Short communication: Goat colostrum quality: Litter size and lactation number effects

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ABSTRACT

The quality of colostrum of Murciano-Granadina goats was studied to establish the transition period and the time when milk can be marketed. Forty-three dairy goats were used: 19 primiparous (15 single births; 4 multiple births) and 24 multiparous (10 single births; 14 multiple births). Samples were collected every 12 h during the first week postpartum. Physicochemical parameters and somatic cell count were determined. Analysis of variance with repeated measures was used to study the effect of different factors: postpartum time, litter size, lactation number, their interactions, and production level on colostrum. Postpartum time had a significant effect on all parameters studied, which decreased along the first week of lactation, whereas lactose, pH, and conductivity increased. Based on these results, colostrum secretion takes place until 36 h postpartum (hpp). In relation to other factors of variation studied, the lactation number influenced most colostrum components, whereas the litter size only affected the pH value, protein and lactose content. The production level influenced only the protein and dry matter contents, with an inverse relationship. Milk produced during the period between 36 and 96 hpp is considered transition milk, which should not be commercialized. Milk collected after 4 d postpartum (96 hpp) could be marketed, ensuring that its composition does not present a risk in the dairy industry.

Key words: colostrum, physicochemical parameter, Murciano-Granadina goat

Short Communication

Feeding goat kids colostrum is a very important livestock practice within artificial goat-raising systems and it is used mainly in intensive farming. This system minimizes or annuls the mother-kid link, which

is established along the first hours postpartum (hpp; Ramírez et al., 1997), thus helping artificial nipples to be accepted. Newborns are hypogammaglobulinemic at birth (Rodríguez et al., 2009); colostrum intake during the first 2 postpartum days reduces mortality, because it provides antibodies (immunoglobulins) to avoid possible diseases and infections; the survival of newborns is related to colostrum quality and the volume ingested (Argüello et al., 2004; Keskin et al., 2007).

Different studies have evaluated goat colostrum composition (Argüello et al., 2006; Yang et al., 2009; Moreno-Indias et al., 2012). Colostrum is characterized by high fat as well as protein and mineral contents compared with milk. It also presents some interesting components from a biological viewpoint, such as protective substances (immunoglobulins, lactoferrin, and lysozymes, among others) and growth factors (vitamins and amino acids), among others. The physicochemical characteristics and production period of colostrum may vary according to different factors such as production, feeding, breed, length of the dry period, season of the year, and animal health status (Csapó et al., 1998; Caja et al., 2006).

From a practical point of view, suitably delimiting the colostrum production period is interesting for farmers, as they can offer good-quality colostrum to feed goat kids. On the other hand, it would also be useful for producers to know from what time milk can be commercialized because, according to the legislation of many countries, milk intended for human consumption may not contain colostrum [Commission Regulation, European Commission (EC) 1662/2006; European Commission, 2006]. Also, for the dairy industry it is important that milk does not contain colostrum, because the presence of a large amount of soluble proteins can negatively affect the production and standardization of some milk products (Raynal-Ljutovac et al., 2005).

Murciano-Granadina is the most common Spanish goat breed, being well adapted to the Mediterranean livestock system. Some authors have studied different aspects of Murciano-Granadina goat milk production and composition (Díaz et al., 2012; León et al., 2012).

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Nonetheless, information about Murciano-Granadina goat colostrum quality is rather limited (Quiles et al., 1991; Caja et al., 2006).

Therefore, this study aims to establish the physicochemical characteristics of Murciano-Granadina goat colostrum by evaluating the influence of hours postpartum, litter size, lactation number, and the animal's production level; in addition, the period of transition from colostrum to milk is determined, establishing the time when goat milk can be marketed.

Experimental animal procedures were approved by the Ethics Committee of Universitat Politècnica de València (UPV, València, Spain). Forty-three dairy goats of the Murciano-Granadina breed belonging to the experimental flock of the Animal Science and Technology Institute of UPV were used. Of these, 19 were primiparous (15 single births and 4 multiple births); and 24 were multiparous (10 single births and 14 multiple births), divided as follows: 3 in second lactation, 10 in third lactation, and 11 in fourth lactation or more. The mean gestation length for the experimental goats was 151 ± 10 d, and the length of dry period was approximately 103 d. The animals presented a suitable health status and were fed the same ration [alfalfa hay (1,050 g), barley straw (330 g), orange pulp (1,615 g), barley (520 g), beet pulp (205 g), soybean (275 g), treacle (40 g), and a vitamin-mineral corrector], using a mixer-feeder wagon, which covers lactation requirements according to the Institut National de la Recherche Agronomique (INRA, 2007).

After birth, goat kids were separated from their mothers and were raised artificially. Machine milking (high line; CASSE $2 \times 12 \times 6$; Alfa Laval, Lund, Sweden) was performed every 12 h (0800 and 2000 h) during the first week of lactation. To obtain colostrum and milk samples (300 mL), a complete milking was carried out, measuring the total volume with milk-recording jars (3.5 L, Sneder; Industrias Berango S.L., Vizcaya, Spain). The samples were stored at 4°C until their subsequent analysis, and 3 aliquots of 1.5 mL were frozen (−40°C) for IgG quantification.

The physicochemical parameters were analyzed in triplicate on the same day of sampling, and the pH value was determined using a portable pH meter (model Basic 20; Crison Instruments SA, Barcelona, Spain). Colostrum density was determined applying a densimeter [ranging between 1,000 and 1,100 kg/m³ (Proton 20°C; GAB Sistemática Analítica S.L., Barcelona, Spain)]. Electrical conductivity was measured using a conductivity meter (model Basic 30; Crison Instruments SA), and the results were expressed in millisiemens per centimeter at 25°C (mS/cm). To determine titratable acidity (AOAC International, 2000), 1 mL of phenolphthalein indicator (1%) was added to 10 mL of

milk, and the mixture was titrated with 0.111 *M* Dornic NaOH (Suministros Químicos Arroyo S.L., Santander, Spain) to a permanent light pink color. Titratable acidity was expressed as °Dornic using the relation $1^\circ\text{D} = 0.1$ mL of Dornic NaOH (1°D is equivalent to a 0.01% lactic acid concentration). The freezing point was measured with a thermistor cryoscope (CryoStar 1; Funke-Dr. N. Gerber Labortechnik GmbH, Berlin, Germany).

Gross composition analysis (fat, protein, lactose, and DM) and SCC were analyzed at the Interprofessional Milking Laboratory of the Valencian Community (LICOVAL; Spain). Composition was determined by infrared spectrophotometry equipment (MilkoScan FT120; Foss Electric A/S, Hillerød, Denmark; IDF, 2000), using a specific calibration for goat milk; SCC was determined according to the electronic fluoro-opto method (IDF, 2006), using a Fossomatic 5000 somatic cell counter (Foss Electric A/S).

Immunoglobulin G analyses were done using the Calokit-Cabra (Zeu-Inmunotec S.L., Zaragoza, Spain), a direct ELISA sandwich-type immunoenzymatic assay, permitting IgG quantification (mg/mL), with a range of 0.01 to 50 mg/mL. The kit is supplied with a microtiter plate for 96 tests, together with reagents. Colostrum and milk samples were analyzed in duplicate following the manufacturer's instructions.

Statistical analyses were performed using SAS (version 9.2, 2001; SAS Institute Inc., Cary, NC). The SAS PROC MIXED for repeated measurements was used to determine the colostrum production period during the first lactation week. The statistical model included the effect of hours postpartum:

$$Y_{ij} = \mu + HPP_i + G_j + \varepsilon_{ij}$$

where Y_{ij} = dependent variable, μ = mean, HPP_i = hours postpartum ($i = 1-14$ h), G_j = goat ($j = 1-43$ goats), and ε_{ij} = residual error. The MIXED procedure of SAS was used to evaluate the effect of different variation factors on colostrum quality characteristics:

$$Y_{ijkl} = \mu + HPP_i + LN_j + LS_k + G_l(LN_jLS_k) + COV + \varepsilon_{ijkl}$$

where Y_{ijkl} = dependent variable, μ = mean, HPP_i = hours postpartum ($i = 1-14$ h), LN_j = lactation number [$j = 0$ (first lactation); $j = 1$ ($\geq$ second lactation)], LS_k = litter size [$k = 0$ (single); $k = 1$ (multiple)], $G_l(LN_jLS_k) = l$ (1–43) goats nested to LN_j and LS_k ; COV = covariate (mean production), and ε_{ijkl} = residual error.

Table 1 provides the physicochemical characteristics of colostrum and milk of Murciano-Granadina goats along the first 156 hpp. All parameters decreased along

the studied period ($P < 0.001$), except pH, electrical conductivity, and lactose, which increased ($P < 0.001$). No significant differences were found with respect to the freezing point ($P > 0.05$).

Changes in parameters studied (Table 1) were distinct for each of them. The pH value increased considerably at 12 hpp and continued its gradual increase until 156 hpp; however, density and Dornic acidity decreased sharply at 12 hpp, and decreased until 156 hpp. The results were similar to those reported by Argüello et al. (2006) in Majorera goats and Tórres Vilar et al. (2008) in Saanen goats. After 60 hpp, the density value was within the ordinary goat milk range (1,030–1,034 g/L; Ludeña et al., 2006). Electrical conductivity increased from birth to 24 hpp and remained constant ($P > 0.05$) until the last day of the experiment. By contrast, DM and fat content decreased drastically from delivery to 24 hpp and then decreased gradually until 156 hpp. Dry matter content changed similarly to that reported by Keskin et al. (2007) in Damascus goats, although Yang et al. (2009) found lower percentages in Saanen goats compared with those presented herein, as the Saanen breed presents a higher production capacity than the Murciano-Granadina breed (Haenlein, 2007). Fat content results obtained in the current study differed from those of other authors; Keskin et al. (2007) observed a significant decrease until 5 d postpartum and, conversely, Argüello et al. (2006) indicated that fat content increased until 24 hpp, and thereafter decreased gradually.

Both protein content and IgG decreased markedly up to 36 hpp and decreased as the lactation period advanced. Protein content change and values were similar to those provided by Argüello et al. (2006) and Tórres Vilar et al. (2008). Other authors found higher percentages of protein (Csapó et al., 1994; Hadjipanayiotou, 1995; Chen et al., 1998) for the first secretions obtained after delivery. The IgG content in the current study agreed with the data reported by other authors (Argüello et al., 2006; Moreno-Indias et al., 2012). Chen et al. (1998) and Yang et al. (2009) found higher values during the first 5 and 2 d postpartum, respectively, which could be related to the methodology used, as electrophoresis tends to overestimate IgG values compared with ELISA (Rudovsky et al., 2008).

Lactose concentration increased up to 36 h, and then more gradually until 156 h. Several authors have also described an increasing lactose concentration (Argüello et al., 2006; Yang et al., 2009; Moreno-Indias et al., 2012) although, in some cases, percentages were lower than those obtained in the present study. Lactose concentration follows a pattern similar to that of milk production, increasing from partum to reach its maximum value and then decreasing (Olechnowicz and Sobek, 2008).

Table 1. Changes in the physicochemical characteristics of goat colostrum and milk during the first 156 h postpartum (n = 602)

Parameter	Hours postpartum															SEM
	0	12	24	36	48	60	72	84	96	108	120	132	144	156		
Production (mL)	1,786.5 ^a	822.2 ^a	897.9 ^{bc}	810.9 ^d	892.2 ^c	907.5 ^{bc}	913.0 ^{bc}	954.4 ^{bc}	914.4 ^{bc}	958.4 ^{bc}	993.9 ^{bc}	1,031.2 ^{bc}	955.9 ^{bc}	1,028.9 ^{bc}	50.774	
Acidity (°Dornic)	36.29 ^a	25.10 ^b	21.99 ^c	19.27 ^{def}	19.33 ^{def}	18.04 ^{def}	18.58 ^{def}	17.69 ^f	17.43 ^{ef}	17.99 ^{def}	16.30 ^{fg}	15.27 ^g	14.94 ^g	15.34 ^g	0.773	
pH	6.38 ^a	6.54 ^{bc}	6.58 ^{bcd}	6.58 ^{bcd}	6.56 ^{bcd}	6.58 ^{bcd}	6.59 ^{bcd}	6.62 ^{cdef}	6.62 ^{cdef}	6.63 ^{cdef}	6.66 ^{gh}	6.68 ^{gh}	6.7 ^h	6.7 ^h	0.023	
Conductivity (mS/cm)	4.45 ^a	4.92 ^b	4.99 ^c	5.07 ^c	4.96 ^c	5.03 ^c	4.97 ^c	5.25 ^c	5.00 ^c	5.14 ^c	5.0 ^c	5.17 ^c	5.07 ^c	5.06 ^c	0.094	
Density (g/L)	1,052.8 ^a	1,039.6 ^b	1,037.7 ^{bc}	1,035.3 ^d	1,034.7 ^{de}	1,033.1 ^e	1,031.8 ^f	1,033.7 ^e	1,031.8 ^f	1,031.5 ^f	1,031.3 ^f	1,030.7 ^f	1,030.1 ^f	1,030.3 ^f	2.746	
Freezing point (°C)	0.484	0.539	0.545	0.553	0.551	0.548	0.553	0.561	0.560	0.548	0.549	0.547	0.549	0.554	40.341	
DM (%)	29.04 ^a	23.39 ^b	19.26 ^c	18.47 ^{cd}	18.24 ^{cd}	18.16 ^{de}	17.48 ^{def}	17.19 ^{def}	17.68 ^{def}	17.28 ^{def}	17.6 ^{def}	16.85 ^{fg}	17.26 ^{fg}	16.5 ^g	0.414	
Fat (%)	9.53 ^a	9.05 ^a	7.42 ^b	7.26 ^{bc}	7.25 ^{bc}	7.05 ^{bc}	6.98 ^{bc}	6.87 ^{bc}	7.26 ^{bc}	6.81 ^{bc}	7.43 ^b	7.31 ^b	6.87 ^{bc}	6.59 ^c	0.272	
Protein (%)	13.64 ^a	8.04 ^b	6.24 ^c	5.58 ^{de}	5.42 ^{de}	5.36 ^{de}	4.99 ^{ef}	4.75 ^{gh}	4.76 ^{gh}	4.74 ^{gh}	4.48 ^{gh}	4.31 ^{gh}	4.25 ^h	4.33 ^{gh}	0.208	
IgG (mg/mL)	28.23 ^a	11.10 ^b	5.03 ^c	2.16 ^d	2.01 ^d	1.86 ^{de}	1.31 ^{de}	1.03 ^{de}	0.93 ^{de}	0.75 ^e	0.77 ^e	0.69 ^e	0.68 ^e	0.73 ^e	1.308	
Lactose (%)	2.9 ^a	3.6 ^b	4.14 ^c	4.37 ^d	4.45 ^d	4.67 ^{efgh}	4.55 ^{ef}	4.59 ^{ef}	4.68 ^{gh}	4.74 ^{gh}	4.76 ^h	4.79 ^h	4.80 ^h	4.82 ^h	0.706	
LSCC ¹	6.01 ^a	6.09 ^a	5.99 ^a	5.93 ^{ab}	5.85 ^b	5.72 ^c	5.65 ^{cd}	5.57 ^d	5.63 ^{cd}	5.57 ^d	5.64 ^{cd}	5.53 ^d	5.58 ^d	5.54 ^d	0.080	

^{a-h}Means within a row with different superscript letters differ significantly ($P < 0.05$).

¹LSCC = log₁₀ SCC.

Somatic cell count decreased from delivery to 60 hpp and no differences were found until lactation d 7. Information on SCC in colostrum is very scarce. Recently, Moreno-Indias et al. (2012) found a higher SCC in Majorera goat colostrum than that presented herein. In general, goat milk presents a high SCC value during the first 2 wk postpartum, which decreases until the second month after parturition and then increases as lactation advances (Zeng et al., 1997). Moreover, many noninfectious factors (breed, parity, and season, among others) contribute to high SCC counts in goat milk (Dulin et al., 1983; Paape et al., 2001).

Based on the results obtained and depending on the parameter used, we established that Murciano-Granadina goat colostrum production takes place during the first 36 hpp. This result is similar to that reported by Quiles et al. (1991), who considered only the protein fraction, and established that transition should take place on the second day after delivery, in the same breed. Also, Yang et al. (2009), in Saanen goats, found no significant differences between 24 and 48 hpp for the composition parameters studied. However, Trres Vilar et al. (2008) considered colostrum to be exclusively the secretion occurring between 0 and 12 hpp.

Furthermore, it is possible to establish the time when milk can be marketed by the dairy industry with no drawbacks given due to the presence of colostrum. In relation to the baseline levels of IgG content in goat milk, several studies exist (Levieux et al., 2002; Raynal-Ljutovac et al., 2005) that indicate that the colostrum content is lower than 1 mg/mL after the first week of lactation. In France, the quality payment system for goat milk (Pirisi et al., 2007) establishes a classification based on the IgG content and other parameters;

this system applies a bonus or penalty by fixing the milk price according to each parameter. Milk category C presents the maximum penalty on IgG values above 1 mg/mL. The secretion of 36 hpp should not be commercialized, as its IgG content is 2.16 mg/mL; however, after 96 hpp (4 d), milk can be marketed because its IgG content is 0.93 mg/mL, which would not present problems in milk processing. Thirty-six to 96 hpp may be considered transition milk, which could be used to feed goat kids, although it does not have a good immunological quality.

Table 2 shows the effect of the lactation number on colostrum quality characteristics (secretion corresponding to 0, 12, 24, and 36 hpp). The lactation number influences ($P < 0.05$) the majority of components. Hence, primiparous goat colostrum is characterized by high Dornic acidity levels and freezing point, as well as higher contents of DM, protein, and lactose than those of multiparous goats; conversely, it presents lower SCC and electrical conductivity values.

The study conducted by Argello et al. (2006) observed that lactation number had no effect on any of the parameters studied. However Trres Vilar et al. (2008) reported that only pH was affected by lactation number and that goats in third lactation gave higher pH values. In a study that evaluated conductivity as a tool for mastitis detection in Murciano-Granadina milk, Romero et al. (2012) observed that both conductivity and SCC were lower in primiparous than in multiparous goats (conductivity: 5.07 vs. 5.45 mS/cm and SCC: 107×10 vs. 494×10 cells/mL, respectively); those results agree with the current work. Several authors have indicated that SCC increases with increasing parity (Salama et al., 2003). The results obtained

Table 2. Effect of lactation number on Murciano-Granadina goat colostrum obtained during the first 36 h postpartum¹

Parameter	Lactation number		
	First lactation	$\geq$ Second lactation	LS ²
Acidity ($^{\circ}$ Dornic)	28.88 ± 1.28	23.11 ± 1.10	**
pH	6.47 ± 0.03	6.53 ± 0.03	NS
Conductivity (mS/cm)	4.53 ± 0.13	5.41 ± 0.11	***
Density (g/L)	$1,039.40 \pm 3.35$	$1,040.58 \pm 0.03$	NS
Freezing point ($-^{\circ}$ C)	562.66 ± 7.83	537.87 ± 6.74	***
DM (%)	23.82 ± 0.46	21.37 ± 0.55	**
Fat (%)	8.33 ± 0.39	8.19 ± 0.33	NS
Protein (%)	9.17 ± 0.46	7.79 ± 0.39	*
IgG (mg/mL)	15.20 ± 3.04	12.85 ± 2.37	NS
Lactose (%)	3.95 ± 0.12	3.52 ± 0.10	*
LSCC ³	5.79 ± 0.12	6.18 ± 0.12	NS

¹Results are presented as means $\pm$ SEM.

²Level of significance.

³LSCC = $\log_{10}$ SCC.

*** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$.

Table 3. Effect of litter size on Murciano-Granadina goat colostrum obtained during the first 36 h postpartum¹

Parameter	Litter size		
	Single	Multiple	LS ²
Acidity (°Dornic)	24.64 ± 0.97	27.31 ± 1.35	NS
pH	6.53 ± 0.02	6.48 ± 0.03	*
Conductivity (mS/cm)	5.05 ± 0.10	4.89 ± 0.13	NS
Density (g/L)	1,039.65 ± 2.55	1,040.33 ± 3.05	NS
Freezing point (°C)	531.29 ± 5.90	535.24 ± 7.28	NS
DM (%)	23.03 ± 0.48	22.16 ± 0.61	NS
Fat (%)	8.36 ± 0.37	8.19 ± 0.39	NS
Protein (%)	9.10 ± 0.43	7.86 ± 0.35	*
IgG (mg/mL)	11.07 ± 2.37	16.98 ± 3.25	NS
Lactose (%)	3.92 ± 0.09	3.57 ± 0.12	*
LSCC ³	5.97 ± 0.08	5.92 ± 0.09	NS

¹Results are presented as means ± SEM.²Level of significance.³LSCC = log₁₀ SCC.**P* < 0.05.

may be due to the fact that milk production is lower in primiparous than multiparous dairy goats, and can produce a component concentration effect. Indeed the production level increases with the lactation number (Zeng and Escobar, 1995).

The influence of litter size was significant (*P* < 0.05), but only in relation to pH and protein and lactose contents (Table 3). Thus, the colostrum of goats of single births contained a higher pH value and percentage of protein and lactose than colostrum of goats of multiple births. Only a limited number of studies exist concerning the effect of litter size on colostrum characteristics, with different and sometimes contradictory results (Csapó et al., 1994; Zygoyiannis, 1994; Argüello et al., 2006). From these results, it can be deduced that increased prolificity may be accompanied by increased milk production and, consequently, a dilution of the components.

The animal's production level significantly influenced (*P* < 0.05) DM and protein percentages, and an inverse relation with the volume produced was found; when milk production is greater, a dilution effect occurs and, therefore, the percentage of these parameters is lower [DM: β (slope of the covariate) = -0.0032 and protein: β = -0.6018]. No significant interactions were detected between time and litter size or lactation number, or between litter size and lactation number.

In conclusion, the colostrum-secretion period in Murciano-Granadina goats was established as occurring between 0 and 36 hpp. Milk produced between 36 and 96 hpp is considered transition milk, which should not be commercialized, as it may cause technological problems in milk processing, but may be used in artificial raising of goat kids. Milk collected after 4 d postpartum could be marketed, thus ensuring that its composition does not present a risk in the dairy industry.

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