Italian Journal of Animal Science

ISSN: (Print) 1828-051X (Online) Journal homepage: https://www.tandfonline.com/loi/tjas20

The influence of pregnancy and the beginning of lactation on pelage traits in cashmere goats

Raffaele Celi, Adriana Di Trana, Pietro Celi, Giuseppe Marsico & Maria Forcelli

The influence of pregnancy and the beginning of lactation on pelage traits in cashmere goats

Raffaele Celi[1], Adriana Di Trana[2], Pietro Celi[2], Giuseppe Marsico[1], Maria Forcelli[3]

[1]Dipartimento di Produzione Animale. Università di Bari, Italy
[2]Dipartimento di Scienze delle Produzioni Animali. Università della Basilicata, Potenza, Italy
[3]Dipartimento di Progettazione e Gestione dei Sistemi Agro-Zootecnici e Forestali. Università di Bari, Italy

Corresponding author: Prof. Raffaele Celi. Dipartimento di Produzione Animale. Università di Bari, Via G. Amendola 165/A, 70126 Bari, Italy – Tel. +39 080 5442827 - Fax: +39 080 5442822 - Email: celir@agr.uniba.it

Paper received July 12, 2004; accepted October 28, 2004

ABSTRACT

The aim of this study was to investigate the effect of pregnancy followed by the beginning of lactation on fibre traits in cashmere goats. Two groups of cashmere-bearing goats aged between 2-3 years were used. The control group (A) included 12 non-lactating, non-pregnant subjects. The experimental group (B) included 12 goats mated during the first week of June, in order to have pregnancy and the beginning of lactation coincide with the period when cashmere normally grows. As expected, Liveweight significantly varied in Group B during the last two months of pregnancy, when foetal growth reaches its maximum, and following delivery. Hair patch weight, because of the continuous growth of primary and secondary fibres, increased significantly during the trial ($P<0.001$). The physiological status considered negatively affected ($P<0.05$) the total mean growth rate of cashmere fibres and, as a result, their length. Cashmere daily growth rate values varied significantly ($P<0.05$) throughout the experiment, while the effect of the physiological status was noted only in November – December. Furthermore, this parameter also seems to be influenced by climatic factors and, in particular, environmental temperature, as shown by the negative correlation ($r = -0.28$; $P<0.05$) between cashmere daily growth rate and environmental temperature. Guard hair length and growth rate did not differ between the two groups, however, they were influenced by time. Cashmere yield and cashmere production were lower in group B ($P<0.05$). No differences between groups were observed for cashmere diameter. Overall, pregnancy and the consequent period of lactation negatively influenced cashmere rather than guard hair fibres. These negative effects were noted in quantitative terms as yield and production dropped by 37% and 43%, respectively. We hypothesise that the complete overlap of pregnancy and lactation with the period of cashmere growth reduced the number of secondary active follicles and their degree of activity and caused an increase in competition for the partitioning of nutrients between hair follicles and the gravid uterus, first, and then the mammary gland, later.

Key Words: Goats, Pregnancy, Lactation, Cashmere, Guard hair.

RIASSUNTO

L'INFLUENZA DELLA GRAVIDANZA E DELL'INIZIO DELLA LATTAZIONE SULLE CARATTERISTICHE DELLE FIBRE PILIFERE IN CAPRE CASHMERE

La prova si è svolta nell'Italia meridionale (40° 38' N- 15° 49' E) ed ha avuto lo scopo di individuare eventuali interferenze tra stato riproduttivo e caratteri della produzione pilifera in capre specializzate per la produzione di cashmere. Sono *stati utilizzati due gruppi di capre di 12 soggetti ciascuno, allevati tradizionalmente al pascolo. Quelle del gruppo testimone (A) non erano né gravide, né in lattazione. Quelle del gruppo sperimentale (B) hanno iniziato la gravidanza nella prima settimana di giugno in coincidenza dell'accrescimento delle fibre cashmere. Sono stati considerati i seguenti parametri: peso vivo; peso dell'hair patch; peso, lunghezza e accrescimenti delle fibre primarie (*guard hair*) e secondarie (*cashmere*); periodo di accrescimento, resa, produzione e diametro delle fibre cashmere. Il peso vivo si è differenziato solo nel periodo autunnale in corrispondenza degli ultimi due mesi di gravidanza e del parto. Il peso del patch, a causa del continuo accrescimento delle fibre primarie e secondarie, aumenta significativamente con il tempo (P<0,001). Gli stati fisiologici considerati, mentre non hanno influenzato il guard hair, hanno condizionato negativamente le caratteristiche quantitative del cashmere. La lunghezza, infatti, che è la dimensione che più incide sull'esito produttivo, è diminuita del 20%. Gli accrescimenti medi giornalieri tendono ad aumentare in ambo i gruppi a fine autunno, ma quelli delle capre del gruppo B risultano significativamente più bassi (P<0,05). Essi, inoltre, variano significativamente (P<0,05) con il tempo e sono altresì correlati con la temperatura ambientale (r = - 0,28; P<0,05). Significativamente più bassi sono risultati la resa e la produzione. Nessun effetto, invece, è stato riscontrato a carico del diametro. I risultati consentono di affermare che lo stato riproduttivo è causa di effetti negativi sullo sviluppo della copertura pilifera ed in particolare sulle fibre secondarie. Verosimilmente, detti effetti potrebbero originarsi non solo attraverso una competizione nella captazione dei nutrienti tra follicoli piliferi secondari e utero gravido prima e alveoli mammari poi, ma anche con una riduzione del numero dei follicoli secondari attivi e del rispettivo grado di attività.*

Parole chiave: *Capre, Gravidanza, Lattazione, Fibre primarie, Fibre secondarie.*

Introduction

Goats are traditionally known for their typical milk and meat production, but some breeds can produce a high quality textile fibre known as cashmere, which originates from the secondary hair follicles. Cashmere grows between the summer and the winter solstices when the photoperiod is decreasing. Then, when day length begins to increase, fibre growth ceases and the secondary fibres are spontaneously released from their follicles. Guard hair shows a similar seasonal pattern of growth, but is not totally lost from the body surface (McDonald *et al.*, 1987). The main factors that affect cashmere characteristics and production, though to varying degree, are of a genetic, environmental and/or physiological nature. In terms of the latter, pregnancy has a negative effect on fibre production (Ariturk *et al.*, 1979 and Nicoll, 1979 cited by Allain *et al.*, 1992; Restall and Pattie, 1989) and it seems that it acts on the hair follicle activity of both the mother and the foetus (Morand-Fehr and Galbraith, 1992). Lactation is another factor that negatively affects fibre production (Restall and Pattie, 1989), but this effect seems to depend on the level of milk productivity (Celi *et al.*, 2002).

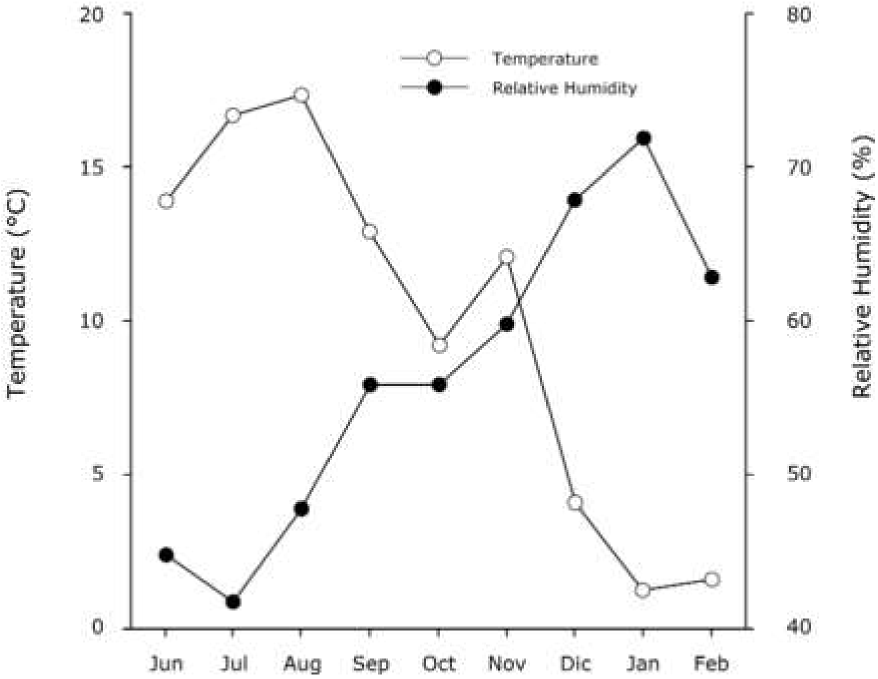
Cashmere goats were only recently introduced in Italy with the aim of diversifying the traditional local meat and milk production, but also to partially meet the needs of the textile industry. Seeing as at our latitudes cashmere growth must coincide with pregnancy timed to meet the request for *capretto* during the Christmas period, it is necessary to establish if the reproductive cycle, including lactation, interferes with the cashmere growth cycle.

The aim of the present study, therefore, is to evaluate whether pelage traits in grazing cashmere-bearing goats are influenced by pregnancy and the consequent period of lactation.

Material and methods

The study, conducted in Southern Italy (40° 38' N - 15° 49' E), used 24 animals chosen from a herd of cashmere bearing goats of Scottish origin, homogeneous for age (3-4 years), Liveweight (42 ± 2.1 kg) and body condition score (3 ± 0.2). The latter was assessed according to the system developed by Santucci *et al.* (1991). In mid May, 12 goats (experimental group; Group B) had their oestrus cycle synchronised and they were subsequently mated so that pregnancy would begin in June, when cashmere fibres generally begin to grow. The goats delivered within the first five days of November. The control group (Group A) was made up of the remaining 12 non-pregnant non-lactating goats. The goats were reared traditionally at pasture and received a daily supplement *ad libitum* of vetch and oats hay (dry matter: 87.8%; crude protein: 9.1%; ether extract: 1.7%; crude fibre: 34.2%; N-free extracts: 45.1%; ash: 9.9%).

Figure 1. Mean environmental temperature, and relative humidity measured throughout the experiment.

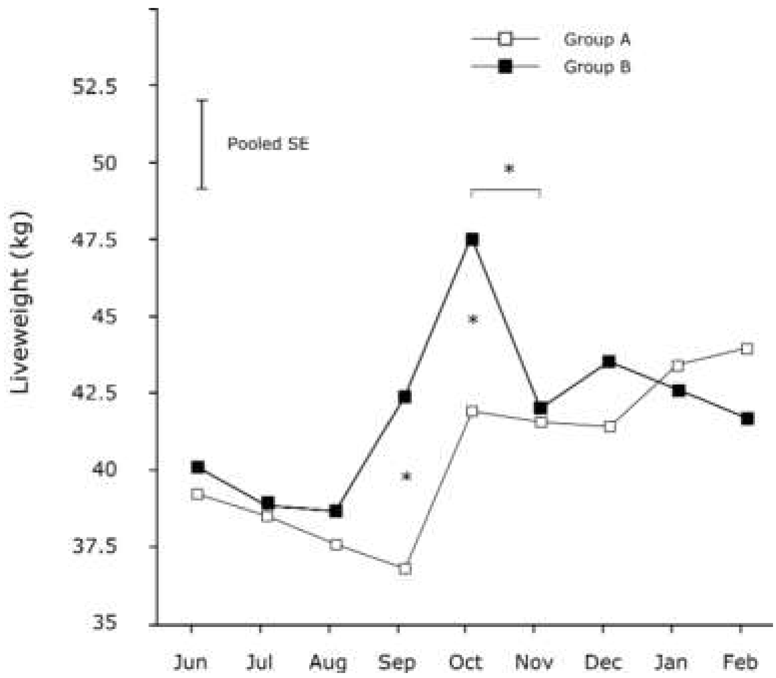


Starting from the 4th month of pregnancy till the end of the trial, the Group B goats were supplemented with 200g/head/day of a commercial concentrate (dry matter: 91.2%; crude protein: 12.2%; ether extract: 2.7%; crude fibre: 7.4%; N-free extracts: 69.9%; ash: 7.8%). During the trial mean environmental temperature and mean relative humidity were recorded (Figure 1).

The animals were weighed monthly to the nearest + 0.1 kg. Also monthly, a single 4 cm^2 hair patch was clipped from the midside, using the left and right flanks alternately at each sampling. The primary and secondary fibres in the patch were manually separated and weighed and the length of both fibres was measured. Daily and total growth rates were calculated for both cashmere and guard hair. Furthermore, the duration of the cashmere growth period was also determined using the method described by Norton and Klören (1995). The patch that gave the maximum cashmere length was then used to measure cashmere diameter and to calculate cashmere yield and production level. The diameter was determined using the Optical Fibre Diameter Analyser method (Zellweger Uster AG – Switzerland). The weight of cashmere fibres compared to that of the entire patch represented cashmere yield. Production level was calculated by extrapolating the weight of the cashmere fibres in the patch with maximum length to the whole body surface. The latter was calculated using the formula reported by Couchman and McGregor (1983).

The statistical analysis of liveweight, hair patch weight, cashmere and guard hair length, cashmere and guard hair growth rate was carried out with the ANOVA procedure for repeated mea-

Figure 2. Liveweight in Group A and Group B. * indicates significant difference (P<0.05) between Groups at the same time point, and within Group B between different time points.



sures, using the SYSTAT statistical package (1992) with a bi-factorial model (physiological state, sampling month and their interaction). The interaction was excluded when not significant. The statistical analysis of cashmere yield, cashmere production, cashmere diameter, overall cashmere and guard hair growth rate used a mono-factorial model (physiological state). The differences between means were tested using Least Significant Difference. The Pearson correlation coefficients were computed between some of the parameters of the study.

Results and discussion

The pattern of liveweight (Figure 2) indicates that the animals did not experience nutritional or health stress during the trial. Liveweight was influenced more by pregnancy than by lactation, although not dramatically so. The only differences, which reached only the minimal significant difference (P<0.05), between the two Groups were noted during September and October, that is the last two months of pregnancy when foetus growth rate peaks. The decrease in body weight observed in Group B in November is the logical consequence of the *partum*. These results are in agreement with the observations made by Celi *et al.* (2002) using lactating goats of the same breed-population reared in the same location.

Pregnancy and lactation did not influence hair patch weight, but a significant effect of time was noted (P< 0.001). In June there were no secondary fibres on the body surface of the animals; thus, the

Table 1. Least square means of hair patch weight (g).

Sampling month	Group A	Group B	All
June	0.083	0.096	0.090 [A]
July	0.102	0.124	0.113 [B]
August	0.136	0.161	0.149 [C]
September	0.159	0.194	0.177 [Da]
October	0.222	0.228	0.225 [EF]
November	0.239	0.234	0.237 [E]
December	0.244	0.237	0.241 [E]
January	0.254	0.235	0.245 [E]
February	0.212	0.217	0.215 [DFb]

SE of sampling month and of physiological status are 0.09 and 0.07, respectively.
In the same column means followed by different capital and small letters differ, respectively, at P<0.001 and at P<0.05.

Table 2. Least square means of cashmere length (cm).

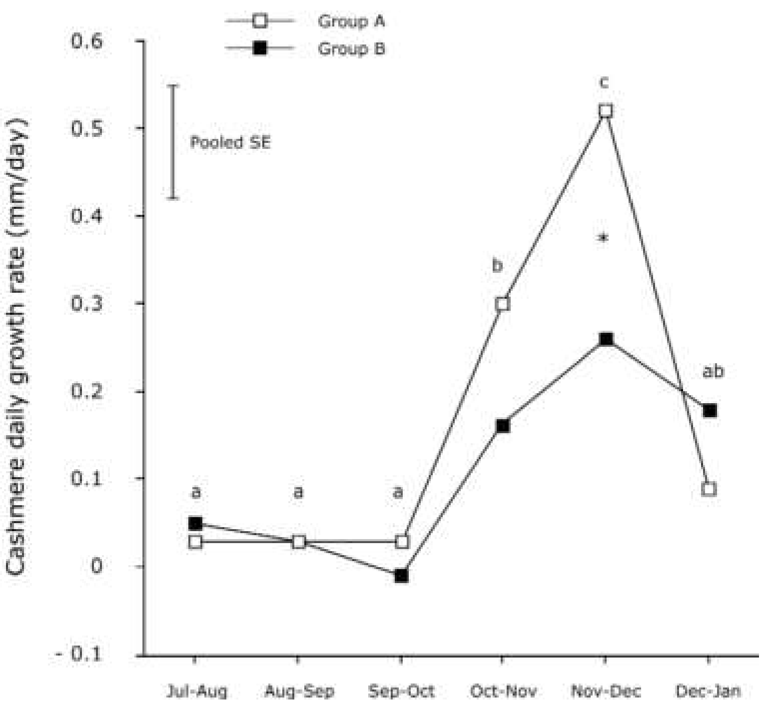
Sampling month	Group A		Group B	All
June	0.0		0.0	0.0
July	1.6		1.7	1.6 [A]
August	1.6		1.8	1.7 [A]
September	1.7		1.8	1.8 [A]
October	1.8		1.9	1.9 [A]
November	2.7		2.3	2.6 [B]
December	4.3		3.1	3.7 [CDa]
January	4.5		3.6	4.1 [Db]
February	3.9		2.5	3.3 [C]
July - February	2.8	*	2.4	

SE of sampling month and of physiological status are 0.19 and 0.14, respectively.
*In the same column means followed by different capital and small letters differ, respectively, at P<0.001 and at P<0.05; * indicates overall significant difference (P<0.05) between groups.*

weight of the patch sampled in this month was determined solely by primary fibres (Table 1). The observed increase in hair patch weight, throughout the experiment, was due to the parallel increase in cashmere and guard hair dimensions. Variations in hair patch weight have been observed in relation to differences in the genotype (Rhind and McMillen, 1995). The decrease in hair patch weight observed in February can be ascribed to the beginning of the moulting process of both primary and secondary fibres.

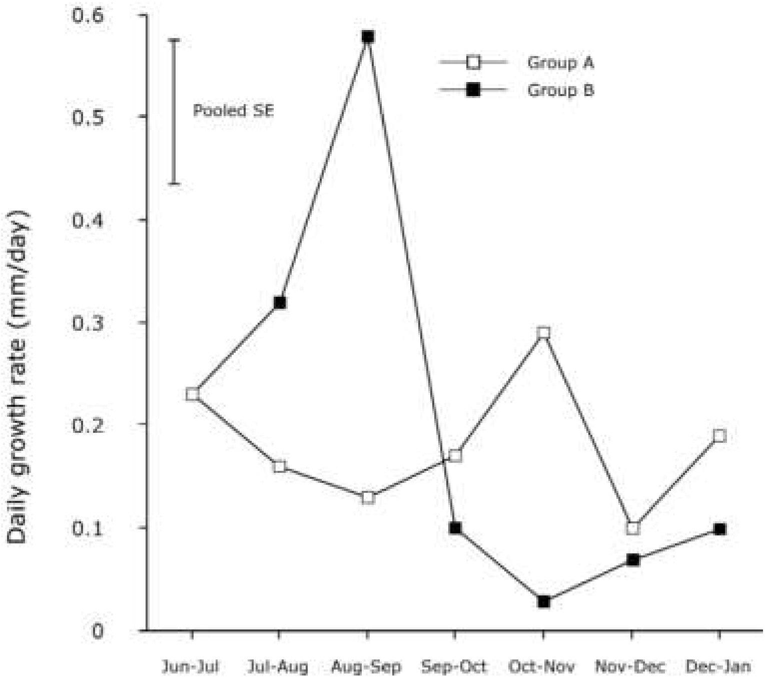
Cashmere length (Table 2) was significantly influenced by the physiological state (P<0.05) and by time (P<0.001). Secondary fibres were first observed in July and presented similar values in both groups of goats until October. Then, cashmere

Figure 3. Cashmere daily growth rate in Group A and Group B. * indicates significant difference (P<0.05) between Groups at the same time point; different small letters indicate significant difference (P<0.05) between different time points.



length significantly increased to reach its maximum value in January. The appearance of secondary fibres on the body surface varies according to the photoperiod, the breed and the environmental conditions present (Kuanhu *et al.*, 1996; Merchant and Riach, 1995; Rhind and McMillen, 1995 and 1996). Previous studies confirm this variability, with the appearance of secondary fibres in July (Celi *et al.*, 2001) and in August (Celi *et al.*, 2000). The effect of the physiological state on cashmere fibre length appears controversial. In fact, whilst Restall and Pattie (1989) report that fibre length decreases by 17% in pregnant goats, 19% in lactating goats, and 28% in pregnant and contemporaneously lactating goats, Celi et al, (2002) did not observe any differences between lactating and dry goats. In the former study the Authors hypothesised that the lack of a negative effect of lactation on cashmere length was due to the incomplete overlap of the lactation peak with the period of maximum cashmere growth. Furthermore, since the breed of goats used is characterised by a poor aptitude for milk production (Di Trana and Sepe, 2000), the negative effect of lactation on cashmere length may not depend on the physiological state itself but on the level of milk production. In the present study, cashmere fibre was 20% shorter in Group B with respect to Group A. Besides the geographical differences in the Authors' work, it is our opinion that the discrepancies described above could be of a genetic, environmental and managerial nature. Upon com-

Figure 4. Guard hair daily growth rate in Group A and Group B.



parison of these findings with those of Restall and Pattie (1989), it seems possible to assert that the negative effect of the physiological states tested on cashmere length varies on an increasing scale. Our hypothesis is that the lowest and highest points of the scale would be reached when the cashmere fibre growth period is made to coincide, respectively, with a single physiological state (pregnancy or lactation) or two physiological states in succession (pregnancy followed by lactation) and two contemporaneous physiological states (pregnancy and lactation).

Cashmere daily growth rate (Figure 3) was significantly influenced by time ($P<0.05$) and by the interaction between time and the physiological state ($P<0.05$). Cashmere daily growth rate values were low at the beginning of the experiment and increased until November - December, when they reached their peak. At that point, cashmere daily growth rate values were significantly lower in Group B than in Group A ($P<0.05$). This confirms the negative effect of the physiological state tested on cashmere fibre growth, which we found to be more sensitive during the last two months of pregnancy and the first month of lactation, in agreement with Klören and Norton (1993). In physiological terms, the complete overlap between pregnancy and lactation and the period of cashmere growth may have resulted in an impairment of nutrients partitioning between the hair follicles and the gravid uterus, first, and the mammary gland, later. Klören and Norton (1993) suggest that the effects of pregnancy and lactation on cashmere growth may be due to physiological changes associated with pregnancy and lactation. As already suggested by Ferguson *et al.* (1965), many hormones may be responsible for the above mentioned impairment in nutrient partitioning,

Table 3. Least square means of guard hair length (cm).

Sampling month	Group A	Group B	All
June	3.5	4.0	3.8 [A]
July	4.2	4.7	4.5 [AC]
August	4.7	5.7	5.2 [ACb]
September	5.1	7.5	6.3 [BCD]
October	5.6	7.8	6.7 [BCD]
November	6.5	7.9	7.2 [BCa]
December	6.8	8.1	7.5 [B]
January	7.4	8.4	7.9 [B]
February	5.9	7.7	6.8 [B]

SE of sampling month and of physiological status are 0.91 and 0.52, respectively.
In the same column means followed by different capital and small letters differ, respectively, at P<0.01 and at P<0.05.

Table 4. Quantitative and qualitative parameters of cashmere fibre (means ± SE).

Group	Production (g)	Yield (%)	Diameter (μm)
A	199.9 ± 27.03	24.0 ± 1.64	17.6 ± 0.51
	*	*	
B	114.5 ± 27.03	15.1 ± 1.64	16.1 ± 0.51

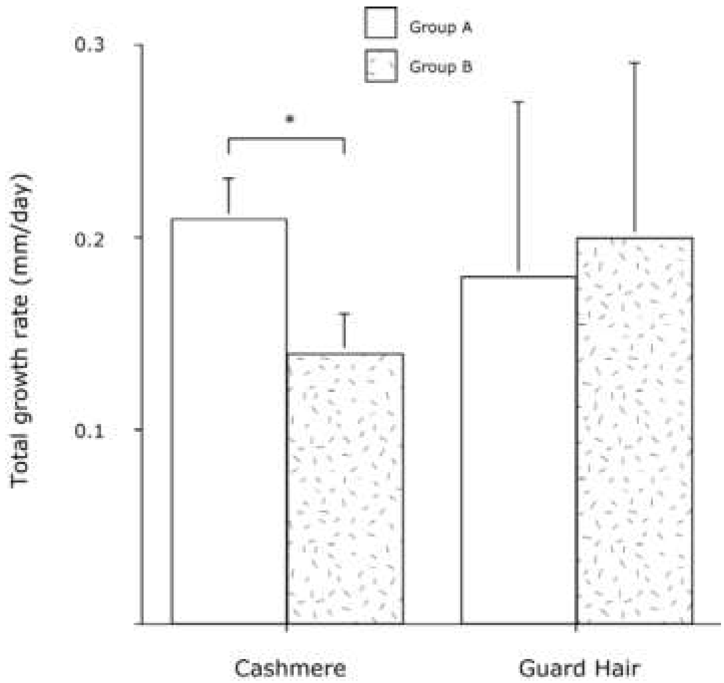
** indicates significant difference (P<0.05) between Groups.*

modifying the responsiveness of hair follicles to the nutrients or by affecting their availability to the follicles. It may be likely that changes in prolactin, insulin, growth hormone, cortisol and thyroid hormones secretion associated with pregnancy and lactation may mediate nutrient partitioning (Forsyth and Lee, 1993; Kornalijnslijper *et al.*, 1997; Khan and Ludri, 2002). We also observed high values of cashmere daily growth rate when the environmental temperature started to decrease. This indicates that environmental cues of climatic origin may play an important role in the control of cashmere growth. Although this hypothesis needs to be tested in further studies, the negative correlation (Table 5) observed between mean daily growth rate and environmental temperature (r = - 0.28; P<0.05) supports this assumption.

Total cashmere growth rate was significantly influenced by the physiological status considered (Figure 5). In contrast with the observations of Klören and Norton (1993), no effect was noted on the duration of the period of cashmere fibre growth, which was 237 ± 15 and 248 ± 15 days, respectively, in Groups A and B. The growth level observed is, on average, inferior to those observed by Celi *et al.* (2001) in goats of the same breed-population reared in the same location. This could be due to a difference in timing of the two studies.

Guard hair length was not affected by the physiological state, but a significant effect of time was noted (P<0.01; Table 3). Guard hair was always

Figure 5. Total cashmere and guard hair growth rate in Group A and Group B. Values are means ± SE. * indicates significant difference (P<0.05) between groups.



present on the body surface of the animals of both Groups. This indicates that primary fibres have a longer period of growth than secondary fibres and that, therefore, it is not strictly related to photoperiod (Celi *et al.*, 2001). It has been reported, in fact, that the period of primary fibre growth varies between 4 and 7 months (Mitchell *et al.*, 1991) or that it can occur throughout the year and that pregnancy has no effect on it (Klören and Norton, 1993). Guard hair continuously grew until January in both groups and its daily growth rate (Figure 4), as well its total growth rate values (Figure 5), were not affected by pregnancy and lactation.

Overall, cashmere production and cashmere yield were lower in Group B than in Group A (P<0.05). No differences between the two groups were observed for cashmere diameter (Table 4).

With an equal number of secondary fibres per body surface unit, cashmere production is strictly dependent upon fibre dimensions. Cashmere production, indeed, was positively correlated with fibre diameter (r = 0.47; P<0.01) and fibre length (r = 0.71; P<0.001; Table 5). Couchman and McGregor (1983) and McDonald (1988) also observed a positive correlation between cashmere production and its length. Cashmere production is decreased by 30% in pregnant goats and it can decrease up to 68% if the animals are contemporaneously lactating (Restall and Pattie, 1989). However, in a previous study we observed only a slight reduction in cashmere production in lactating goats (Celi *et al.*, 2002). The results of the present study indicate that pregnancy followed by lactation negatively affected cashmere production, which was reduced by 43%. Considering that cashmere length values reached only the minimal sig-

Table 5. Significant phenotypical coefficients of correlation.

	CD	CL	CP	CW	CY	PW	GHW	CGR	ET
CD	-	0.38*	0.47**		0.40*				
CL		-	0.71***						
CP			-	0.96***	0.91***	0.61***			
CW				-		0.65***			
CY					-	0.41**			
PW						-	0.71***		
GHW							-		
CGR								-	-0.28*
ET									-

*CD: Cashmere diameter; CL: Cashmere length; CP: Cashmere production; CW: Cashmere weight; CY: cashmere yield; PW: Patch weight; GHW: Guard hair weight; ET: Environmental Temperature; CGR: Growth rate. ***:P<0.001; **:P<0.01; *:P<0.05.*

nificant difference between the two groups, it was reasonable to expect that cashmere production values would not be vastly different. If this did not occur, it could be because pregnancy and lactation, in addition to the decreased fibre length previously described, may have negatively influenced the number of active secondary follicles and their degree of activity. This hypothesis remains to be tested in future studies.

Cashmere yield was reduced in pregnant and lactating goats by 37%. The values, however, fall within the range (15% - 50%) reported by Pattie and Restall (1992). This decrease cannot be explained by the reduction in fibre diameter as this parameter did not differ between the two groups, but it could have been influenced by the decrease in cashmere length and also by the decreased density of active secondary follicles. Cashmere yield, which is of difficult determination, could be extrapolated from the diameter of the secondary fibres and from the patch weight, both of which were positively correlated to it (r = 0.40; P<0.01; Table 5).

We did not observe any significant effect of pregnancy and lactation on cashmere diameter. Our observations, together with the results of our previous study (Celi *et al.,* 2002) and with those of Restall and Pattie (1989), seem to indicate that lactation does not influence cashmere diameter. This indicates that cashmere diameter varies more as an effect of genetic rather than physiological factors. Cashmere diameter was positively correlated with length (r = 0.38; P< 0.05), cashmere production (r = 0.47; P< 0.01) and cashmere yield (r = 0.40; P< 0.05). Therefore improving the quantitative parameters would compromise fibre quality.

Conclusions

In conclusion, maximal guard hair length and growth were more sensitive to the effect of time rather than that of the physiological state considered. Pregnancy and the subsequent period of lactation affected secondary fibres, which are shorter in the experimental group compared to the control animals. This slight decrease does not seem to fully explain the decrease in cashmere yield and cashmere production noted in Group B. One likely explanation, which needs to be tested, could be that the negative effects of pregnancy and lactation are exerted on the density of active secondary hair follicles and their degree of activity and through nutrient partitioning. Pregnancy and lactation did not affect cashmere diameter, which is the major determinant of fibre quality.

The Authors would like to thank Mr. Piero Lacalaprice for his precious contribution made during the trial.

This study was supported by MURST (40% & 60% grants).

REFERENCES

ALLAIN, D., 1992. Genetic improvement programmes for Angora goats. In: H. Galbraith (ed.) New Developments in Goat Husbandry for Quality Fibre Production, University of Aberdeen ed., Aberdeen, UK, pp 82-91.

CELI, R., DI TRANA, A., COLONNA, M. A., TOTEDA, F., FACCIOLONGO, A. M., RUBINO, R., 2000. Influence of altitude on Cashmere production in goats reared in southern Italy. pp 652-654 in Proc. 7th Int. Conf. on Goats, Tours, France.

CELI, R., LABATE, M., DI TRANA, A., DE SANTIS, S., RUBINO, R., CIRILLO, F., 2001. Percentage of active primary and secondary follicles and fibre length in cashmere goats reared at different altitudes. pp 523-525 in Proc. 14th Nat. Congr ASPA, Firenze, Italy.

CELI, R., DI TRANA, A., CELI, P., 2002. The influence of lactation on the quantity and quality of cashmere production. Ital. J. Anim. Sci. 1: 79-86.

COUCHMAN, R. C., MCGREGOR, B. A., 1983. A note on the assessment of down production in Australian cashmere goats. Anim. Prod. 36: 317-320.

DI TRANA, A., SEPE, L., 2000. Milk production traits of cashmere goats in southern Italy. Page 612 in Proc. 7th Int. Conf. INRA on Goats, Tours, France.

FERGUSON, K. A., WALLACE, A. L. C., LINDNER, H. R., 1965. Hormonal regulation of wool growth. In: A.G. Lyne and B. F. Short (eds.) Biology of the Skin and Hair Growth, Angus and Robertson, Sydney, Australia, pp 655-677.

FORSYTH, I. A., LEE, P. D., 1993. Bromocriptine treatment of periparturient goats: long-term suppression of prolactin and lack of effect on lactation. J. Dairy Res. 60: 307-317.

KLÖREN, W. R. L., NORTON B. W., 1993. Fleece growth in Australian cashmere goats. II. The effect of pregnancy and lactation. Aust. J. Agric. Res. 44: 1023-1034.

KHAN, J. R., LUDRI, R. S., 2002. Hormone profile of crossbred goats during the periparturient period. Trop. Anim. Health Pro. 34: 151-162.

KORNALIJNSLIJPER, J.E., KEMP, B., BEVERS, M.M., VAN OORD, H.A., TAVERNE, M. A., 1997. Plasma prolactin, growth hormone and progesterone concentrations in pseudopregnant, hysterectomized and pregnant goats. Anim. Reprod. Sci. 49: 169-178.

KUANHU, D., XIAOWU, L., SHUCHANG, W., KAILLANG, Z., 1996. Seasonal variation in fleece growth of Liaoning Cashmere goats. pp 458-461 in Proc. 6th Int. Conf. on Goats, Beijing, China.

MCDONALD, B. J., HOEY, W. A., HOPKINS, P. S., 1987. Cyclical fleece growth in cashmere goats. Aust. J. Agric. Res. 38: 597-609.

MCDONALD, B. J., 1988. Estimation of cashmere fibre length in goats. Aust. J. Agric. Res. 28: 37-39.

MERCHANT, M., RIACH, D. J., 1995. The influence of nutrition and shearing on timing of the moult in cashmere goats. In: J.P. Laker and A.J.F. Russel (eds.) The nutrition and grazing ecology of specialty fibre producing animals. European Fine Fibre Network. Occasional Publ. No. 3, Craigiebuckler, Aberdeen, UK, pp 51-59.

MITCHELL, R. J., BETTERIDGE, K., GURSEY, M. P., WELCH, R. A. S., 1991. Fibre growth cycles of cashmere-bearing, reproducing does in southern Hawkes Bay, New Zealand, over a 30 - month period. New Zeal. J. Agr. Res. 34: 287-294.

MORAND-FEHR, P., GALBRAITH, H., 1992. Nutritional characteristics and feeding strategies for fibre producing goats. In: H. Galbraith (ed.) New Developments in Goat Husbandry for Quality Fibre Production, University of Aberdeen ed., Aberdeen, UK, pp 40-66.

NORTON B. W., KLÖREN, W. R. L., 1995. Measurement of the components of the cashmere growth cycle in Australian cashmere goats. Small Ruminant Res. 17: 263-268.

PATTIE, W. A., RESTALL, B. J., 1992. Genetical and environmental factors affecting cashmere production. pp 502-512 in Proc. 5th Int. Conf. on Goats, New Delhi, India.

RESTALL, B. J., PATTIE, W. A., 1989. The inheritance of cashmere in Australian goats. I. Characteristics of the base population and the effects of environmental factor. Livest. Prod. Sci. 21: 157-172.

RHIND, S. M., MCMILLEN, S. R., 1995. Seasonal patterns of secondary fibre growth, moulting and hair follicle activity in Siberian and Icelandic X Scottish feral goats offered high and low levels of dietary protein. Small Ruminant Res. 16: 69-76.

RHIND, S. M., MCMILLEN, S. R., 1996. Effect of methylthiouracil treatment on the growth and moult of cashmere fibre in goats. Anim. Sci. 62: 513-520.

SANTUCCI, P. M., BRANCA, A., NAPOLEONE, M., BOUCHE, R., AUMONT, G., POISOT, F., ALEXANDRE, G., 1991. Body condition scoring in goats in extensive conditions. In: P. Morand-Fehr (ed.) Goat Nutrition, Pudoc, Wageningen, The Netherlands, pp 241-255.

SYSTAT, 1992. Statistics, Version 5.2 Edition. Evanston, IL, USA.