Milkability and milking efficiency improvement in Murciano-Granadina breed goats

N. Fernández*, A. Martínez, J. V. Martí, M. Rodríguez, C. Peris

Instituto de Ciencia y Tecnología Animal, Universitat Politècnica de València, Camino de Vera, s/n, 46022 Valencia, Spain

*Corresponding author: Nemesio Fernández; Instituto de Ciencia y Tecnología Animal, Universitat Politècnica de València, Camino de Vera, s/n, 46022 Valencia, Spain,

Phone number: +34 963879432; Fax number: +34 963877439; E-mail: nfernand@dca.upv.es

ABSTRACT

The aim of this study was to verify the effect of cluster, udder characteristics and milking parameters on milkability and milking efficiency of Murciano-Granadina breed goats, in order to improve them. The cluster used is well adapted to the goats, except that the teat-floor distance is too short for the teat-cup used and the cluster rests on the platform instead of hanging from the udder, something apparently attributed to a poor udder conformation rather than an excessively long teat-cup. Udder parameters studied are classified as medium or medium-high by the Murciano-Granadina breed association, and do not seem to represent a problem for good milkability except for the teat sphincter strength, which reduced milk flows ($P<0.001$) and increased milking times ($P<0.001$). Maintaining 60% as pulsator ratio, a combination 42 kPa:120 ppm (vacuum level : pulsator rate) milking parameters reduced total milking time by 22 s per goat compared to 40 kPa:90 ppm, commonly used in this flock, but increased teat thickness measured before and after milking. Studies of longer duration are needed to ensure that the new milking parameters do not affect the udder health status.

Keywords**:** machine milking, milking efficiency, goat.

INTRODUCTION

There is evidence (N. Fernández, unpublished data) that in some herds, including the one used in this experiment, the average milking time of Murciano-Granadina goats drops from about 5 to around 3 min as the lactation curve evolves, representing a mean milk flow between 600 and 700 mL/min, which is considered to be improved without harming the milk fractioning during milking or the health status of the udder**.** These flows are much lower than the 939 mL/min observed by Le Du and Benmederbel (1984), despite needing 35 kPa average vacuum to open the teat sphincter in Saanen goats, suggesting some kind of problem that could result in low milkability and milking efficiency of those herds. Some of the parameters that determine milkability (Labussière, 1984) are milk fractioning and milk flows during milking. One of the usual ways of assessing milkability is through milk emission kinetics (Peris et al., 2010), as it gives milk fractioning during milking, the latency, the maximum and average milk flow and the total milking time, among other possible data. For milk fractioning interpretation when using a routine with machine stripping, the higher the percentage of the machine milking milk fraction and the lower the percentage of machine stripping milk fraction, the greater is the ability for milking (Labussière, 1984). A high milk flow is also positive for good milkability because it improves milking efficiency. Milk flow during milking may be affected by udder morphology characteristics (Marnet et al., 2000), especially teat sphincter strength (Marnet et al., 2001), or the features of the cluster used, especially by the mouthpiece lip flexibility (Fernández et al., 1997). In addition, the variation of the possible combinations among the operating parameters of machine milking (vacuum level, pulsator rate and pulsator ratio) can also affect milk flows and milk fractioning (Fernández et al., 1999). The aim of this study was to test the relationships among udder and cluster characteristics and milking parameters, as variables, in order to improve milkability and milking efficiency in Murciano-Granadina goats, using milk emission kinetics as assessment methodology.

MATERIALS AND METHODS

Housing and handling of the experimental animals followed the mandatory principles for care and use experimental animals in Spain (Real Decreto 1201/2005, Boletín Oficial del Estado 252: 34367-34291).

Goats and General Procedures

Forty multiparous (3±0.4 years) Murciano-Granadina breed goats (45±2 kg) were used at the experimental farm of the Universitat Politècnica de València (Spain). Mating was synchronized by intravaginal sponges (30 mg fluorogestone acetate and 450 IU PMSG; Chrono-gest, CEVA Salud Animal, Intervet, Salamanca, Spain) and all births took place over a 14-d period. At parturition, goats were assigned to an artificial rearing system, similar to McKusick et al. (2001), where kids were separated from their dams at kidding, fed of colostrum then artificially reared in straw-bedded pens (size = 0.3 m^2/kid; 2 bowl water troughs) from birth and goats were milked once-a-day until 36 wk of lactation. All goats received the same total mixed ration twice daily (at 0900 and 1800 h) and were kept together in the same pen (size = 1.5 m^2/goat; feeder = 0.5 m/goat; 5 bowl water troughs). The ration was formulated according to Sauvant et al. (2007) and consisted of: 1) a basal diet to meet minimum recommendations for maintenance plus 1.0 L milk/d (8.71 Mj NE; 99 g MP; 8.7 g Ca; 4.9 g P) included alfalfa hay (30% as DM), barley straw (26%), beetroot pulp (18%), orange pulp (26%), and 2) a commercial concentrate for dairy goats (6.78 Mj NE, 135 g MP, 9 g Ca and 4 g P per kg of DM) to meet a total average milk yield of 2.5 L per goat per day, at the period of the experiment. Rations were offered to the does in an amount 10% higher than the calculated voluntary feed intake. A high line Casse type milking parlor (2 platforms; 12 goats per platform; 6 milking units) was used; machine milking parameters were set to: vacuum = 40 kPa, pulsation rate = 90 ppm and pulsation ratio = 60%, until the experimental period. Does were machine-milked without any udder preparation and using the following routine: machine milking, machine stripping and post-milking teat-dipping (Proactive Plus. 0.15% iodine, 4% glycerin, and 4% sorbitol-based emollient, DeLaval, Drongen, Belgium).

Machine stripping involved a vigorous udder massage for 15-20 s just before the teat-cups were removed.

Experimental Design

On 40 goats at weeks 17, 18 and 19 of lactation, for 11 consecutive days (day 1-11), the experiment was carried out. The study of udder morphology was conducted on day 1 of the experiment. Between days 2 and 9 of the experiment (8 d), the milk emission kinetics and teat thickness change after milking were performed on different combinations of vacuum and pulsator rate milking parameters, in a Latin square design 4 x 4: four groups of 10 goats, four combinations of parameters (40 kPa : 90 ppm; 40 kPa: 120 ppm; 42 kPa : 90 ppm; 42 kPa : 120 ppm) and eight days (two milkings per combination). Pulsator ratio was always 60%. On 10 and 11 days of the experiment, teat sphincter strength measurement was carried out.

Cluster characteristics

Characteristics of the cluster used are presented in Table 1 and Fig. 1, according to ISO 3918 (2006). Most of the barrel measurements were taken from plaster moulds. The lip mouthpiece deflection corresponded to the descending value of the lip when a 0.5 kg weight was applied to a stopper closing the mouthpiece bore (O’Shea et al., 1983). Barrel rigidity was determined from the minimum necessary vacuum, applied to the liner end, needed to close the barrel within the shell (Le Du et al., 1978). Diameter of the barrel was measured 75 mm from the mouthpiece (ISO 3918, 2006).

Morphology of the udder

On day 1 of the experiment, the udder characteristics (teat length; teat width at the base; teat width at the central section; implantation angle from the rear; implantation angle from the lateral; udder height; Labussière, 1984), teat-floor distance, and, on days 10 and 11 of the experiment, teat sphincter strength (**SS**) were measured. Teat sphincter strength was performed increasing the level of vacuum, from 0 kPa and without pulsation, applied at the end of the teat-cup until the appearance of the first spurt of milk (Marnet et al., 2001). Average values of SS measurements were considered.

Milk emission kinetics

Milk emission kinetics was used to evaluate the effect of four different combinations of milking parameters on milk fractioning, milk flow and milking time. A milk meter (MM25SG; DeLaval, Tumba, Sweden) and an own software for data interpretation were used for recording. Data collection was performed every 2s. The kinetic characteristics were taken from these records: machine milking milk volume (**MM**); machine stripping milk volume (**MS**); milk flow in the first minute after the onset of foremilk (**MF60**); machine milking average flow (**MMAF**); machine milking maximum flow (**MMMF**); machine stripping average flow (**MSAF**); machine stripping maximum flow (**MSMF**); latency, time elapsed from teat-cup attachment to milk flow appearance in the claw; time for maximum machine milking (**TMMM**), time elapsed from teat-cup attachment to the maximum flow of MM; machine milking duration (**MMT**), time elapsed from teat-cup attachment to MM completion; time for maximum machine stripping (**TMMS**), time elapsed from MMT to the maximum flow of MS; machine stripping duration (**MST**), time elapsed to obtain MS; total milking duration (**TMT**), time elapsed from teat-cup attachment to the end of milking.

Teat thickness

Teat-end edema created by the milking machine was estimated with a cutimeter (nº 33865; Hauptner, D-42651 Solingen), measuring the teat thickness change immediately after milking, according to Hamann et al. (1996). The difference in thickness measured before and after milking reflects changes in the mass of tissue and fluid in the teat (Hamann and Mein, 1990). Teat thickness was defined as the distance (mm) between the cutimeter jaws for a given applied pressure. The cutimeter had a new spring that exerted a force of 6.7 N (400 mm^2, 0.01675 N/mm^2), similar to Díaz et al. (2013). These authors demonstrated a high correlation between ultrasound and cutimeter methods for measuring teat-end edema after milking. Measurements of each teat were performed before and after milking, as the difference between the readings taken (mm = post-milking reading – pre-milking reading), on days 2 to 9 of the experiment, for the four milking parameter combinations, after milk emission kinetics recording and expressed in percentage of the value measured before milking. Measurements were taken in duplicate; after the first application, the cutimeter was opened and the thickness gauged again without changing the device's position (Isaksson and Lind, 1992).

Statistical analysis

Variables from kinetic milk emission (milk yield and fractioning, flows and times) and percentage of teat-end edema were analyzed using the GLM procedure (SAS Inst. Inc., Cary, NC), with a model that included the fixed effects of day (8 days; days 2 to 9 of the experiment) and milking parameters (40 kPa : 90 ppm; 40 kPa: 120 ppm; 42 kPa : 90 ppm; 42 kPa : 120 ppm), the random effect of animal (1 to 40) and residual error. Separation of means, if appropriate, for the determination of a significant ($P < 0.05$) main effect was using pairwise contrasts (PDIFF option from SAS). The relationship between variables was carried out following the SAS Corr Procedure.

RESULTS AND DISCUSSION

Animal factor, for all studied variables, and milking parameters, for some of them (see Tables 3 and 4), were statistically significant, while day factor was not significant in any case.

Udder morphology and teat-cup design

The average udder morphology values are presented in Table 2. Length and width of the teats are medium-high, while the remaining teat parameters are considered medium values by the Murciano-Granadina breed association (Ruiz, 2008). The sphincter strength value was 30.1 kPa, with a low standard error but with a maximum of 38.5 kPa (not shown), a value very close to the milking vacuum (40 kPa) and higher than that reported by Marnet et al. (2001) in Alpine and Saanen breeds (26.1 kPa). These breeds were milked twice daily whereas in this experiment one milking per day was performed, as it is common in Murciano-Granadina breed. The high hardness sphincter in this breed could be related to the habitual high intramammary pressure (Marnet et al., 1999; Skapetas et al., 2008) due to the accumulation in the udder of milk produced for a day. Regarding the correlations among the teat characteristics, beyond those expected, such as significant and positive between length and width or significant and negative between angle implantation and length, the strength of the sphincter was not significantly related to any of the udder measurements taken.

Analyzing the relations between udder morphology (Table 2) and liner characteristics (Table 1 and Fig. 1), the diameter of the teats on the basis (55 mm) was greater than the internal diameter of the mouthpiece lip (21 mm), but only slightly greater than the assembly of mouthpiece lip diameter + mouthpiece mouth diameter (48 mm; 3 + 2 + 3, Fig. 1). The thickness (2.34 mm) and deflection (7.5 mm) of the lip were similar to those considered suitable (2 mm and 20 mm, respectively) by Fernández et al. (1997). These authors found that mouthpiece lip deflection was more important than its diameter for a good milk fractionation during milking. The liner throat (40.8 mm) was slightly wider than the diameter of the teat in the middle (38 mm), whereas the suggestion is that the liner throat should be 1 to 2 mm narrower than the teat (Mein, 1992) to avoid teat movement and cluster climbing during milking. Mein (1992) also indicates that cow teats become longer by 40-50% during milking. In this experiment, this would represent an average teat length of 91.4 mm after elongation, which is much shorter than the liner barrel (144 mm). On the other hand, the length of the teat-cup (202 mm) was greater than the average distance between the lower surface of the udder and the floor of the milking platform (177 mm), which means that, for the majority of animals, the milking unit was not hanging from the udder but rested on the platform. This teat-floor distance is much lower than that reported by Peris et al (1999) for the same breed (242-258 mm), but the liner meets their recommendations for the same breed, in the sense that it should be longer than 120 mm. Teat-floor distance was correlated (- 0.87, $P < 0.001$; result not shown) negatively with the height of the udder, which may indicate the need to control udder drop.

Milk emission kinetics

Milk fractioning was not altered by the milking parameter combinations tested (Table 3), and in all cases, the machine stripping milk volume (**MS**) represented a low percentage (from 7.8 to 10.6%) of the total milk yield, when compared with that obtained (17%) by Peris et al. (1994), for the same breed.

All milk flows, except the maximum flow of MS, were affected by the milking parameters, the highest values corresponding, in general, to the higher vacuum and higher pulsation rate (42 kPa : 120 ppm). Thus, the combination 42 kPa :120 ppm required less time for evacuation of the machine milking milk volume (**MM**) than the rest of the parameter combinations, but similar to the 40 kPa :120 ppm for the total milking duration. This latter fact could be related to the greater amount of MS (+ 37 mL) to be evacuated after obtaining the MM. Therefore, the use of the 42 kPa : 120 ppm combination could reduce total milking duration at the max by 22 s per animal relative to 40 : 90 commonly used, which was one of the objectives of this work. However, when the vacuum level rises the udder health risk is greater because the teat edema increases (Table 4), so it is necessary to perform long-term studies with the combination of parameters 42 kPa : 120 ppm to be sure it does not affect the health status of the udder, taking into account, among other variables, microbiology and somatic cell count in milk. From Table 4, it is possible to infer that the increment of pulsation rate from 90 ppm to 120 ppm, for the same level of vacuum (40 kPa or 42 kPa), increases teat edema after milking by 1.38% or 2.18%, respectively, while the increment of vacuum from 40 kPa to 42 kPa, for the same pulsation rate (90 ppm or 120 ppm), increases teat edema after milking by 2.61% or 3.41%, respectively. This potential effect of vacuum level on udder health was also observed by Fernández et al. (1999). The fact that lower differences (P = 0.03 and P = 0.08) for milk flows were associated to the peak flows suggests that the morphological characteristics of the udder, possibly sphincter strength, are affecting them. The longer latency times correspond to the higher pulsator rate values, a fact that is difficult to explain, because they did not agree with the shortest times for machine milking time or total milking time obtained by 120 ppm. Fernández et al. (1999) also proved the relationship between a higher pulsation rate and a lower milking time.

Milk emission kinetics and udder morphology correlations

Correlations among the parameters of the milk emission kinetics and of the teat were virtually nonexistent (not shown), with the exception of those related to the sphincter (P < 0.001, Table 4). The sphincter strength is correlated with all parameters of milk emission kinetics except with fraction volumes of milk, and flows and durations of the MS (results not shown). These results differ from those obtained by Marnet et al. (1999), who found a positive correlation between the volumes of milk and sphincter strength, which they interpreted as the strength of the sphincter increasing as intramammary pressure rose. The parameters associated with MS can vary depending on the force exerted by the milker. However, the effect of the sphincter strength seems to be very important, as it relates ($P < 0.005$) positively with all time parameters and negatively with all flow parameters that do not involve the milker. Similar results were found by Le Du and Benmederbel (1984), which led them to define the strength of the sphincter as one of the most important parameters to explain milkability of animals.

CONCLUSION

The cluster used to milk is adequate, although this flock looks to have a problem related to a poor udder conformation. For a pulsator ratio of 60%, a combination 42 kPa : 120 ppm (vacuum level : pulsator rate) of milking parameters reduced 22 s total milking time per goat compared to 40 kPa : 90 ppm, but affected teat thickness measured before and after milking. It is necessary to carry out a new experiment with the combination of parameters 42 kPa : 120 ppm to be sure it does not affect the health status of the udder.

REFERENCES

Díaz, J.R., Alejandro, M., Peris, C., Fernández, N., 2013. Use of ultrasound scanning to estimate teat wall thickness in Murciano-Granadina goats. Livest. Sci. 155, 114-122.

Fernández, N., Díaz, J.R., Peris, C., Rodríguez, M., Molina, M.P., Torres, A., 1999. Machine milking parameters for the Manchega sheep breed, in: 6th International Symposium on the Milking of Small Ruminants, ed. EAAP, Athens, Greece, pp. 233-238.

Fernández, N., Requena, R., Beltran, M.C., Peris, C., Rodríguez, M., Molina, M.P., Torres, A., 1997. Comparison of different milking clusters on dairy ewes with large size teats. Ann. Zootech. 46, 207-218.

Hamann, J., Mein, G.A., 1990. Measurement of machine-induced changes in thickness of the bovine teat. J Dairy Res. 57, 495-505.

Hamann, J., Mein, G.A., Nipp, B., 1996. Recommended method for measuring changes in thickness of the bovine teat with spring-loaded calipers. J. Dairy Res. 63, 309-313.

Isaksson, A., Lind, O., 1992. Teat reactions in cows associated with machine milking. J. Vet. Med. 39, 282-288.

ISO/FDIS 3918., 2006. Milking machine installations. Vocabulary, ed. ISO, Geneva, Switzerland.

Labussière, J., 1984. Projet d'étude des caractéristiques de traite des différentes races de brebis laitières exploitees dans le Bassin Méditerranéen, in: 3rd International Symposium on the Milking of Small Ruminants, ed. Sever-Cuesta, Valladolid, Spain, pp. 768-790.

Le Du, J., Benmederbel, B., 1984. Aptitude des chèvres de race Saanen à la traite mécanique. Relations avec les caractéristiques physiques du trayon. Ann. Zootech. 33, 375-384.

Le Du, J., Labussière, J., Douaire, M., Combaud, J.F., 1978. Effect de la conception de l'embouchure du manchon trayeur sur les caractéristiques de traite des brebis Préalpes du Sud. Ann. Zootech. 27, 571-581.

Marnet, P. G., Billon, P., Da Ponte, P., Martin, J., Manfredi, E., 2001. Aptitude à la traite mécanique chez la chèvre: variabilité génétique et bases physiologiques du débit du lait. Renc. Rech. Ruminants 8, 321-327.

Marnet, P. G., Combaud, J.F., Dano, Y., 1999. Relationships between characteristics of the teat and milkability in Lacaune ewes, in: 6th International Symposium on the Milking of Small Ruminants, ed. EAAP, Athens, Greece, pp. 41-44.

Marnet, P.G., Combaud, J.F., Da Ponte, P., 2000. Etude du déterminisme des variations inter-animal du débit de lait au cours de la traite, in: La cinetique d'émission du lait et l'aptitude à la traite chez la chèvre, compte rendu nº 20031002, ed. Institut de l'Elevage, Paris, France, pp. 56-76.

McKusick, B. C., Thomas, D.L., Berger, Y.M., 2001. Effect of weaning system on commercial milk production and lamb growth of East Friesian dairy sheep. J. Dairy Sci. 94, 1660-1668.

Mein, G. A., 1992. Action of the cluster during milking, in: Bramley, A.J., Dodd, F.H., Mein, G.A., Bramley, J.A., Machine Milking and Lactation, ed. Insight Books, Berks, UK, pp. 97-140.

O'Shea, J., O'Callaghan, E., Walsh, J.P., 1983. Machine milking research, in: Moorepark 25th Anniversary Publication. Part II: Animal Health and Machine Milking, ed. J. O'Shea, An Foras Talúntais, Dublin, Ireland, pp. 115-214.

Peris, S., 1994. Características de la curva de lactación y aptitud al ordeño mecánico de cabras de raza Murciano-Granadina. PhD Diss. Universitat Autonoma de Barcelona, Barcelona, Spain.

Peris, S., Caja, G., Such, X., 1999. Relationships between udder and milking traits in Murciano-Granadina dairy goats. Small Rumin. Res. 33, 171-179.

Peris, C., Mehdid, M.A., Martínez, B., Gómez, E.A., 2010. Effect of the number and stage of lactation on milk kinetics in Murciano-Granadina breed goats, in: XXXV Congreso de la S.E.O.C., Valladolid, Spain, pp. 102-106.

Ruiz, I., 2008. Valoración morfológica en ganado caprino lechero. Cabra Murciano-Granadina, ed. Comunidad Autónoma de la Región de Murcia, Murcia, Spain.

Sauvant, D., Giger-Reverdin, S., Meschy, F., 2007. Alimentation des caprins,.in: Alimentation des bovins, ovins et caprins, ed. Quae, Versailles, France, pp. 137-148.

Skapetas, B., Katanos, J., Laga, V., Sinapis, E., Hatziminaoglou, I. 2008. Vacuum level for opening the teat sphincter and the change in the teat end wall thickness in response to the machine milking of indigenous Greek goats. Czech J. Anim. Sci. 53, 112-118.

Table 1. Characteristics of the commercial cluster used in the experiment

Characteristics	Nº in Fig. 1	
Cluster		
Total weight (g)		620
Claw		
Weight (g)		191
Volume (mL)		100
Rigid shell		
Weight (g)		80
Teatcup		
Length (mm)		202
Liner		
Weight (g)		59
External width of mouthpiece (mm)	1	58
Diameter of mouthpiece lip (mm)	2	21
Length of the mouthpiece lip (mm)	3	14
Thickness of the mouthpiece lip (mm)	4	2.3
Deflection of the mouthpiece lip (mm/0.5 kg)		7.5
Height of mouthpiece (mm)	5	12
Volume of mouthpiece (mL)	6	22
Throat of liner (mm)	7	41
Bore at the bottom of the liner (mm)	8	21
Length of barrel (mm)	9	144
Volume of barrel (mL)	10	74
Diameter of the barrel (mm)		20
Rigidity: tightening vacuum compression (kPa)		9.3

Table 2. Udder morphology[a] of the goats (m ± SEM)

L (mm)	W1 (mm)	W2 (mm)	α (º)	L (º)	SS (kPa)	TF (mm)	H (mm)
63 ± 4	55 ± 4	38 ± 3	45.2 ± 3.3	46.6 ± 3.4	30.1 ± 0.5	177 ± 7	277 ± 0.5

[a]Udder morphology: L = teat length; W1 = teat width at the base; W2 = teat width at the central section; α = teat implantation angle from the rear; L = teat implantation angle from the lateral; SS = teat sphincter strength; TF = distance from the bottom of the udder to the floor; H = height of the udder.

Table 3. Milk emission kinetics and milk fractioning

Item	Milking parameters (kPa : ppm)[c]				SEM	*P*
	40 : 90	40 : 120	42 : 90	42 : 120		
Milk fractioning[d] (mL/d)						
MM	2,083	1,980	2,091	2,027	44	0.28
MS	175	204	190	241	18	0.09
TM	2,258	2,184	2,281	2,268	50	0.65
Milk flow[e] (mL/min)						
MF60	809^{a}	805^{a}	847^{ab}	900^{b}	22	0.001
MMAF	733^{a}	732^{a}	753^{a}	810^{b}	19	0,01
MMMF	$1,203^{ab}$	$1,172^{b}$	$1,188^{b}$	$1,268^{a}$	25	0.03
MSAF	300^{a}	351^{b}	344^{ab}	372^{b}	16	0.01
MSMF	644	677	677	749	30	0.08
Time[f] (s)						
Latency	5.4^{a}	6.6^{b}	5.1^{a}	6.1^{ab}	0.4	0.02
TMMM	88	90	83	84	4.3	0.62
MMT	186^{a}	174^{a}	180^{a}	160^{b}	4	0.001

TMMS	13	12	13	15	1	0.35
MST	33	30	30	37	2	0.07
TMT	219^{a}	204^{ab}	209^{a}	197^{b}	3	0.001

[a-b] Within a row, means without a common superscript differ ($P < 0.05$).

[c]Kilopascals : Pulsations per minute.

[d]Milk fractioning: MM = machine milking milk volume; MS = machine stripping milk volume: TM = total milk volume.

[e]Milk flow: MF60 = milk flow in the first minute after the onset of foremilk; MMAF = machine milking average flow; MMMF = machine milking maximum flow; MSAF = machine stripping average flow; MSMF = machine stripping maximum flow.

[f]Time: Latency = time elapsed from teat-cup attachment to milk flow appearance in the claw; TMMM = time for maximum machine milking flow; MMT = machine milking duration; TMMS = time for maximum machine stripping flow; MST = machine stripping duration; TMT = total milking duration.

Table 4. Percentage of teat-end edema (mm) created by different combinations of vacuum level and pulsator rate of milking machine

Milking parameters (kPa : ppm)[c]					
40 : 90	40 : 120	42 : 90	42 : 120	SEM	*P*
- 1.42[a]	- 0.04[ab]	1.19[b]	3.37[b]	1.1	< 0.0001

[a-b] Within a row, means without a common superscript differ ($P < 0.05$).

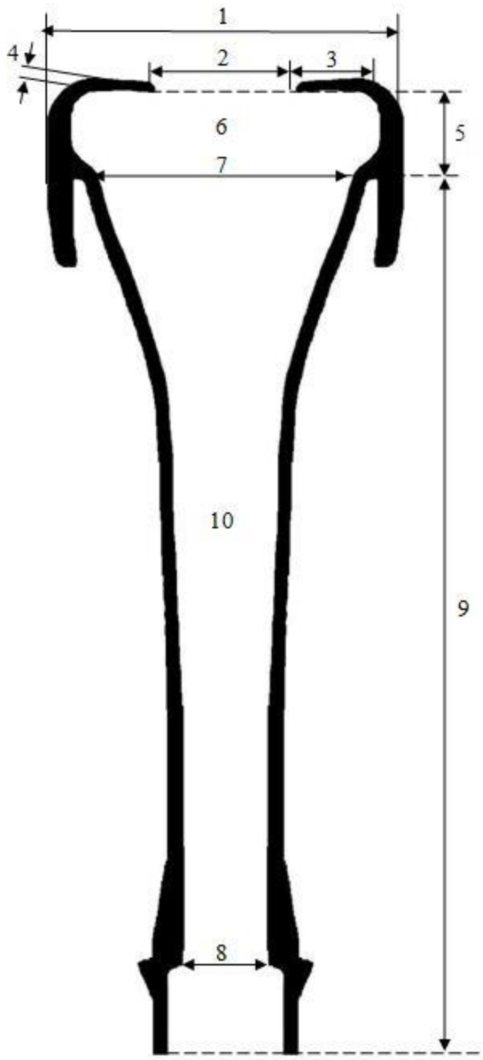
[c]Kilopascals : Pulsations per minute.

Table 5. Correlations among some parameters of milk emission kinetics and the teat sphincter strength

Item	Milk emission kinetics parameters[a]						
	Latency	MMT	TMMM	TMT	MF60	MMAF	MMMF
Teat sphincter strength	0.68 ***	0.69 ***	0.60 ***	0.65 ***	- 0.62 ***	- 0.59 ***	- 0.63 ***

***$P < 0.001$.

[a]Kinetic parameters: MMT = machine milking duration; TMMM = time for maximum machine milking; TMT = total milking duration; MF60 = milk flow in the first minute after the onset of foremilk; MMAF = machine milking average flow; MMMF = machine milking maximum flow.



Fernández N.

Figure 1. Section of the liner used in the experiment