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Training small producers in Good Manufacturing Practices for the development of goat milk cheese

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Abstract

Training in Good Manufacturing Practices enhances quality during food processing. This paper evaluates GMP training aimed at improving the chemical, sensory and microbiological quality of goat milk cheese. We worked with 26 families that produce cheese as their main source of income. Semi-structured interviews and observation were conducted to select relevant topics. The manufacturing processes were compared and samples were analyzed before and after GMP training. We trained 80% of the producers. Before receiving training, they used to make cheese from raw milk in unhygienic conditions and with little equipment. The products obtained had bad sensory characteristics, cracks, eyes on the pasta, a high number of aerobic mesophilic bacteria and total coliforms. After training, the producers pasteurized the milk and standardized processing procedures, resulting in final products that contained higher protein and calcium content, suitable sensory characteristics, and a significant reduction in microorganisms, with total coliforms falling to $\leq 5.10^3$ UFC/g. Therefore, this study shows that the manufacturing process and the chemical, sensory and microbiological parameters of goat milk cheese improved after GMP training.

Keywords: cheese; goat milk; Good Manufacturing Practices.

Practical Application: Enhance the manufacturing conditions in terms of nutrition, sensory characteristics, and hygiene.

1 Introduction

There are 86 million goats worldwide, mainly distributed in Asia (60% of the total) and Africa (34%). The rest is distributed in South America (2.5%), Europe (2.1%), Central America (1%) and North America and Oceania (less than 0.5% overall). In South America there are 21 million goats (Food Agricultural Organization of the United Nation, 2014).

Goat dairy in South America has a long tradition, but its full development has been hindered by regional economic fluctuations. However, milk production has gained considerable momentum in recent years as a result of the creation of commercial farms and the implementation of programs to improve this activity (Medina et al., 2011).

In Argentina there are 4,238,370 million heads of cattle, with 327,570 heads (Sistema Integrado de Gestión de Sanidad Animal, 2014) in Northwest Argentina (NOA). Most of these animals feed on grasslands, resulting in a lower cost for producers. At present, traditional goat production systems are characterized by low productivity and profitability of herds, predominance of extensive farming on natural grasslands and/or a type of land called *monte* in arid and semi-arid areas (Instituto Nacional de Tecnología Agropecuaria, 2006). Act No. 26.141, "Recovery, Promotion and Development of Goat Activity" (Argentina, 2006), was enacted in Argentina in September 2006 to improve production systems, maintain, develop, and increase jobs and settlement of rural populations, leading to a better quality of life. Since then, the production of cheese made from goat milk has increased from 1,319 tons (2006) to 4,800 tons (2012) (Sistema Integrado de Gestión de Sanidad Animal, 2014).

Goat farming in Argentina is associated with the livelihood of many families who live in arid agro-ecological regions susceptible to degradation by overgrazing and indiscriminate felling, with the resulting shortage of fodder (De Gea et al., 2006). In fact, goat is among the species best adapted to transform natural resources into products such as leather, meat, milk, and cheese, thus presenting encouraging prospects in domestic and international markets.

Non-traditional dairy farms, which produce and/or process goat milk, play an important role in the economic and social development of NOA regions (Instituto Nacional de Tecnología Agropecuaria, 2006), especially in the provinces of Salta, Jujuy, Catamarca, and Santiago del Estero. Thus, the inhabitants of a small community called El Rodeo (Salta, Argentina), located

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3,767 meters above sea level, make a living as traditional producers of goat milk cheese. They are able to obtain a particular and distinctive flavor, by following ancestral handmade techniques.

The Argentinian legislation does not provide a definition for this cheese, but it does for a similar one called *Queso Criollo.* It is described as cheese with high moisture and fat, prepared with whole milk or standardized milk, acidified by lactic bacteria and coagulated by rennet and/or specific enzymes (Administración Nacional de Medicamentos, Alimentos, y Tecnología Médica, 2015).

The producers and their families have some problems in common, mainly related to their low educational level and inadequate use of sanitary measures. Therefore, the implementation of Good Manufacturing Practices (GMP) during milking and dairy processing might prevent or reduce the contamination of dairy products by biological, chemical, and physical hazards (Administración Nacional de Medicamentos, Alimentos, y Tecnología Médica, 2015), while improving the chemical, sensory, and microbiological characteristics of goat milk cheese.

The aim of this work was to study the chemical, microbiological, and sensory qualities of goat milk cheese made by producers of El Rodeo. The samples were analyzed in two stages: before and after GMP training delivered to the producers.

2 Materials and methods

2.1 The population and animals

We worked with 26 aboriginal families that produce goat milk cheese in El Rodeo, Calchaquí Valley, Salta. Semi-structured interviews were administered in order to characterize the study population and goats. Direct observation was also conducted through home visits (homes and animal pens). The variables analyzed were educational level of the household head; family members; work activity; type of housing; number of animals, breed, type of feed, veterinary control, and vaccination.

2.2 Training in Good Manufacturing Practices

To select the areas for GMP training, a situation diagnosis was previously conducted through direct observation of the manufacturing process used by each producer. A check-list based on the resolution of MERCOSUR Technical Regulation No. 80/96 (Argentina, 2006) was used. This diagnosis comprised 4 areas: i) raw materials; ii) equipment and utensils; iii) place and hygiene during the production of cheese; and iv) handlers.

Each item on the check-list was evaluated so as to select the areas which the training would be based on. The subjects were invited to participate by radio broadcast and the training involved modular courses following the workshop methodology and including participatory activities, which made it possible to observe the skills and abilities learned by the participants. Each course included a final evaluation (Celi Soto & Pacheco Léon., 2009). The training sessions were conducted within a rural-marginal sector in order to help improve goat milk cheese producers' knowledge. The training was also replicated with students, teachers and principal at a nearby school, as well as the communities health workers and nurses. Posters and brochures were designed and made available to each producer family, and also distributed at the school, health center, and parish church.

2.3 Cheese production process and physicochemical, sensory, and microbiological characterization

The process of goat milk cheese production was characterized by means of direct observation of each producer, in two stages: before and after training, repeated twice each time. Timing, volume, and temperature, as well as the hygienic conditions of the site, utensils and handling were recorded during the manufacturing process.

The goat milk cheese was also analyzed before and after the educational intervention. Sliced and homogenized samples were wrapped in polyethylene film and packed in hermetically sealed styrofoam boxes. They were then transported to the Laboratory of Food Analysis at 3 °C, and stored refrigerated until chemical and sensory analysis.

The samples used for microbiological analysis were packed in sealed and individual PVC containers, and refrigerated at 3 °C until processing and homogenization in aseptic conditions under ultraviolet light. Then 25 grams of sample was homogenized and diluted in 150 cc of 0.85% sodium chloride solution ; pH 7, sterile (autoclaved at 121 °C for 15 min.). Dilutions were made from 10^{-3} to 10^{-5}.

Chemical Analyses: moisture (Association of Official Analytical Chemists, 1998); carbohydrates by difference; proteins; fats by Gerber (Administración Nacional de Medicamentos, Alimentos, y Tecnología Médica, 2015); total ash; phosphorus, and calcium (Association of Official Analytical Chemists, 1998). All determinations were performed in triplicate.

Sensory Analyses: A panel consisting of 10 trained assessors evaluated the characteristics of final products before training and in the field. The panelists received instructions from and exchanged views with a panel leader. Cheese samples were cut into cubes of uniform size, weighing approximately 30 ± 2 g, served at room temperature (25 °C) in disposable and transparent containers coded with a randomly chosen 3-digit number.

The evaluated aspects were general appearance (external); appearance and color of cheese rind; appearance and description of the cheese paste; and color of the cheese paste; odor/aroma and flavor of cheese paste. After GMP training, an evaluation was conducted at the Laboratory of Food Sensory Analysis, Facultad de Ciencias de la Salud, Universidad Nacional de Salta.

Microbiological analyses: Samples were plated in sterile Petri dish. They were determined by aerobic mesophilic plate count method; total coliforms were determined by Agar VRBA; *Escherichia coli (E. coli)* on EMB agar and *Staphylococcus aureus* on Baird Parker agar and Mannitol Salt, all incubated at 37 °C for 48 ± 2 hours. Microbiological standards were followed. Norms and values accepted by Argentinian law were used (Administración Nacional de Medicamentos, Alimentos, y Tecnología Médica, 2015). The results were reported as colony forming units per gram of food (CFU / g).

2.4 Statistical analysis

The chemical data were expressed as mean ± standard deviation (SD). After verification of a normal distribution of data, ANOVA and Duncan tests were used. Differences were considered significant at $P < 0.05$.

3 Results and discussion

3.1 Characterization of the population and animals

El Rodeo (Salta, Argentina) is located at 3,767 meters above sea level, in the Calchaquí Valley, where the homonymous Calchaquí river flows, irrigating the crops. The climate is temperate to cold, with little rainfall. It is a small and dispersed mountain community, which is difficult to reach. There is a health center with a permanent nurse, three community health workers and a doctor, who sees patients once a week; there is also a primary school where 70 children go and a Catholic parish church. People from other settlements like Molino Totoral, Orozco, La Falda, Las Peras, La Mesada, La Quesería and Sauzalito - located within 2-10 km - meet at El Rodeo. We worked with families from the whole area.

Concerning the educational level of the household head, 50% did not complete primary school, 40% completed it, and 6% did not attend school. Other authors also found a low educational level among goat cheese producers (De Gea et al., 2006), probably due to poor economic and social development, which characterizes isolated rural and mountain communities.

About 53% and 23.5% of the families were composed of 4-6 and 7-9 members, respectively, all families making a living as goat milk and cheese producers, associated with small-scale subsistence agriculture (broad beans, potatoes, peppers, corn) and domestic farming. Goats involve low investment costs, which makes them ideal for limited resource families. In addition, the ability of goats to utilize a wide variety of landscapes and their high production potential make them a good resource for rural women and kids.

Goat production is common in this region of the Calchaquí Valleys; each producing family has between 30 and 400 animals. About 350 goats (females at reproductive age) are required for profitable production. While some producers are far from the ideal figure, others approach it, thus constituting somewhat efficient units of production (Instituto Nacional de Tecnología Agropecuaria, 2006). The main breeds in this area are Creole, Saanen, or their cross breeds. Animals graze freely on natural areas, under the supervision of children, women or elderly men.

The manufacture of homemade cheese from goat milk is possibly due to socio-cultural and economic factors; it is a major source of food and nutrients and an important source of income for small farmers. Monzón (2013) argues that goat production in Argentina takes place in marginal geographic areas where feed resources are composed of the *monte* or natural grassland and show seasonality in the availability of dry matter.

No veterinary checks (vaccination or de-worming) are performed and some producers vaccinate their livestock by acquiring the medication on their own, so the animals do not possess a certificate issued by National Service of Agricultural and Food Safety (SENASA). Therefore, sanitary conditions would lead to occurrence and/or spread of diseases like brucellosis, symptomatic anthrax, and gangrene, among others.

3.2 Training in Good Manufacturing Practices

The following production practices were observed:

i) Raw material: 90% of the producers performed hand milking in the pen under poor hygienic conditions and using inadequate containers; 50% cooled the product with water from an irrigation ditch, not reaching 5 °C. All farmers used a piece of cloth to filter the milk.

ii) Equipment and utensils: The producers had no equipment to pasteurize goat milk, and they were short of utensils and elements required for proper manufacturing.

iii) Place and hygiene during the production of cheese: 30% of the farmers used a specific place for this process; the others manufactured goat milk cheese in the same physical space where family meals were prepared. Their houses have dirt floors, adobe walls, tin or thatched roof, with only one door and no windows. No sanitation programs are available. Pets (chickens, dogs, and cats) were observed inside the house. The water supply comes from a nearby river; it is stored in tanks and made drinkable by adding an adequate product (chlorine solution).

iv) Handlers: They wore everyday clothes, did not cover or tie back their hair, did not possess sanitary records, and their habits and behavior did not meet hygienic standards.

Before GMP training, several items that may pose great risks to food safety were found. For example, the lack of material resources (tools, uniforms, elements for pasteurization) and the low educational level of producers may contribute to establishing food-borne pathogens in the environment where cheese is processed, which may lead to persistence of microorganisms and contamination of the final product. Similarly, in a small mozzarella cheese-processing unit in Brazil, 60% of non-conformities with GMP were found concerning "personal hygiene" (Costa Dias et al., 2012).

As explained above, the topics selected for the training modules were as follows: importance of implementing hygienic and health practices by the dairy product handler; zoonoses and food-borne diseases; GMP at milking yards and dairy processing sites and in dairy production, labeling and packaging of goat milk cheese.

The training program reached 80% (n = 20) of the producers, who acquired hygienic habits. Each family was given equipment including stove, gas cylinder, thermometer; common and vacuum packaging machines; uniforms (apron, gumboots, cap); and utensils (measuring cup, airtight containers, wooden spoons). In addition, training in participatory techniques and activities led the producers to acquire knowledge and skills in their real context, which created a suitable atmosphere for learning.

3.3 Cheese production process and physicochemical, sensory, and microbiological characterization of goat milk cheese

Figure 1 shows the production process flow before and after training. Producers began working without proper hygienic conditions. The animals were milked in the pen, built with branches and stone walls, under unhygienic conditions, which led hair, dirt and other materials to fall into the milk, thus altering its quality. It is very important to note that the facilities should provide comfort and safety to the animals and facilitate their handling.

They should be built on easily accessible land that is well-drained, protected from winds, and having adequate water availability.

The amount of milk obtained ranged from 300-800 ml milk/day/animal, as compared with a proper goat milk production system, which yields a minimum output of 1500 ml per goat in optimum conditions (fodder, climate, and environment) (Monzón, 2013).

The amount of milk obtained ranged from 300-800 ml milk/day/animal, as compared with a proper goat milk production system, which yields a minimum output of 1500 ml per goat in optimum conditions (fodder, climate, and environment) (Monzón, 2013). The raw unpasteurized goat milk was transferred from the pen to the place where cheese was processed. The milk was filtered with a piece of cloth. The process took 2 hours. Production of cheese from raw milk, using traditional techniques is a common practice among producers in Northwest Argentina (Oliszewski et al., 2007).

Handmade rennet involves some advantages in that it is possible to maintain the local taste of cheese, thus conserving the sensory characteristics which account for its differentiation (Monzón, 2013). However, a lack of standardization was observed in the amount of rennet and salt added; similarly, neither timing nor temperature were recorded before proceeding to the next step.

Proper clotting point was determined empirically by introducing a finger in the curd. When the curd did not adhere to the finger, the producers considered that it was ready to be cut and used. The curd was cut and table or rock salt was added according to family tradition. Molding was performed with braided plant fibers called *cinchos* (adjustable belts) made by the producers themselves from a plant called *cortadera*, which

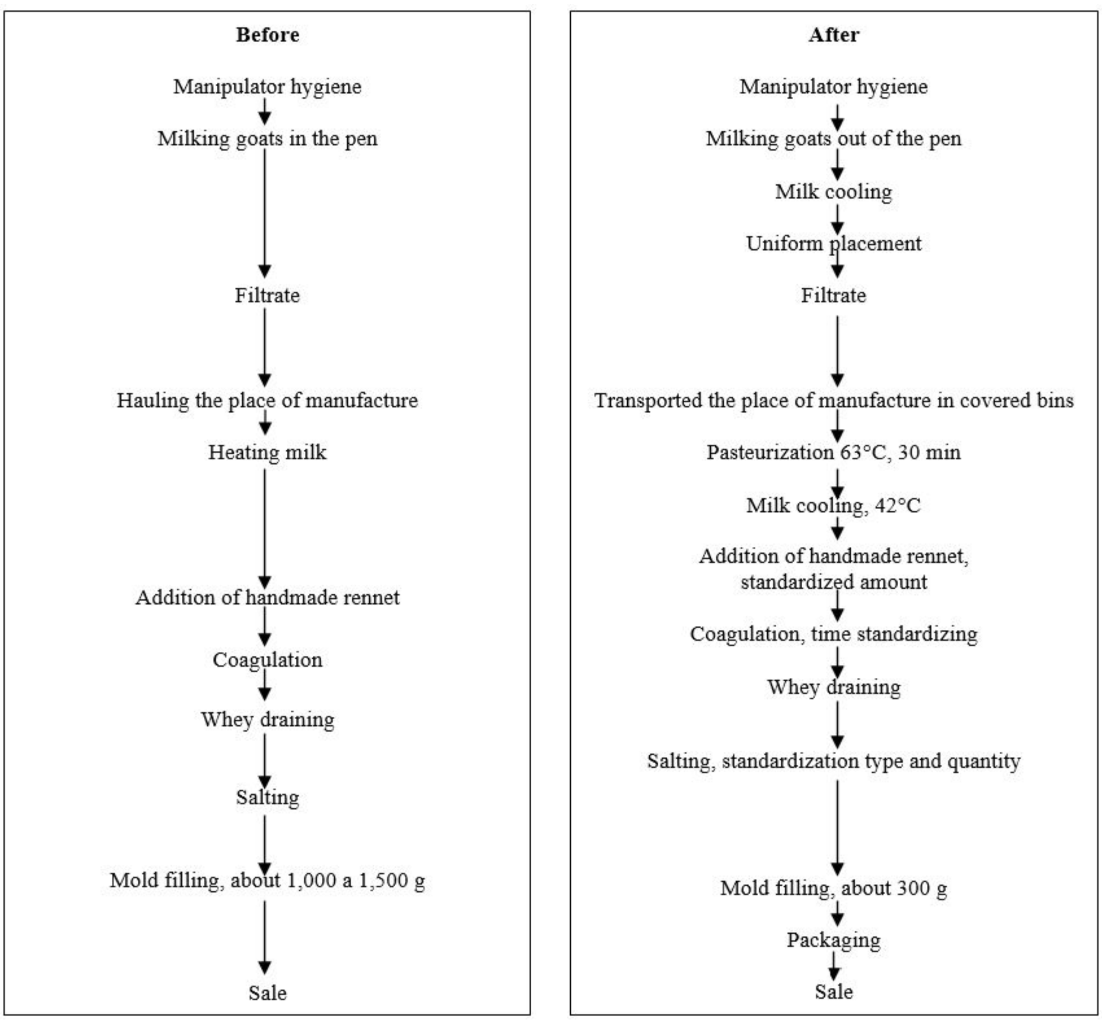

Figure 1. Goat milk cheese production process before and after training.

grows at river or stream banks. The diameter of the molds used ranged from 20 to 25 cm, yielding goat milk cheeses of approximately 1,000 to 1,500 g.

The curd was pressed between large stones for 24 hours. The cheeses were put on a shelf at room temperature to complete the draining. They had no rind or any covering, and were therefore exposed to air, which would favor microbial contamination. The cheeses were marketed in unhygienic conditions, through an intermediary agent, or by taking them to fairs in nearby villages.

The producers did not take into account the minimum monitoring checkpoints, such as temperatures, storage of raw materials (milk and rennet), washing and sanitizing mixing vessels, utensils, molds, and press. A similar situation was found in cheese producers of goat milk in Santiago del Estero, Argentina, who obtain milk by hand milking in the pen and process cheese from unpasteurized milk using natural rennet. Their cheeses weigh approximately 1,500 g., are stored in household refrigerators, sold through an intermediary on the route or by direct sales house to house (Monzón, 2013). Likewise, cheese from raw goat milk made in northern Morocco follows non standardized processes, where the raw material is clotted immediately after milking using natural rennet or the aqueous extract from *Cynara cardunculus* flowers. The curd is cut manually and the salting (1-2 g) helps to complete the draining process without pressing. The cheeses are kept in braided palm-leaf molds until they are sold (El Galiou et al., 2015).

After the training, the producers acquired adequate hygienic habits and personal behaviors. The utensils were sanitized before and after use, to prevent undesirable adhesion of milk residues which would result in microorganisms growth. The animal's udders were washed and milked in an exclusive place (pen sectorization). Producers wore uniforms (apron, gumboots, and cap). The cooling and storage processes were controlled when cheese making was not initiated immediately. The raw material was transported and pasteurized on a portable gas cooker; a digital thermometer and various utensils were used to facilitate the thermal process, carried out at 63 °C for 30 min. Pasteurization is considered beneficial because it decreases the initial loading of bacteria and therefore increases the life of products (Singh & Waungana, 2001). The goat milk was cooled at 42 °C (verified with thermometer) and the amount of rennet and the timing were standardized according to milk volume. The lyrate was performed using a knife and the draining was initiated.

Although molding was still performed by using plant fibers, the fibers were renewed and prepared for smaller products, weighing approximately 300 g. The product was salted by surface friction. Then the cheeses were pressed in improved hygienic conditions, allowed to mature in a closed place, and then packaged. The producers were provided with two types of packaging machine: traysealer with weight control and vacuum packaging. The type of marketing promoted was local direct sale, which benefits from tourist activity and fairs in nearby towns, where the selling price is increased.

Variations in the manufacturing process resulted in cheeses with different chemical composition. Statistical analyses of the compositional data showed that milk pasteurization significantly influenced the moisture, protein, and calcium and phosphorus contents of the cheese, but did not affect their fat content.

Figure 2 shows the mean values of the different components determined in the cheese. The moisture content of cheeses made from pasteurized milk was lower than that observed in cheeses made from raw milk.

The heat treatment of milk causes physicochemical changes that affect the chemical composition and cheese yield. When milk was heated above 60 °C, whey proteins were denatured by the deployment of polypeptide chains, the side chain groups in the native structure. Thus, the κ-casein deployed interacts with the surface of casein micelles or form aggregates with other serum proteins or other κ-casein, wherein reactions of thiol-disulfide exchange, ionic bonds and hydrophobic interactions occur (Singh & Waungana, 2001). In descending order, immunoglobulin, bovine serum albumin, β-lactoglobulin

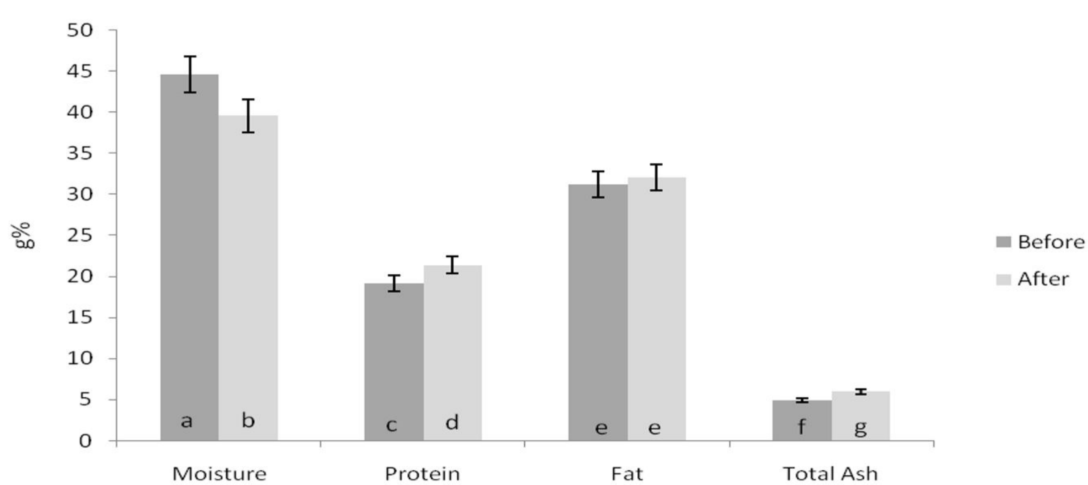

Figure 2. Mean values ± standard deviation for moisture, protein, fat and total ash of cheese samples before and after GMP training. (a-g) Different superscript letters indicate significant differences ($P < 0.05$).

(β-Lg)>, α-lactalbumin (α-La) are more sensitive to heat. The heat treatment induces the interaction between them, particularly the β-Lg, and casein, resulting in increased transfer of protein to curd (Morales-Celaya et al., 2012). Lau et al. (1991) reported that pasteurization of milk to make cheese had little effect on the retention of fat, but improved recovery of nitrogen.

A similar process of making fresh goat milk cheese was made in Morocco, with freshly milked raw milk and where the values obtained from protein, fat and ash were lower (9,8; 16,2 and 1,12 g / 100g), with a solids content of 24.9 to 31.2%. The differences observed may be due to the intensity of draining and the original composition of the raw material (El Galiou et al., 2015).

The calcium content was significantly lower in the cheeses prepared from raw milk than in those made from pasteurized milk (Figure 3). Metzger et al. (2000) mentioned that the calcium retained is contained in the casein micelles, while non micellar calcium is lost in the whey. Calcium phosphate migrates within and outside the casein micelle with increases in temperature, and while changes in the equilibrium between dissolved and colloidal phosphate calcium are easily reversible at moderate temperatures, at higher temperatures the reversibility becomes slower and incomplete. Heating the milk causes precipitation of calcium phosphate, and during cooling the concentration of dissolved calcium increases at the expense of micellar calcium phosphate (Fox & McSweenev, 1998).

On the other hand, before GMP training increased moisture content and lower content of calcium were observed in the samples. O'Mahony et al. (2006) reported an inverse relationship between the concentration of colloidal calcium phosphate and the moisture content in Cheddar cheese, due to increased swelling and hydration of the para-casein matrix of the cheese, wherein the colloidal calcium phosphate is solubilized.

Simultaneously, Guinee et al. (2002) also reported that the decrease in calcium concentration in Mozzarella cheese resulted in an increase in moisture content.

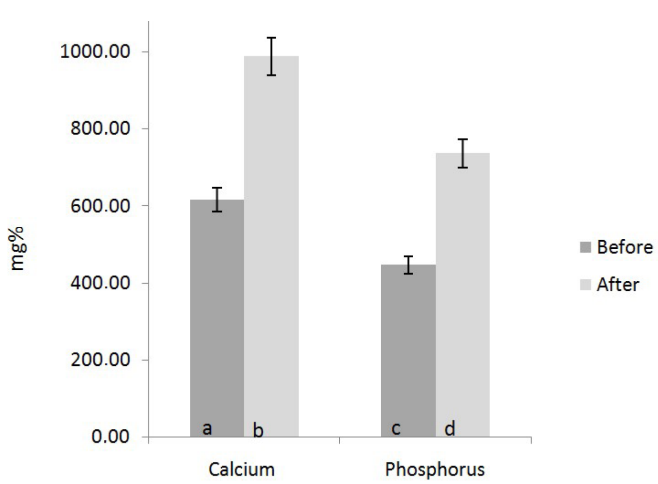

Figure 3. Mean values ± standard deviation for calcium and phosphorus in cheese samples before and after GMP training. (a-d) Different superscript letters indicate significant differences (P < 0,05).

During field evaluation before GMP training, each producer presented his/her product of a different size, arguing that size conforms to the amount of milk obtained daily. The cheeses had several cracks and deformations on the rind and the interior had variable size and orientation; yellow or gray-yellow cheese rinds; creamy white to yellowish white paste; cracked spotted surface, "unhygienic aspect"; presence of numerous small eyes in the pasta; intense caprine smell; with trigeminal sensations perceived as acidic, very spicy, sour, or bitter, persisting for a long time in the mouth.

Sensory laboratory analysis of the samples, after the training, showed an average weight of 350 ± 50 g, cylindrical shape (15-20 cm diameter) and irregular aspect; uniformly colored rind; smooth yellow texture; pasta with some small eyes, soft and moist texture, moderately crisp and adherent to cutting knife; soft yellow to creamy white; lactic flavor; moderately salty and lactic flavor, softly caprine and slightly acidic; some samples left trigeminal itching sensation or some astringency.

Cheese is an excellent medium for the growth of microorganisms due to its high water content and great variety of nutrients. Microbiological analysis showed a high total aerobic mesophilic count before GMP training, without specifying the type of microorganism. This reflects poor hygienic conditions of the raw materials and in the way the cheeses were handled during processing, which may indicate presence of pathogens and alteration of the product (Red Oficial de Laboratorios de Análisis de Alimentos, 2014).

Total coliform microorganisms are used as indicators of microbiological quality of food and the high levels observed in these cheeses are worrisome from a Public Health perspective (Psoni et al., 2003). High total coliform counts were also observed by El Galiou et al. (2015) and Martín-Platero et al. (2009).

As shown in Figure 4, after GMP training, the aerobic mesophilic bacteria and total coliforms decreased to levels accepted by the Argentinian legislation (<= 5.10^3 UFC / g for total coliforms) (Administración Nacional de Medicamentos, Alimentos, y Tecnología Médica, 2015). This situation was also found in homemade cheeses produced from raw milk and heat-treated (Oliszewski et al., 2007). The high numbers of these two microbial groups were similar to those reported in

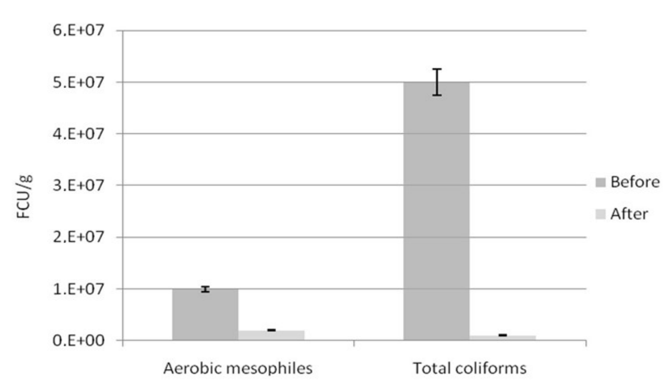

Figure 4. Highest values for total coliforms and aerobic plate counts of cheese samples before and after training in GMP.

the literature for other types of goat milk cheese, which may be explained by the low microbiological quality of raw milk, the high contamination during cheese processing, and the high moisture content (El Galiou et al., 2015).

While growth in EMB and ABP plates was observed, the colonies did not show the typical characteristics of growth of *E. coli* and *St. aureus* positive coagulase, respectively. For this reason, the presence of these pathogens was considered negative in the samples analyzed. The presence of coagulase-negative *Staphylococcus Aures* (+) was also observed by El Galiou et al. (2015), Psoni et al. (2003) and Bontinis et al. (2008).

4 Conclusions

GMP Training was conducted due to the sanitary and standardization problems observed during the production of goat milk cheese, which resulted from lack of resources and technical knowledge of small producers. Such shortcomings gave rise to unsound management of the manufacturing process, inefficient production, sanitary deficiencies, and chemical and sensory weaknesses in the products obtained. The chemical, sensory, and microbiological parameters of the cheeses improved after training, which is very important for the producers of El Rodeo from an economic point of view.

Adequate technology that is currently available makes it possible to continue improving the conditions of traditional goat production systems. In addition, various strategies have been recorded and made available to foster productivity, proper hygienic-sanitary management, and profitability of the products obtained.

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