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. Physico-chemical 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, while lactose, pH and conductivity increased. Based on these results, colostrum secretion takes place until 36 hours postpartum (hpp). In relation to other factors of variation studied, the lactation number influenced ($P <0.05$) most colostrum components, while the litter size only affected ($P <0.05$) 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. After 4 days postpartum (96 hpp) milk could be marketed, ensuring that composition does not present a risk in the dairy industry.

Keywords: colostrum, physico-chemical parameters, Murciano-Granadina goats

Feeding goat kids colostrum is a very important livestock practice within artificial rearing 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., 1996), thus helping artificial nipples to be accepted. Besides, newborns are hypogammaglobulinemic at birth (Rodriguez et al., 2009), colostrum intake during a first 2 postpartum days reduces mortality, because it provides antibodies (immunoglobulins) to avoid possible diseases and infections; their survival 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 when compared to milk. It also presents some interesting components from a biological viewpoint, such as protective substances (immunoglobulins, lactoferrin, lysozymes, etc.), growth factors (vitamins and amino acids), among others. The physico-chemical characteristics and production period of colostrum may vary according to different factors such as production, feeding, breed, length of 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, (EC) 1662/2006). Also, for the dairy industry it is important that milk does not contain colostrum, since 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´s milk production and composition (Díaz et al., 2012; León et al., 2012). Nonetheless, information about Murciano-Granadina goat's colostrum quality is rather limited (Quiles et al., 1991; Caja et al., 2006).

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

Experimental animal procedures were approved by the Ethical Committee of Universitat Politècnica de València (UPV, 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 of the second lactation, 10 of the third lactation and 11 of the fourth lactation or more. The mean gestation length for the experimental goats was 151 ± 10 days, and the length of dry period was approximately 103 days. The animals presented a suitable health status and were fed the same ration, basically alfalfa hay (1,050 g), barley straw (330 g), orange pulp (1,615 g), barley (520 g), beet pulp (205 g), soya (275 g), treacle (40 g) and a vitamin-mineral corrector, using a mixer-feeder wagon, which covers lactation requirements according to INRA (2007).

After birth, goat kids were separated from their mothers and underwent artificial rearing. Machine milking (high line; CASSE 2x12x6; Alfa Laval®, Lund, Sweden) was performed every 12 h (8 am and 8 pm) 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 ºC until their subsequent analysis, and 3 aliquots of 1.5 mL were frozen (-40 ºC) for IgG quantification.

The physico-chemical parameters were analyzed in triplicate on the same day of sampling, and the pH value was determined using a portable pH meter (Crison, model Basic 20, Crison Instrument, Barcelona, Spain). Colostrum density was determined applying a densimeter (ranging between 1000 and 1100 kg/m^3 (Proton 20 ºC, GAB Sistematica Analitica S.L, Barcelona, Spain). Electrical conductivity was measured using a conductivity meter (Crison, model Basic 30, Crison Instruments, Barcelona, Spain), and the results were expressed in millisiemens per centimetre at 25 ºC (mS/cm). To determine titratable acidity (AOAC, 2000), 1 mL phenolphthalein indicator (1 %) was added to 10 mL of milk, and the mixture was tritated with Dornic NaOH, 0.111 M (Suministros Químicos Arroyo, S.L, Santander, Spain) to a permanent light pink color. Titrable acidity was expressed as º Dornic using the relation: 1 ºD = 0.1 mL Dornic NaOH (1ºD is equivalent to 0.01 % lactic acid concentration). The freezing point was measured with a thermistor cryoscope (Cryostar l, Funke- Dr.N. Gerber Labortechnik GmbH, Berlin, Germany).

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

IgG 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 0.01-50 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 procedure 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:

$$Y_{ijk} = \mu + HPP_i + G_j + \varepsilon ijk$$

where: Y_{ijk}= dependent variable, μ=mean, HPP_i= hours postpartum, G_j= goat and εijk= residual error. SAS Proc Mixed was used to evaluate the effect of different variation factors on colostrum quality characteristics:

$$Y_{ijkl} = \mu + HPP_i + NL_j + LS_k + C_l\,(NL_j\ LS_k) + COV + \varepsilon_{ijkl}$$

where: Y_{ijkl}= dependent variable, μ= mean, HPP_i= hours postpartum, LN_j= lactation number, LS_k= litter size, COV= covariate (mean production) and ε_{ijkl}= residual error.

Table 1 provides the physico-chemical characteristics of colostrum and milk of Murciano-Granadina goats along the first 156 hpp. All parameters lowered 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 rose considerably at 12 hpp, and continued its gradual increase untill 156 hpp; however density and dornic acidity dropped 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 Vilar et al. (2008) in Saanen goats. After 60 hpp, the density value was similar within the ordinary goat's 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 dry matter and fat content drastically lowered from delivery to 24 hpp, and then dropped gradually until 156 hpp. Dry matter evolved similarly to that reported by Keskin et al. (2007) in Damascus goats, although Yang et al. (2009) found lower percentages in Saanen goats when compared to those presented herein, as that breed presents a higher production capacity than Murciano-Granadina (Haenlein, 2007). Fat results obtained differed from other authors; Keskin et al. (2007) observed a significant decrease until day 5 postpartum; and, conversely, Argüello et al. (2006) indicated that fat increased until 24 hpp, and thereafter decreased gradually.

Both protein content and IgG lowered markedly up to 36 hpp, which dropped as the lactation period advanced. Protein evolution and values were similar to those provided by Argüello et al. (2006) and 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. IgG content 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 days postpartum, respectively, which could be related to the methodology employed, as the electrophoresis method tends to overestimate IgG values in comparison with the ELISA method (Rudovsky et al., 2007).

Lactose increased up to 36 h, and then more gradually until 156 h. Several authors have also described an increasing lactose evolution (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. The lactose follows an evolution similar to milk production, increases from partum to reach its maximum value and then decreases (Mioč et al., 2008).

SCC decreased from delivery to 60 hpp, and no differences were found until lactation day 7. Information on SCC in colostrum is very scarce. Recently, Moreno-Indias et al. (2012) found a higher SCC in Majorera goat's colostrum than that presented herein. In goat milk the SCC increases as lactation advances and there are many factors (day lactation, parity, infection…) that contribute to high values of SCC (Zeng et al., 1997; Dulin et al., 1983).

Based on the results obtained and depending on the parameter employed, it can be established that the Murciano-Granadina goat colostrum production period 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 2nd day after delivery, in the same breed. Also, Yang et al. (2009) in Saanen goats, found no significant differences between 24 hpp and 48 hpp for the composition parameters studied. However, Vilar et al. (2008) considered colostrum to be exclusively the secretion occurring between 0 h and 12 hpp.

Furthermore, it is possible to establish the time when milk can be marketed by the dairy industry with no drawbacks given the presence of colostrum. In relation to the baseline levels of IgG content in goat's milk, there are several studies (Levieux et al., 2002; Raynal-Ljutovac et al., 2005) which indicate that this content is lower than 1 mg/mL after the first week of lactation. In France, the quality payment system for goat's 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 days) 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 (LN) on colostrum quality characteristics (secretion corresponding to 0, 12, 24 and 36 hpp). LN influences ($P < 0.05$) the majority of components. Hence, primiparous goat's colostrum is characterized by high dornic acidity levels and freezing point, as well as a higher content of dry matter, protein and lactose than that of multiparous goats; conversely, it presents lower SCC and electrical conductivity values.

The study conducted by Argüello et al. (2006) observed that LN had no effect on any of the parameters studied. However Vilar et al. (2008) reported that only pH was affected by LN and that those of a 3rd lactation gave higher values. In a study which evaluated conductivity as a tool for mastitis detection in Murciano-Granadina´s milk, Romero et al. (2012) observed that both conductivity and SCC were lower in primiparous than in multiparous goats (conductivity: 5.07 mS/cm *vs*. 5.45 mS/cm and SCC: 107 x 10 cel/mL^{-1} *vs*. 494 x 10 cel/mL^{-1}, respectively); results agree with this work. Several authors have indicated that SCC increases with increasing parity (Salama et al., 2003). The results obtained 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 LN (Zeng and Escobar, 1995).

The influence of litter size (LS) was significant ($P < 0.05$), but only in relation to pH, protein and lactose contents (Table 3). Thus, the colostrum of goats of single births contained a higher value of pH and percentage of protein and lactose than colostrum of goats of multiple births. There are only a limited number of studies concerning the effect of LS on colostrum characteristics, with different and sometimes contradictory results (Zygoyiannis, 1994; Csapó et al., 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 ($P < 0.05$) dry matter and protein percentages, and an inverse relation with the volume produced was found; when milk production is greater occurs dilution effect, therefore the percentage of these parameters is lower (dry matter: βx_e= -0.0032 and protein: βx_e= -0.6018). No statistical interactions were detected between time and LS or LN effects, or between LS and LN.

In conclusion, the colostrum secretion period in Murciano-Granadina goats is established 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 which may be used in artificial rearing of goat kids. After 4 days postpartum, milk could be marketed, thus ensuring that composition does not present a risk in the dairy industry.

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Table 1. Evolution of the physico-chemical characteristics of goat's colostrum and milk during the first 156 hours postpartum (n=602)

Parameter	Hours Postpartum (hhp)														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}	±50.773
Acidity (ºDornic)	36.29^{a}	25.10^{b}	21.99^{c}	19.27^{def}	19.33^{def}	18.04^{def}	18.58^{def}	17.69 ^{ef}	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^{bcde}	6.58^{bcde}	6.56^{bcd}	6.58^{bcde}	6.59^{bcde}	6.6^{cdef}	6.62^{defg}	6.63^{efg}	6.66^{fgh}	6.68^{gh}	6.7^{h}	6.7^{h}	±0.0227
Conductivity	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}	±0.0944
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^{ef}	1,033.7^{e}	1,031.8^{ef}	1,031.5^{ef}	1,031.3^{f}	1,030.7^{f}	1,030.1^{f}	1,030.3^{f}	±2.7456
Freezing Point (-ºC)	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	±40.34
Dry Matter (%)	29.04^{a}	23.39^{b}	19.26^{c}	18.47^{cd}	18.24^{cde}	18.16^{de}	17.48^{defg}	17.19^{efg}	17.68^{def}	17.28^{efg}	17.6^{defg}	16.85^{fg}	17.26^{efg}	16.5^{g}	±0.4137
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^{fgh}	4.76^{fg}	4.74^{fgh}	4.48^{gh}	4.31^{gh}	4.25^{h}	4.33^{gh}	±0.208
IgG[1] (mg/mL)	28.23^{a}	11.10^{b}	5.03^{c}	2.16^{d}	2.01^{de}	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^{de}	4.67^{efgh}	4.55^{ef}	4.59^{ef}	4.68^{fgh}	4.74^{gh}	4.76^{h}	4.79^{h}	4.80^{h}	4.82^{h}	±0.716
LSCC[2]	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}	±0.0801

$^{a\text{-}h}$ The means in the same row with different letters differ significantly ($P < 0.05$); [1]IgG: Immunoglobulin G; [2]LSCC: Log_{10} Somatic Cell Count.

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

Parameter	Lactation Number		
	1st Lactation ± SEM	**≥ 2nd Lactation ± SEM**	**L.S[1]**
Acidity (ºDornic)	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 ± 3.35	1,040.58 ± 0.03	ns
Freezing Point (-ºC)	562.66 ± 7.83	537.87 ± 6.74	***
Dry Matter (%)	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[2] (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

[1]LS: Level of significance *** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$ ns: $P > 0.05$; [2]IgG: Immunoglobulin G; [3]LSCC: Log_{10} Somatic Cell Count.

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

Parameter	**Litter Size**		
	Single ± SEM	**Multiple ± SEM**	**L.S[1]**
Acidity (ºDornic)	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 (-ºC)	531.29 ± 5.90	535.24 ± 7.28	ns
Dry Matter (%)	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[2] (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

[1]LS: Level of significance *** P < 0.001; ** P < 0.01; * P < 0.05 ns: P > 0.05; [2]IgG: Immunoglobulin G; [3]LSCC: Log_{10} Somatic Cell Count.