



Ciência e Tecnologia de Alimentos

ISSN: 0101-2061

revista@sbcta.org.br

Sociedade Brasileira de Ciência e
Tecnologia de Alimentos
Brasil

PAZ, Noelia Fernanda; GONÇALVES DE OLIVEIRA, Enzo; VILLALVA, Fernando Josué;
ARMADA, Margarita; RAMÓN, Adriana Noemí

Effect of pH at drainage on the physicochemical, textural and microstructural
characteristics of mozzarella cheese from goat milk

Ciência e Tecnologia de Alimentos, vol. 37, núm. 2, abril-junio, 2017, pp. 193-201

Sociedade Brasileira de Ciência e Tecnologia de Alimentos
Campinas, Brasil

Available in: <http://www.redalyc.org/articulo.oa?id=395951059005>

- How to cite
- Complete issue
- More information about this article
- Journal's homepage in redalyc.org

redalyc.org

Scientific Information System

Network of Scientific Journals from Latin America, the Caribbean, Spain and Portugal

Non-profit academic project, developed under the open access initiative

Effect of pH at drainage on the physicochemical, textural and microstructural characteristics of mozzarella cheese from goat milk

Noelia Fernanda PAZ¹, Enzo GONÇALVES DE OLIVEIRA¹, Fernando Josué VILLALVA¹, Margarita ARMADA², Adriana Noemí RAMÓN^{3*}

Abstract

The aim of this study was a contribution to standardization the process of making mozzarella cheese from goat milk by draining at different pH values: 5.0 (MC50), 5.3 (MC53) and 5.6 (MC56), so as to obtain a product with suitable physicochemical, microstructural and textural characteristics. MC50 had lower protein and calcium, with very few strands. MC53 had adequate moisture content, fat, protein and calcium. The cheese yield was higher, the hardness parameters were lower, and the microstructure revealed the presence of long, thin strands, giving it the distinctive texture for this type of cheese. MC56 curd did not reach a good stretching property, requiring longer exposure to heating to obtain the yarn. This resulted in lower retention of fat, lower cheese yield, increased calcium and hardness values, and absence of strands. Overall, the goat milk presented aptitude for processing this type of cheese, however the pH 5.3 was selected to obtain a product with suitable physicochemical, textural and microstructural characteristics.

Keywords: goat milk; mozzarella; cheese; pH; microstructure.

Practical Application: Product development for technology transfer to small producers of cheeses made from goat's milk.

1 Introduction

Cheese may be defined as a structure of bi-continuous gel consisting of a porous protein matrix interspersed with fat globules. Mozzarella, a variety of pasta filata cheese originally made from buffalo milk in Italy, is one of the most widely consumed cheeses in the world (Vogt et al., 2015). It is characterized by its particular structure and plastic consistency (Niro et al., 2014), resulting from the thermo-mechanical stretching to which the curd is subjected during processing. This process aligns the casein fibers parallel, interlacing them with fat and serum channels (Vogt et al., 2015).

The physicochemical properties, and the textural and microstructural characteristics of mozzarella cheese are affected by several variables involved in processing, such as milk composition, whey pH prior to stretching, straining time and temperature, and storage conditions (Cavalier-Salou & Cheftel, 1991; Ennis & Mulvihill, 1999; Hennelly et al., 2005; Lee et al., 2004). However, the whey pH at draining is the most influential variable in the ability of the curd to be laminated and stretched in hot water (Yazici et al., 2010), determining the point at which the yarn is possible.

In conventional production of mozzarella cheese from cow milk, the pH drops to a range between 5.4 to 5.1 (Yazici et al., 2010), thus favoring the solubilization of micellar calcium

phosphate and the hydration of the para-casein, and increasing the proportion of soluble colloidal calcium (Guinee et al., 2002), which can affect final product quality (Yun et al., 1995).

Goat milk is a natural source of oligosaccharides derived from lactose, conjugated linoleic acid, A- and B-complex vitamins, and calcium (Haenlein & Anke, 2011; Paz et al., 2014). It also tolerates different technological treatments, thus yielding products with the ability to meet consumer demands in terms of health, nutritional value, safety and sensory attributes, indicating a promising future for the dairy goat sector. Thus any effort to encourage the production and scientific research in this field is positive (García et al., 2014).

Several studies have reported the effects of pH on the physicochemical properties of mozzarella cheese made from cow milk (Yun et al., 1993; Joshi et al., 2002, 2004; Zisu & Shah, 2005) and buffalo milk (Yazici et al., 2010), but no in goat milk. In this sense, the definition of appropriate pH for the obtain of goat mozzarella cheese with appropriate characteristics, is of great interest.

Therefore, the aim of this study was contribute to standardize the making of mozzarella cheese from goat milk, by trying different whey pH at draining, in order to obtain a product with suitable physicochemical, textural and microstructural characteristics.

Received 25 June, 2016

Accepted 08 Nov., 2016

¹ Consejo Nacional de Investigaciones Científicas y Técnicas – CONICET, Facultad de Ciencias de la Salud, Universidad Nacional de Salta - U.N.Sa., Campo Castañares, Salta, Salta, Argentina

² Consejo Nacional de Investigaciones Científicas y Técnicas – CONICET, Instituto de Investigaciones para la Industria Química - INIQUI, Facultad de Ingeniería, Universidad Nacional de Salta - U.N.Sa., Campo Castañares, Salta, Salta, Argentina

³ Consejo de Investigación de la Universidad Nacional de Salta – C.I.U.N.Sa., Facultad de Ciencias de la Salud, Universidad Nacional de Salta - U.N.Sa., Campo Castañares, Salta, Salta, Argentina

*Corresponding author: ramon@unsa.edu.ar

2 Materials and methods

2.1 Materials

Pasteurized goat's milk variety Saanen and Creole (80:20) (15 L), was obtained from producers in the town of Vaqueros, Salta, Argentina in November; and it was transported to the Food Laboratory, of Facultad de Ciencias de la Salud, in 4-liter jerry cans of high-density polyethylene, in storage containers at 4 °C, in about 7 min. *It was stored at 4 °C in cans of high-density polyethylene (4 L), for 7 minutes* Mozzarella cheese was prepared with CHY-MAX™ clotting enzyme (Chr. Hansen, Córdoba, Argentina), 100% pure Chymosin produced by fermentation, which requires lower dosage and facilitates better control of manufacturing processes; lyophilized lactic bacteria for direct inoculation as growing starters: *Streptococcus thermophilus* (ST-M7®) and *Lactobacillus helveticus* (LB-12®) (Chr. Hansen, Córdoba, Argentina); calcium chloride (Anedra laboratory, Buenos Aires, Argentina) and sodium chloride (Merck, Buenos Aires, Argentina).

2.2 Physicochemical analysis of goat milk

The pH was determined with digital HI8424 pH meter (Hanna Instruments, Buenos Aires, Argentina) calibrated with standard buffers 4 and 7 (Merck laboratory, Buenos Aires, Argentina); Titratable acidity: by titration (Association of Official Analytical Chemists, 2000; method 920.124); moisture: gravimetrically by drying in an oven (Association of Official Analytical Chemists, 2000; method 948.12); lactose: by difference [100 - (moisture + protein + fat + ash)]; proteins: by formol titration method (Egan, Kirk & Sawyer, 1991); fat: Gerber (Association of Official Analytical Chemists, 2000; method 933.05); total ash calcination in muffle (Association of Official Analytical Chemists, 2000; method 935.42); calcium and sodium: atomic absorption spectrophotometry was performed in accordance to Kahlhofer (1971); phosphorus: molecular absorption spectrophotometry according to ISO 9874 (International Organization for Standardization, 2006); and total solids: were by the oven method in accordance to ISO 6731 (International Organization for Standardization, 2010).

2.3 Standardization of the concentration of coagulant enzyme and starter cultures

Seven servings of goat milk, 100 mL each, were inoculated with starters, alone and combined, in different ratios and quantities, as recommended by the supplier (Table 1). The sample selected was the one reaching a pH of 6.0 in the shortest time, at which point

the enzyme has been shown to present the highest proteolytic activity on casein (Van Hooydonk et al., 1986).

From the above test result, the milk temperature was raised up to 45 °C, and Chymosin was added at the minimum, medium and maximum concentration recommended by the supplier: 0.001, 0.002, and 0.003 g 100 mL⁻¹, respectively. The sample was allowed to stand for 30 min at the same temperature until a firm, homogeneous and glossy clot was obtained. The gel hardness was measured with a QTS texture analyzer (Brookfield), and the enzyme concentration providing the greatest consistency to the curd was chosen.

2.4 Cheese manufacture

CaCl₂ at 0.02 g 100 mL⁻¹ was added to the pasteurized whole milk and then the selected concentrations of the starter cultures obtained in the previous assays were added. Chymosin was then added and allowed to clot for 30 min. The curd was cut into 2 x 2 x 2 cm cubes, i.e., large pieces to promote the moisture retention required for this type of soft to very soft cheese. The whey was partially removed and maturation took place under whey, up to a pH value that would allow subsequent kneading and stretching of the curd to obtain yarn-like threads.

According to the literature review, the general ranges of pH drainage for making pasta filata cheese (Cheddar, Oaxaca, Mozzarella) from different milks (cow, buffalo, goat, sheep, and mixtures thereof), could range from 4.9 to 5.8 (Zisu & Shah, 2005; Yazici et al., 2010; Bermúdez-Aguirre & Barbosa-Cánovas, 2012; Morales-Celaya et al., 2012; Ganesan et al., 2014; Niro et al., 2014; Ong et al., 2014). At pH 5.0 (results not shown) yarn not occur, possibly by excessive demineralization mass, accompanied by protein denaturation and proximity to its isoelectric point that would remain unstable. Therefore, this study tested three-point pH (Figure 1):

-5.0 (MC50)

-5.3 (MC53)

-5.6 (MC56)

Then, curd was immersed in hot water and spun until it was elastic and fibrous. After shaping (moulding), and to stop the cooking, it was then immersed in cold brine (5 ± 1 °C) at 20 g 100 mL⁻¹ NaCl, for 30 min. Finally, it was allowed to stand for 24 h before the analysis was performed.

Table 1. Combinations of starter culture at various ratios and concentrations used to achieve a pH of 6.0.

Samples	Relation cocci:bacilli ST-M7:LB-12	Concentration (g 100 mL ⁻¹ of milk)	Incubation Temperature (°C)
1	1:0	0.010:0.000	37
2	1:0	0.010:0.000	45
3	0:1	0.000:0.010	37
4	1:1	0.010:0.010	37
5	1:1,5	0.010:0.015	37
6	2:1	0.020:0.010	37
7	3:1	0.030:0.010	37

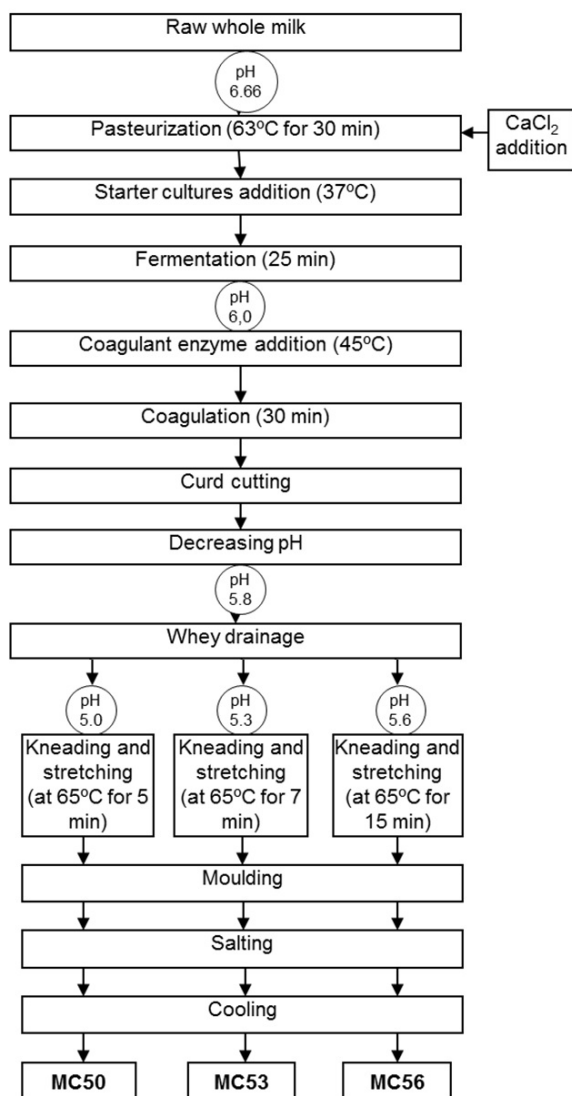


Figure 1. Flow chart of processing of mozzarella cheeses made from goat milk.

2.5 Physicochemical analysis of mozzarella cheese and yield (CY)

Cheeses from each treatment ($n=3$) were used for physicochemical and technological analyses of the final product (day 1). Moisture: gravimetrically by drying in an oven (Association of Official Analytical Chemists, 2000; method 948.12); pH: 10 g of the sample diluted with 70 mL; proteins: by Kjeldahl method (Association of Official Analytical Chemists, 2000; method 920.123); fat: Gerber (Association of Official Analytical Chemists, 2000; method 933.05); total ash: calcination in muffle (Association of Official Analytical Chemists, 2000; method 935.42); calcium and sodium: atomic absorption spectrophotometry; and phosphorus: molecular absorption spectrophotometry (Association of Official Analytical Chemists, 2000).

The CY was expressed as the nutrient recovered from milk (Solorza & Bell, 1998), which is especially related to the content

of protein, fat and calcium in the clot associated with moisture. The actual performance of each batch of cheese was expressed as kg of cheese produced per 100 kg of goat milk used in its production.

2.6 Texture Profile Analysis (TPA)

The textural characteristics (hardness, cohesiveness, adhesiveness, elasticity and chewiness) of the cheeses were analyzed with QTS (Brookfield) equipment. Details of the selected parameters have been previously described (Pons & Fiszman, 1996). Refrigerated specimens (4 °C) were cut with a cylindrical mold of 20 mm in diameter x 15 mm in length, and allowed to equilibrate at room temperature (~ 22°C) for 10 min. A 500N load cell with a flat plunger was used at a speed of 30 mm min⁻¹. A 50% compression was selected to permit deformation without breaking the sample. Data were collected through Pro v2.0 software. In addition, a Hewlett Packard C3180 scanner was used to photograph the macrostructure of the samples during the process.

2.7 Scanning Electron Microscopy (SEM)

A Jeol scanning electron microscope (JSM 6480 LV, Tokyo, Japan) was used. The equipment has a capacity acceleration voltage of between 0.2 and 30 kV, including sensors for secondary and backscattered electrons, working with high and low vacuum. The cheeses were analyzed using cylindrical cuts of 5 mm in diameter and 2 mm in height and fixed in 36% formaldehyde at refrigeration temperature for 2 months. Subsequently dehydrated with a graded series of ethanol (30, 50, 70, 80, 90 and 100 g per 100 g, 15 min each) and dried by critical point, they were metallized with gold and finally placed in the SEM tubes to determine their internal microstructure, according to that described by Morales-Celaya et al. (2012), with some modifications. The most representative SEM micrographs were selected for presentation.

2.8 Color analysis

A ColorTec PCM colorimeter® (Accuracy Microsensor Inc., Pittsford, USA) was used for instrumental color evaluation. The CIE Lab color scale ($L^*a^*b^*$) was used with a D⁶⁵ illuminant (standard daylight) and measuring angle of 10°. The visual sensations that are sent to the brain create the three dimensions of colour judgment response that is often referred to as three-dimensional colour space. In the CIE Lab system, these dimensions are expressed as: L^* related to lightness varying from black (zero) to white (100), and other two related to chromaticity, a^* from green ($-a^*$) to red ($+a^*$) and b^* from blue ($-b^*$) to yellow ($+b^*$). The L^* , a^* and b^* parameters were determined according to the Commission Internationale de l'Eclairage. Using reference plates, the apparatus was calibrated in the reflectance mode with specular reflection excluded. A 10-mm quartz cuvette was used for the readings. Measurements were performed in triplicate using the inner section of the cheeses immediately after unpacking.

2.9 Statistical analysis

All analyses were carried out in triplicate. The means of the results were evaluated using analysis of variance (ANOVA), and Duncan test was used to compare significant differences ($P < 0.05$) by the statistical software StatPro™ (Microsoft® Office Excel® 2007, version 12.0.4518.1014). The data are presented as mean \pm standard deviation of replicate measurements.

3 Results and discussion

3.1 Physicochemical analysis of milk

The results of the physicochemical analysis of the pasteurized goat milk are shown in Table 2.

The pH was 6.66; this value depends mainly on the stability of casein and is affected by the weaning period, the diet, the breed and the presence of carbon dioxide bubbles released during milking, cooling and transport of milk (Albenzio & Santillo, 2011). The acidity was lower than the range set (14–22 °D) by Administración Nacional de Medicamentos, Alimentos, y Tecnología Médica (2014). The presence of casein, minerals and ions increase the acidity titratable, during the spring-summer period. The protein content was similar to those reported in the literature (Albenzio & Santillo, 2011; Paz et al., 2014), but lower than the minimum established by law (2.8 g 100 g⁻¹) (Administración Nacional de Medicamentos, Alimentos, y Tecnología Médica, 2013). The fat was higher than the minimum set (3.0 g 100 g⁻¹) by Administración Nacional de Medicamentos, Alimentos, y Tecnología Médica (2014), mainly influenced by the diet of the animals (Park et al., 2007). The non-fat dry matter was also below the established minimum (9.0 g 100 g⁻¹) (Administración Nacional de Medicamentos, Alimentos, y Tecnología Médica, 2013). The minimum content of protein, fat dry matter not less than the minimum established by law and reduced ability to produce mozzarella cheese goat milk compared with cow, would turn into a difficult procedure to perform (Niro et al., 2014).

3.2 Standardization of the concentration of coagulant enzyme and starter cultures

Table 2. Physicochemical parameters of milk used in the production of mozzarella cheese.

Physicochemical parameters	Pasteurized goat milk
pH	6.66 \pm 0.01
Titratable acidity (°D)	10.83 \pm 0.19
Moisture (g 100 g ⁻¹)	89.14 \pm 0.42
Lactose (g 100 g ⁻¹)	3.87 \pm 0.26
Protein (g 100 g ⁻¹)	2.52 \pm 0.05
Fat (g 100 g ⁻¹)	3.48 \pm 0.02
Total Ash (g 100 g ⁻¹)	0.99 \pm 0.00
Calcium (mg 100 g ⁻¹)	219.99 \pm 20.23
Sodium (mg 100 g ⁻¹)	132.82 \pm 11.48
Phosphorus (mg 100 g ⁻¹)	272.62 \pm 0.34
Non-fat dry extract (g 100 g ⁻¹)	7.38 \pm 0.22
Total Solids (g 100 g ⁻¹)	10.86 \pm 0.15

Mean \pm standard deviation ($n=3$).

Sample 5 showed the shortest pre-maturation time (30 minutes), with a concentration of 0.010: 0.015 g 100 mL⁻¹ of milk with *Streptococcus thermophilus* and *Lactobacillus helveticus*, respectively. While the initial pH of goat milk is around 6.7, this may change if one resorts to the use of freeze-dried lactic cultures or organic acids, with the latter products of low sensory quality (Morales-Celaya et al., 2012). Furthermore, it has been shown that the lower the pH, the faster the coagulation time (Hannon et al., 2006). The effect of low pH in milk accelerates the activity of the clotting enzyme, reduces the electrostatic repulsion between casein micelles, and alters the distribution of calcium between micelles and serum phase (Ong et al., 2012), resulting in a shorter product development time.

Regarding the clotting enzyme, it was observed that the higher the concentration (0.003 g Chymosin per 100 mL⁻¹ milk), the greater the hardness of the gel (9 g).

3.3 Physicochemical analysis of goat mozzarella cheese

The data of the physicochemical analysis of the mozzarella cheeses made from goat milk are summarized in Table 3.

The pH of the samples were slightly higher than the drainage pH prior to kneading and stretching, for each cheese. Moisture of the MC50 and MC53 samples was higher than that of MC56; however, they were all “high humidity” according to the general classification of cheese (46 to 54.9 g 100 g⁻¹) (Administración Nacional de Medicamentos, Alimentos, y Tecnología Médica, 2013). The protein content was similar among the products, but greater at higher pH of the whey.

The lower retention of fat was obtained in the MC56 sample, which had to be subjected to heating for a longer time for the strains to form; this could have caused a greater loss of fat in the hot water used for stretching the curd, caused by the smaller fat globules present in the goat milk (Paz et al., 2014). However, all the samples exceeded the minimum required by law for this type of cheese (35.0 g 100 g⁻¹) (Administración Nacional de Medicamentos, Alimentos, y Tecnología Médica, 2013). Total ashes were similar between samples. Furthermore, calcium retention was higher at higher pH (Ong et al., 2014); this was due to the shorter time required for solubilization of micellar calcium phosphate and to the increase in the proportion of colloidal soluble Ca (Guinee et al., 2002). With respect to sodium, although our country does not record benchmarks in terms of content for this type of cheese, the values were lower than those of commercial mozzarella reported in other studies (Agarwal et al., 2011). As to phosphorus, all samples had a Ca/P ratio greater than 1, so this would not be the factor triggering bone loss (Teegarden et al., 1998).

The cheese yield was lower at pH 5.6, because of the prolonged exposure to stretching and kneading in hot water, with resulting loss of moisture and fat.

3.4 Texture Profile Analysis (TPA)

The macro-photographs, taken during the manufacture of cheese (Figure 2) show that at first the curd lacked structure, because 15 minutes would not be enough for the clotting enzyme

Table 3. Physicochemical parameters, texture and color of the mozzarella cheeses made from goat milk.

Variables	Samples		
	MC50	MC53	MC56
Physicochemical pH	5.42 ± 0.12 ^b	5.70 ± 0.05 ^{a,b}	5.94 ± 0.09 ^a
Moisture (g 100 g ⁻¹)	49.35 ± 0.18 ^a	47.51 ± 0.42 ^a	46.11 ± 0.10 ^b
Protein (g 100 g ⁻¹)	25.70 ± 0.43 ^a	26.50 ± 0.51 ^a	28.87 ± 0.51 ^a
Fat (g 100 g ⁻¹)	42.44 ± 0.05 ^b	45.07 ± 0.28 ^a	38.33 ± 0.28 ^c
Total Ash (g 100 g ⁻¹)	2.64 ± 0.10 ^a	2.98 ± 0.12 ^a	3.27 ± 0.17 ^a
Calcium (mg 100 g ⁻¹)	601.30 ± 1.00 ^c	725.95 ± 14.31 ^b	853.58 ± 24.45 ^a
Sodium (mg 100 g ⁻¹)	284.97 ± 3.75 ^a	277.20 ± 9.50 ^a	298.70 ± 6.42 ^a
Phosphorus (mg 100 g ⁻¹)	573.64 ± 0.29 ^c	620.25 ± 0.68 ^b	644.28 ± 0.84 ^a
CY (g 100 g ⁻¹)	10.82 ^a	11.20 ^a	9.44 ^b
<i>Texture</i>			
Hardness (N/min)	1421.33 ± 52.08 ^b	1194.00 ± 149.92 ^c	1798.00 ± 117.38 ^a
Cohesiveness	0.44 ± 0.05 ^a	0.70 ± 0.05 ^a	0.65 ± 0.04 ^a
Adhesiveness	5.78 ± 0.00 ^b	12.98 ± 0.00 ^b	0.08 ± 0.00 ^a
Elasticity	7.08 ± 0.30 ^a	6.58 ± 0.09 ^a	6.26 ± 0.54 ^a
Chewiness	7236.94 ± 1023.84 ^a	6601.53 ± 917.72 ^a	8485.57 ± 334.57 ^a
<i>Color</i>			
L*	78.06 ± 0.44 ^a	77.42 ± 0.28 ^a	78.31 ± 1.07 ^a
a*	5.88 ± 0.24 ^a	4.61 ± 0.99 ^a	5.06 ± 0.39 ^a
b*	22.83 ± 0.71 ^a	24.00 ± 0.39 ^a	21.45 ± 0.31 ^a

The following abbreviations are used: MC50, curd kneaded and stretched at pH 5.0; MC53, curd kneaded and stretched at pH 5.3; MC56, curd kneaded and stretched at pH 5.6. Mean ± standard deviation ($n=9$). Different letters on the same line indicate significant differences.

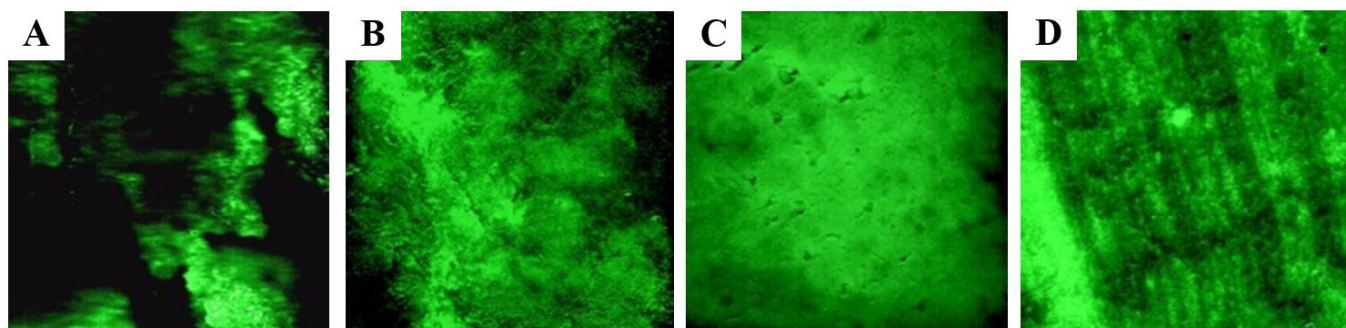


Figure 2. Photographs of the different stages of the curd: (A) 15 min post addition of Chymosin, pH 6.57; (B) at 90 min post addition of Chymosin, pH 6.00; (C) at 150 min post addition of Chymosin, pH 5.77; and, (D) mozzarella cheese from goat's milk after kneading and stretching.

to have an effect; at 90 minutes protein aggregation gradually formed, and at 150 minutes the curd looked more even and continuous. In addition, there was a big difference between the curd and the finished product, where clearly a fibrous structure was observed. The characteristic texture of the pasta filata cheese can be explained by the structural rearrangement that casein molecules (α S, β and κ , which are part of the decalcified micelles) suffer when the curd is subjected to heating and mechanical work, altering its β -plate and α -helix conformation (Ren et al., 2013). Stretching spatially in one direction positions and “aligns” the proteins as if they were “threads”. In addition, butterfat would function as a lubricant aligning the casein fiber (Yazici et al., 2010).

Regarding the texture, the MC56 sample showed the highest hardness value (Table 3), which could be related to the lower moisture content caused by long kneading and stretching in

warm water, and to the higher content of protein and, therefore, of micellar calcium retained in the curd, all of this resulting in a less adhesive product.

For the remaining parameters (cohesiveness, elasticity and chewiness), no significant differences were observed among the samples.

3.5 Scanning Electron Microscopy (SEM)

The microstructure changes influence the physicochemical properties of the cheese, so it is essential to study how they affect the processing conditions. Figure 3 shows the SEM micrographs of cheeses at different pH of draining.

The MC50, MC53 and MC56 samples have different structural arrangements according to the pH used for processing, mainly

regarding the presence and distribution of the casein threads (Figure 3). Components such as fat and moisture were removed from the cheese during preparation of the samples; therefore, the solid background of each micrograph represents the protein matrix, while the empty black areas represent air sacs, originally occupied by fat cells or serum that may have sublimated. The fat globules of milk have been considered responsible for forming the

spherical empty spaces inside the protein matrix of mozzarella cheese (Oberg et al., 1993).

The presence of large conglomerates of protein that can be seen in the figures, possibly merged during the formation of the curd, resulting in a compact structure within the matrix. MC50 has few threads (thickness of about $21.5\mu\text{m}$) and pores (between $24.4\text{--}55.7\mu\text{m}$ diameter). In MC56 no threads were observed, but

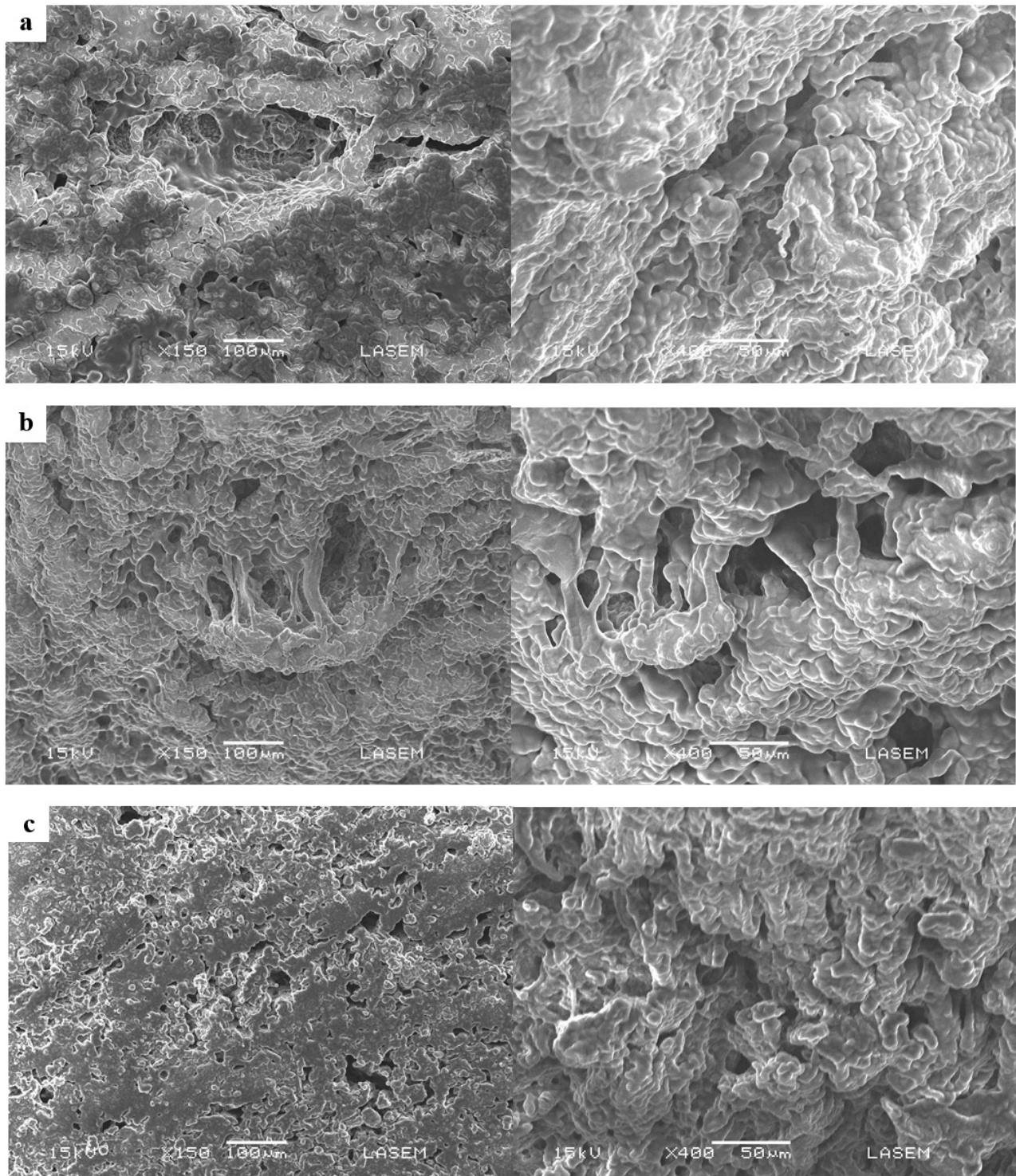


Figure 3. Microstructure of mozzarella cheese yarn made from goat milk at different drainage pH: 5.0 (a) 5.3 (b) and 5.6 (c).

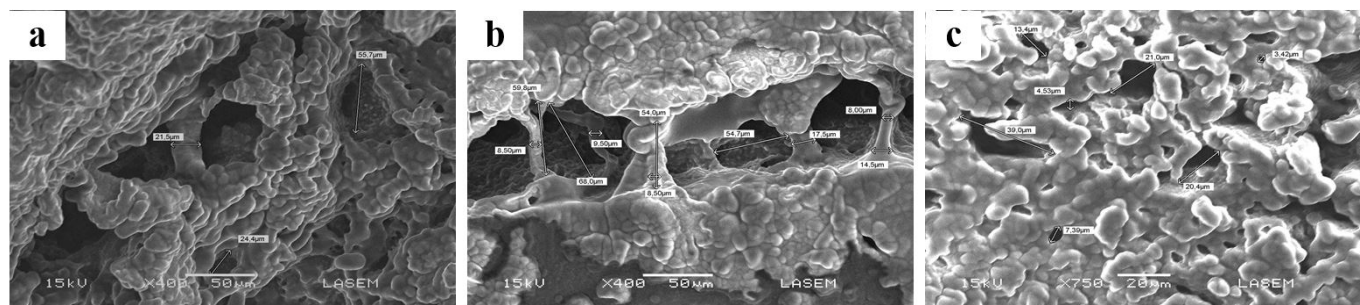


Figure 4. Dimensions of the yarns present in mozzarella cheese from goat, kneaded at different drainage pH: 5.0 (a) 5.3 (b) and 5.6 (c).

several small pores were present (between 3.42–39.0 μm). Because of the high pH of this sample, the curd had to be subjected to longer time in hot water, thus causing loss of moisture in the product. When the volume of the aqueous phase diminished, casein micelles were able to get closer together, leaving little space for the formation of large pores. Finally, MC53 showed the presence of long (up to 60 μm) and thin (5.60–9.20 μm) threads, keeping the same network within the matrix and even in fissured surface areas (Figure 4).

3.6 Color analysis

The average L^* values found for all the samples in this study (Table 3) were lower than those found by Niro et al. (2014) for pasta filata cheese (Caciocavallo) made from a mixture of cow milk and goat milk. In color evaluation, the parameter L^* indicates the lightness and the capability of an object to reflect or transmit light on a scale of 0 to 100. Therefore, higher brightness values result in lighter objects (Ramos do Egypto Queiroga et al., 2013).

The parameter a^* is higher than that observed by Niro et al. (2014). High values of a^* (green component) in goat milk products have been primarily attributed to their fatty acid profiles. Cheeses made from goat milk are generally whiter because goats are capable of converting β -carotene into vitamin A and also produce milk fat globules that are smaller in diameter than those in cow milk (Lucas et al., 2008; Park, 2006). Thus, when the cheeses are made from milk mixtures, increasing values of a^* are directly related to the higher proportion of goat milk (Sheehan et al., 2009).

Parameter b^* (yellow component) showed no significant differences between samples. However, their values were lower than those reported by Niro et al. (2014). The increase in b^* values has been associated with the Maillard reaction, which decreases brightness due to the production of browning compounds (Lucas et al., 2008).

In general, the tested samples showed high levels of luminosity (L^*), with a predominance of the yellow component (b^*), instead of the green component (a^*), suggesting that white-yellow is the predominant color feature in this type of cheese.

4 Conclusions

To conclude, the goat milk had adequate aptitude for processing this type of cheese, but only at whey drainage pH 5.3 was it

possible to obtain a product of adequate moisture, fat, protein and calcium, as well as higher cheese yield; lower hardness and microstructure revealed the presence of long, thin threads, which gave it a distinctive texture. Additionally, given the almost total absence of scientific articles in this type of spun paste cheese, the results provide a clearer characterization of this product.

Acknowledgements

This work was supported by Consejo de Investigaciones de la Universidad Nacional de Salta (Project N° 20/G087) and by a Doctorate fellowship (INIQUI-CONICET) granted to the author NF Paz. The authors wish to thank Lic. Alejandra Scotti for the language assistance and Lic. Patricia Giménez by the use of texture analyzer.

References

- Administración Nacional de Medicamentos, Alimentos, y Tecnología Médica – ANMAT. (2013). *Código Alimentario Argentino*. Argentina: Ministerio de Salud. Retrieved from http://www.anmat.gov.ar/alimentos/normativas_alimentos_caa.asp
- Administración Nacional de Medicamentos, Alimentos, y Tecnología Médica – ANMAT. (2014). *Código Alimentario Argentino*. Argentina: Ministerio de Salud. Retrieved from http://www.anmat.gov.ar/alimentos/codigoo/CAPITULO_VIII.pdf
- Agarwal, S., McCoy, D., Graves, W., Gerard, P. D., & Clark, S. (2011). Sodium content in retail Cheddar, Mozzarella, and process cheeses varies considerably in the United States. *Journal of Dairy Science*, 94(3), 1605–1615. PMID:21338828. <http://dx.doi.org/10.3168/jds.2010-3782>.
- Albenzio, M., & Santillo, A. (2011). Biochemical characteristics of ewe and goat milk: effect on the quality of dairy products. *Small Ruminant Research*, 101(1-3), 33–40. <http://dx.doi.org/10.1016/j.smallrumres.2011.09.023>.
- Association of Official Analytical Chemists – AOAC. (2000). *Official methods of analysis* (17th ed., Vol. 2). Gaithersburg: AOAC International.
- Bermúdez-Aguirre, D., & Barbosa-Cánovas, G. V. (2012). Fortification of queso fresco, cheddar and mozzarella cheese using selected sources of omega-3 and some nonthermal approaches. *Food Chemistry*, 133(3), 787–797. <http://dx.doi.org/10.1016/j.foodchem.2012.01.093>.
- Cavalier-Salou, C., & Cheftel, J. C. (1991). Emulsifying salts influence on characteristics of cheese analogs from calcium caseinate. *Journal of Food Science*, 56(6), 1542–1547. <http://dx.doi.org/10.1111/j.1365-2621.1991.tb08636.x>.

- Egan, H., Kirk, R., & Sawyer, R. (1991). *Pearson's composition and analysis of foods* (8th ed.). London: Longman.
- Ennis, M. P., & Mulvihill, D. M. (1999). Compositional characteristics of rennet caseins and hydration characteristics of the caseins in a model system as indicators of performance in Mozzarella cheese analogue manufacture. *Food Hydrocolloids*, 13(4), 325-337. [http://dx.doi.org/10.1016/S0268-005X\(99\)00015-6](http://dx.doi.org/10.1016/S0268-005X(99)00015-6).
- Ganesan, B., Brown, K., Irish, D. A., Brotherson, C., & McMahon, D. J. (2014). Manufacture and sensory analysis of reduced- and low-sodium Cheddar and Mozzarella cheeses. *Journal of Dairy Science*, 97(4), 1970-1982. PMID:24485677. <http://dx.doi.org/10.3168/jds.2013-7443>.
- García, V., Rovira, S., Boutoia, K., & López, M. B. (2014). Improvements in goat milk quality: a review. *Small Ruminant Research*, 121(1), 51-57. <http://dx.doi.org/10.1016/j.smallrumres.2013.12.034>.
- Guinee, T. P., Feeney, E. P., Auty, M. A. E., & Fox, P. F. (2002). Effect of pH and calcium concentration of some textural and functional properties of Mozzarella cheese. *Journal of Dairy Science*, 85(7), 1655-1669. PMID:12201515. [http://dx.doi.org/10.3168/jds.S0022-0302\(02\)74238-0](http://dx.doi.org/10.3168/jds.S0022-0302(02)74238-0).
- Haenlein, G. F. W., & Anke, M. (2011). Mineral and trace element research in goats: a review. *Small Ruminant Research*, 95(1), 2-19. <http://dx.doi.org/10.1016/j.smallrumres.2010.11.007>.
- Hannon, J. A., Lopez, C., Madec, M. N., & Lortal, S. (2006). Altering renneting pH changes microstructure, cell distribution, and lysis of *Lactococcus lactis* AM2 in cheese made from ultrafiltered milk. *Journal of Dairy Science*, 89(3), 812-823. PMID:16507673. [http://dx.doi.org/10.3168/jds.S0022-0302\(06\)72144-0](http://dx.doi.org/10.3168/jds.S0022-0302(06)72144-0).
- Hennelly, P. J., Dunne, P. G., O'Sullivan, M., & O'Riordan, D. (2005). Increasing the moisture content of imitation cheese: effects on texture, rheology and microstructure. *European Food Research and Technology*, 220(3), 415-420. <http://dx.doi.org/10.1007/s00217-004-1097-9>.
- International Organization for Standardization – ISO. (2006). *ISO 9874:2006 (IDF 42:2006): milk e determination of total phosphorus content e method using molecular absorption spectrometry*. Geneva: ISO.
- International Organization for Standardization – ISO. (2010). *ISO 6731:2010 (IDF 21:2010): milk, cream and evaporated milk -- determination of total solids content (reference method)*. Geneva: ISO.
- Joshi, N. S., Muthukumarappan, K., & Dave, R. I. (2002). Role of soluble and colloidal calcium contents on functionality of salted and unsalted part skim Mozzarella cheese. *Australian Journal of Dairy Technology*, 57, 203-210. Retrieved from <https://www.diaa.asn.au/publications/australian-journal-of-dairy-technology/issues/article/australian-journal-of-dairy-technology/23-adjt-articles/726-role-of-soluble-and-colloidal-calcium-contents-on-functionality-of-salted-and-unsalted-part-skim-mozzarella-cheese>
- Joshi, N. S., Muthukumarappan, K., & Dave, R. I. (2004). Effects of reduced calcium, test temperature and storage on stretchability of part skim Mozzarella cheese. *Australian Journal of Dairy Technology*, 59, 60-64. Retrieved from <http://www.diaa.asn.au/publications/australian-journal-of-dairy-technology/issues/article/australian-journal-of-dairy-technology/23-adjt-articles/832-effects-of-reduced-calcium-test-temperature-and-storage-on-stretchability-of-part-skim-mozzarella-cheese>
- Kahlhofer, H. (1971). Die Bestimmung von Kalium, Natrium, Calcium und Magnesium in Milch, Trockenmilch und Käse (Edamer) mit Hilfe der Atomadsorption. *Österreichische Milchwirtschaft*, 26, 33-36.
- Lee, S. K., Anema, S., & Klostermeyer, H. (2004). The influence of moisture content on the rheological properties of processed cheese spreads. *International Journal of Food Science & Technology*, 39(7), 763-771. <http://dx.doi.org/10.1111/j.1365-2621.2004.00842.x>.
- Lucas, A., Rock, E., Agabriel, C., Chilliard, Y., & Coulon, J. B. (2008). Relationships between animal species (cow versus goat) and some nutritional constituents in raw milk farmhouse cheeses. *Small Ruminant Research*, 74(1-3), 243-248. <http://dx.doi.org/10.1016/j.smallrumres.2007.03.011>.
- Morales-Celaya, M. F., Lobato-Calleros, C., Alvarez-Ramirez, J., & Vernon-Carter, E. J. (2012). Effect of milk pasteurization and acidification method on the chemical composition and microstructure of a Mexican pasta filata cheese. *LWT - Food Science and Technology*, 45, 132-141.
- Niro, S., Fratianni, A., Tremonte, P., Sorrentino, E., Tipaldi, L., Panfili, G., & Coppola, R. (2014). Innovative Caciocavallo cheeses made from a mixture of cow milk with ewe or goat milk. *Journal of Dairy Science*, 97(3), 1296-1304. PMID:24440270. <http://dx.doi.org/10.3168/jds.2013-7550>.
- Oberg, C. J., McManus, W. R., & McMahon, D. J. (1993). Microstructure of mozzarella cheese during manufacture. *Food Structure*, 12, 251-258. Retrieved from <http://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1318&context=foodmicrostructure>
- Ong, L., Dagastine, R. R., Kentish, S. E., & Gras, S. L. (2012). The effect of pH at renneting on the microstructure, composition and texture of Cheddar cheese. *Food Research International*, 48(1), 119-130. <http://dx.doi.org/10.1016/j.foodres.2012.02.020>.
- Ong, L., Soodam, K., Kentish, S. E., Powell, I. B., & Gras, S. L. (2014). The addition of calcium chloride in combination with a lower draining pH to change the microstructure and improve fat retention in Cheddar cheese. *International Dairy Journal*, 46, 53-62. <http://dx.doi.org/10.1016/j.idairyj.2014.07.003>.
- Park, Y. W. (2006). Goat milk-chemistry and nutrition. In Y. W. Park & G. F. W. Haenlein (Eds.), *Handbook of milks of non bovine mammals* (pp. 34-58). Ames: Blackwell Publishing.
- Park, Y. W., Juárez, M., Ramos, M., & Haenlein, G. F. W. (2007). Physico-chemical characteristics of goat and sheep milk. *Small Ruminant Research*, 68(1-2), 88-113. <http://dx.doi.org/10.1016/j.smallrumres.2006.09.013>.
- Paz, N. F., Oliveira, E. G., Kairuz, M. S. N., & Ramón, A. N. (2014). Characterization of goat milk and potentially symbiotic non-fat yogurt. *Food Science and Technology*, 34(3), 629-635. <http://dx.doi.org/10.1590/1678-457x.6409>.
- Pons, M., & Fiszman, S. M. (1996). Instrumental texture profile analysis with particular reference to gelled systems. *Journal of Texture Studies*, 27(6), 597-624. <http://dx.doi.org/10.1111/j.1745-4603.1996.tb00996.x>.
- Ramos do Egypto Queiroga, R. C., Melo Santos, B., Pereira Gomes, A. M., Monteiro, M. J., Teixeira, S. M., Leite de Souza, E., Dias Pereira, C. J., & Estevez Pintado, M. M. (2013). Nutritional, textural and sensory properties of Coalho cheese made of goats' cows' milk and their mixture. *LWT - Food Science and Technology*, 50(2), 538-544. <http://dx.doi.org/10.1016/j.lwt.2012.08.011>.
- Ren, D., Chen, B., Chen, Y., Miao, S., & Liu, J. (2013). The effects of k-casein polymorphism on the texture and functional properties of mozzarella cheese. *International Dairy Journal*, 31(2), 65-69. <http://dx.doi.org/10.1016/j.idairyj.2013.01.005>.
- Sheehan, J. J., Patel, A. D., Drake, M. A., & McSweeney, P. L. H. (2009). Effect of partial or total substitution of bovine for caprine milk on the compositional, volatile, nonvolatile and sensory characteristics of semi-hard cheeses. *International Dairy Journal*, 19(9), 498-509. <http://dx.doi.org/10.1016/j.idairyj.2009.03.009>.
- Solorza, F. J., & Bell, A. E. (1998). Effect of calcium on the minerals retention and cheesemaking parameters of milk. *International Journal of Dairy Technology*, 51(2), 37-43. <http://dx.doi.org/10.1111/j.1471-0307.1998.tb02505.x>.

- Teegarden, D., Lyle, R. M., McCabe, G. P., McCabe, L. D., Proulx, W. R., Michon, K., Knight, A. P., Johnston, C. C., & Weaver, C. M. (1998). Dietary calcium, protein, and phosphorus are related to bone mineral density and content in young women. *The American Journal of Clinical Nutrition*, 68(3), 749-754. PMID:9734757.
- Van Hooydonk, A. C. M., Hagedoorn, H. G., & Boerrigter, I. J. (1986). The effect of various cations on the renneting of milk. *Netherlands Milk and Dairy Journal*, 40, 369-390.
- Vogt, D. J., Smith, J. R., Seymour, J. D., Carr, A. J., Golding, M. D., & Codd, S. L. (2015). Assessment of the changes in the structure and component mobility of Mozzarella and Cheddar cheese during heating. *Journal of Food Engineering*, 150, 35-43. <http://dx.doi.org/10.1016/j.jfoodeng.2014.10.026>.
- Yazici, F., Dervisoglu, M., Akgun, A., & Aydemir, O. (2010). Effect of whey pH at drainage on physicochemical, biochemical, microbiological, and sensory properties of Mozzarella cheese made from buffalo milk during refrigerated storage. *Journal of Dairy Science*, 93(11), 5010-5019. PMID:20965315. <http://dx.doi.org/10.3168/jds.2009-2908>.
- Yun, J. J., Barbano, D. M., & Kindstedt, P. S. (1993). Mozzarella cheese: impact of milling pH on chemical composition and proteolysis. *Journal of Dairy Science*, 76, 3629-3638. [http://dx.doi.org/10.3168/jds.S0022-0302\(93\)77708-5](http://dx.doi.org/10.3168/jds.S0022-0302(93)77708-5).
- Yun, J. J., Barbano, D. M., Kindstedt, P. S., & Larose, K. L. (1995). Mozzarella cheese: impact of whey pH at draining on chemical composition, proteolysis, and functional properties. *Journal of Dairy Science*, 78(1), 1-7. PMID:8596014. [http://dx.doi.org/10.3168/jds.S0022-0302\(95\)76609-7](http://dx.doi.org/10.3168/jds.S0022-0302(95)76609-7).
- Zisu, B., & Shah, N. P. (2005). Textural and functional changes in low-fat Mozzarella cheeses in relation to proteolysis and microstructure as influenced by the use of fat replacers, pre-acidification and EPS starter. *International Dairy Journal*, 15(6-9), 957-972. <http://dx.doi.org/10.1016/j.idairyj.2004.09.014>.