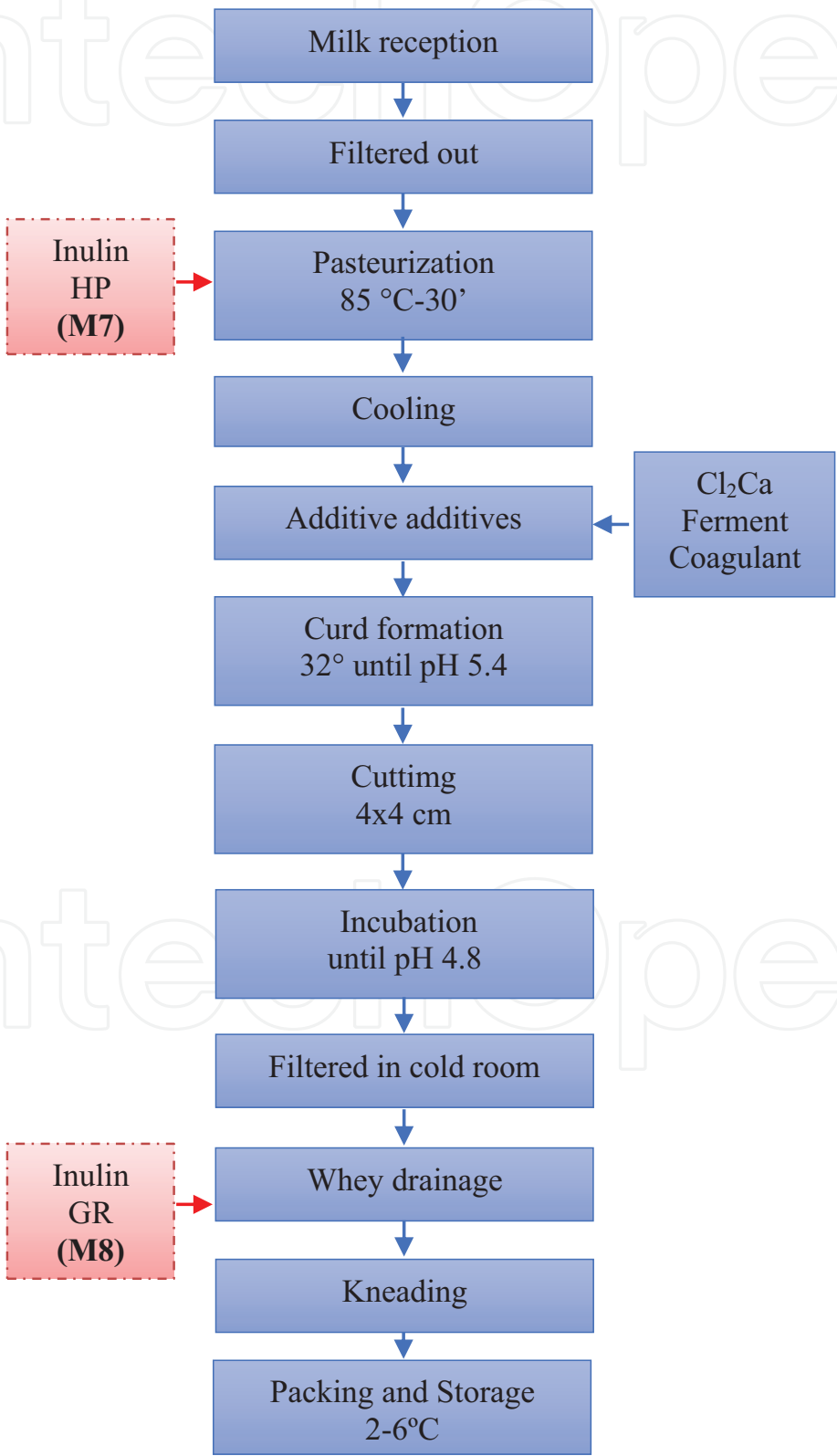


Figure 4.
Flowchart of the cream cheese making process.



Figure 5.
(a) Kneader used in the production of cream cheese (b) and cream cheese.

$33 \pm 1^\circ\text{C}$, optimum temperature for the addition of ferment and other additives. In this case, 0.042 g/l of ferment (Sacco M032), 0.13 g/l of CaCl_2 (78% purity), and 0.5 ml/l of rennet Chy Max M200 (1/100 dilution) were added, and it was left incubating until it reached pH 5.4. A control sample without inulin was reserved, and the rest incorporated the polysaccharide in different percentages. Short-chain inulin GR was used in concentrations of 3 and 5% (w/w) and long-chain HP at 5% (w/v).

Once the curd was formed, cuts of 4×4 cm were made with a lyre and led to take out the whey in a cold chamber until reaching a pH of 4.8 ± 0.1 ; for this, a cheesecloth was used, like in the production of soft cheeses. It was allowed to run through the night, and then the shaking or texturing stage was reached with a Hobart mixer (USA), shown in **Figure 5a**. The process consisted of 30 s of shaking at speed 1 and then 1.5 min at speed 2, adding inulin during this stage. After shaking, the product was placed in plastic pots (**Figure 5b**) to be taken to the cold room where they were stored for 24 h before making the physicochemical determinations.

Inulin GR (native or short-chain inulin) was added in the texturing or kneading stage, in the form of rain, continuously kneading until a homogenous mixture was obtained. The amounts added were 3% (28.35 g) and 5% (47.25 g), obtaining the samples denominated as M7, M8. HP inulin was added in the pasteurization stage, since it is much more soluble than GR and only in the 5% concentration (47.25 g) reaching to sample M9.

2.5 Analysis

Raw materials and cheeses samples were analyzed in duplicate according to standard replication AOAC [8]. Analyses were performed after 48 h of sample elaboration.

pH was measured using a digital pH-meter (Testo 206-pH 2, Germany).

The 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 6.38 (AOAC 991.22). The fat content was measured by the Rosse-Gottlieb method (AOAC 933.05). Total solids were determined by weight difference, drying in an oven at $70 \pm 1^\circ\text{C}$, during 24 h (AOAC 925.23). The moisture content was determined by

gravimetric method (IDF 1982). 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 total carbohydrates (lactose plus fructan) was carried out in whey, sub-product of cheese manufacture, using a refractometer (Arcano, China, range 0–32°Brix) in which the soluble compounds are expressed as °Brix. The measurement takes only few seconds [2]. The determination of fructan was made by difference between the amount of total carbohydrates measured and the lactose recorded in the control sample. The fructan value retained in cheeses was obtained by difference between the amount of fructan added and the amount found in the whey.

Also inulin was determined by anion-exchange high-performance liquid chromatography (HPLC) method following water extraction of inulin. HPLC conditions included an Aminex HPX-87C column (Bio-Rad), deionized water at 85°C as the mobile phase with a flow rate of 0.6 ml/min, and a refractive index detector [9].

The surface color was measured by a digital spectrophotometer (Mini Scan EZ, USA) provided with the software. The chromometer was calibrated with the standard white and black color. The results reported are averages of measurements of three slices (five measurements per slice), using CIELAB L^* , a^* , and b^* values. L^* value is the lightness variable from 100 for perfect white to zero for black, while a^* and b^* values are the chromaticity values, +redness/-greenness and + yellowness/-blueness, respectively.

Instrumental texture analysis was determined using the TAXT Stable Microsystems analyzer (London, United Kingdom). A compression test was carried out, using a 5-mm cylindrical test tube and with the following test parameters: pretest speed, 2 mm/seg; test speed, 1 mm/seg; distance, 10 mm; and trigger, 3 g. The assessment was performed in triplicate at $9 \pm 2^\circ\text{C}$.

The sensory evaluation was carried out following different protocols. The samples of soft cheese were tested in a uniformly illuminated room, by 45 members of a semi-trained panel selected from a pool of students and staff members of our department. Prior to assessment, each model cheese sample was divided into various portions and equilibrated at room temperature ($22 \pm 2^\circ\text{C}$). A discrimination test was employed in which the evaluator had to establish the difference between a control sample and one or more problem samples, using a scale from 0 (no difference) to 6 (very much different). The samples were coded with three-digit random numbers and were presented in pairs: control vs. sample and control vs. control (as blind witness). The attributes evaluated comparatively were flavor, color, texture, sweetness, and acidity. Panelists were exposed to each sample on an individual Petri plastic dish and were asked to assess a number of specific attributes. Water was provided for rinsing between samples, to clean the palate [10]. The average for all attributes of the sample was calculated, and the differences were analyzed with the analysis of variance using the statistical software GraphPad InStat.

The analysis of samples of cream cheese were carried up by a panel composed of 10 blind and visually impaired people belonging to INTI-Dairy (Buenos Aires), which was selected and trained according to IRAM Norms 20,001/20,002/20,004/20,005 and 20,006.

For the determination of the texture and flavor profiles, the Quantitative Descriptive Analysis (QDA) technique contemplated in IRAM Standards 20,012 and 20,013 was used. These standards contemplate the analysis of the texture profile and procedures indicated in the “Guide D’Evaluation Sensorielle de la Texture des fromages a pâte dure ou semidure,” 1994, of the European Union.

From the texture profile, the following descriptors were determined: (a) adherence, work that must be done with the tongue to detach a product stuck on the palate and the teeth; (b) solubility, a sensation that is highlighted when the sample melts very quickly in the saliva after chewing it four times with the

molars; (c) humidity impression, perception of the moisture content of a food by means of tactile receptors in the mouth; (d) creaminess, a combination of properties such as viscosity, particle size, and lubrication; and (e) microstructure, related with geometric properties, particle size, shape, and arrangement, of the particles.

In the analysis of the flavor profile of cream cheeses, the following descriptors were evaluated, salty taste, sweet taste, bitter taste acid, and global persistence, relative to the response to a stimulus associated with a measurable period of time (IRAM 20001). Increasing continuous scales from 1 to 7 were used to express the intensity perceived in each descriptor. The panelists worked individually in booths analyzing in triplicate a number of two samples per session. Before performing the analysis, the samples were stabilized for 1 h at $9 \pm 2^\circ\text{C}$ and were presented inside sterilized glass vessels.

Data from the cheesemaking trials was statistically analyzed using the computer program “GraphPadInStat.” The obtained data were statistically evaluated by the Tukey-Kramer multiple comparison test in the cases where two or more comparisons were considered. Otherwise, the t-test was used, assuming that a $p < 0.05$ was statistically significant [11].

3. Characterization of the skimming of raw milk by microfiltration

The raw material analysis indicated that it has a pH of 6.89 ± 0.02 and the following composition in w/100 g, 3.50 ± 0.08 of proteins, 2.00 ± 0.18 of fat, 50.00 ± 0.30 of saccharides, and 0.70 ± 0.05 of ash.

The results obtained showed that a fat content reduction of 76% (w/v) was achieved during the first stage, confirming that milk skimming by microfiltration was effective to obtain samples reduced in fat. The conventional operation to perform the separation of fat globules from milk is centrifugation. The decantation and spontaneous coalescence of the fat globules on the surface of the milk is slow; for this reason it is necessary to accelerate it by means of centrifugal separators. However, this technique presents difficulties during the separation of the fatty phase and requires the application of a high mechanical force. In the case of MF, fats are retained in the membrane. Thus, filtration technology is an effective way to achieve superior quality and safety, without compromising the fundamental sensory characteristics of the product. Also elimination of unwanted ingredients, such as microorganisms or sediments, which have a negative effect on quality, can be done, improving the texture of the final product and increasing its duration. On the other hand, it can shorten the stages of production and increase the yield, allowing a high degree of selectivity, and its energy costs are reduced. Similar results were reported in Refs. [12, 13].

4. Physicochemical and sensory characterization of cream cheeses with and without FOS

The results of the physicochemical characterization of the products are shown in **Table 1**. As expected, the highest change was in the fat cheese composition, between the full-fat cheese control and the rest of samples ($p < 0.05$). The codex general standard for cheese [14] determined that the FFCC obtained corresponds to a medium-fat cheese (25–45% w/w fat on dry basis) and the rest of the samples developed, to a low-fat cheese (10–25% w/w fat on dry basis). As the fat content

Sample	Moisture (%w/w)	Proteins (%w/w)	Fat (%w/w)	Ash (%w/w)	Carbohydrates (%w/w)
FFCC	46.05 ± 2.5	23.06 ± 1.5	24.07 ± 3.45	3.8 ± 0.32	3.02 ± 1.05
LFCC	48.95 ± 4.35	26.18 ± 1.01	15.83 ± 1.17	4.05 ± 0.35	4.99 ± 1.15
M1-inuline (5%)	49.09 ± 1.35	25.52 ± 1.02	13.98 ± 0.40	3.89 ± 0.44	7.52 ± 0.50
M2-inuline (1.5%)	49.01 ± 1.46	26.37 ± 2.17	14.16 ± 2.69	4.27 ± 0.47	6.144 ± 2.46
M5-agave fructan (0.5%)	48.14 ± 1.67	28.45 ± 0.76	12.98 ± 0.55	4.05 ± 0.19	6.38 ± 1.92
M6-agave fructan (5%)	47.46 ± 1.90	30.58 ± 0.54	12.52 ± 0.14	3.67 ± 0.13	5.77 ± 0.72

Table 1.
Physicochemical characterization of cream cheeses with and without FOS, at different concentrations (means ± SD).

of cheese is lowered, moisture content increases, and protein plays a greater role in texture development [15]. Thus, according to the Argentinean legislation [16], the samples correspond to cheeses of high moisture (46–54.9% w/w of moisture content) and reduced in fat (10.0–24.9% w/w of fat content).

The samples M3 and M4, with inulin added as gel in different steps of cheese-making (**Figure 2**), have similar composition with that of M2 samples.

The samples with fructans showed an appropriate protein retention, higher than other results reported in Ref. [17], being the formulations with native fructans which retained the higher amount of fructans (M5 and M6), where a higher concentration of the NF affects greater protein retention ($p < 0.05$). This difference is attributed to the fact that, as mentioned, these fructans have a branched structure that can contribute better to forming a protein-saccharide network. The role of the agave fructans in the cheese matrix is significant, taking into account that they are considered as soluble fiber from natural and abundant sources, categorized as prebiotics. Thus, they become a valuable alternative as a functional ingredient in order to obtain functional foods.

Regarding the carbohydrate values, the amount of specific FOS retained by the matrix was determined by HPLC. The results are presented in **Table 2**.

The results showed that the amount of inulin retained in M1 and M2 was very low probably due to its high solubility. The inulin incorporated as a gel at different times of the elaboration stage showed better results in terms of retention; however, it did not meet the expectations for the formulation of a functional type of cheese. Greater retention was achieved in the case of native agave fructan, probably as mentioned by the type of structure and lower solubility that allowed obtaining a microstructure with the proteins very similar to that of the whole control cheese sample, as was reported by SEM studies by [2].

The color determination in the samples is presented in **Table 3**.

Control samples and cheeses with fructans showed high L^* value (> 80) which indicates the degree of luminosity; this parameter has a greater impact on the perceived appearance of the product. The values obtained were similar to other soft cheeses reported in the literature [18]. The values of a^* were positive close to zero without presenting significant differences between the samples ($p > 0.05$). The positive value of b^* indicated the degree of yellow hue. These values are adequate considering that they are low-fat cheeses and the elimination of fat imparts a translucent appearance. In effect, the colorimetric parameters obtained were in the order

Sample	Inulin (%w/w)
FFCC	—
LFCC	—
M1-inuline (5%)	1.04 ± 0.11
M2-inuline (1.5%)	0.65 ± 0.09
M3-inuline gel	1.80 ± 0.11
M4-inuline gel	1.30 ± 0.17
M5-agave fructan (0.5%)	0.90 ± 0.11
M6-agave fructan (5%)	4.12 ± 0.15

Table 2.
Determination of FOS in the samples of cheese (means ± SD).

Sample	L	a	b
FFCC	85.30 ± 2.14	1.20 ± 0.11	18.37 ± 2.43
LFCC	86.11 ± 3.41	0.19 ± 0.16	14.89 ± 2.57
M1-inuline (5%)	84.58 ± 2.12	0.57 ± 1.12	17.32 ± 0.6 5
M2-inuline (1.5%)	82.26 ± 2.14	0.27 ± 0.15	16.90 ± 1.14
FN 0.5	81.50 ± 1.01	0.48 ± 0.18	16.32 ± 1.13
FN 5	89.60 ± 1.14	0.34 ± 0.09	16.66 ± 0.45

Table 3.
Surface cheese-like product color (means ± SD).

of those reported for low-fat cheeses without coloring [19]. The results verified that the presence of fructans did not significantly affect the color of the samples with respect to the control cheese.

The sensorial analysis indicates a good acceptance of all the products according to the concentration range employed and did not present significant difference with regard to the control samples, indicating that the FOS did not affect these parameters. Even though it would be difficult to mimic entirely a full-fat cheese after fat has been removed, the presence of fructans in reduced fat formulations suggests an acceptable likeness in relation to structure and general characteristics of the full-fat control cheese. This fact constitutes a technological challenge.

5. Characterization of soft cheeses with added inulin

5.1 Physicochemical composition

Table 4 shows the physicochemical composition of the soft cheese samples carried out by the process described in **Figure 4**, with inulin GR and HP added at 3% and 5% (w/v), which were also compared with a control samples without the polysaccharide (LFCC).

Each of these determinations was carried out in duplicate following the methodologies described for cream cheeses.

The results show that the cheeses are of high-moisture, higher than 70% w/w and low in fat minor of 11% w/w. In the case of carbohydrates, it is demonstrated that the addition of inulin was effectively retained in the cheese matrix, in

Sample	Moisture (%w/w)	Fat (%w/w)	Protein (%w/w)	Carbohydrates (%w/w)	Ash (%w/w)
LFCC	74.06 ± 0.88	10.90 ± 0.14	10.79 ± 1.28	3.61 ± 0.57	0.65 ± 0.02
GR3	73.54 ± 3.31	10.23 ± 1.91	10.21 ± 1.75	6.52 ± 0.46	0.61 ± 0.03
GR5	73.56 ± 2.59	9.50 ± 1.41	8.57 ± 1.58	7.76 ± 0.42	0.63 ± 0.00
HP5	74.48 ± 1.20	10.80 ± 1.33	9.48 ± 0.99	5.36 ± 0.40	0.68 ± 0.00

Table 4.
Physicochemical characterization of soft cheeses with and without FOS, at different concentrations (means ± SD).

Sample	Inulin (%w/w)*
C	0 ± 0.00
GR3	2.91 ± 0.13
GR5	2.84 ± 0.19
HP	0 ± 0.00
HP (in whey)	5.29 ± 0.01

*Detection limit: 0.01 g/100 g

Table 5.
Inulin determination in soft cheese by HPLC (mean ± SD).

particular for the GR inulin since the increments found correspond to the quantities actually added. The determination by HPLC corroborated this result as it is shown in **Table 5**.

Cream cheese samples with inulin GR showed a retention of almost 100% of the added inulin. However, the HP inulin added to the sample was completely lost in the serum corresponding to that sample.

The AFC (Chap. XVII, Art. 1386) indicates that for a food to be considered with added fiber, it must have at least 3 g/100 g in the case of solid foods and 1 g/100 ml of liquid foods. In the USA, the recommended daily consumption is 1–4 g/day, while in Europe a consumption of 3–11 g/day is suggested. Taking into account the results, we can say that the inulin content is high with respect to the recommended amounts and that the cheeses were effectively enriched in fibers.

5.2 Sensory evaluation of soft cheese with and without inulin

The results obtained in the sensory evaluation carried out by the trained panel of INTI-Dairy are presented in **Table 6**.

In this analysis, a sample of commercial spreadable cheese (CC), with similar characteristics, without fructans was added. The results of the sensory analysis indicated significant differences in the sweet flavor attribute and in the texture attribute creaminess and microstructure. The rest of the parameters analyzed did not show significant differences. Regarding the sweet taste, the difference found between the control sample (LFCC) and the sample with 5% inulin GR (GR5) may be due to the sweetening power of inulin, which, although much lower than that of sucrose, is considered a natural sweetener and when increasing the concentration it seems that it begins to be noticed. The differences found in the creaminess and the microstructure may be due to the kneading conditions, as it is known that this mechanical treatment significantly influences the expression of the aforementioned parameters.

Sample	Sweet	Salad	Acid	Bitter	Persistence	Adherence	Creaminess	Moisture Impression	Microstructure	Solubility
LFCC	2.06 ^a ± 0.78	2.38 ± 0.99	4.19 ± 0.75	2.63 ± 0.86	3.75 ± 0.83	3.13 ± 1.83	5.13 ^a ± 1.36	3.25 ± 1.48	2.06 ^a ± 1.18	5.63 ± 0.92
CC	2.50 ^{a,b} ± 0.93	2.63 ± 1.11	4.56 ± 1.11	3.44 ± 0.46	4.00 ± 1.41	3.75 ± 2.22	3.81 ^{a,b} ± 0.86	3.56 ± 1.26	2.75 ^{a,c} ± 1.09	5.50 ± 1.31
GR3	2.50 ^{a,b} ± 1.31	2.06 ± 0.95	4.00 ± 0.87	3.31 ± 0.66	3.69 ± 1.48	1.94 ± 1.13	3.06 ^b ± 1.33	4.13 ± 1.62	5.25 ^b ± 0.97	5.25 ± 1.58
GR5	3.63 ^b ± 1.22	2.19 ± 0.61	4.00 ± 0.87	2.56 ± 0.68	3.25 ± 0.97	3.06 ± 2.01	5.00 ^a ± 1.22	3.81 ± 1.27	1.94 ^a ± 0.81	5.38 ± 1.19
HP5	2.25 ^{a,b} ± 0.86	2.5 ± 0.85	4.38 ± 1.24	3.13 ± 0.91	3.63 ± 1.22	3.29 ± 1.78	4.94 ^a ± 1.21	3.60 ± 1.31	3.69 ^c ± 0.94	5.19 ± 1.22

The supra-indices a, b, and c indicate significant differences between the results in the same column ($p < 0.05$).

Table 6.
Sensory analysis results of soft cheeses with inulin GR and HP (mean ± SD).

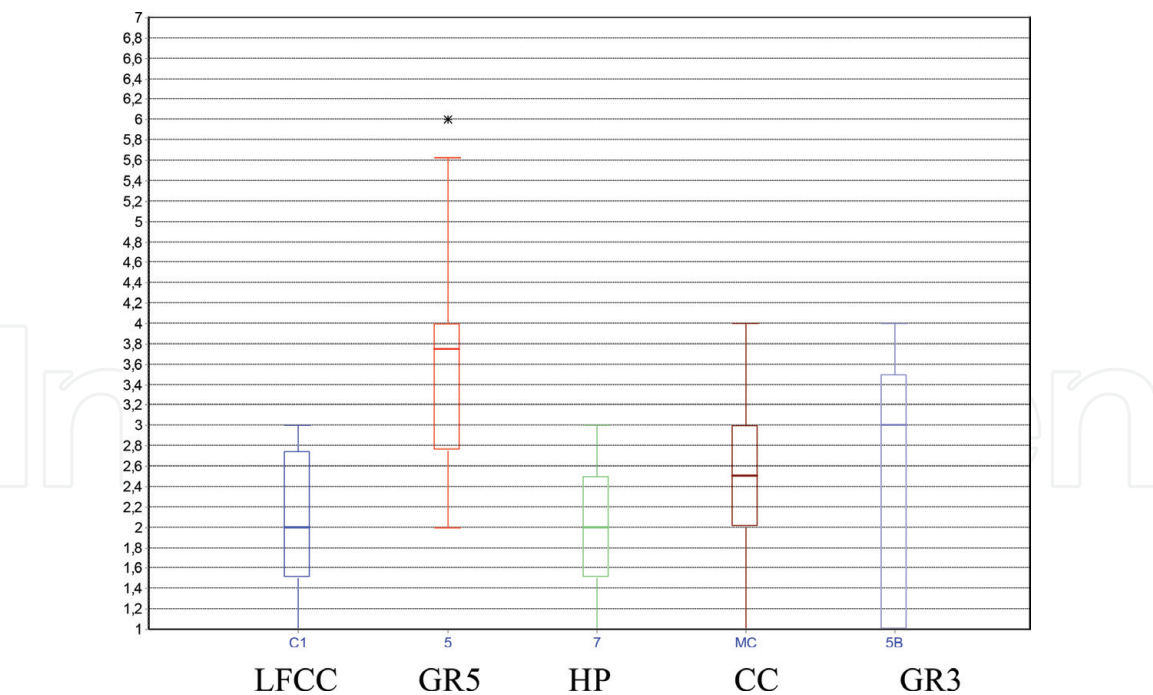


Figure 6.
Box plots for the sweet taste attribute of the spreadable soft cheeses.

Sample	Adhesion (g/sec)	F _{max} (g)	Elasticity	Work _{max} (g/sec)
LFCC	88.28 ± 6.15	20.41 ± 1.09	9.96 ± 0.06	151.24 ± 10.31
GR3	86.21 ± 3.61	15.77 ± 0.88	9.96 ± 0.02	114.48 ± 4.70
HP5	83.78 ± ±8.74	16.57 ± 0.50	9.97 ± 0.03	118.95 ± 7.35

Table 7.
Instrumental texture of soft cheeses with and without inulin (mean ± SD).

Additionally, a statistical analysis of boxes and mustache or box plots was made for the different attributes. **Figure 6** shows the graph obtained for the sweet taste, where the significant difference between the control sample and the GR5 inulin sample can be seen more clearly.

The data obtained for instrumental analysis texture is presented in **Table 7**. This analysis was performed in triplicate.

Significant differences were found in the maximum work values between the cheese samples with inulin and the control sample. In this sense, inulin in general modifies the hardness of foods, increasing this parameter according to the food formulation in which it is applied, as was previously shown [20]. However, in the hardness results of the samples analyzed, they show a decrease in this parameter.

This may be due to the fact that the presence of serum proteins disturbs the fine structure that is formed between the inulin crystals by Van der Waals bonds, allowing the gel formation, generating a decrease in hardness [7].

6. Conclusions

In this chapter, different experiments of incorporation of fructans in cheese-making matrices were carried out, trying to obtain a reduced fat cheese additive with compounds that behave like prebiotics and act as dietary fiber. This search led to the testing the incorporation of inulins of different origin and degree of polymerization to two types of cheese: soft and cream cheese.

From the wide experimentation carried out, it was possible to conclude that in the development of soft cheeses with inulin, in all cases the samples had a reduced fat content and high humidity. The texture and the micrographs showed adequate similarity with the control cheeses without the addition of inulin. However, the inulin retention was insufficient to have a food with the desired functional characteristics.

In the case of cheeses with agave fructans, a greater retention of the oligosaccharide was shown, given that it has a more branched structure that probably contributes to a better retention through the protein matrix. On the other hand, the determinations of color, texture, and sensory analysis did not show significant differences by the addition of the fructan. This conclusion is important since it opens the possibility of diversifying the uses of agave, a plant of rapid and widespread growth in America.

Finally, the experiments made with creamy cheeses, type spreads indicated that the composition of these samples responded to a high content of moisture and low-fat content, where proteins and carbohydrates adequately compensated the texture of the samples. But in this case, it was determined that GR inulin (native or short-chain inulin) was retained 100% in the cheese matrix, obtaining a product with the desired functional characteristics.

The sensory and texture profiles additionally showed that they are cheeses similar to the control samples with adequate parameters that make the product obtain a spreadable cheese with functional characteristics according to the needs of the market.

Even though it would be difficult to mimic entirely a full-fat cheese after fat has been weakened, the presence of FOS in reduced fat formulations suggests an acceptable likeness in relation to structure and general characteristics of the full-fat control cheese. This fact constitutes a technological challenge. The role of fructans in the cheese matrix is significant, taking into account that they are considered as soluble fiber from natural and abundant sources, categorized as prebiotics. Thus, they become a valuable alternative as a functional ingredient in order to obtain functional foods.

Future work should be carried out to confirm these findings and thus optimize the addition of fructans in different formulations of dairy products.

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Conflict of interest

There is no conflict of interest in the work presented.

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Acronyms

AFC	Argentine Food Code
AOAC	Association of Official Agricultural Chemists
FFCC	full-fat control cheese
FOS	fructooligosaccharide
GR	native or short-chain inulin
HP	high-performance inulin
HPLC	high-performance liquid chromatography
IRAM	Instituto Argentino de Normalización y Certificación
LFCC	low-fat control cheese
MF	microfiltration
NF	native fructans

Author details

Diana Palatnik¹, Noelia Rinaldoni¹, Diego Corrales², María L. Rolon², Haydée Montero², Germán Aranibar², María L. Castells², Noemi Zaritzky² and Mercedes E. Campderrós^{1*}

1 Faculty of Chemistry, Biochemistry and Pharmacy, National University of San Luis, Chemical Technology Research Institute (INTEQUI), CONICET, San Luis, Argentina

2 Center of Research and Development in Food Criotechnology CIDCA (UNLP-CONICET—CIC), Faculty of Engineering, University of La Plata UNLP, La Plata, Buenos Aires, Argentina

*Address all correspondence to: mcampd@gmail.com

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