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ABSTRACT

This study is part of a much wider research programme to evaluate the possibility of producing valuable textile fibres, such as cashmere, from goat breeds reared in Italy. In order to achieve this, we have used crossbreeding. The first stage of the programme consisted of evaluating cashmere production in F_1 kids obtained by crossing white-haired Jonica does, which have no secondary fibres, with Scottish Cashmere bucks. The trial lasted one year starting in March 2007, and took place in the Department of Animal Production of the University of Bari (Italy). We used 14 male kids: 7 Scottish Cashmere (SC group), and 7 F_1 (SC x J group) derived from crossing Scottish Cashmere bucks with does of the Jonica breed, commonly reared in southern Italy. All the parameters considered (live weight, number and active percentage of primary and secondary follicles, S/P ratio, patch weight, growth and length of guard hair and down, yield, down production and diameter, blood protein and T_3 and T_4) were significantly influenced (P<0.01) by age. Genotype also had a significant effect (P<0.01) on all parameters except for the active percentage of primary follicles and the blood protein level. The factors which influence down production showed the heterosis effect to a varying extent in F_1, but they still produced significantly less than the SC group kids (38.5±4.04 *vs* 68.5±9.16 g; P<0.01). These results are largely due to both their low number of secondary follicles (30.0±1.46 *vs* 39.3±1.02; P<0.01), which also have a lower percentage of activity (64.7±2.47 *vs* 90.0±1.53; P<0.01), and also to the down length which was 28% shorter than in SC group. This genetic combination is clearly unsatisfactory so others must be sought, probably by using more rustic local breeds, as well as more productive breeds for crossbreeding.

Key words: Cashmere, Kids, Breeding, Hair follicles, Fibres.

RIASSUNTO

PRODUZIONE DI CASHMERE DA CAPRETTI SCOTTISH CASHMERE E SCOTTISH CASHMERE X JONICA

Questo lavoro rientra in un programma di ricerca ben più vasto che mira a valutare la possibilità di far produrre alle razze caprine italiane, fibre tessili di alto pregio come il cashmere. Per raggiungere tale scopo

è stato utilizzato l'incrocio ed in questa prima fase è stata valutata la produzione di cashmere in soggetti F_1 ottenuti dall'accoppiamento della razza locale Jonica che è la più allevata nell'Italia meridionale per la produzione del latte ma che è priva di copertura pilifera secondaria, con becchi Scottish Cashmere. La prova è durata un anno a partire da marzo 2007 ed è stata condotta presso l'azienda del Dipartimento di Produzione Animale dell'Università degli Studi di Bari ed ha utilizzato 14 capretti maschi di cui 7 di razza Scottish Cashmere e 7 F_1 (Scottish Cashmere x Jonica). Tutti i parametri considerati (peso vivo, numero e percentuale di attività dei follicoli primari e secondari, rapporto S/P, peso del patch, lunghezza e accrescimento del guard hair e del down, resa, produzione e diametro del down, concentrazione ematica delle proteine e degli ormoni tiroidei T_3 e T_4) sono stati influenzati significativamente (P<0,01) dall'età, mentre l'effetto del genotipo è stato nullo solo per la percentuale dei follicoli primari attivi e per la concentrazione ematica delle proteine. Negli F_1 i parametri che condizionano la produzione di down hanno evidenziato, in varia misura, un effetto eterotico ma, nonostante ciò, la performance produttiva è significativamente inferiore a quella dei capretti Scottish Cashmere (38,5±4,04 vs 68,5±9,16 g; P<0,01). A determinare questi risultati hanno largamente contribuito sia il basso numero di follicoli secondari (30,0±1,46 vs 39,3±1,02; P<0,01), che tra l'altro sono percentualmente meno attivi (64,7±2,47 vs 90,0±1,53; P<0,01), che la lunghezza del down che rispetto a quella riscontrata nei capretti Scottish Cashmere è ridotta del 28%. Poiché trattasi di una combinazione genetica non molto soddisfacente bisogna ricercarne delle altre utilizzando anche razze locali più rustiche e, probabilmente, anche razze incrocianti più produttive.

Parole chiave: Cashmere, Capretti, Incrocio, Follicoli piliferi, Fibre.

Introduction

Rhind and McMillen (1995) state that the ability of goats to produce cashmere is not typical of a certain breed but is present in about 300 breeds, most of which are reared in the cold areas of Asia and Eastern Europe. These breeds have a double layer of fleece consisting of primary external hairs which are long and coarse and have a mostly mechanical function (guard hair), as well as secondary internal hairs which are short and fine with the function of insulating the animal (cashmere or down).

Production levels are very variable due to genetic and environmental factors, and the weight of cashmere yielded as a percentage of the total weight of the fleece varies between 75.3% for Chinese goats and 10% for Spanish goats (Burns *et al.*, 1962).

Italian goats do not produce cashmere fibres, so that Italian textile firms - whose products are in great world demand - are obliged to import all raw materials from abroad.

In order to find a way around this problem, different attempts have been made to introduce breeds which are specialised in the production of cashmere fibres; however despite the positive results in terms of adaptation (Celi *et al.*, 2000; Di Trana *et al.*, 2001) and productivity (Celi *et al.*, 2005), this is a difficult solution to apply because of the considerable expense involved.

It may be possible to solve the problem with a programme of crossing local goat breeds with bucks from cashmere-bearing breeds. The crossbreeds obtained may be able to partially satisfy the textile industry's demand for raw materials and may also serve to diversify and complement traditional goat production.

The Jonica breed is one of the most commonly reared in southern Italy and so we decided to start with this breed in order to evaluate whether the genetic combination achieved when crossing with specialised cashmere-bearing breeds could guarantee satisfactory returns for farmers.

Material and methods

Location
The research was carried out at the Ex-

perimental Teaching Farm belonging to the Department of Animal Production of the University of Bari (Italy) situated at 50 m above sea-level (41° 07'N; 16° 52'E).

Animals

We used 14 male singleton kids born in the first ten days of March 2007; seven were Scottish cashmere goats (SC) specialized in the production of cashmere, and seven were crosses (SC x J) derived from mating males (SC) with female Jonica (J) goats. Jonica is a breed specialized in the production of milk which has a simple white fleece formed only of primary fibres.

Management

During the suckling period of two months, the kids were kept indoors, and thereafter they were reared on pasture rich in gramineae, utilized with a continuous system for 7h/d. They received a daily feed supplement consisting of poor quality vetch and oat hay *ad libitum*, and 100 g/head of commercial concentrate (Table 1).

Collection of samples

The kids were weighed at birth and then at intervals of 30 days until the age of one year. Each time live weight was measured, samples were taken from all kids - alternating the left and right sides - by clipping

the hairs on a patch measuring 4 cm². The weight of each patch was recorded and then the guard hair was separated from the down. Both primary and secondary fibres were weighed and then spread out on a velvet cloth to measure their length, from which we calculated the average total growth. We took a skin sample for biopsy at the centre of every clipped skin patch in order to evaluate the number and activity of the primary (P) and secondary (S) follicles (SACPIC method as modified by Nixon, 1993) and to calculate the ratio (S/P).

When the cashmere fibres reached their maximum length, the diameter was evaluated and both the yield and the production of cashmere were calculated. The diameter was measured using the Optical Fibre Diameter Analyser (OFDA) method. Yield was calculated from the ratio between the weight of the cashmere fibres in the patch to the weight of the patch. Production was calculated by extrapolating the weight of cashmere fibres in the patch to the whole body surface using the formula reported by Couchman and McGregor (1983).

Finally, the heterosis effect was calculated on some parameters as the difference between the average performance of crossbreeds and the average performance of their purebred parent lines.

Table 1.   Chemical composition of food utilized.

		Hay	Concentrate	Pasture		
				Spring	Summer	Autumn-winter
Dry matter	g/kg	875	908	200	336	297
Crude protein	g/kg DM	85	126	172	141	84
Crude fibre	"	346	74	206	246	310
Ether extract	"	18	29	36	26	23
N-free extract	"	447	694	486	509	465
Ash	"	104	77	100	78	118

Collection of blood samples and chemical analyses

Every month, between 6.30 and 7.00 am, a blood sample (10 ml) was taken from the jugular vein of all animals. Blood was then centrifuged (3000 g for 20 min) within 30 min and plasma was harvested and stored at -20°C until assayed to determine proteinemia and tri-iodothyronine (T_3) and tyroxine (T_4).

The thyroid hormones were measured using the direct ELISA method, while total proteins were measured using the biuret method.

Statistical analyses

Data were analysed using the GLM procedure of the SAS application package (SAS, 2000). The statistical analysis of live weight, primary and secondary follicle number, S/P ratio, % of active primary and secondary follicle, guard hair and down length, patch weight, proteinemia, T_3 and T_4 was carried out using the ANOVA model for repeated measurements, which considered the genotype (G), the kids' age (A) and the interaction G x A. Interactions that were non-significant were removed from the model. A monofactorial (genotype) model was used for the average total guard hair and down growth, as well as for yield, production and down diameter. The averages were compared using Student's T test. Pearson's correlation coefficients were calculated between some of the research parameters.

Results

Live weight

Live weight was significantly (P<0.01) affected by genotype and age (Table 2). The average live weight at birth in both groups was 3 kg. Afterwards, weight differences appeared and became more pronounced, especially from the age of nine months onwards,

when the SC x J group kids resulted significantly (P<0.01) heavier (Figure 1).

Number of primary and secondary follicles and S/P ratio

A significant effect of genotype (P<0.01) and age (P<0.01) was noted on the number of primary and secondary follicles (Table 2). The number of primary follicles was always higher in the SC x J group, but the statistically significant differences (P<0.01) were found in the first two months after birth, from the 6th to the 8th month and at one year (Figure 2).

As age increased, the secondary follicles increased so that they had tripled at two months and reached their highest levels at five months in SC x J group and six months in SC group (Figure 2).

The genetic differences became evident from the third month onwards, when SC group kids always presented secondary follicles with a greater density (P<001).

The S/P ratio varied significantly (P<0.01) both according to age, genotype and their interaction (Table 2). Highest levels were reached at six months old for both SC group (6.9) and SC x J group (4.3) and were always found to be higher in SC group (Figure 2).

Percentage of active primary and secondary follicles

The percentage of active primary follicles was not influenced by the genotype, but significant (P<0.01) variations were noted in correspondence with age (Table 2). The percentage was 43% at birth and increased constantly until reaching its highest levels at the age of six months (75% for SC x J group and 80% for SC group). It then fell until the end of the trial (Figure 3).

The percentage of active secondary follicles varied according to the genotype (P<0.01), age (P<0.01) and their interaction (P<0.01). It was the same at birth and reached the

Table 2.   Variance analysis of the parameters considered.

Parameters	F and P Value		
	G	A	G x A
Live weight	20.13 **	800.54 **	-
Primary follicle number	43.84 **	8.69 **	-
% of active primary follicle	0.03	43.18 **	-
Secondary follicle number	324.31 **	112.19 **	7.89 **
% of active secondary follicle	309.78 **	278.43 **	34.39 **
S/P ratio	209.00 **	42.45 **	4.89 **
Guard hair length	33.34 **	31.98 **	4.22 **
Total guard hair growth	17.96 **	-	-
Down length	391.74 **	200.92 **	9.25 **
Total down growth	21.91 **	-	-
Patch weight	27.74 **	26.13 **	-
Down yield	115.09 **	-	-
Down production	148.14 **	-	-
Down diameter	48.83 **	-	-
Proteinemia	3.65	8.04 **	-
T3	378.02 **	59.17 **	28.40 **
T4	8.33 **	38.34 **	-

**: P< 0.01.

highest levels at the age of five months for SC (90%), and at the age of seven months for SC x J (65%). Subsequently the levels fell in both groups and reached the lowest point at the age of one year (Figure 3)

Patch weight

The weight of the patch varied significantly (P<0.01) according to the kids' age and genotype (Table 2). It was always greater in SC group, the significant differences were seen especially from the age of eight months onwards (Figure 4).
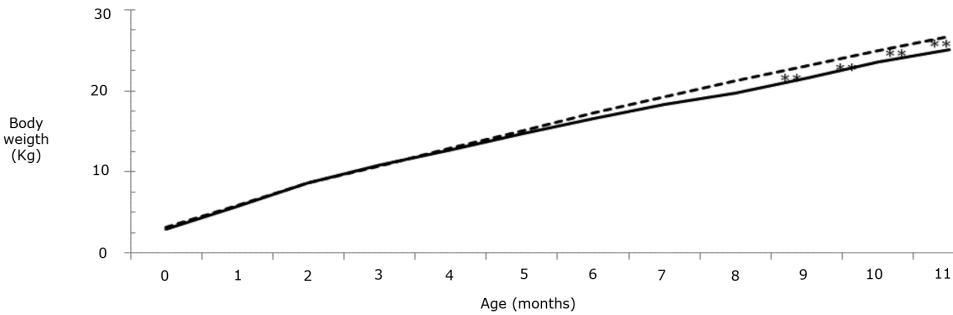
Length of guard hairs and down

The length of the guard hairs varied significantly (P<0.01) both in relation to age,

genotype and their interaction. At birth the longest fibres were found on SC group (3.9 vs 2.4 cm; P<0.01). This difference remained until the age of seven months and then disappeared. From the age of nine months onward the longest fibres were found on SC x J group (Figure 5).

We noted a significant effect (P<0.01) of genotype, age and their interaction on length of down (Table 2).

The length of the down increased constantly and the significantly highest levels (P<0.01) were always found in SC group (Figure 5). The maximum length of down was found at the age of ten months for SC (4.3 cm) and at eleven months for SC x J (3.1 cm).

Figure 1.   Live weight in SC (———) and SC x J (----) kids.

Between genotypes, **: P<0.01. Mean Standard Deviation =0.9008.

Total guard hair and down growth rate

Average total daily growth of guard hair (Figure 6) was significantly (P<0.01) influenced by genotype and SC x J group presented the highest level (0.14 *vs* 0.09 mm).

Total down growth (Figure 6) was significantly greater in SC group (0.23 *vs* 0.14 mm/d; P<0.01).

Down yield, production and diameter

The yield, production and diameter data are shown in Table 3 measured when the down yield showed a strong significant difference (P<0.01) between the two genotypes compared (Table 2), amounting to 34.0±2.61% in SC group and 21.8±3.60 % in SC x J group.

Production was 68.5±9.16 g for SC group and 38.6±4.04 g for SC x J group, and the difference, which is significant for P<0.01, shows that the level of production is largely influenced by the genotype (Table 2).

The fibre diameter was significantly greater (Table 2) in SC x J group (13.9±0.21 *vs* 13.4±0.10 µm; P<0.01).

Proteinemia and thyroid hormones

Proteinemia was not affected by genotype, but a significant effect (P<0.01) of age was noted (Table 2).

Both T_4 and T_3 were influenced by genotype and age (Table 2). Apart from the variability of the two hormones found during ageing, the differences of genotype showed at the start of the trial for T_4, while T_3 was significantly higher in the crossbreeds until the age of six months. Subsequently, the differences in T_3 disappeared, reappearing in the last two months of the trial, when higher levels were found in SC x J group (Figure 7).

Discussion

Live weight

Increases in live weight diminish with age, and the highest weights were found during the suckling period, as shown by Merchant and Riach (1996) in Icelandic x Scottish Feral and Siberian kids.

The change from liquid to solid food probably contributed to this, as did the subsequent gradual quantitative and qualitative impoverishment of the grass sward, typical of the low-lying pastures of southern Italy, especially from summer onwards.

Growth and development processes affecting the whole body - typical of the first year of life - probably caused the establishment of positive significant phenotype correlations (Table 5) between the live weight

Figure 2.   Primary (a) and secondary (b) follicle numbers and S/P ratio (c) in SC
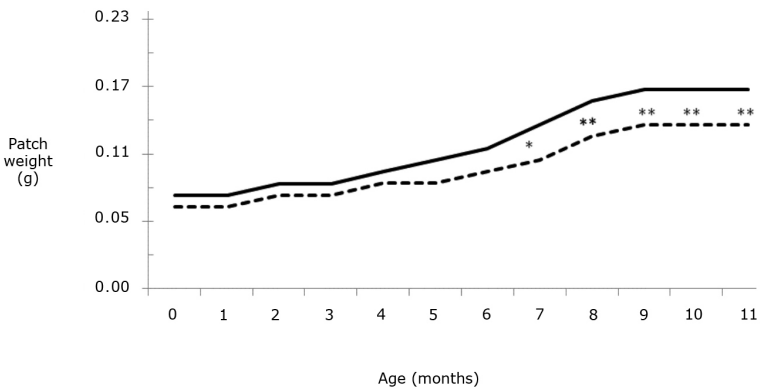   (——) and SC x J (----) kids
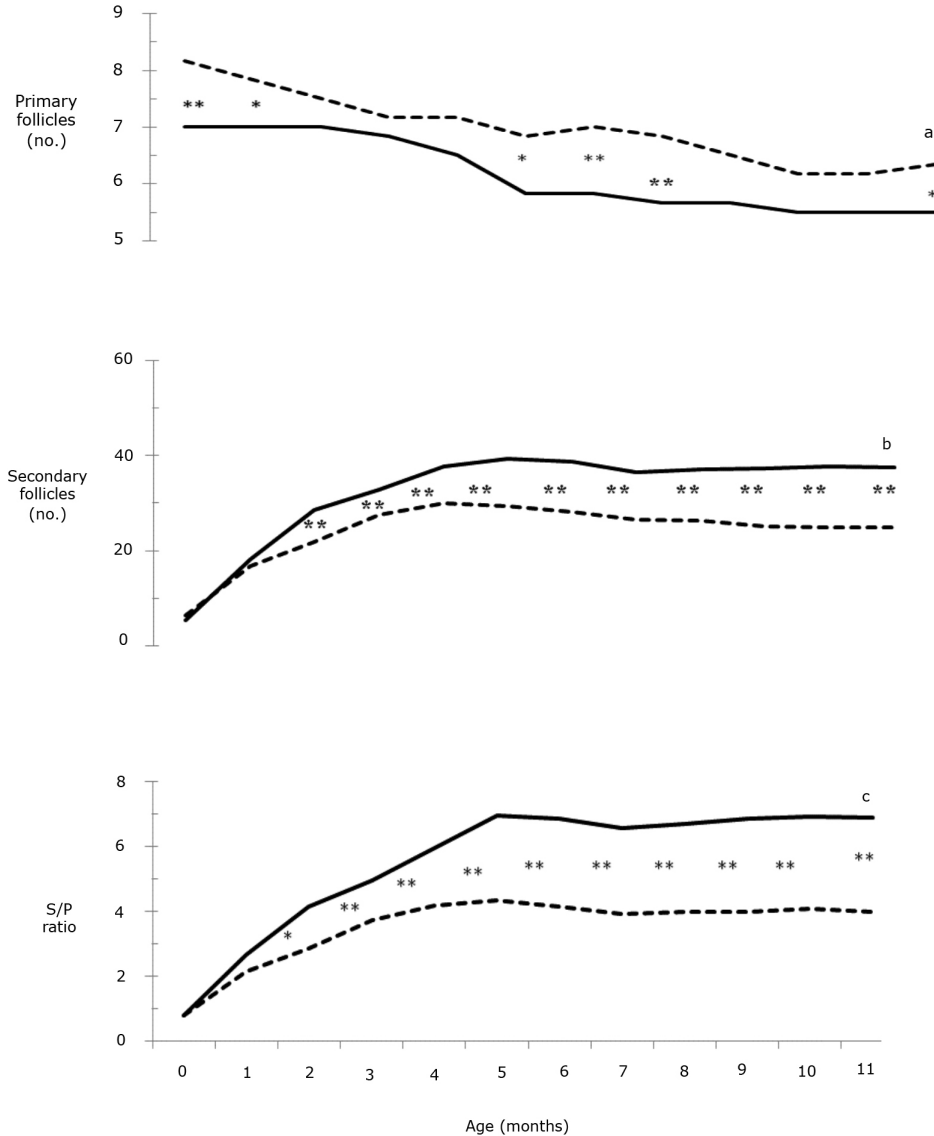
Between genotypes, *: P<0.05; **: P<0.01.   Mean Standard Deviation =0.7425, 2.7348 and 0,8140 for a, b and c, respectively.

Figure 3.   Percentage of active primary (a) and secondary (b) follicles in SC (⸺)
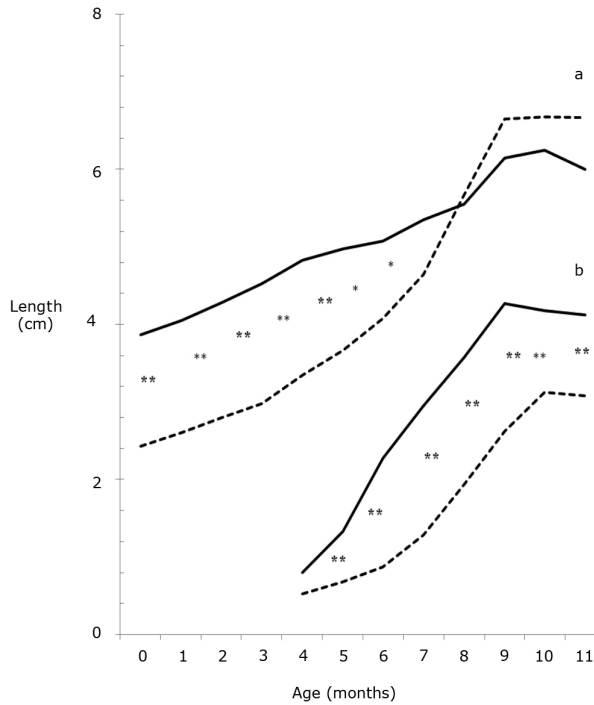and SC x J (---) kids.
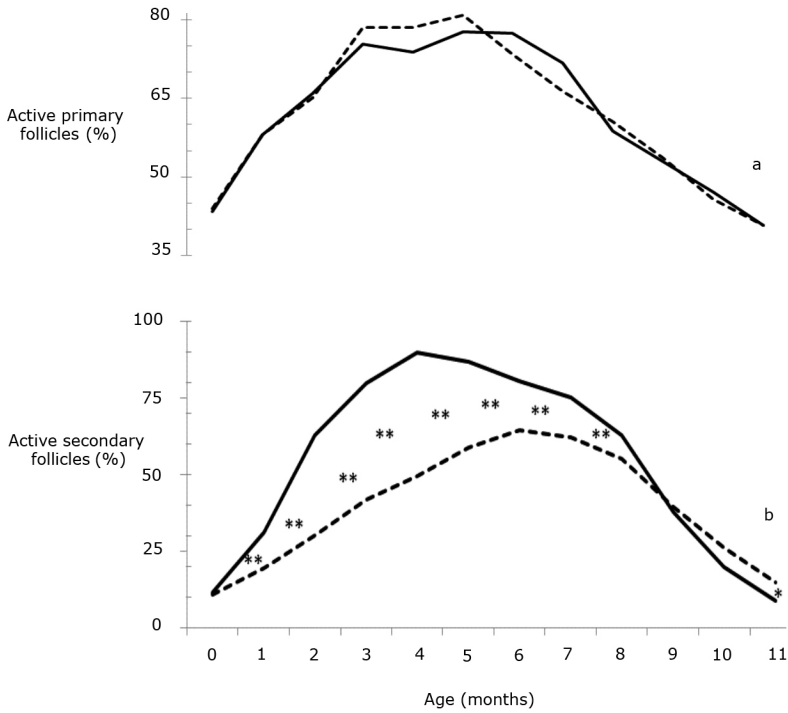
*Between genotypes, *: P<0.05; **: P<0.01. Mean Standard Deviation =7.2817 and 4.9667 for a and b, respec-
tively.*

Figure 4.   Patch weight in SC (⸺) and SC x J (---) kids

*Between genotypes, *: P<0.05; **: P<0.01. Mean Standard Deviation =0.0220.*

Figure 5.   Guard hair (a) and down (b) length in SC (——) and SC x J (---) kids

*Between genotypes, *: P<0.05; **: P<0.01 . Mean Standard Deviation =0.7533 and 0.2908 for a and b respectively.*

Figure 6.   Total growth rate of down and guard hair.
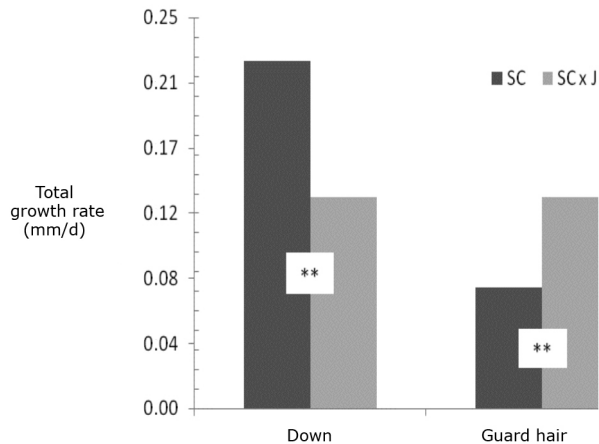
**: P<0.01. Mean Standard Deviation =0.019 and 0.021 for down and guard hair, respectively.

Table 3. Effect of genotype on down yield, down production and down diameter.

| Genotypes	Down yield (%)	Down production (g)	Down diameter (μm)
SC	34.0 ± 2.61[A]	68.5 ± 9.16[A]	13.4 ± 0.10[A]
SC x J	21.8 ± 3.60[B]	38.59 ± 4.04[B]	13.9 ± 0.21[B]

A, B: P<0.01

and patch weight (r=0.55; P<0.01).

Number of primary and secondary follicles and S/P ratio

Both groups presented primary fleece cover from birth and this shows that the histological formation and the maturation of the respective follicles take place in the uterus. The follicle density did not always differ significantly between the two groups, perhaps because the groups were genetically close. However, when these results were compared with those of previous authors, the genetic effect is much more evident, so that the average numbers of primary follicles are more than double those found by

Figure 7. Plasma concentration of total proteins (a), thyroxine (b) and tri-iodothyronine (c) in SC (——) and SC x J (---) kids.
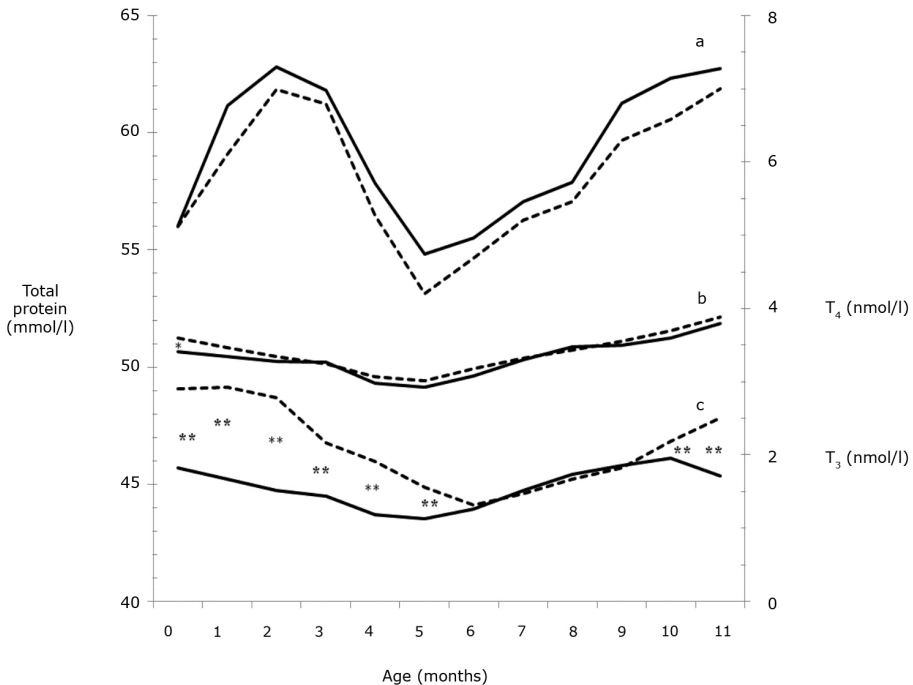
*Between genotypes, *: P<0.05; **: P<0.01. Mean Standard Deviation =3.6098, 0.1415 and 0.1659 for a, b and c, respectively.*

Merchant and Riach (2003) in five-month-old Scottish cashmere goats, but are very similar to those of Parry *et al.* (1992) found in one-year-old Australian cashmere goats.

The fall seen as the kids aged is only apparent and is due to the increased distance between follicles caused by the increase in body surface. This is confirmed by the correlation coefficient (r= -0.43; P<0.01) established by the two parameters (Table 5).

The fact that histological differentiation of the secondary follicles begins in the last stage of pregnancy is the reason for the low density of secondary follicles found at birth in both groups.

Completion of follicle differentiation took much longer than the times referred by Lambert *et al.* (1984) and Parry *et al.* (1992), but these differences are probably due to genetic factors or else to factors relating to the feed given to the dams during the last stage of pregnancy or to the kids in the first few months of life.

This parameter, in any case does not seem to help with improvement of the quantity and quality of the cashmere fibres because - apart from the expense of the analysis - it is not correlated to any of the fundamental parameters which influence down production, except for the S/P ratio (r=0.82; P<0.01)

The different times involved in the formation and maturation of the two types of follicles, their different positions in the skin thickness, the different techniques used to prepare the biopsy, and the different levels of activity of the follicles during the year, are all variables which make it very difficult to evaluate the S/P ratio objectively. However, this continues to be considered at present because it represents an index of secondary follicle development, and consequently provides useful data about the completeness of the animal's fleece. This increases until the secondary follicles develop, which takes place up until the age of 6 months, in a similar pattern to that found by Merchant and Riach (1996). The pattern was different from that found by Parry *et al.* (1992) who reported an increase in the S/P ratio up until the age of 10 months. These differences are mainly due to the genotype and could have an effect on productive performances because early stabilization of the S/P ratio may cause less differentiation of secondary follicles, and consequently less down production.

Percentage of primary and secondary follicles activity

As found by Rhind and Kyle (2004), the percentage of follicle activity varies according to the age of the animals and the pattern shown in Figure 3 is similar to that found in adult animals (Mitchell *et al.*, 1989; Merchant and Riach, 1995; Villar *et al.*, 2000). In general, there is an increase until the late summer, followed by a fall. This could be due respectively to the positive and negative stimuli of the photoperiod on the follicles.

The pattern described is also similar to that of the percentage of active secondary follicles and this results in a strong significant correlation (r=0.55; P<0.01) between the two parameters (Table 5). This situation could probably cause an imbalance in the availability of nutrients between the two types of follicles, with eventual negative effects on the dimensions of the respective fibres, particularly on the secondary fibres.

The negative correlation between the percentage of active primary follicles and the down length (r= -0.51; P<0.01) leads to the hypothesis that the imbalance exists, and that the secondary follicles produce shorter down because they are most affected.

Figure 5 shows that not all of the secondary follicles are active and this confirms the findings of Celi *et al.* (2002) in adult subjects, with the difference that adults present a lower percentage of activity than the kids used for the present research.

The low percentages of follicle activity at birth are due to their incomplete differentiation, and the low percentages at the end of the kids' first year - also found by Mitchell *et al*. (1989), Merchant and Riach (1995), Rhind and McMillen (1996), Villar *et al*. (2000) and Rhind *et al*. (2004) in adult subjects - are due to the imminent end of the first cycle of follicular activity as the follicles prepare to enter into a resting stage.

Apart from the last three months of the trial, follicular activity was always significantly lower in SC x J group, although the levels observed do show a positive heterosis effect (Table 4).

Patch weight

The lack of cashmere fibre on the body surface of the subjects in the first four months of life meant that the patch weight was the same as that of the primary fibres (Figure 4).

The significant variations (P<0.01) observed during the trial are due to the growth of both primary and secondary fibres, particularly as respects their length. For this reason the patch weight correlates positively to the length of fibres (r=0.64; P<0.01). As found by Rhind and McMillen (1995) in adult goats, the patch weight is also influenced by the genotype (Table 2) and was always greater in SC group, particularly from the age of 8 months onward, when down production in this group starts to become more substantial.

Guard hair and down length

The lengths of guard hair recorded during the trial show a very similar pattern to the down. Both guard hair and down reached their maximum lengths in the same period, so that they are positively correlated (r=0.46; P<0.01) in agreement with McDonald *et al.* (1987). However, based on the fact that lengthening lasts longer than for cashmere (Celi *et al.,* 2000), at least seven months (Mitchell *et al*., 1991), and up to 10-11 months as shown by these results, it can be deduced that the lengthening of the hair is not strictly controlled by the photoperiod.

According to Margolena (1959), Wentzel and Wosloo (1975), Merchant and Riach (2003), and Rhind and Kyle (2004), the genotype determines the emergence of the down. These results tend to confirm this diversity in that the first down length was longer in SC group, although not significantly. This suggests that the appearance of down happened early in this group. In any case, the first measurable length was reached in July, just as found in adult Scottish Cashmere goats reared in the same environment (Celi *et al*., 2002, 2005).

The genetic distance of the parent generation resulted in a heterosis effect on the F_1 down length of 0.9 (Table 4). This however, is short and not technically excellent.

The down length was negatively affected by the percentage of active primary follicles, and also seems to be negatively affected by the number of active secondary follicles, because the correlation here is negative (r= -0.38; P<0.01). This could show the existence

Table 4.   Heterosis effects for some parameters considered.

% of active secondary follicle	19.6
Down length	0.9
Yield	5.0
Down production	1.7
Diameter	7.2

Table 5.	Phenotypic correlations among some parameters considered.
Parameters	r and P value
Live weight:	
- Patch weight	0.55 **
Primary follicle number:	
- Body surface	-0.43 **
% of active primary follicles:	
- % of active secondary follicles	0.55 *
- Down yield	-0.46 **
Secondary follicle number:	
- S/P ratio	0.82 **
Down length:	
- % of active primary follicles	-0.51 **
- % of active secondary follicles	-0.38 **
- Patch weight	0.62 **
- Guard hair length	0.46 **
- Down production	0.83 **
- Down yield	0.78 **
- T3	0.32 **
- T4	0.55 **
Patch weight:	
- Guard hair length	0.64 **
Down production:	
- % of active primary follicles	-0.56 **
- Patch weight	0.65 **
- Proteinemia	0.36 **
- Down yield	0.79 **
Proteinemia:	
- Down yield	0.28 **
- T4	0.22 **
- T3	0.15 **
T3:	
- T4	0.36 **

*: P<0.05; **: P<0.01.

of competition for nutrients also between the secondary follicles, in the sense that the availability of nutrients at the follicular level diminishes as the percentage of active follicles increases.

Finally, if we consider that the down length is the fundamentally important production parameter, the correlations between down length and yield (r=0.78; P<0.01) and between down length and down production (r=0.83; P<0.01) were expected (Table 5). Although these correlations are greater, they agree with those found in one-year-old New Zealand kids by Newman and Paterson (1992).

Yield, production and down diameter

Since Celi *et al*. (2003) found that kids with the same age, same rearing conditions and same breed as SC group used in this study gave higher average yields, it can be deduced that the parameter is likely also to vary because it is affected by annual changes in climate and feed.

However, the yields (Table 3) fall within the range indicated by Pattie and Restall (1992), although SC x J group yield lies towards the lower end of the range, and shows that a very small heterosis effect (Table 4). In agreement with Couchman and McGregor (1983), the yield correlates strongly (Table 5) to the production of cashmere (r=0.79; P<0.01). The same correlation is noted with the down length, and since this is of the same magnitude it is possible to evaluate the yield from the down length, a method which is much simpler and less expensive.

Cashmere production depends strictly on the number of secondary fibres per unit of surface area, and their respective dimensions, and the correlation which production establishes (Table 5) with the fibre length (r=0.83; P<0.01) confirms the findings of Couchman and McGregor (1983), Millar (1986) and Newman and Paterson (1992) regarding kids the same age as these present

trial groups, and also results obtained using adult goats (McGregor and Butler, 2008).

The effect of the genotype seen from these results (Table 3) is very much in agreement with other authors studying kids of the same age, who report productive performances of 300 g for purebreds (Yin Changan, 1992), and ranging between 43 g (Couchman, 1988) and 192 g (Couchman and McGregor, 1983) for crossbreeds.

However, the production level cannot be considered as satisfactory, especially in SC x J group, despite the heterosis effect of 1.7 (Table 4).

The diameter measurements show that the fibre produced is of excellent quality. This is confirmed by the fact that the results achieved (Table 3) fall within the range identified for cashmere fibres and also have a smaller diameter than the fibres found on purebred kids of the same age (Newman and Paterson, 1992) or crossbreeds (Couchman and McGregor, 1983; Yerxat and Yalejean, 1995). According to Bishop and Russel (1994), the down diameter is not excessively influenced by heterosis. In this research this effect was 7.2 (Table 4) and this meant that SC x J group down was significantly coarser (P<0.01) than SC group.

Proteinemia and thyroid hormones

Variations in proteinemia due to time are probably related to the great changes in feeding during the trial. Proteinemia is high during the suckling period and falls to minimum levels in summer as the quantity and quality of the pasture deteriorates. It then rises again gradually as the climatic conditions allow grass re-growth.

In any case, proteinemia is positively correlated with yield and cashmere production (r=0.28 and 0.36, respectively; P<0.01) (Table 5). This result should be verified because, apart from the relation between food proteins consumed and proteinemia, this

would admit a positive effect on down production of protein supply - obviously above the level of maintenance - in contradiction with the findings of McGregor (1988) and Russel (1995).

Hypothesising a relationship between proteinemia and cashmere production, Antova and MkRtychyan cited by Millar (1986) affirm that this effect is not due to the level of blood proteins as such, but to polymorphism, in that they found the highest levels of fibre production in subjects which were heterozygotic for haemoglobin type.

Another hypothesis is perhaps more probable, but still needs to be checked, and is that proteinemia may act indirectly on the quantitative characters of the cashmere fibres through greater synthesis of thyroid hormones, which are known to positively stimulate the activity of hair follicles. This could be supported by the positive correlation (P< 0.01) between proteinemia and thyroid hormones (Table 5).

In agreement with Villar *et al*. (2000), Merchant and Riach (2002), Celi *et al*. (2003), Rhind and Kyle (2004) and Rhind *et al*. (2004), the concentrations of T_3 and T_4 in the blood vary significantly over time. Considering that the subjects were reared with the same management system and received the same feeds, it is possible to ascribe these variations to the seasonal climatic variations.

The correlations established by the two hormones (r=0.36; P<0.01) derive from the fact that the respective weather patterns are generally similar (Table 5).

The increase in incretions of the thyroid hormones during the growth period of the cashmere fibres results in a significant positive correlation of both T_3 (r=0.32; P<0.001) and T_4 (r=0.55; P<0.001) to the length of the cashmere (Table 5), and confirms that these hormones are involved in the growth of the fibres, as shown by Villar *et al*. (1998).

Conclusions

The results of this research allow us to conclude that from an experimental point of view, F_1 presented productive characters which were all positive, and that these all showed the effect of heterosis, although to different degrees.

The same results take on a different significance when considered in terms of commercial viability. Although the cashmere fibres are of excellent quality, the quantity is not sufficient to give added value to the returns of goat farming.

The weak point in F_1's poor production lies in the significant low number of secondary follicles, in their low percentage of activity and in the fact that the cashmere fibres produced were significantly short, despite a longer growth period.

Overall, the genetic combination used is weak in terms of production, and this means that others must be studied. More rustic and less specialised local breeds could be used, or even F_2, although this would require a re-organisation of management and rearing techniques.

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