

Genetic and environmental factors influencing the quality of pelt traits in Karakul sheep

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This review covers those aspects which are important in the breeding of Karakul sheep. Obviously, it is not possible to do justice to the vast amount of information reported in the literature. Yet, it emphasizes the importance of and inheritance of colour variation, breeding problems, important traits affecting the price of the product, genetic parameters as well as the influence of certain environmental factors on fur traits. It is therefore an attempt to highlight those aspects which can make an impact on the improvement in Karakul pelt production.

Hierdie oorsig handel oor dié aspekte wat van belang is in die teling van Karakoel-skape. Vanselfsprekend is dit onmoontlik om aan die enorme hoeveelheid inligting wat in die literatuur opgeteken is, reg te laat geskied. Dit beklemtoon egter die belang en oorerwing van kleurvariasie, probleme met die teel daarvan, die belangrikste eienskappe wat die prys van die produk beïnvloed, hulle genetiese parameters sowel as die invloed van sekere omgewingsfaktore wat pelseienskappe beïnvloed. Daar is derhalwe gepoog om dié aspekte wat 'n impak op die verbetering in Karakoelpelsproduksie teweeg kan bring, uit te lig.

Keywords: Colour variation, environmental effects, genetic improvement, Karakul pelts

Introduction

Since the importation of the first Karakul sheep into the then German South West Africa in 1907 by the then Governor von Lindequist, the Karakul industry was established and later on, it became a cornerstone in the agriculture and economy of this country. The foresight of the late A.D. Thompson virtually came true when he said: '... but that in time — even if that time may still be far distant — the industry will and must expand until South West Africa becomes the premier Karakul breeding country in the world' (Thompson, 1938). It was mainly during the years 1930 to 1939, that Karakul sheep numbers expanded rapidly in South West Africa and also into the arid western areas (mostly Gordonia) of the Republic of South Africa (Viljoen, 1981). Factors responsible for this development were: droughts, the depression of the early thirties, a sharp decrease in wool prices and the adaptability of the Karakul under severe drought conditions (Rawlinson, 1994). By 1970, more than 95% of the 4.4 million sheep in the then South West Africa were Karakuls, while in 1979 almost 5 million pelts were exported from South and South West Africa to the European markets.

Sadly, however, the Karakul industry almost totally collapsed. This started in 1981 as a cumulative result of various factors of which economic recession conditions in consumer countries, changes in fashion and an anti-pelt campaign were the most important. Lifestyle had changed within a short period of time from formal to very informal; also in fashion. This had a very negative impact on the sale and consumption of fur.

Presently, only approximately 6% of the 2.5 million sheep in Namibia are Karakul, while the number of pelts exported has declined to approximately 120,000. However, the past two auctions since December 1997, average pelt price has increased by 67% (from R97.36 to R162.51). There was a strong demand by buyers from Italy, Germany, Spain and France. Pelt garments are becoming very popular again in Europe, even amongst young people. This fairly acceptable price is largely supported by the favourable exchange rate which has changed from R/£ 1.69 in July 1982, to approximately 10.2 presently.

Prospects for a recovery of the Karakul industry to its original status are not encouraging. Some of the positive factors which may play a role are the increase in demand, as was noticed during the last auctions, and the possibility of a decrease in real meat prices. However, owing to its high labour intensity, sheep breeders will be reluctant to change back to pelt production.

In this paper, the traits which are important from an economic point of view, are reviewed. The inheritance and problems associated with the different colours and the genetic and environmental factors influencing important fur traits will be included.

Colour variation and inheritance

Predominant coat colours in Karakul pelts are black, grey, white and brown. Almost 75% of all pelts marketed in 1983 were black, while the rest were made up of grey (21.0%), white (2.0%), brown (1.5%) and spotted (0.6%). Since then, the percentage of black pelts has increased to approximately 90% at present, with a decline in the demand for grey pelts.

The mode of inheritance of these coat colours was studied in Karakul and related North European breeds and discussed by several authors, the most detailed by Nel (1966), Ryder (1980), Adalsteinsson (1983) and Greeff *et al.* (1984). Five loci contribute to the expression of these important coat colours in the Karakul. Two alleles have been found at the B-locus responsible for the expression of a black colour, with B dominant, producing black, and b, recessive, producing a chocolate brown (or moorit) colour (Adalsteinsson, 1980; 1983). This allele is also responsible for the expression of the black colour encountered in the Merino.

In Karakul and related breeds the E-locus is mainly responsible for the expression of black (Rae, 1956; Adalsteinsson, 1980; 1983). Two alleles are found at this locus, with E^D dominant, resulting in the black colour and completely inhibiting the expression of all alleles at the A-locus, and e (or sometimes also E) recessive, allowing the full expression of all the alleles at the A-locus. The effect of E^D in animals of genotype bb at the B-locus is expected to result in a chocolate (or moorit) brown colour. Earlier work (Nel, 1966) suggested a multi-allelic series at the E-locus, with order of dominance of $E^C > E^D > e^b > e^t$ for the expression of dark coffee brown, black, brown and dobermann, respectively. For the inheritance of the rare dobermann colour, Adalsteinsson (1980) initially suggested a separate locus, Do, expressing this colour but later on (Adalsteinsson, 1983) postulated it to be expressed by the A^W allele or another allele on the A-locus (A^{Do}) with a similar effect.

At the A-locus, responsible for the expression of a variety of colours and colour patterns, 12 alleles have been postulated by Adalsteinsson (1983) with A^{wh} top dominant and responsible for the expression of red and white in the Merino and other breeds. Genes at other loci eliminate the tan (red) pigment making the animal completely white. According to Adalsteinsson (1983), the dominant dark coffee brown colour in Karakul sheep is also caused by the A^{wh} allele, with genotype: $A^{wh}A^{wh}BBee$.

Brown Karakul lambs differ considerably in shades and intensity. Heritability estimates for both shades and intensity are high (Gouws, 1974; Adalsteinsson, 1975). Brown shades with a silver and especially a golden tinting are preferred types in the market (Gouws, 1974).

Grey Karakul sheep are either black-roan or brown-roan, indicating that the roan or grey gene

changes the base colour (black or brown) into a roan. Many authors found the roan allele to be epistatic to the base colour in several sheep breeds (Adametz, 1917; Contescu, 1938; Boiko, 1949; 1962; Nel, 1950; 1966). When grey animals are mated *inter se* a 3:1 grey:base colour ratio is expected and usually found. The allele responsible for the expression of the roan or grey colour, W^R , is an allele of W , expressing the white colour in Karakul sheep (Nel, 1966). The dominant grey is lethal when homozygous ($W^R W^R$) (Glembozki, 1935; Contescu & Epureanu, 1939; Giginisvili, 1949; Nel, 1950; 1966). Grey Karakuls are therefore heterozygous ($W^R w$). In grey \times grey matings, segregation occurs in a genotypic ratio of 1:2:1 where 25% of lambs carry the sublethal factor and eventually die at a relatively young age (Nel, 1950; Nel & Louw, 1953).

The intensity of the grey colour varies considerably, depending on the ratio of black (brown): white fibres in the pelt. It varies from a very light (almost white) to a very dark and almost black with a few grey points (usually on the tail, ears or legs). It was shown by Nel (1966) and Adalsteinsson (1983) that the heritability of the intensity of the grey colour is high (0.35 to 0.70).

The white colour is not inherent to Karakul sheep, but was introduced through crosses between the black Karakul and the white woolled Persian (Wahl & Thompson, 1920; Thompson, 1938; Nel, 1966). The allele responsible for the expression of this white colour (W) is incompletely dominant (or more correctly partially epistatic) to the base colour black or brown (B and E loci). Homozygous lambs for the WW locus (e.g. $A^{wh}A^{wh}BBE^D E^D SSSWW$) are practically pure white (A-white), while heterozygous lambs (Ww) are usually white with broken black (or brown) in the face and other extremities and sometimes also small spots on the body (B- or C-white).

Furthermore, it is indicated that the white Karakul in its homozygous form (WW) is almost similar to the homozygous grey, subjected to a subvital effect, which is, however, less severe and lambs survive for a longer period after weaning than in the case of the grey Karakul (Schoeman, 1980). The effect thereof on mortality and conception rates is illustrated in Tables 1 and 2, respectively.

Table 1 The influence of coat colour variation in a white Karakul flock on pre- and postweaning mortality rates of lambs (Schoeman, 1980)

Colour	Mortality rate (%)				Total
	<i>n</i>	Preweaning	<i>n</i>	Postweaning	
A-white	75	4.00	72	16.67	20.00
B/C-white	305	2.95	296	7.77	10.49
Black	250	2.71	251	5.18	7.75

Table 2 Conception rates of maiden ewes and percentage of ewes completing reproductive life of six years in a white Karakul flock (Schoeman, 1980)

Colour	<i>n</i>	*Percentage not mated	Percentage conceived of those mated	Percentage completed reproductive life
A-white	50	16.00	42.9	46.3
B/C-white	188	11.17	85.0	77.4
Black	144	12.50	87.3	83.9

*Not mated for not reaching target weight.

Several other authors (Adalsteinsson, 1975; Dyrmondsson & Adalsteinsson, 1980; Ricordeau *et al.*, 1982) also claimed that the A^{wh} allele is responsible for an adverse effect on reproductive performances in breeds related to the Karakul.

Both grey and white affected lambs develop quite well during the suckling period, but develop signs such as distended rumens filled with fine, frothy material and sometimes (mostly in grey) sand impacted abomasa when fed on roughage. The sizes of the abomasa are accordingly larger in black lambs and smaller in white and grey lambs. The walls of the rumens and abomasa are thin and very little muscle appears to be present. In affected lambs, owing to the improper closing of the oesophageal groove, milk goes into the rumen first instead of being bypassed directly into the abomasum (Nel & Louw, 1953). Differences in the size of the rumen between black, white and grey lambs are illustrated in Table 3 (Groenewald & Booth, 1989). There is also large variation in the dimensions of the rumens in grey and white lambs as compared to black lambs. Nel (1965) furthermore illustrated that homozygous grey lambs can be identified with great accuracy at birth by a lack of pigmentation of the tongue, palate and ears, enabling the breeder to eliminate the problems in the breeding of grey Karakul to a large degree. Mostly, breeders avoid mating grey to grey. Likewise, using A-white in breeding should be restricted to mating A-white rams to black ewes. In white Karakul flocks mating should be restricted to B-white to B-white.

Table 3 Means (\pm SD) of rumen size in black, white and grey one-day-old Karakul lambs (Groenewald & Booth, 1989)

Colour	<i>n</i>	Length (cm)	Width (cm)	Volume (ml)
Black	10	5.4(\pm 0.44)	4.8(\pm 0.36)	55(\pm 2.3)
White(A)	15	6.6(\pm 0.71)	6.0(\pm 0.76)	64(\pm 17.8)
Grey	13	7.4(\pm 0.93)	6.7(\pm 1.00)	108(\pm 41.66)

Important fur traits in karakul lamb skin

From an economic point of view, it has been shown by various authors that within different colours, the pelt price is predominantly determined by curl type, pattern score, hair quality score and hair length traits (Nel, 1966; Schoeman, 1968; 1984a; Schoeman & Nel, 1969; Van Niekerk, 1972; Gouws, 1974). Some of the results are presented in Table 4. Traits such as pelt thickness and hair thickness are also correlated to the price, though their contributions are minimal. It was furthermore indicated that the relative weight for pattern score becomes less important and for hair quality score it becomes more important with a decrease in curl development. In addition, properties such as colour intensity and colour tinting become more important in the coloured pelts.

Curl type

Curl type refers to the degree of curl development which varies from a smooth type (galliac and watersilk) to a curly type (pipe curl) and is determined by the degree of circling of the fibres. A higher degree of development is negatively associated with pelt price (Nel, 1966; Schoeman, 1968; Schoeman & Nel, 1969; Van Niekerk, 1972).

Fully developed curls were inherent to Karakul pelts. However, since early years it has been difficult to breed pipe curl types of good quality. When mated together, there was a tendency for this type of pelt to develop curls which became too small and accordingly caused a deterioration in hair quality (Thompson, 1938). Consequently, the late A.D. Thompson decided to select for less deve-

Table 4 Relative economic importance of various fur traits (standard partial regression coefficients) expressed as percentage contributed

Trait	Authors		
	*Nel (1966)	*Schoeman & Nel (1969)	*Van Niekerk (1972)
Curl type	-14.5	-11.8	-12.6
Pattern score	28.6	35.3	39.5
Hair quality score	16.4	19.0	21.0
Hair length	-11.3	-10.2	-15.6
Pelt thickness	-	-5.2	-5.5

*Individual values are means of several estimates

loped types, which ultimately resulted in the smooth types for which South West African Karakul (SWAKARA) became popular.

Pattern score

Pattern score, assigned to Karakul lambs by breeders, gives expression to the attractiveness of the pelt which in turn is the result of a complicated interaction between several pattern-forming characteristics, which either contribute positively or negatively to pattern score (Anonymous, 1982; Schoeman, 1991). They are in turn affected by properties of the skin and follicles (Nel, 1950; Hugo, 1982; Dreyer, *et al.*, 1983). Earlier work by Hornitschek (1938) also found large differences in follicle distribution and arrangement between various pattern types.

Hair quality

The quality of hair in the Karakul fur greatly influences the durability of the pelt garment. It also influences the appearance thereof. Hair quality scores, as assigned by the breeders, are determined by the texture and lustre of the individual fibres. Both are also affected by the thickness of the fibres.

In the mid seventies problems were experienced with fibre losses and reduced durability of SWAKARA garments (Kunze, 1979). Possible reasons for this from a breeding point of view were discussed by Le Roux (1979) and Schoeman (1984b) and will not be dealt with here. Physical test methods, developed by the Leather Industries Research Institute (LIRI) at Grahamstown, were then used to measure fibre losses in the Martindale simulated wear tests (Campbell & Russell, 1975; Russell, 1979). The effect of hair thickness (see Figure 1) and quality (see Figure 2) on fibre loss (abrasion rates in g/100 cycles) irrefutably demonstrated the importance of good hair quality on the durability of SWAKARA garments.

In another study (Matter, 1991) positive relationships were obtained between the metal contents (Cr, Fe, Ni and Ag) of fibres and hair quality. The underlying physiological mechanisms and reasons for these correlations have not been investigated.

For brown and grey pelts, other additional traits become important, while traits such as pattern score become relatively less important (Gouws, 1974). Colour intensity and especially tinting, which may be either golden or silver, are preferred. In grey Karakul, colour intensity is equally important. Schoeman (unpublished) demonstrated the importance of manipulating matings to ensure an intermediate colour which favours both pattern as well as hair quality. The lighter shades

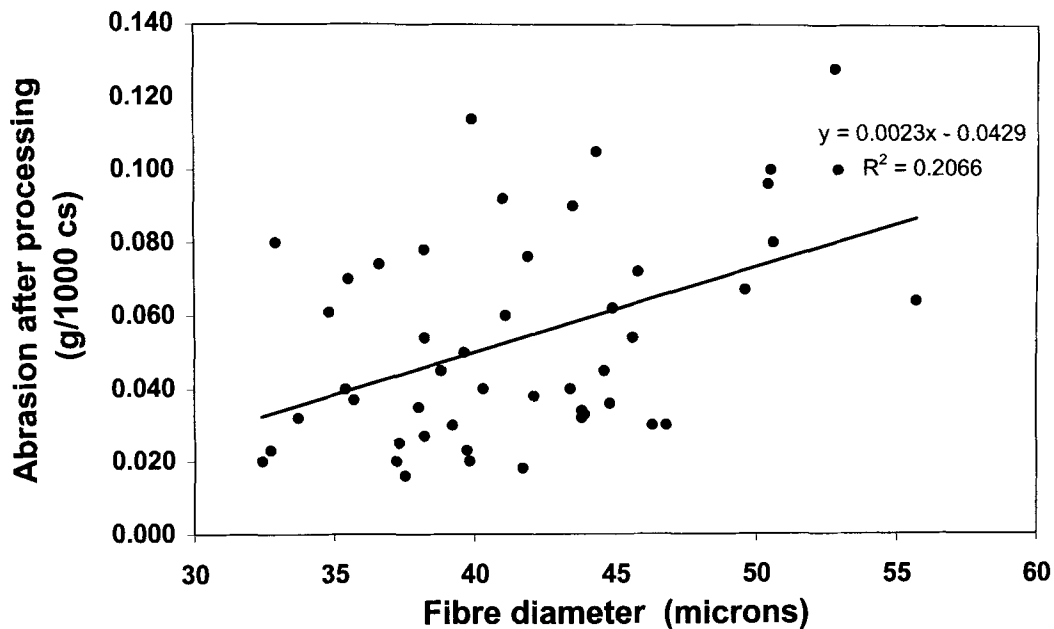


Figure 1 The regression of hair thickness on fibre loss in processed SWAKARA pelts (Campbell & Russel 1975).

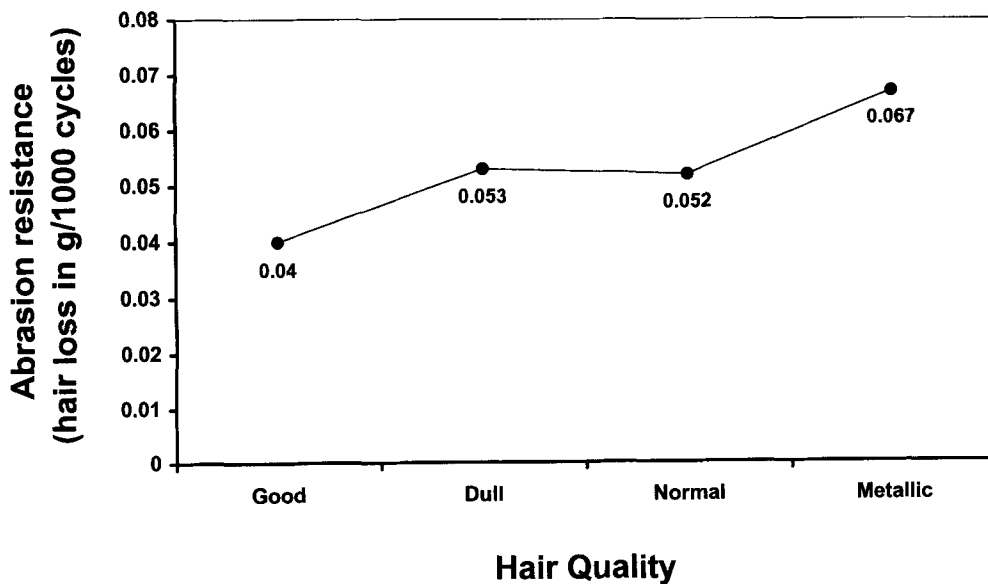


Figure 2 The influence of hair quality categories on mean fibre loss in processed SWAKARA pelts (Russel, 1979).

tend towards poorer pattern, longer but better hair quality, whereas the darker shades have better pattern but poorer quality (see Table 5). It is recommended that breeders concentrate on intermediate colour types which have the advantage of an acceptable pattern combined with an above average hair quality. It was furthermore shown by Albertyn *et al.* (1993) that black lambs born from black × grey, grey × black and grey × grey matings were inferior to those from black × black matings for all traits, except for pattern score. The reason for this is not clear, but it may be related to a higher genetic merit in the larger black population.

Table 5 Mean values for fur traits of different shades in grey pelts (Schoeman, unpublished)

Shade	Pattern	Mean values for	
		hair quality	*Hair length
Light	3.9	6.6	3.2
Medium/light	4.0	6.5	3.3
Medium	4.4	6.5	3.4
Medium/dark	4.4	6.4	2.7
Dark	4.5	6.1	2.1

*Subjectively evaluated with the longest hair the highest score

Evaluation of fur traits

Economically important fur traits are normally evaluated by the allocation of scores (Anonymous, 1982). Although this subjective evaluation procedure is fairly inaccurate and inconsistent (Schoeman, 1968; 1969; Albertyn & Schoeman, 1990), at present there is no other method of assessing fur traits and it will most probably still be used in the future. One exception, however, is hair length where relatively simple and accurate techniques were proposed by Schoeman (1968) and Nel *et al.* (1974). They are, however, not applied in practice.

Score allocations are mostly done on an ordinal scale (Stevens, 1958), while an interval scale is wrongly assumed (Albertyn & Schoeman, 1990; Randall, 1993; Schoeman & Albertyn, 1993) (see Figure 3) and linear methods for the analysis thereof used. In a comparison of threshold and linear

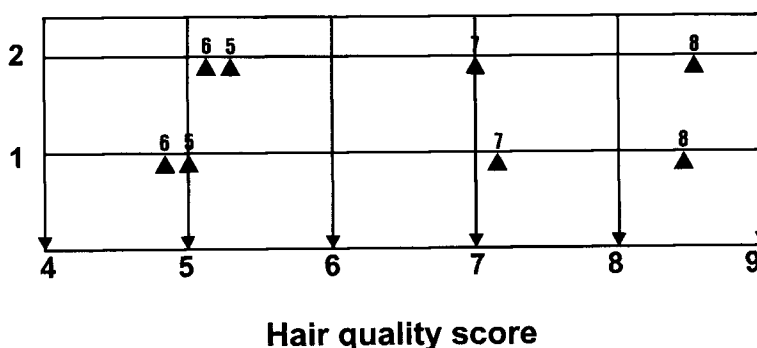


Figure 3 The positioning of scores assigned for hair quality in two independent samples relative to an assumed Karakul Breeders Association interval scale (Albertyn & Schoeman, 1990).

models applied in the analysis of pelt traits, it was, however, indicated that the use of a linear model gave acceptable heritability estimates in traits with more categories and where the continuous variation is fully or partially expressed in the scoring scale (Louwrens *et al.*, 1997).

Genetic parameters in fur traits

Heritabilities

Heritabilities were estimated for a variety of pelt traits by various authors using different statistical methods. A summary of the estimates for the important fur traits in Karakul lambs is given in Table 6.

Table 6 Summary of heritability estimates for important fur traits in Karakul lambs, published by various authors*

Trait	<i>n</i> ^a	Range	Median value	Unweighted mean
Curl type	12	0.10–0.77	0.44	0.42
Curl size	11	0.16–0.34	0.25	0.26
Hair length	12	0.20–0.48	0.34	0.32
Pattern score	12	0.02–0.39	0.21	0.24
Hair quality score	12	0.12–0.49	0.31	0.25
Lustre	6	0.13–0.44	0.29	0.29
Texture	4	0.12–0.31	0.22	0.20
Pelt thickness	9	0.11–0.45	0.28	0.25
Hair thickness	6	0.16–0.66	0.41	0.41

^a Number of estimates reported

* Yao, *et al.* (1953), Malan (1959), Nel (1966), Feddersen (1968), Van Niekerk *et al.* (1968), Van Niekerk (1972), Botma (1981), Greeff *et al.* (1991a), Schoeman & Albertyn (1992).

Estimates for individual traits are characterised by a high degree of inconsistency. They vary from 0.10 to 0.77 for curl type. These individual estimates are a characteristic of the population in which they were estimated and they may change over time owing to selection and management decisions. They may in some cases be biased and thus either under or overestimated. Standard errors for individual estimates varied considerably and were in some cases not even reported. Standard errors are therefore ignored. No attempt is made to eliminate individual estimates on grounds of bias and inaccuracy. The mean values are not weighted means and do not take the number of observations (or number of sires) per estimate into consideration. The low heritabilities in some studies may, despite inaccuracy owing to insufficient numbers, also be related to the result of inaccuracy of subjective score allocation.

Median and unweighted mean values are moderate to high, indicating that substantial progress is possible in most flocks under phenotypic selection. In both a private owned stud flock (Schoeman & Albertyn, 1992) and in the single trait selection lines at the Upington Karakul Research Station (Greeff *et al.*, 1993a), high annual responses were recorded for all important traits, expressed as the mean predicted breeding values per year of birth. The fastest response ($b = -0.22$), as one would expect, was recorded in curl type (Greeff *et al.*, 1993a).

Table 7 Summary of estimates of genetic correlations between important fur traits in Karakul lambs, published by various authors*

Trait	<i>n</i> ^a	Range	Median value	Unweighted mean
Curl type and hair quality score	8	-0.50 to -0.06	-0.28	-0.32
and pattern score	8	-0.62 to 0.42	-0.10	-0.07
and hair length	7	0.05 to 0.64	0.35	0.22
Pattern score and hair quality score	7	-0.37 to 0.61	0.12	0.18
and hair length	7	-0.66 to -0.39	-0.53	-0.51
and hair thickness	2	0.04 and 0.29	0.17	0.17
Hair quality score and hair length	7	-0.34 to 0.45	0.05	0.21
and hair thickness	2	-0.58 and -0.09	-0.43	-0.34
Hair length and hair thickness	2	-0.25 and -0.20	-0.23	-0.23

^a Number of estimates reported

* Nel (1966), Feddersen (1968), Van Niekerk *et al.* (1968), Van Niekerk (1972), Greeff *et al.* (1991a), Schoeman & Albertyn (1992).

Genetic correlations

A summary from literature of important genetic correlations is given in Table 7. Published estimates of genetic correlations vary considerably and cover almost the entire parameter space (e.g. the correlation between pattern score and hair quality score which varies from -0.37 to +0.60). Simple correlations between heritability estimates and corresponding genetic correlations in the same population were not obtained (owing to the small number of estimates). Such correlations, when high, could be the effect of selection and the quality and scope of the statistical methods used (Koots *et al.*, 1994). However, in some individual cases, heritability estimates were high/low when corresponding genetic correlations were also high/low (Feddersen, 1968; Van Niekerk *et al.*, 1968; Schoeman & Albertyn, 1992). The large variation in genetic correlations between the same traits could also be the result of the inaccuracy and inconsistency of the subjective scoring methods. Differences in genetic correlations between flocks may therefore be due to lamb evaluation peculiarities or to genetic differences between flocks. The fixation of pleiotropic genes as a result of selection on both traits may eventually change a positive genetic correlation into a negative one (Sheridan & Baker, 1974). This may probably have been one of the most important reasons for a negative genetic correlation in a highly selected flock (Schoeman & Albertyn, 1992), as opposed to a positive genetic correlation as was obtained by Greeff *et al.* (1991a) in the Upington control flock. Curl type is negatively correlated with hair quality score, supporting the observations made by Thompson (1938) and ultimately leading to the development of the shallow curl types. Of particular interest is the genetic correlation between pattern score and hair quality score, since these are economically the most important traits. These values varied from -0.37 to 0.61, but were in most cases negligible. Pattern score is negatively correlated with hair length, so that selection for a higher pattern score would result in hair becoming shorter. An improvement in hair quality score will, on the other hand, result in longer hair. Selection for shorter hair will therefore result in an improvement of pattern score, but with thicker hair. Hair thickness is also negatively correlated with hair quality score. In general, despite the positive mean correlation between hair quality score and pattern score, there seems to be a possible complicated, negative antagonism between these two traits. Breeders

should take this into consideration in an effort to breed fur of both high quality and attractive pattern.

In the single-trait selection lines at the Uppington Karakul Research Station, Greeff *et al.* (1993b) obtained significant correlated responses in hair length (-0.05) and hair thickness (0.04) in the pattern plus line, while in the hair quality plus line significant correlated responses were recorded in pattern score (0.10), curl development (-0.31) and hair thickness (-0.08). In the curl development minus line pattern score improved (0.33), hair quality deteriorated (-0.06) and hair thickness increased (0.07). In general, these observations were in accordance with expectations based on the estimated genetic correlations.

Selection

Selection of lambs takes place at birth through visual appraisal. Mostly, some form of independent culling levels is practiced. Selection of rams on auction takes place on photographic copies of the lamb taken shortly after birth, scores allocated by the breeder to the lamb shortly after birth and a registration score assigned by the Karakul Breeders Association at a later stage. Selection indices for a variety of black Karakul flocks have been constructed by Nel (1966), Schoeman (1968) and Van Niekerk (1972). These indices vary between flocks, owing to differences in flock-specific parameters used in the construction thereof. In practice they are only used on a very limited scale and mostly as an additional aid in the selection process.

In many traits intermediate values are preferred, e.g. hair length, hair thickness and hair quality. For hair quality the preferred value is a combination of silkiness with a good lustre and some degree of elasticity, resulting in an outstanding hair quality score (Albertyn & Schoeman, 1986) Silkiness gives the pelt a pleasant soft touch, while elasticity retains the pattern during processing and wearing. The breeder, therefore, must obtain both elastic and silky animals to create the desired combination. Consequently, disassortative matings will always play an important part in Karakul breeding.

During the peak period in the Karakul industry, several breeds were also used for crossbreeding purposes. These breeds mainly included the Blackhead Persian and Afrikaner breeds (e.g. the Namaqua Afrikaner). This practice was primarily aimed at increasing the Karakul ewe numbers and was an attempt to breed animals with improved constitution and higher reproductive rates. However, it was indicated (Schoeman, 1979; Faure *et al.*, 1983) that crossbreeding for pelt production is highly unfeasible, mainly because of inferior pelt quality resulting from such crossbreedings. In terms of profitability, this practice did not exceed purebred Karakul breeding.

Non-genetic factors influencing fur traits

A variety of environmental effects, both internal and external, have an influence on fur traits. Fur traits usually vary between years and between seasons within years. These differences are normal phenomena and are a reflection of the nutritional status of the veld, especially during the last third of pregnancy. Several traits are also influenced by internal effects such as sex of lamb and age of dam. Probability values (p) for some environmental effects as reported by Greeff *et al.* (1991b) are presented in Table 8.

Greeff *et al.* (1991b) reported significant ($p \leq 0.01$) differences between years for all traits, as was found in some other studies as well (Schoeman & Albertyn, 1992).

Month of birth had a significant ($p \leq 0.01$) effect on curl type, pattern score and hair texture (Table 8). In another study season of birth (summer vs winter) also had a significant effect ($p \leq 0.01$) on hair quality score (Schoeman & Albertyn, 1992). As feeding conditions follow a seasonal pattern, it obviously follows that fur traits should be affected by season. According to Viljoen *et al.*

Table 8 Probability values (p) of significance for fixed effects on fur traits (Greeff *et al.*, 1991b)

Trait	Fixed effects				
	Year	Age of dam	Sex	Month of birth	Type of birth
Curl type	0.00	0.64	0.00	0.00	0.88
Pattern score	0.00	0.45	0.02	0.01	0.91
Hair length	0.00	0.00	0.00	0.44	0.58
Hair quality score	0.00	0.68	0.18	0.09	0.62
Lustre	0.00	0.25	0.58	0.05	0.14
Texture (hair stiffness)	0.01	0.80	0.01	0.02	0.73
Hair thickness	0.00	0.70	0.00	0.05	0.13
Skin thickness	0.00	0.00	0.00	0.26	0.78

(1958) and Steyn (1972; 1974), most pelt traits are negatively affected by high feeding conditions. Generally, it is assumed that the better the feeding conditions, the heavier the lamb at birth and accordingly, the heavier and thicker the pelt with longer and thicker hair, more curl development and a deterioration in pattern and hair quality scores. Significant seasonal effects ($p \leq 0.01$) were also reported for most traits by Albertyn *et al.* (1993). Pattern scores were higher in winter-born lambs than those born in summer, while the reverse was evident in both hair quality and texture scores. Fibres were also thicker in winter and thinner in summer-born lambs. However, in most other studies no significant ($p > 0.05$) differences in pattern and hair quality scores between high and low levels of nutrition were recorded (Steyn & Barnard, 1972; Steyn, 1972; 1974; Gouws *et al.*, 1973). According to Gouws *et al.* (1973) an increase in curl development and hair length was mainly the result of a high protein level and not due to a high energy level. Le Roux & Van Wyk (1976) succeeded in improving some pelt traits and pelt price by artificially shortening the gestation period in pregnant ewes by approximately 7 days. Russian workers (Stefanescu & Tafta, 1971) found that the S:P follicle ratio in pelts increased from 1.44 at a low protein diet fed to pregnant ewes to 1.93 for ewes fed a high protein diet. Since pipe curl types have a wider S:P ratio than shallow curl types (Scheepers, 1959; Hugo, 1982), this may be the underlying reason for changes in curl development owing to changes in nutritional level.

Age of dam had a significant ($p = 0.00$) influence only on hair length and skin thickness (Table 8). In other studies curl type, pattern score, hair quality score and hair thickness were all significantly influenced by age of dam (Mostert, 1963; Le Roux & Van der Westhuizen, 1970; Van Niekerk, 1972; Schoeman & Albertyn, 1992; Albertyn *et al.*, 1993). Curl development increased with age of dam, whereas pattern and hair quality scores deteriorated with increasing age of dam. Using statistical methods handling discrete data, Albertyn *et al.* (1993) indicated that age of dam effects were more prominent in certain curl types than in others, which complicates adjustment for this effect.

Almost all traits were significantly affected by sex of lamb, except hair quality score and lustre (Table 8). In general, this is supported by results obtained by Nel (1966), Van Niekerk (1972), Schoeman & Albertyn (1992) and Albertyn *et al.* (1993), whereas Viljoen (1958) did not find any difference between ram and ewe lambs for skin thickness, hair thickness and hair length. Although only of theoretical importance, as one cannot choose the sex of the lamb to be born, these differences are still important especially for the adjustment of these traits for the estimation of genetic

parameters and prediction of breeding values.

The influence of type of birth was non-significant ($p > 0.13$) for all traits (Table 8). However, birth weight was included into the model as a covariable. Observed differences between single-born and twin-born lambs are therefore mainly due to differences in birth weight. One would expect twin-born lambs to have thinner skins, shorter hair and less curl development. In all other studies (Nel, 1966; Van Niekerk, 1972; Schoeman & Albertyn, 1992; Albertyn *et al.*, 1993) twin-born lambs were excluded from the analysis, because of the low percentage of only 2.1% of twin-born lambs reported for Karakul sheep (Schoeman & Albertyn, 1992).

General comments

The Karakul industry will in future be a small one. It will not easily recover to its previous status. Dramatic changes in fashion, and other factors, which took place during approximately one decade, rendered this exciting industry to an almost negligible one. All efforts should thus be placed on the production of outstanding quality pelts, making it an exclusive industry. These efforts should include foregoing research and the possible exploitation of exclusive markets.

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