The stability of genetic markers as identified in goats

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The first part of the investigation included a study of the frequency of blood factors in different goat breeds from Europe and South Africa using sheep blood typing reagents detecting related red cell antigens in the goat. It appeared that the European breeds — mainly the breeds from Switzerland — differed from the Angora and Boer goats from South Africa. The next part of the investigation summarized typing of the most important goat breeds in South Africa — Angora, Boer and native goats — with locally produced goat blood typing reagents. Furthermore, other genetic markers were used and haemoglobins, albumins and transferrins were useful in the establishment of breed differences, whilst no polymorphisms could be found in the 6-PGD, PGI, PGM, acid phosphatase and carbonic anhydrase. The selection of Boer goats from the native goats did not lead to measurable differences in gene frequencies of the known genetic markers. It became clear that polymorphism like blood groups and enzyme types are less responsive to artificial selection. Preliminary breeding experiments indicate that presumably one major gene changed the exterior of the multiple-coloured native goats to the typical white bodied red headed Boer goat pattern.

In die eerste deel van die ondersoek is die bloedfaktor-frekwensie van verskillende Europese bokrasse met die bokrasse van Suid-Afrika vergelyk deur gebruik te maak van skaapbloedgroep-reagente wat rooisel-antigene by bokke identifiseer. Dit het geblyk dat Europese rasse — hoofsaaklik die van Switserland — duidelik verskil van Angora- en Boerbokke van Suid-Afrika. In die tweede deel is die belangrikste bokrasse — Boerbokke, Angorabokke en inheemse bokke — vergelyk op die basis van bokbloedgroep-reagente wat plaaslik geproduseer is. Verder is ander genetiese merkers gebruik en hemoglobiene, albumiene en transferriene is aangewend tydens die bepaling van rasverskille, maar geen polimorfisme kon gevind word in die 6-PGD, PGI, PGM, suurfosfatase en karboniese anhidrase nie. Die seleksie van Boerbokke uit die inheemse bokke het nie gelei tot enige groter verskil in geenfrekwensies in die bekende genetiese merkers nie. Dit was duidelik dat polimorfismes soos bloedgroepe en ensiemtipes minder reageer op kunsmatige seleksie. Voorlopige teelproewe dui daarop dat een hoofgeen waarskynlik verantwoordelik is vir die eksterieur-verandering van die bontgekleurde inheemse bok na die tipiese witliggaam-rooikop Boerbokpatroon.

Keywords: Goat, genetic markers, blood groups, polymorphic proteins, breeding

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Introduction

The Boer goat was derived principally from Hottentot stock which inhabited the semi-arid country north of the Cape Peninsula. The name Boer goat probably came into being to distinguish the type from Angora goats imported during the 19th century.

Commencing in the early 1920s, much effort has gone into improvement through selective breeding for meat production, and there is a preferred colour pattern of brown head and neck, with white body and legs and pigmented skin on exposed parts as a protection against sunburn. The horns are prominent, and the ears broad and drooping. The hair covering is short to medium, and the body has good meat conformation. Mature improved Boer goat females weigh 50 – 65 kg in good condition, males reach up to 80 kg. Boer goats have a high reproductive rate (7% triplets, 50% twins), yield a good milk supply (1,3 – 1,8 kg per day), and also produce a useful skin.

All these characteristics were selected for in a large South African flock of native goats. The mentioned results show what can be achieved when proper selection and management are applied. The native goats seldom reach a mass of 50 kg and they appear in all colours. The present study was aimed at the elucidation of genetic markers which could possibly be linked to the improvement of production traits in the Boer goats. Since both populations exist next to each other a direct comparison was possible.

Materials and Methods

Different numbers of blood samples from different breeds were collected at different times of the investigation. In the preliminary investigation performed by Schmid, Odermatt & Kunz (1975), 105 samples from the Swiss Appenzeller, 134 from the Toggenburger, 122 from the Walliser Black-Neck, 118 from the Japanese Saanen, 118 from the German 'Edelziege', 133 from the South African Angora and 150 from the Boer goat were collected and tested with 45 iso-immune sera from

sheep, seven immune sera from goats and the anti-J-cattle serum. In later studies in the South African laboratory 147 Angora blood samples, 154 Saanen, 213 Boer goat and 188 blood samples from native goats were included in blood typing tests with goat blood typing reagents produced locally. The classification of blood group systems was performed according to Schmid & Suzuki, 1971. Varying numbers of blood samples were included in a search for other genetic markers, i.e. haemoglobins, transferrins, albumins, acid phosphatase, phosphoglucomutase in erythrocytes and leucocytes, 6-phosphogluconate dehydrogenase, carbonic anhydrase and the 'X' protein. The blood samples were collected at different experimental farms, private farms or from smallholders in the homelands. The degree of relationship between animals appeared to be low in the Boer goat and native goat population, but no family studies could be performed in any of the four breeds investigated.

Starch gel techniques and staining for the different proteins and enzymes were carried out as described previously (Tucker, Suzuki & Stormont, 1967; Tucker & Young, 1976; Schoeman, 1977; Tucker & Clarke, 1980).

Results

The frequencies of comparable goat blood factors in the A, C, D, M, R-O, V-W sheep blood group systems are listed in Table 1 together with three new systems (Hel, PV and Con-A) for seven breeds. The three new systems could be detected with the protectin anti-A_{HP} from the protein gland of *Helix pomatia* and the lectins (phytohemagglutinins) PV or *Phaseolus vulgaris* and Con-A from *Canavalia ensiformis*.

Table 2 depicts the frequency of the comparable goat factors in the B sheep blood group.

The factor frequencies of the Swiss and German breeds were published earlier (Schmid, *et al.*, 1975) and are given again for direct comparison. Japanese data were included for the same reason (Schmid & Suzuki, 1971). Interesting differences in the factor frequencies of all seven breeds, could be depicted. The most interesting fact, however, is that sheep anti-sera could be used to differentiate between goat breeds. It implies that sheep and goats possess cross-reacting blood group antigens. Besides these common antigens, the sheep possess several species-specific antigens and the goats likewise. Schmid, *et al.*, 1975 have discussed the possible relationship between the different Swiss goat breeds but it is interesting to see that breeds distantly related to the Swiss and German breeds, like the Angora and Boer goats, in some cases have similar factor frequencies (I_2, I_{x1}, Y_x, N, T', M_x and V) and differ markedly in others. The differences between the Angora and Boer goats were expected since these two breeds have entirely different backgrounds.

Table 1 The frequency of blood factors in different goat breeds (arranged according to sheep blood group systems)

	Breed*						
Blood group system	Appenzeller (105)	Japanese Saanen (118)	German 'Edelziege' (118)	Toggenburger (134)	Walliser Black-Neck (122)	Angora (133)	Boer goat (150)
A system							
Aa	0,62	0,92	0,54	0,57	0,80	0,55	0,31
A_4	0,78	0,74	0,36	0,37	0,74	0,55	0,53
A'	0,66	0,28	0,10	0,32	0,42	0,35	0,22
C system							
Cx	0,03	0,23	0,00	0,01	0,00	0,32	0,00
D system							
D	0,00	0,00	0,00	0,00	0,00	0,00	0,00
M system							
Ma	1,00	0,89	0,98	0,83	0,91	1,00	0,49
Mc	1,00	0,66	0,97	0,84	0,91	0,98	0,99
Mx	1,00	0,92	0,97	1,00	0,91	–	1,00
R-O-system							
R	0,00	0,25	0,01	0,00	0,00	0,04	0,00
O	0,07	–	–	0,66	0,58	0,91	0,94
V-W-system							
V	0,00	0,02	0,01	0,00	0,00	0,00	0,00
Con-A	0,24	–	–	0,07	0,16	0,26	0,19
Hel	0,98	–	–	0,17	0,81	0,93	0,77
PV	0,48	–	–	0,26	0,18	0,09	0,51

* Numbers given in parentheses

Table 2 The frequency of blood factors in different goat breeds (arranged according to the sheep B blood group system)

Blood group system	Breed* Appenzeller (105)	Japanese Saanen (118)	German 'Edelziege' (118)	Toggenburger (134)	Walliser Black-Neck (122)	Angora (133)	Boer goat (150)
B system							
Bb	0,27	0,05	0,09	0,00	0,75	0,45	0,45
I_1	0,71	0,50	0,37	0,15	0,84	0,41	0,00
I_2	0,90	0,90	0,86	0,71	0,84	0,82	0,85
I_{x1}	1,00	0,79	1,00	0,85	0,91	1,00	0,99
Y_1	0,07	0,04	0,00	0,00	0,01	0,00	0,01
Y_2	0,90	0,24	0,26	0,14	0,69	0,80	0,37
Y_3	0,98	0,32	0,30	0,52	0,84	0,90	0,50
Y_x	1,00	0,95	0,97	1,00	0,91	1,00	0,99
N	0,97	0,92	0,92	0,73	1,00	0,90	0,96
I_1'	0,01	0,01	0,26	0,00	0,25	0,00	–
I_2'	0,40	0,85	0,47	0,40	0,64	0,00	0,01
O_1'	–	0,72	0,08	–	–	0,99	0,99
O_x'	0,47	–	–	0,41	0,56	–	0,55
T'	1,00	0,84	0,98	0,96	0,91	1,00	1,00

* Numbers given in parentheses

The next step in the investigation included blood typing tests with iso-immune reagents produced in goats. In Table 3 the frequencies of blood factors in South African goat breeds are depicted.

Several of the blood factors, e.g. G9, G11 and G12, had a very high frequency in all breeds whilst others showed a very low frequency. The most interesting aspect, which could point to the selective advantages of Boer goats out of local goats, was the investigation of blood factor frequency differences between these two breeds. Differences were there, but only to stimulate further investigations into other genetic marker differences. Most genetic markers are cryptic markers and are as such not involved in any direct selection procedures of the animals. They could be very useful if any genetic change in the animal's conformation or production could be linked to gene-polymorphic characters.

A series of genetic markers were involved in the comparison of local goats and the Boer goats selected out of the gene pool of the former.

In Table 4 the distribution of haemoglobin types is given, the table combines results of two different investigations (Schoeman, 1977 and Tucker, Clarke, Osterhoff & Groenewald, 1983).

The Boer and the Angora goats possessed only the faster migrating A band except for one Boer goat animal being heterozygous. In the native goat group 32 animals possessed the B band, whilst the Saanen had the lowest frequency of Hb^A.

Table 3 The frequency of blood group factors in SA goat breeds

Blood group factor	Breed* Angora (147)	Saanen (154)	Boer goat (213)	Native goat (188)
G 9	0,68	0,95	0,97	0,80
G10	0,02	0,04	0,08	0,05
G11	0,63	0,95	0,91	0,76
G12	0,83	0,96	0,94	0,62
G13	0,79	0,84	0,73	0,64
G15	0,43	0,79	0,93	0,44
G16	0,10	0,18	0,85	0,18
G17	0,88	0,72	0,80	0,53
G18	0,05	0,21	0,15	0,10
G19	0,76	0,96	0,86	0,40
G20	0,51	0,59	0,68	0,18
G22	0,23	0,41	0,40	0,19
G23	0,85	0,82	0,87	0,51

* Numbers given in parentheses

Table 4 Distribution of haemoglobin types in SA goat breeds

Breed	No investigated	Phenotypes AA	AB	BB	Gene frequency Hb^A	Hb^B
Boer	268	267	1	0	0,998	0,002
Native	387	355	29	3	0,950	0,050
Saanen	164	91	61	12	0,740	0,260
Angora	157	157	0	0	1,000	0,000

In the albumin types almost no variation could be observed. The Al^A allele was only found in six of the Angora goats (Table 5).

Of the four alleles reported in the transferrin of goats only two, Tf^A and Tf^B, were observed in the samples investigated. The frequency of the transferrin phenotypes is given in Table 6.

The differences between the Boer and native goats seem to be great in the Tf system, but are not significant ($X^2 = 1{,}109$ n.s.). That the Boer goats are closer to the Saanen seems to be incidental and cannot be explained. In the enzyme systems phosphohexose-isomerase, 6-phosphogluconate dehydrogenase, phosphoglucomutase, acid phosphatase and carbonic anhydrase no polymorphism was observed. In the carbonic anhydrase system only one band migrating the same distance as the CAS allele of sheep was found in all the samples examined. This was also confirmed by Tucker, *et al.* (1983).

The phenotypic patterns observed in the other four systems are given in Table 7.

Tucker, *et al.* (1983) also investigated the 'X' protein, which apparently has esterase activity. The phenotypes appear as either being 'X' positive or 'X' negative. The positive phenotype was predominant in the four goat populations tested, the lowest frequency being found in the Angora goat breed. The percentage positive-'X' types were 73 in local goats, 100 in Boer and Saanen and 57 in Angora goats.

Angora goats were also the ones being different in PGM_3-polymorphic studies in leucocytes (Pretorius, Schmid, Osterhoff & Albert, 1976). Boer goats presented no polymorphism, while the PGM_3-F allele had a frequency of 0,62 in Angora goats.

Table 5 Distribution of albumin types in SA goat breeds

Breed	No investigated	Phenotypes AA	AB	VV	Gene frequency Al^A	Al^B
Boer	241	0	0	241	0,00	1,00
Native	219	0	0	219	0,00	1,00
Saanen	150	0	0	150	0,00	1,00
Angora	150	0	6	144	0,02	0,98

Table 6 Distribution of transferrin types in SA goat breeds

Breed	No investigated	Phenotypes AA	AB	BB	Gene frequency Tf^A	Tf^B
Boer	216	67	115	34	0,58	0,42
Native	217	136	69	12	0,79	0,21
Saanen	150	53	76	21	0,61	0,39
Angora	150	93	52	5	0,79	0,21

Table 7 Phenotypic patterns of enzymes in SA goat breeds

Breed	No investigated	Patterns in starch gels
Boer	241	Acid phosphatase: two spots — intensity
Native	219	of the spots differed slightly in some
Saanen	169	samples
Angora	150	PGM: Two bands
		6-PGD: one band
		PHI: one band

Discussion

The selection of Boer goats from the native goats did not lead to major differences in gene frequencies of most of the genetic markers investigated. Therefore, it was decided to start a breeding experiment with female native goats, mating them to a Boer goat ram. Eight females presenting mainly black or dark red colour were served and all produced lambs with the exact Boer goat pattern: brown head and neck, white body with white legs, ears broad and drooping. The average mass of the lambs was 3,5 kg and they grew as fast as pure-bred Boer goat lambs. At 4,5 months they were weaned and had an average mass of 18,5 kg, again no difference to pure-bred Boer goat lambs. Five backcross matings were performed mating the F1 to a native goat ram — three lambs had the Boer goat and two the native goat markings. Four matings of the F1 crosses with a Boer goat ram resulted in F2 lambs indistinguishable from pure-bred Boer goat lambs.

The conclusion drawn from these preliminary experiments was the postulation of a major gene being responsible for the typical body colouring of the Boer goat and possibly associated with fast growth and development. The investigated genetic markers appear to be stable, although the Boer goat was selected for production from the native goat type.

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