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From goat colostrum to milk: Physical, chemical, and immune evolution from partum to 90 days postpartum

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ABSTRACT

This study focused on the study of the changes originated in the milk from partum until d 90 of lactation. Ten multiparous Majorera goats, bred carefully under animal health standards, with a litter size of 2 kids (the average in this breed is 1.83 prolificacy) and similar gestation length (149 ± 1 d) were used. Goat kids were removed from their dams to avoid interferences with the study. Compositional content (fat, protein, and lactose) were measured, as well as some other properties, including pH, density, titratable acidity, ethanol stability, rennet clotting time, and somatic cell count. Moreover, immunity molecules (IgG, IgA, and IgM concentrations and chitotriosidase activity) received great attention. Fat and protein content were higher in the first days postpartum, whereas lactose content was lower. Density, titratable acidity, rennet clotting time, and somatic cell count decreased throughout the lactation period, whereas pH and ethanol stability increased. Relative to the immunological parameters, each measured parameter obtained its maximum level at d 0, showing the first milking as the choice to provide immunity to the newborn kids. On the other hand, this study might be used to establish what the best use is: processing or kid feeding.
Key words: goat colostrum, milk composition, immunological parameter, technological property

INTRODUCTION

Colostrum is the initial milk secreted by mammals during parturition and the first few days after birth. It provides protection to the immune system of newborns and provides passive immunity against pathogens. The transition period is marked by nutritional, metabolic, hormonal, and immunological changes that have an effect on the incidence of infections and metabolic diseases. During the transition from colostrum to normal milk, gradual or sometimes sudden changes may occur in composition and properties (Arain et al., 2008). Tsioulpas et al. (2007) reported changes in physical and technological parameters from colostrum to milk in cows, and Argüello et al. (2006) observed that caprine colostrum exhibits some extreme physical properties. Abd El-Fattah et al. (2012) reported in buffalo and cows that the compositions of both colostrums approach those of normal milk within 5 d after parturition. Some studies have focused on the composition of goat milk through the lactation curve (Delgado-Pertíñez et al., 2009); Argüello et al. (2006) described how the number of lactations and litter size affect the immune and physical goat colostrum characteristics until 5 d postpartum. But to our knowledge, no studies about immune characteristics are available as far as 5 d postpartum of dairy goats.

Complete knowledge of the changes occurring in the lactation period is critical for the establishment of milk quality criteria, as part of the payment system for milk, which will ensure better quality of the final dairy products (Raynal-Ljutovac et al., 2005). Those authors reported some observations, such as the legislation-restricted IgG content in milk because of the negative effects of colostrum on cow milk (e.g., less-effective pasteurization, decreased heat stability of milk, and lower cheese yield and curd firmness). These effects were linked to the increase in total soluble protein content, and greatly depend on the colostrum addition. Indeed, Suchanek et al. (1978), when adding 10% of colostrum from d 4 to 7 postpartum in cow milk, did not observe significant modification of parameters such as acidification ability, rennet coagulation, heat stability at 135°C, and cheese-making parameters of Edam-type cheese. Zawistowski and Mackinnon (1993) reported that the presence of high levels of bovine IgG could adversely affect the human immune system. Argüello (2011) presented the most up-to-date trends in goat research, remarking that it needs to progress rapidly to reach the level of knowledge of other species such as cattle and sheep. Due to lack of information in goats, the aim

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of the present study was to evaluate the evolution of physical, chemical, and immune parameters in the goat transition period from colostrum to milk during the first 90 d postpartum.

MATERIALS AND METHODS

Animals and Samples Collection

Experimental animal procedures were approved by the Ethics Committee of the Universidad de Las Palmas de Gran Canaria (ULPGC, Arucas, Spain). Goat colostrum and milk samples were collected from the ULPGC farm at partum and each day postpartum at 0800 h from 10 Majorera dairy goats; the samples were transported to the laboratory and divided into 2 aliquots, one of which was stored at 4°C and the other at −20°C. Dairy goats enrolled in the present experiment had been through the dry period for 2 mo and did not show any health problems during the experimental period (weekly microbial tests and visual observations were performed for ensuring this statement). Goat colostrum and milk were measured using recording jars at the milking parlor and samples were collected on the first 5 d postpartum and then on selected days (d 15, 30, 60, and 90).

Proximal Composition

Fat, protein, lactose, colostrum DM and SNF, and milk content were determined by routine laboratory procedures using the automated infrared method (DMA2001 Milk Analyzer; Miris Inc., Uppsala, Sweden).

Physical Properties

The pH of the undiluted colostrum and milk was determined using a portable pH meter (Jenco model 6009 portable pH meter; Jenco Instruments Inc., San Diego, CA); pH determinations were made in triplicate. The density of the undiluted colostrum and milk was determined using a portable densitometer with a range between 1,000 to 1,100 g/L (Alla; Alla S.A., Madrid, Spain); density determinations were made in triplicate. The ethanol stability (**ES**) was determined according to Tsioulpas et al. (2007). The strongest concentration of ethanol that did not cause coagulation was defined as the ES. For the determination of acidity, titratable acidity analysis was performed. One milliliter of phenolphthalein indicator (concentrated) was added to 10 mL of milk and the mixture was titrated with 0.111 *M* NaOH to a permanent faint pink color, which was the titration endpoint (pH 8.3). For rennet-clotting time (**RCT**) evaluation, 5 mL of milk was poured into a glass test tube and maintained in a 30°C water bath. The sample was left at 30°C for 10 min and then 100 μL of freshly prepared rennin at 0.1 mg/mL (Sigma-Aldrich, St. Louis, MO) was added. The time (min) from thorough mixing to the first sign of sudden breakdown of the film on the test tube wall was measured and defined as the RCT. The SCC was determined using a DeLaval somatic cell counter (DeLaval International AB, Tumba, Sweden) immediately after samples were obtained, with a soak time of 1 min before the count, following the instructions of Sanchez-Macias et al. (2010a).

Immunological Parameters

IgG, IgA and IgM quantifications in colostrum and milk were performed using goat IgG, IgA, and IgM ELISA kits (Bethyl Laboratories, Montgomery, TX). Chitotriosidase (**ChT**) activity was measured according to Argüello et al. (2008) by incubating 1 μL of undiluted colostrum or milk with 100 μL of a 22 m*M* solution of an artificial substrate (4-methylumbelliferyl-d-N,N′,N″ triacetylchitotriose) in 0.5 *M* citrate phosphate buffer (pH 5.2) for 15 min at 37°C. The reaction was stopped with 5 mL of 0.5 *M* Na_2CO_3-$NaHCO_3$ buffer (pH 10.7). Fluorescence was measured with a fluorometer (PerkinElmer, Norwalk, CT), at 365-nm excitation and 450-nm emission. The ChT activity is expressed as nanomoles of substrate hydrolyzed per milliliter per hour.

Statistical Analysis

Statistical analyses were performed using SAS (version 9.00; SAS Institute Inc., Cary, NC). The SAS MIXED procedure for repeated measurements was used to evaluate the effect of postpartum time on the immune and physical parameters and proximate composition on colostrum and milk samples. The Tukey test was used to evaluate the differences during the evolution time at a significance level of $P < 0.05$.

RESULTS AND DISCUSSION

Proximal Composition

The proximal composition is displayed in Table 1. Argüello et al. (2006) reported similar values and evolution in the same breed at 5 d postpartum. Fat percentage at partum was higher than d 2 and the following days. The fat percentage remained high until d 5 and reached normal milk goat fat percentage at d 15, in accordance with previous results for the same breed

Table 1. Proximal composition, including fat, protein, lactose, DM, and SNF, of colostrum and milk samples from partum to d 90 postpartum (n = 10 Majorera-breed goats)

	Days postpartum										
Item	0	1	2	3	4	5	15	30	60	90	SEM
Fat, %	7.70[a]	6.86[ab]	6.26[b]	6.15[b]	6.43[b]	6.20[b]	4.28[c]	3.88[c]	4.31[c]	4.31[c]	0.22
Protein, %	10.47[a]	6.84[b]	5.73[c]	5.64[c]	5.20[c]	4.89[c]	3.49[d]	3.35[d]	3.44[d]	3.36[d]	0.28
Lactose, %	2.44[a]	3.53[b]	4.15[c]	3.98[bc]	4.20[c]	4.45[c]	5.10[d]	5.34[d]	5.48[d]	5.44[d]	0.13
DM, %	21.57[a]	18.36[b]	16.17[c]	16.83[c]	16.88[c]	16.54[c]	13.68[de]	13.34[e]	13.96[de]	14.26[d]	0.35
SNF, %	13.87[a]	11.50[b]	10.90[c]	10.68[c]	10.44[cd]	10.34[cd]	9.40[d]	9.44[d]	9.66[d]	9.94[d]	0.17

[a–e]Means within a row with different superscripts differ ($P < 0.05$).

(Sánchez-Macías et al., 2010b). According to Laakso et al. (1996), colostrum contained substantially less stearic and oleic acids and more myristic and palmitic acids than the normal milk fat; thus, the mixture of colostrum from d 3, 4, or 5 might change the normal FA distribution in milk, with consequences of goat cheese lipolysis. The protein percentage was reduced 45% at d 2 postpartum, but after that no significant differences were observed until d 5 postpartum. The protein content during this period consists of greater amounts of casein and globulin (Tsioulpas et al., 2007). Protein percentages after d 15 were lower percentages before d 15 and similar to those of the Tinerfeña breed (Capote, 1999) and Majorera breed goat milk (Sánchez-Macías et al., 2010b). Results in other breeds showed a similar decrease in total protein content in colostrum and in total protein levels (Graf et al., 1970; Linzell and Peaker, 1974). At partum, Csapó et al. (1994) found 16.2% total protein in colostrum from white Hungarian goats, Hadjipanayiotou (1995) observed 16.0% in colostrum from Damascus goats, and Chen et al. (1998) discovered 16.5% in colostrum from Nubian goats. Thus, differences between breeds are more pronounced in milk production, with total protein content being lower in high-producing breeds (Pritchett et al., 1991; Quigley et al., 1994). Lactose percentage displayed an increasing pattern, as has been described previously by Akinsoyinu et al. (1979), Hadjipanayiotou (1995), and Argüello et al. (2006) in different goat breeds. According to Ontsouka et al. (2003), lactose production causes water influx in milk through osmotic effects, and values observed by those authors in cows were lower in colostrum than in mature milk. However, these authors reported that concentrations of Na and Cl, which are osmotically active molecules in milk, were elevated in colostrum compared with mature milk. Thus, the electrolyte transfer from blood into milk through leaky tight junctions (Nguyen and Neville, 1998) is expected to increase the milk volume during the colostral period despite relatively low lactose secretion. That may be the explanation to results regarding the volume produced (Table 2), which was greater at partum.

Physical and Technological Properties and SCC

Physical and technological characteristics, as well as SCC of goat colostrum and milk are displayed in Table 2. The density decreased from partum to 90 d postpartum. The density curve profile was closer to that described by Rudovsky et al. (2008) for goat colostrum, and the final value was similar to that observed by Fresno et al. (1992) and Sánchez-Macías et al. (2010b) in milk from Majorera goats.

The pH displayed the lowest values at partum; after that, no differences were observed. Similar values and profiles have been described previously by Argüello et al. (2006) on goat colostrum. In cows, Tsioulpas et al. (2007) described lower values than observed in the present study during the first 5 d postpartum, but the d-90 pH values were similar in cows and goats. According to Edelsten (1988), pH values <6.5 in cow milk indicate the presence of some colostrum, although low pH values could also occur due to bacterial contamination. In the present study, the milk postpartum displayed the normal pH value for processing.

The titratable acidity profile postpartum showed a decrease of approximately 36% from partum to d 1 and after that, 26% more until d 90, in accordance with Güzeler et al. (2010). Titratable acidity measures components that exert some buffering capacity, in addition to lactic acid; these include proteins, phosphates, citrates, and carbon dioxide (Tsioulpas et al., 2007). Titratable acidity plays a fundamental role in all phases of milk coagulation, including the aggregation rate of paracasein micelles and the reactivity of rennet (De Marchi et al., 2009). The titratable acidity profile was inversely proportional to those of lactose and pH.

Ethanol stability showed an irregular trend during the observed period, briskly decreasing at d 90. The ES values from the current study are much higher than those reported by Guo et al. (1998) who reported ES values of 44% in bulk goat milk. Goat milk has been found to have much lower ES than cow milk (44 vs. 70%), mainly due to sodium and potassium balance. Guo et al. (1998) observed that the addition of sodium

to goat milk increases the ES. Park et al. (2007), comparing goat, sheep, and cow milk, reported that goat milk has a higher Ca, P, K, Mg, and Cl, and lower Na and S content than cow milk.

Colostrum samples did not clot at d 0, something that might be explained by the fact that colostrum contains a protease inhibitor that protects immunoglobulin from proteolytic damage in the gastrointestinal tract and during absorption (Sandholm and Honkanen-Buzalski, 1979). In addition, colostrum has more trypsin inhibitor than mature milk. Previous studies observed that trypsin secreted by the small intestine can degrade colostral antibodies (Quigley et al., 1995). After that, RCT displayed a decreasing pattern until d 90. Goat colostrum samples (first 5 d postpartum) should not be treated as milk for dairy applications, because their properties are different from normal, stable goat milk. Tsioulpas et al. (2007) observed that RCT was high on the first day, decreased sharply, remained constant for the next 3 d, and then increased steadily, following a similar pattern to pH except on d 1. Fox and McSweeney (1998) and Madsen et al. (2004) reported that RCT increases when pH increases and decreases when protein content increases. Results observed in the present study are opposite to those observed by Tsioulpas et al. (2007) after 5 d. These differences might be explained because according to Calvo (2002), the normal RCT for cows is 12 min and for goats is 7 min.

Results of statistical analysis for SCC were not significantly different during the experimental time due to the high interanimal variability. The SCC was much higher in colostrum than in d-90 milk. This is in accordance with previous results in cows (Hallberg et al., 1995; Andrew, 2001; Ontsouka et al., 2003). Mastitis pathogens are not infrequently found in colostrum (Andrew, 2001), but no signs of clinical mastitis were observed in the experimental animals, and colostrum appearance was always normal according to the criteria described by Hallberg et al. (1995) for cows. After d 5, values for SCC in goat milk were in accordance with those previously reported in the same breed (Sánchez-Macías et al., 2010b). High SCC in colostrum in the current study was of a physiological nature, and it probably was most likely due to penetration of cells through leaky tight junctions between the mammary epithelial cells (Nguyen and Neville, 1998).

Immunological Parameters

Immunoglobulin G, IgA, and IgM concentrations and ChT activity profiles during the first 90 d of lactation are displayed in Table 3. The highest IgG colostrum concentration was observed at partum, and decreased quickly after that, as also reported by Moreno-Indias et al. (2012) during the first 10 h postpartum in the same breed, and by Castro et al. (2011a), studying the effect of induction of parturition on goat colostrum concentration of IgG. Also, Castro et al. (2011b) reviewed some management factors that affect to the colostrogenesis in small ruminants, reporting that via inactivation of IgG1-specific receptors on alveolar epithelial cells, the immunoglobulin transfer is downregulated by increasing prolactin during lactogenesis. On the other hand, kids are agammaglobulinemic at birth (Argüello et al., 2004); therefore, they need to be fed colostrum during the first hours after birth, as this is a principal IgG source during the first month of life. This information supports the idea that goat managers might use the first colostrum removed to provide a good immune passive transfer when colostrum bottle feeding is used, as well to avoid the induction of partum in goats.

The IgA and IgM profiles through lactation are similar to that described previously for IgG, decreasing fast in the 2 d after delivery. No references about the concentrations of IgA or IgM in goat colostrum or milk have been found in the literature. However, Moreno-Indias et al. (2012) observed a decrease in the first 10 h postpartum for both molecules (from 2.2 to 0–3 and from 0.6 to 0.1 mg/mL for IgM and IgA, respectively), whereas Hernández-Castellano et al. (2011) found values of 0.08 (IgM) and 0.03 (IgA) mg/mL for the period of early lactation. Recently, Abd El-Fattah et al. (2012), working with buffalos and cows, reported similar trends for IgG and IgM concentrations, with the values stabilizing at around 120 and 72 h, respectively. Östensson and Lun (2008) stated that IgA in milk is produced from a local synthesis of mammary tissue, specifically in a place close to epithelial tissues of the udder. However, it is necessary to investigate deeply the origin of IgA and IgM in colostrum and the role of these 2 immunoglobulins in the newborn ruminant, because Rodríguez et al. (2009) demonstrate that these immunoglobulins are absorbed by newborn goat kids.

The IgG content in milk is critical for some properties, leading to less-effective pasteurization (Maurice, 1979) or a decrease in the heat stability of milk, off-flavors in pasteurized milk, and decreased cheese yield and curd firmness linked to the increase in total soluble protein content (Feagan, 1979). However, no studies have been found relative to the repercussions of the IgA and IgM content on the milk characteristics.

Colostrum and milk ChT activity ranged from 2,775 nmol/mL per hour at partum to 178 nmol/mL per hour at 90 d postpartum. Colostrum ChT activity was significantly greater at partum. Similarly, activity 1 d postpartum was less than at partum, as indicated previously by Moreno-Indias et al. (2012), measuring a reduction during the 10 first hours postpartum. A similar profile

Table 2. Values of volume, density, pH, ethanol stability (ES), titratable acidity (TA; mL of 111 *M* NaOH 0), rennet-clotting time (RCT), and SCC of colostrum and milk samples from partum to d 90 postpartum (n = 10 Majorera-breed goats)

	Days postpartum										
Item	0	1	2	3	4	5	15	30	60	90	SEM
Volume, mL	2,358.57^{a}	696.43^{b}	1,278.57^{b}	1,389.29^{b}	1,464.29^{b}	1,553.57^{ab}	1,710.71^{ab}	1,939.29^{ab}	1,917.86^{ab}	1,838.79^{ab}	142.82
Density, g/mL	1.048^{a}	1.038^{b}	1.036^{bc}	1.032^{cd}	1.032^{cd}	1.033^{cd}	1.030^{cd}	1.029^{d}	1.028^{d}	1.028^{d}	0.006
pH	6.40^{b}	6.61^{a}	6.68^{a}	6.66^{a}	6.64^{a}	6.65^{a}	6.66^{a}	6.75^{a}	6.70^{a}	6.71^{a}	0.09
TA, mL	4.2^{a}	2.7^{b}	2.2^{bc}	2.6^{bc}	2.2^{bc}	2.2^{bc}	1.6^{c}	1.5^{c}	1.5^{c}	1.6^{c}	0.08
ES, %	70.00^{ab}	63.43^{bc}	66.57^{ab}	72.86^{ab}	71.43^{ab}	76.29^{ab}	84.57^{a}	86.29^{a}	81.43^{ab}	55.33^{c}	9.21
RCT, min	—	16.6^{ab}	17.57^{a}	16.00^{ab}	14.14^{b}	10.14^{c}	6.57^{cd}	5.43^{cd}	3.43^{d}	2.67^{d}	5.6
SCC, $\times 10^3$ cells	8,449	6,539	4,624	4,828	2,983	1,433	804	467	458	846	2,697

[a–d]Means within a row with different superscripts differ ($P < 0.05$).

Table 3. Immunoglobulin G, IgA, and IgM concentrations and chitotriosidase (ChT) activity of colostrum and milk samples from partum to d 90 postpartum (n = 10 Majorera-breed goats)

	Days postpartum										
Item	0	1	2	3	4	5	15	30	60	90	SEM
IgG, mg/mL	32.99^{a}	20.13^{b}	8.23^{c}	6.05^{cd}	2.16^{d}	1.87^{d}	1.02^{d}	1.09^{d}	0.80^{d}	0.88^{d}	1.38
IgA, mg/mL	0.86^{a}	0.40^{b}	0.24^{bc}	0.19^{bc}	0.17^{bc}	0.11^{c}	0.11^{c}	0.12^{c}	0.10^{c}	0.07^{c}	0.04
IgM, mg/mL	3.84^{a}	1.20^{b}	0.70^{bc}	0.59^{bc}	0.38^{c}	0.38^{c}	0.22^{c}	0.16^{c}	0.18^{c}	0.20^{c}	0.16
ChT activity, nmol/mL per hour	2,775.04^{a}	1,705.73^{b}	741.90^{c}	591.48^{cd}	393.75^{cd}	337.85^{cd}	222.75^{d}	181.14^{d}	200.63^{d}	178.28^{d}	112.29

[a–d]Means within a row with different superscripts differ ($P < 0.05$).

was described by Argüello et al. (2008) and Castro et al. (2011a) up to 5 d postpartum. A similar decrease in colostrum ChT activity around partum was reported in humans by Musumeci et al. (2005), but ChT activity in human colostrum was lower than in goats, indicating that ChT might to play more of a protective role in goats than in humans. So, although the implication on goat kid immunity is clear, no implications have been described on the technological properties.

CONCLUSIONS

Goat colostrum at partum is richer in fat, protein, SCC, lactic acid, and immunity molecules than the subsequent secretions during early lactation. Goat colostrum is considered transitioned to milk after 5 d, when all measured parameters are according to the normal ranges described in the literature for goat milk. From d 1 to 5, the secretion can be considered as transitional goat milk; it is not good colostrum due to the low immunological quality, although it is high in fat and protein content, and it is not good milk to use for dairy processing because of the high RCT, acidity, and immunoglobulin content. However, pouring transitional milk of 1 or 2 does into the bulk milk tank 3 d postpartum could result in a dilution of its components without inconvenience for dairy processing. This assumption must be evaluated for practical purposes in the future.

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