BLOOD GROUPS AND BIOCHEMICAL POLYMORPHISM IN THE MALABARI BREED OF GOAT AND ITS EXOTIC CROSSES

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "BLOOD GROUPS AND BIOCHEMICAL POLYMORPHISM IN THE MALABARI BREED OF GOAT AND ITS EXOTIC CROSSES" is a bonafide record of research work done by me during the course of research work and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or other similar title, of any other University or Society.

Mannuthy,
28-4-1989.

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CERTIFICATE

Certified that this thesis entitled "BLOOD GROUPS AND BIOCHEMICAL POLYMORPHISM IN THE MALABARI BREED OF GOAT AND ITS EXOTIC CROSSES" is a record of research work done independently by Sri.B. Nandakumaran under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to him.

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Dedicated to

my beloved parents

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Introduction

INTRODUCTION

An epoch making discovery was made by Karl Landsteiner at the beginning of this century on the serological differences in the red blood cells of man. Differences between the blood of animals from the same species were also demonstrated in the same year by Ehrlich and Morgenroth in the red blood cells of goats using immune sera. The succeeding decades witnessed an ever increasing interest in this field. Systematic work on animal blood groups was initiated first by Prof. M.R. Irwin and his co-workers at the University of Wisconsin in the United States of America which was followed by the establishment of large number of laboratories all over the world to carry out intensive research in this area. The methodology of sera production was then standardized. Knowledge on the inheritance pattern of the blood group factors in several species of animals gradually accumulated and this gave rise to a new branch of genetics called Immunogenetics which encompasses the areas of overlap and interaction between the science of Immunology and Genetics.

In the 1950s, the upsurge of biochemical methods such as Smithies starch gel electrophoresis led to the identification of numerous genetically controlled biochemical variants known as Biochemical polymorphism.

The studies based on immunogenetics and biochemical polymorphism generated their usefulness in solving certain problems connected with animal breeding. Attempts were made to establish pleiotropic or linkage relationship of biochemical variants or serum types with production, reproduction and resistance to diseases. Practical application in animal breeding included accurate parentage determination, diagnosis of monozygosity and freemartinism and identification of breed structure of an animal population. The intensity of heterozygosity or homozygosity of a population is often measured using biochemical polymorphism.

Realising the importance of blood groups and biochemical polymorphism in solving the disputed parentage cases and verification of pedigree records, it was insisted by several breed association and those engaged in livestock enterprises in many developed countries that the record of blood type of each animal should be maintained in the commercial or experimental breeding farms.

At present the information available on the blood groups and biochemical polymorphism of goats (Capra hircus) is meagre, though goats play an important role in almost all farming systems of the tropics and subtropics. The small body size, high reproductive performance and efficient adaptibility make it possible for goats to be reared in extreme environmental conditions. Goat is a multi-purpose animal which provides milk, meat and skin. For the vast majority of small farmers who own these animals meat production is an important source of income and a means of alleviating rural poverty. The demand for goat meat is associated with factors such as the preference for a relatively high lean meat content and the absence of religious taboos. In absolute figures, goats make a tiny contribution to world milk production but they guarantee man's survival in adverse environmental conditions.

It was estimated that 27.4 per cent of the world population of goats are in the Indian sub continent. The popularity of goats in India can be seen from the growth of its population, observed in five yearly quinquennial census from 1957 to 1982. India had 4.72 crores of goats in 1951 and its number increased to 9.67 crores in 1982.

The percentage of increase (104.8) was formidable compared to other livestock species inspite of a 43 per cent annual removal rate mainly in the north western arid and semi arid regions and the fact that there is no massive programme launched by the Government. In Kerala State too the picture exhibits more or less a similar situation as the national trend. In 1982 goat population in Kerala was around 20 lakhs.

The only recognised breed of goat native to Kerala is the Malabari (also called Tellichery). Malabari breed type was developed in Old Malabar of erstwhile Madras state now in North Kerala. It is believed that centuries ago, Arab merchants who came to this area for trade brought with them Mesopotamian goats which are crossed to local and Kutch strains in large numbers along the sea coast. The more important, it is also believed that Jamnapari, Surti and Sindhi breeds were also introduced in the area. Thus the Malabari goat is considered as a mixture of two or more types with preponderance of Surti blood and owes its origin to Arabian and Mesopotamian goats.

In order to raise goats under stallfed conditions and to increase the milk production through scientific method of breeding, feeding and management, Indian Council

of Agricultural Research has launched during IVth five year plan, a fairly large programme of research called All India Co-ordinated Project on Goats for Milk initially at two centres, Karnal in Haryana state and Mannuthy in Kerala State. In the All India Co-ordinated Research Project on goats for milk at Mannuthy, the Malabari goats were crossed with Saanen and Alpine breeds with an objective of evolving a milch breed adapted to Kerala.

Polymorphic nature of certain biochemical traits like red cell electrolytes, haemoglobin and certain red cell enzymes has been established and some are found to be related to economic traits in different species of livestock. Erythrocyte glutathione (GSH), a tripeptide of glycine, cystine and glutamic acid is another biochemical trait, reported to be polymorphic.

Realising the importance of goats in our country in general and particularly in the State of Kerala, and the usefulness of blood groups and biochemical polymorphism in animal breeding the present study in the Malabari goats and their exotic crossbreds was undertaken with the following objectives:

a) to identify the blood group antigens in the red blood cells,

b) to investigate the polymorphism of haemoglobin, blood potassium and erythrocyte glutathione (GSH),

c) to study the pattern of inheritance of different genetically controlled variants,

d) to find out correlation if any, between haemoglobin variants and blood potassium and GSH and

e) to determine the association, if any, between blood group system, polymorphic system and traits of economic importance.

Review of Literature

REVIEW OF LITERATURE

Blood groups

Ehrlich and Morgenroth (1900) first demonstrated the immunological differences in the blood cells of goats using immune isoantibodies.

Kinsen (1950) reported three new blood groups Z_1, Z_2 and Z_1Z_2 in goats. The relative frequency of these groups in the material studied was 12.0, 60.0 and 28.0 per cent respectively. Matings between Z_1 parents gave only Z_1 offspring and mating between Z_2 parents gave only Z_2 offspring. Mating between Z_2 and Z_1 gave Z_1Z_2 offsprings. In matings between Z_1Z_2 goats, between Z_1 and Z_1Z_2 goats and between Z_2 and Z_1Z_2 goats, the ratios obtained were 25 Z_1: 25 Z_2: 50 Z_1Z_2; 50Z_1:50 Z_1Z_2 and 50 Z_2: 50 Z_1Z_2 respectively.

Suzuki *et al.*(1956) demonstrated two agglutinogens G_1 and G_2 and two haemolysinogens Y_1 and Y_2 on the erythrocytes of goats employing anti A and anti B human blood typing reagents. Of the 281 goats, 78.65 per cent goats had type G_1 blood and 21.35 per cent had type G_2 blood.

Watanabe et al.(1965) identified four erythrocyte antigens ch_1, ch_2, ch_3 and ch_4 using isoimmune sera. These four antigens were different from G_1 and G_2 reported earlier. The frequency distribution of the four newly designated antigens were 18.8, 67.5, 29.8 and 72.0 per cent respectively amongst 372 Saanen goats and 7.3, 29.9, 30.6 and 22.9 per cent amongst 301 native and crossbred goats. The blood types of highest frequency were ch_2 (22.9 per cent) and ch_4 (22.0 per cent). No goat was of types ch_1 and ch_3 or ch_1/ch_3.

Suzuki et al. (1967) distinguished sixteen types of blood classified on the basis of different antigenic factors.

Preparing the reagents from isoimmune haemolysins Suzuki and Watanabe (1968) classified the blood groups in goats. Different patterns were observed among the reactions of isoimmune antisera for blood cells of individual goats. Absorption tests were performed on the antisera to isolate the specific antibodies. Four haemolytic reagents, ch_1, ch_2, ch_3 and ch_4 differing from anti G_1 and anti G_2 were produced. Four cellular antigenic factors corresponding to these reagents were controlled by dominant genes.

Goats have a J-O system analogous as the R-O blood group system in sheep, identified by naturally occurring antibodies. Cross reaction occur between the antigens and antibodies of these systems (Tucker et al., 1971).

Osterhoff and Wardcox (1972) could not detect any naturally occurring antibodies in three South African goat breeds. Initial immunisations were carried out using Angora donors and Dorset sheep recipients at randon. They could produce eight types of antibodies, viz. G_1, G_2, G_3, G_4, G_5, G_6, G_7 and G_8 from twelve donor-recipient pairs, all eight being haemolysins. Three more monospecific reagents were produced using goat donors against goat recipients. Using the first eight reagents, a preliminary survey was carried out on 62 Angora, 89 Indigenous and 109 Boer goats. Several fatalities were reported when goat recipients were used. Of the first eight reagents used two, viz, G_3 and G_4 did not react with any sheep cells and appeared to be goat specific.

Odermatt (1973) typed blood of 134 Toggenburg and 127 Grison striped goats and reported 27 phenogroups in the B system. The J blood group system of goat was found to be similar to J system of cattle. The accuracy of percentage determination using blood group was estimated to be 75.79 per cent in Toggenburg and 72.31 per cent in the Grison striped goats.

.e - VI Cross section of the shoot apex of SM-97
--- medium lignification in the hypodermal
cells and semi-compact vascular bundles (x160)

Nguyen et al. (1975) reported similarity between blood immunogenetic substances of sheep and goat. They indicated the possibility of utilising sheep blood typing reagents, for typing blood of goats.

The blood groups were investigated in 105 Appenzell, 127 Grison striped, 134 Toggenburg, 118 Verzasca and 122 Valais Black neck goats (Schmid et al., 1975). All the populations were in genetic equilibrium. Some significant differences in gene frequencies of certain factors were found between breeds. Factor B, I_x, N, M_1, M_x, M' and T' occurred very frequently in all breeds ie, with gene frequency of < 0.60. However the factors D, R, V, C_x, M^+, Y', M_{u-10} and M_{u-29} either did not occur at all or with gene frequency of < 0.10.

Nguyen and Bunch (1980) tested blood samples from 260 domestic goats with 31 sheep blood typing reagents. The goats had blood group antigens related to those of the B, C, M, R and F_{30} system of sheep.

Tucker and Clarke (1980) reported that J blood group substance of goat was analogous to the R blood group substance of sheep and goat 0 to sheep 0. The rare non-R, non-0 blood type, i was also observed in both species.

Using two isoimmune antisera and the double diffusion technique Caparelli et al. (1985) identified six serum protein allotypes in a sample of 186 goats belonging to Maltese, Saanen, Gargano and Potenza breeds. Allotype 1 was monomorphic in Maltese and Gargano and polymorphic in Saanen and Potenza. Allotype 2 was polymorphic in all breeds. Allotype 3 was monomorphic in all samples tested. Allotype 4 was absent in Maltese and Saanen while allotype 5 was absent in Maltese and Gargano and allotype 6 was absent in Gargano. Breeding experiments indicated that allotypes 1, 2, 4, 5 and 6 were dominant to their absence and it was concluded that the allotypes were controlled by Mendelian genes at different loci.

Marti Rothen (1985) performed alloimmunisation in 22 goats of three different breeds after typing the goats with sheep antisera and produced 22 different monospecific antisera. Genetic studies conducted with sire-dam-progeny sample indicated that the blood factors in goats were also expressed co-dominantly. The specificity of the reagents was classified into 13 groups; six groups had single specificity, five groups had two specificities and two groups had three specificities When 1,005 goats were typed, the observations made were: (a) significant

differences in gene frequencies between breeds (b) detection of super fecundity in two cases and (c) 16 of the 22 specificities were found in wild goats.

Haemoglobin

Haemoglobin, the pigment of red blood cells, is a complex iron containing conjugated protein compounds of a pigment and a simple protein, globin, a histone. The red color of haemoglobin is due to heme, a multiple compound containing an iron atom. The molecular weight of haemoglobin in most species varies from 66,000 - 69,000. Haemoglobin is present in the blood of all mammals and of many animals of far below mammals. Each haemoglobin molecule consists of four polypeptide chains normally occurring in two pairs of identical chains.

Pauling et al.(1949) studied haemoglobin in man by means of paper electrophoresis and found a fraction called HbS the haemoglobin responsible for sickle cell anaemia which was different from normal haemoglobin, HbA. This study gave further scope of electrophoretic studies of haemoglobin in other species.

Cabannes and Serain (1955) observed polymorphism in haemoglobin locus in Algerian breed of goats and reported three haemoglobin types.

Two adult haemoglobin phenotypes and a foetal haemoglobin in goats were described by Harris and Warren (1955).

Khanolker et al. (1963) reported the existence of three haemoglobin phenotypes viz. HbAA, HbBB and HBAB in a study on 100 Indian goats. The gene frequencies of Hb^A and Hb^B in goats studied were 0.925 and 0.075 respectively. It was also reported that the haemoglobin alleles Hb^A and Hb^B inherited as co-dominant alleles.

Some preliminary investigations to establish different haemoglobin types in two West German breeds, viz. Braune deutsche Edelziege and Weisse deutsche Edelziege were carried out by Bernhardt (1964). He reported the existence of three phenotypes viz. HbAA, HbAB and HbBB. The gene frequency of Hb^A in the Breune and Weiss was 0.927 and 0.980 respectively.

Efremov and Braend (1964) studied the haemoglobin polymorphism in the Native Norwegian goats with starch gel electrophoresis, but could not observe any polymorphism at the haemoglobin locus. All the goats had only one type of haemoglobin which was indistinguishable from HbBB of sheep.

Watanabe et al. (1965) demonstrated haemoglobin polymorphism in Japanese Saanen, Takara and Takara crossbreds, German colored, Italian Alpine and Hungarian Saanen goats. The frequency of Hb^A in the above breeds respectively were 0.915, 0.966, 0.979, 0.882, 0.404 and 0.462. They could not find polymorphism in Saanen goats from Switzerland, which were all of HbAA type.

Boyer (1967) observed that in anemic sheep and goats, Hb^C replaced the normal allele of Hb^A. He also observed that HbC differed from HbA and HbB in the beta chain only and that the beta chain was the product of a distinctive gene.

Based on the electrophoretic mobility Braide and Enyenihi (1969) reported three haemoglobin phenotypes in three Nigerian goat breeds viz. West African Dward, Mambilla and Kano Brown. These types included the haemoglobin with relatively fast migration towards anode, another with relatively slower migration and a third type with intermediate electrophoretic mobility.

Garrick and Charlton (1969) detected four haemoglobin types in Algerian goats by means of zonal electrophoresis. Breeding data suggested that type I and II were the two homozygotes at a structural locus for which type III was a heterozygote and type IV a variant at another locus. It

was also shown by starch gel analysis that type II and III were alpha chain variants and type IV a beta chain variant.

Five different haemoglobin types (HbA, HbB, HbD, HbD Malta and HbE) were detected in adult goats by electrophoretic and chromatographic techniques (Huisman, 1970).

Ricordeau and Grosclaude (1970) observed haemoglobin polymorphism in French Alpine, French Saanen and French Poitevine goat breeds and reported high frequency of Hb^A allele in all the three breeds viz. 0.97, 0.99 and 0.94 respectively.

Three haemoglobin phenotypes HbAA, HbAB and HbBB controlled by two co-dominant alleles Hb^A and Hb^B were reported in three South African goat breeds viz. Boer goat, Indigenous, and Angora (Osterhoff and Ward-Cox,1972). The gene frequency of Hb^A was 0.91, 0.95, 0.93 and 0.94 in Boer goat, Indigenous and Angora (Aborters) and Angora (Non aborters) respectively. The differences in gene frequency were not significant.

Tjankov (1972) studied the haemoglobin polymorphism in 241 goats consisting of 19 Toggenburg, 24 Bulgarian

native goats, 101 goats from the F_1 generation and 97 goats from the F_2 generation of crosses involving Toggenburg male goats and aboriginal goats. The haemoglobin was fixed by using tris-borate buffer, pH 9.2 on the starch gel. The author could not detect any polymorphism at haemoglobin locus.

Odermatt (1973) reported two haemoglobin alleles Hb^A and Hb^B in Toggenburg goats with the frequency of Hb^A being 0.951. But he could not observe polymorphism in Grisons striped goats. All the Grisons striped goats typed were of HbAA phenotype.

Electrophoretic analysis of 414 blood samples from Adult Nigerian Red Sokoto, Kano Brown and Sahel (West African long-legged) goats were carried out by Enyenihi (1974). Three electrophoretically distinct haemoglobin types were found in Red Sokoto and Kanon Brown goats, whereas blood samples from Sahel goats revealed four electrophoretically distinct haemoglobin types. Three bands were identical with those of the first two goat breeds. (Hb-N, Hb-S and Hb-F). The fourth type (Hb-S') was extremely slow in migration towards the anode.

Galzon et al. (1976) demonstrated haemoglobin polymorphism in 30 Granada goats by using electrophoresis. The gene frequencies of Hb^A and Hb^B were 0.88 and 0.12

Kunz (1974) studied haemoglobin polymorphism in three goat breeds of Switzerland viz. 105 Appenzell, 118 Verzasca and 122 Valais Black neck. Except few Appenzell goats (HbAB) all the animals had only HbAA type. The frequencies of Hb^A and Hb^B alleles in Appenzell goats were 0.981 and 0.019 respectively.

Schmid and Kunz (1974) described that foetal haemoglobin Hb-F could persist in kids upto the age of 34 days. The change over from foetal Hb to adult Hb took place gradually and in individual kids it occurred at different times.

Joshi et al. (1975) studied haemoglobin polymorphism of 76 Barbari and 70 Jamnapari goats employing horizontal paper electrophoresis and reported three haemoglobin phenotypes HbAA, HbAB and HbBB with 89.5, 2.6 and 7.9 per cent respectively in Barbari goats and 90.0, 1.4 and 8.6 per cent in Jamnapari goats.

Naik (1975) investigated haemoglobin polymorphism in 166 Indian goats. He could observe only two haemoglobin variants which were determined by co-dominant alleles.

Garzon et al. (1976)demonstrated haemoglobin polymorphism in 30 Granada goats by using electrophoresis. The gene frequencies of Hb^A and Hb^B were 0.88 and 0.12 respectively.

Employing starch gel electrophoresis, Goel and Nair (1976) reported haemoglobin variants in 224 goats belonging to Alpine, Beetal, Alpine x Beetal and Anglo-Nubian breeds. The gene frequency of Hb^A in these four breeds were 0.88, 0.92, 0.94 and 0.92 respectively.

Antova and Mkrtchyan (1977) investigated 567 Russian Altain mountain goats for haemoglobin polymorphism. Apart from the usual alleles Hb^A and Hb^B, a new allele Hb^H, at a frequency of 0.0044 was also reported. The frequency of Hb^A was 0.82.

Employing starch gel electrophoresis Singh et al. (1977) tested 275 non-descript, 38 Barbari, 16 Beetal and 63 Barbari-Beetal crossbred goats for haemoglobin polymorphism. Two haemoglobin phenotypes HbAA and HbAB were observed in non-descript goats. 93.82 percentage of goats typed belonged to HbAA type and 6.18 percentage belonged to HbAB type. All the goats of Barbari, Beetal and Barbari-Beetal crosses were of HbAA phenotype. The faster haemoglobin variant was designated as Hb^A and the slower Hb^B.

Bannister et al. (1979) typed 327 inbred goats of Malta breed. The frequency of Hb^D was found to be 0.255 compared with an expected value of 0.065. Analysis of haemoglobin from goats homozygous for type D revealed that

these animals also carried 1 to 5 per cent type C, which was controlled by Hb^C, a gene not allelic to Hb^A and Hb^D.

Mostaghni (1979) investigated haemoglobin types of 208 Iranian goats employing electrophoresis on cellulose acetate. Three haemoglobin types (A, B and C) were separated electrophoretically. They could observe only four phenotypes B, AB, BC and ABC. Haemoglobin B type predominated (61.5 per cent) and had the gene frequency of 0.577. The percentage of goats with phenotypes AB, BC and ABC were 9.6, 23.0 and 5.7 respectively. The gene frequencies of Hb^A and Hb^C were 0.194 and 0.229. It was indicated that the presence of HbC may be due to the occurrence of an earlier anaemia in the goats studied, with a partial or complete switch from haemoglobin AB.

Native Japanese (37), Ogasawara (25), Yakushima (5), Philippine (80), Thailand (122) and Pakistan (3) goats did not show any polymorphism at haemoglobin locus. All the goats belonged to HbAA type (Watanabe et al., 1979). In two populations of Jaapanese Saanen (79 and 21 goats) all were HbAA type except 2 and 3 goats respectively which were of HbAB type. The frequency of Hb^B gene was 0.013 and 0.074 for the two populations respectively. It was suggested that the Hb types were controlled by a pair of co-dominant alleles, Hb^A and Hb^B.

Employing horizontal starch gel electrophoresis Baruah and Bhat (1980) typed 230 goats of Jamnapari, Black Bengal and Barbari breeds. Two haemoglobin phenotypes HbAA and HbAB were observed in Barbari goats. The frequencies of Hb^A and Hb^B genes were respectively 0.97 and 0.03. They could not observe haemoglobin variants in Jamnapari and Beetal goats. All the animals were of HbAA type.

Tucker and Clarke (1980) reported that goat haemoglobin (HbA, B, D and E) were heterogenous because they have multiple α and β structural genes. They could observe four phenotypes HbAA, HbAD, HbAB and HbBB in 20 Saanen goats. HbE had an almost identical electrophoretic mobility to that of HbA.

Bhuvanendran et al. (1981) reported three haemoglobin variants (Hb^F, Hb^S and Hb^N) and five phenotypes viz. HbNN, HbNS, HbFS, HbN^F and HbSS in 104 Red Sokol goats of over one year age and 49 kids. The gene frequencies of Hb^F, Hb^N and Hb^S were found to be 0.077, 0.591 and 0.327 respectively.

Ricordeau (1981) observed two more variants for the haemoglobin system apart from the foetal Hb and anaemic Hb, type ^{A} being the fast and type B the slow fraction. High frequency of Hb^A was reported in breeds of European origin and in the South African Angora and Boer breeds.

Bhat et al. (1983) could not observe haemoglobin polymorphism in 89 Jamnapari goats. All the animals were of HbAA type. Two phenotypes HbAA and HbAB were reported in Barbari goats. The gene frequencies of Hb^A and Hb^B were 0.98 and 0.02 respectively.

High frequency of 0.954 was reported for the Hb^A allele in Hungarian native goats (Fesus et al., 1983). Among the offspring born from parents with known haemoglobin type, there were no significant differences between the expected and observed number of the individual haemoglobin types.

Kazanooskii et al. (1983) reported the presence of two alleles at haemoglobin locus in a study on Soviet Mohair goats.

Stavsio et al. (1983) investigated protein polymorphism in 990 Sardinian goats belonging to 22 farms. Three haemoglobin phenotypes were observed. The overall frequency of Hb^A was 0.76.

Tucker et al. (1983) investigated haemoglobin polymorphism employing isoelectric focusing in few British and South African goats. They could not observe haemoglobin variants in Angora and Saanen goats. All the animals of the above two breeds were of HbAA type. Hb^A had the

highest frequency in all the breeds studied. Anaemic goats of Hb^A, HbAB and HbBB all produced a HbC with an identical electrophoretic pattern.

Barbancho *et al*. (1984)could observe the two most common haemoglobin types (HbA and HbB) in four Spanish goat breeds, viz. Granadina, Murciana, Mulaguena and Serrana ^{A}. Three haemoglobin phenotypes HbAA, HbAB and HbBB were reported in all the four breeds studied except in Murciana, which showed only HbAA and HbAB. HbAA had highest frequency in all breeds followed by HbAB and HbBB.

In a study on 398 Saanen goats and their 568 kids, three phenotypes HbAA, HbAB and HbBB in adult goats and two other types representative of foetal Hb(AF and F) were found in young goats (Sartore *et al*., 1984). The method employed was starch gel electrophoresis. The gene frequencies in adults were in genetic equilibrium. Data from various mating types confirmed that Hb types were controlled by two co-dominant autosomal alleles Hb^A and Hb^B.

Rizzi *et al*. (1985) reported the polymorphic nature of haemoglobin in 95 chamois colored goats.

The haemoglobin loci of 592 Jamnapari and 30 Sirohi goats were studied by starch gel electrophoresis (Bhat, 1986). The author could observe HbAA with a high frequency of 0.99 and HbAB with a very low frequency of 0.006. The possible third phenotype HbBB was not observed in the goats studied. The gene frequencies of Hb^A and Hb^B were 0.99 and 0.01 respectively. All the Sirohi goats tested were of HbAA type.

Shamsuddin et al. (1986) reported the existence of HbAA and HbAB phenotypes in Malabari and its crossbreds with Saanen and Alpine goats. They could not observe HbBB phenotype. All the population were in genetic equilibrium. HbAA had highest frequency in all the populations. The gene frequency of Hb^A in Malabari, Saanen half breds and Alpine half breds respectively was 0.975, 0.979 and 0.967.

Bhat (1987) studied the haemoglobin polymorphism in Pashmina goats. The studies conducted on 206 Cheghu and 52 Changthangi goats revealed no polymorphism of haemoglobin. All the animals were of HbAA type.

Braend et al. (1987a) studied the expression of haemoglobin in 260 Norwegian dairy goats by Immobiline technique at pH ranges 6.7 - 7.7, 6.9 - 7.6 and 6.9 - 7.5. Majority of goats exhibited three or four band patterns. In two band

types the average ratio between the anodal and cathodal band was 74:26. Polyacrylamide gel electrophoresis with 8 M urea distinguished three phenotypes for the beta chains, providing that the Hb variation described was in the beta chain. Segregation data in 106 complete sire-dam-offspring families agreed with the existence of four β-globin alleles - A_2, A_4, A_6 and A_8. Twenty seven animals had reversed ratios (R) of Hb bands. In two band phenotypes the average ratio was 36:64. In 15 complete families where one of the parents had reversed ratio, eight offspring received the R type, indicating a simple genetic control. After urea polyacrylamide gel electrophoresis the R animals all showed the same alpha chain phenotype which differed from that of goats having common ratios of bands. An additional polymorphism was observed in nine animals as three-and five-band patterns which is assumed to be the result of heterozygosity for IIα and for II α and β globin genes respectively.

Braend et al. (1987b) studied the haemoglobin structure of 150 Norwegian dairy goats. In isoelectric focusing over pH range 6.0 - 8.0, 145 samples were of haemoglobin type A and five were of type AD. The haemoglobin A was resolved into further types by separation over pH 6.9 - 7.5 in immunobiline polyacrylamide gels. A two- or four-band pattern

was present in 136 of the samples. A genetic hypothesis based on four or more different haemoglobin A variants was proposed. Fourteen samples had a three-, five- or six band pattern. It was assumed that these are heterozygous for a variant of the II ∝ gene.

Erkoc et al. (1987) could observe the three common haemoglobin types HbAA, HbAB and HbBB in that order in angora goats of Turkey.

Potassium

The cell protoplasm is composed mainly of five basic substances - water, electrolytes, protein, lipids and carbohydrates. Potassium (K) is one of the most important electrolyte in the cell. Its functions include maintaining the acid base balance, regulating the osmotic pressure and developing cellular membrane potentials.

Evans and Phillipson (1957) reported potassium polymorphism in British Saanen, Anglo-Nubian and four Middle East breeds viz. Damascus, Maltese, Negev and Syrian mountain goats based on the potassium concentration in blood. Out of the seventy goats of British Saanen typed, sixty eight were of high and two were of low potassium types.

Out of the twelve Anglo-Nubian goats eleven were of high potassium type. But the low potassium type was predominant in all the Middle East Breeds.

Tucker and Ellory (1972) reported the existence of high potassium type (HK) and low potassium (LK) in goats. 227 goats belonged to the HK type with levels greater than 65 mM and 19 goats of LK type with less than 65 mM.

Joshi (1975) observed potassium polymorphism in Barbari goats and reported a higher frequency of HK type.

Mostaghni (1979) classified 208 Iranian goats into high potassium (87.5 per cent) and low potassium (12.5 per cent). The mean whole blood concentration of potassium in the high blood potassium group was 21.2±2.3 meq/l and in low potassium group the corresponding value was 8.9±1.4 meq/l.

Potassium polymorphism was reported in Shiba goats (Komatsu et al., 1980). The gene frequency of HK gene was 0.500. They could not observe any polymorphism in Saanen goats. All the Saanen goats were of high potassium type.

Tucker and Clarke (1980) reported that the association between M-L blood group system and potassium type has not been clearly defined in goats. They reported that the HK/LK polymorphism occurs in all the caprine studied.

Bhat et al.(1983) investigated the polymorphism of potassium and their relationship with haemoglobin and transferrin types. A total of 269 Jamnapari and Barbari goats were typed for potassium concentration. The mean whole blood potassium concentration was 18.5±0.45 meq/l with coefficient of variation of 32.8 per cent and 20.47±0.38 meq/l with a coefficient of variation of 17.5 per cent in Barbari and Jamnapari respectively. The mean potassium concentration obtained showed a normal distribution and no bimodality with respect to potassium type. A definite variation from low to high values existed.

Khan and Taneja (1983) typed 322 healthy adult male Marwari goats and could distinguish two potassium types viz. low (LK) and high (HK) types. Out of the 322 animals sampled 53 per cent were of HK type and 47 per cent were of LK type. The whole blood potassium concentration in the LK type goat varied from 9 to 19 meq/l and in the HK from 21 to 34 meq/l. Significant differences existed between LK and HK with respect to whole blood potassium concentration.

Bhat (1986) could not observe potassium variation in Jamnapari goats. All the animals were of HK type. The mean potassium concentration (meq/l) in whole blood was 21.2±0.2

with coefficient of variation of 21.4 per cent. The mean packed cell volume was 24.8±0.2 percentage with coefficient of variation of 22.3 per cent.

Braend et al. (1987) could observe only HK type animals in a study of 150 Norwegian dairy goats. The concentration of potassium varied from 60 - 125 mm/l red cells. None of the animals were positive for the LK associated antigen, Mb.

Pashmina goats viz. Cheghu and Changthangi had only HK animals (Bhat, 1987). The mean potassium concentration in whole blood was 29.05±0.39 meq/l with coefficient of variation of 21.67 per cent. The packed cell volume was 34.78±0.52 per cent with coefficient of variation of 24.01 per cent.

Erkoc et al. (1987) reported polymorphism of potassium in Angora goats by classifying them into HK and LK groups and reported high frequency of LK types.

The existence of polymorphism for erythrocyte potassium was confirmed in certain Spanish breeds of goats (Tunon et al., 1987). A statistical boundary was established between the two caprine population. Low (LK) and high (HK) red cell potassium, the dividing line being set at 45 meq/l of RBC. Both types were shown to be controlled genetically by an

autosomal locus with two alleles K^L and K^H, with dominance by the former. The percentage of HK anımals was found to be higher than that of LK ones in all breeds, except Blanca Celtiberica. Red Cell potassium was polymorphic in all the Spanish goat breeds studied, ıts variability being very high in most of them. The HK gene frequencies ranged from 0.93 ın Palmera to 0.54 in Blanca Celtiberica.

Erythrocyte glutathione (GSH)

Glutathione (r-glutamyl-cysteinyl-glycine) is a widely occuring peptide that is found relatively large amounts in the liver, kidney and erythrocytes. Glutathione has been implicated in the control of the feeding response in Hydra, regulations of the initıation of protein synthesis, transport of amino acids across all membranes, protection of haemoglobin and enzyme sulphydryl groups from oxidation and detoxication of drugs and carcınogens. It has also been suggested that glutathıone protects intracellular components from oxidative attack and thus plays a significant part ın maintaining the viability of erythrocytes. In addition to ıts contrıbution as a general

antioxidant, erythrocyte GSH has also featured in numerous investigations in the search of biochemical markers of production potentials in various domestic species. More recently, the activities of the two enzymes, associated with glutathione metabolism, glutathione peroxidase and glutathione reductase have been shown to be dependent on the availability of different dietary components, and their determination in erythrocyte samples has been shown to be of diagnostic value in cases of nutritional deficiency. In erythrocytes, glutathione is normally maintained in the reduced sulphydryl form (GSH) (Board and Agar, 1983).

Based on the concentration of erythrocyte glutathione, sheep were classified as GSH low and GSH high types (Tucker and Kilgour, 1970). They also reported that these two GSH types are inherited in a simple Mendelian manner and are controlled by a pair of autosomal genes for GSH high (GSH^H) being dominant to GSH low (GSH^h).

Agar and Smith (1974) failed to demonstrate the presence of GSH polymorphism in the Spanish Mutton breed of goat in United States of America.

Agar et al. (1974) reported the existence of two red blood cell GSH types in goats similar to those found in the

sheep. The studies were conducted in 374 adult goats of the Angora, aAnglo-Nubian, British Alpine, Saanen and Toggenburg breeds. Goats with GSH values under 60 mg/100 ml red blood cells were classified as GSH-low type and those above this values as GSH high type. 334 goats out of tne 374 goats belonged to the GSH-high and 40 goats belonged to the GSH-low type. GSH-low animals were absent in Toggenburg and Anglo-Nubian goats. The mean values of GSH level in mg/100 ml RBC in the GSH-high type goats were 90.9±17.1 in Saanen, 78.3±128.8 in Angora, 110.7±13.3 in British Alpine, 107.9±17.4 in Toggenburg and 88.4±16.9 in Anglo-Nubian goats respectively. The mean GSH level in mg/100 ml RBC in the GSH-low type of first three breeds respectively were 52.4±6.5, 54.7±5.8 and 55.2±6.4.

More (1983) studied the Red Cell Glutathione polymorphism in 180 goats belonging to Jamnapari, Barbari, Beetal, Black Bengal, certain crossbreds and Sirohi. Animals with GSH values under 60 mg per 100 ml red cells were classified as GSH-low type. The goat breeds examined were mainly of GSH high type. GSH polymorphism could not be observed in Black Bengal goats. All the Black Bengal goats examined were of GSH high type. The frequency percentage of GSH-high type was highest in Barbari

(96.0 per cent) and lowest in Sirohi goats (55.5 per cent). The concentration of GSH was estimated in lactating and dry females, bucks and pooled animals of each genetic group. Generally lactating animals showed lower GSH concentration than those of dry animals within the GSH type. The concentration of GSH (mg/100 ml RBC) in pooled animals of GSH high type was 79.91±2.007 in Jamnapari, 78.25±3.117 in Barbari, 83.84±3.519 in Beetal, 79.67±3.910 in Black Bengal and 69.66±4.948 in Sirohi. The GSH concentration in GSH-low type goats was 53.13±1.734 in Jamnapari, 58.00 in Barbari, 54.02 in Beetal and 50.85±4.61 in Sirohi. The crossbred bucks below eight months old displayed lower values of GSH than that of values in natural goats.

Atroshi et al. (1985) classified the dairy goats into high GSH type and low GSH type based on the glutathione quantity in 100 ml RBC. Goats with 75 mg/100 RBC were grouped into high GSH types and 50 mg/100 ml RBC as low GSH types.

Rizzi et al. (1985) could not observe polymorphism of reduced erythrocyte glutathione in chamois colored goats. The reduced erythrocyte glutathione obtained was 85.36 mg/100 ml erythrocytes. All the animals were of the high concentration type.

Association among blood groups, haemoglobin Potassium and Glutathione

Tucker and Ellory (1972) classified the goats into two groups viz. HK and LK type based on the quantity of K in the red cells. The red cells of these goats were tested for the presence of the L and M antigens. Red Cells from 116 of the 132 goats tested were haemolysed by the M reagent whereas the L reagent did not haemolyse any of the red cells. Absorption of L reagent with LK sheep red cells removed both the serological activity of sheep red cells and the ability to stimulate the potassium pump of LK sheep and goat red cells. Absorption of L reagent with LK goat red cells removed the pump stimulatory activity of goat red cells, but did not affect the serological activity of anti-L agent sheep LK red cells. To explain the results, the authors put forward a hypothesis that there were to specification for L antigen, LS and LP. Specificity LP is concerned with active K transport and LS with strong serological activity. The difference in sheep LK red cells and goat LK red cells was that sheep have LP and LS and goat red cells only LP.

Mostaghni (1979) classified 208 Iranian goats into different groups based on haemoglobin phenotypes, viz. HbB, HbAB, HbBC and HbABC and concentration of potassium in whole blood into high potassium and low potassium. The mean packed cell volume (per cent) in HbA, HbAB, HbBC and HbABC were 26.9±6.3, 29.2±6.1, 27.5±7.2 and 26.1±6.9 respectively and the K (meq/l) in the four groups respectively were 15.4±1.6, 18.3±2.2, 19.5±1.9 and 17.7±1.7.

Khan and Taneja (1983) could observe significant differences between LK and HK types with respect to whole blood, plasma potassium, Sodium concentration and packed cell volume. The LK type goats had significantly lower whole blood potassium than that of HK (13.73±0.18 and 27.08±0.22 meq/l respectively), significantly lesser whole blood sodium content (132.56±0.14 and 114.80±0.29 meq/l respectively), significantly higher plasma potassium (5.73±0.36 and 5.51±0.02 meq/l respectively), significantly lesser plasma sodium (148.00±0.20 and 149.95±0.19 meq/l respectively), and significantly higher packed cell volume (28.98±0.27 and 26.74±0.23 per cent respectively).

Correlation with economic traits

Haemoglobin.

Gopinathan and Nair (1976) could observe significantly lower age at first kidding by 2.5 months in females of HbAA phenotype than females of other Hb phenotypes.

Antova and Mkrtchyan (1977) reported the superiority of haemoglobin heterozygotes over the homozygotes in body weight of goats in 567 Alta mountain goats. The Hb heterozygotes were slightly heavier (by about 3 per cent) than the homozygotes in under coat yield. Double heterozygotes (HbA/HbB, TfA/TfB) were significantly heavier than HbAA/AB animals. Under coat yield was significantly higher in AA/AB animals than in AB/AB, AA/AA, AA/BB and AB/AA animals.

Significant differences in the helminth egg counts among Hb phenotypes were observed in Red Sokoto goats (Bhuvanendran *et al.*, 1981). The heterozygotes had significantly lower egg counts than homozygotes. It was also postulated that the discrepancy in the ratios of haemoglobin phenotypes in the other groups was probably due to the differential susceptibility to helminth infection.

Fesus et al. (1983) could not observe any significant differences between the reproductive performance of the female having different haemoglobin types in the hungarian native breed of goats.

Potassium.

Dev et al. (1979) classified the Barbari goats into HK and LK types based on the blood potassium values. Analysis of variance of data on milk yield and composition of the HK and LK goats showed a significant difference in total milk protein. The LK animals had higher total milk proteins (3.13±0.068 g/100 ml) than that of HK animals (2.92±0.170 g/100 ml). Total milk yield, specific gravity, lactose, fat, total solids and solids-not-fat concentrations were similar in both the potassium types.

Erkoc et al. (1987) could not observe any significant correlation between the two potassium phenotypes (HK and LK) and the mohair staple length, fibre diameter or the percentage of medullated fibres in Angora goats.

Glutathione.

Atroshi et al.(1985) reported that goats with high GSH content (> 50 mg/100 ml RBC) had significantly higher

milk yield (380.49 kg) than goats with low GSH content (368.20 kg). The somatic cell counts in milk from goats with higher erythrocyte GSH contents were significantly higher than in milk from goats with low erythrocyte GSH content (mean log cell counts 6.11 vs 5.86).

Materials and Methods

MATERIALS AND METHODS

Blood samples collected from 305 goats aged above one year, maintained at the All India Co-ordinated Research Project on Goats, Kerala Agricultural University, Mannuthy formed materials for the study. Of the total goats, 45 belonged to Malabari (MM) (Fig.1), 95 to Saanen x Malabari crossbred (SM) (Fig.2) and 165 to Alpine x Malabari crossbred (AM) (Fig.3).

All the goats were maintained in semi-intensive system of management. The goats were fed with concentrate mixture and roughages according to approved nutritional standards. All the animals were reared under optimum health cover and management.

Collection of blood

About 5 ml of whole blood was collected from each animal aseptically by jugular vein puncture in four sterilized test tubes. For blood group studies and haemoglobin polymorphism, the blood was collected in a tube containing suitable anticoagulant. The composition of

Fig. 1 Malabari

Fig.2 Saanen x Malabari

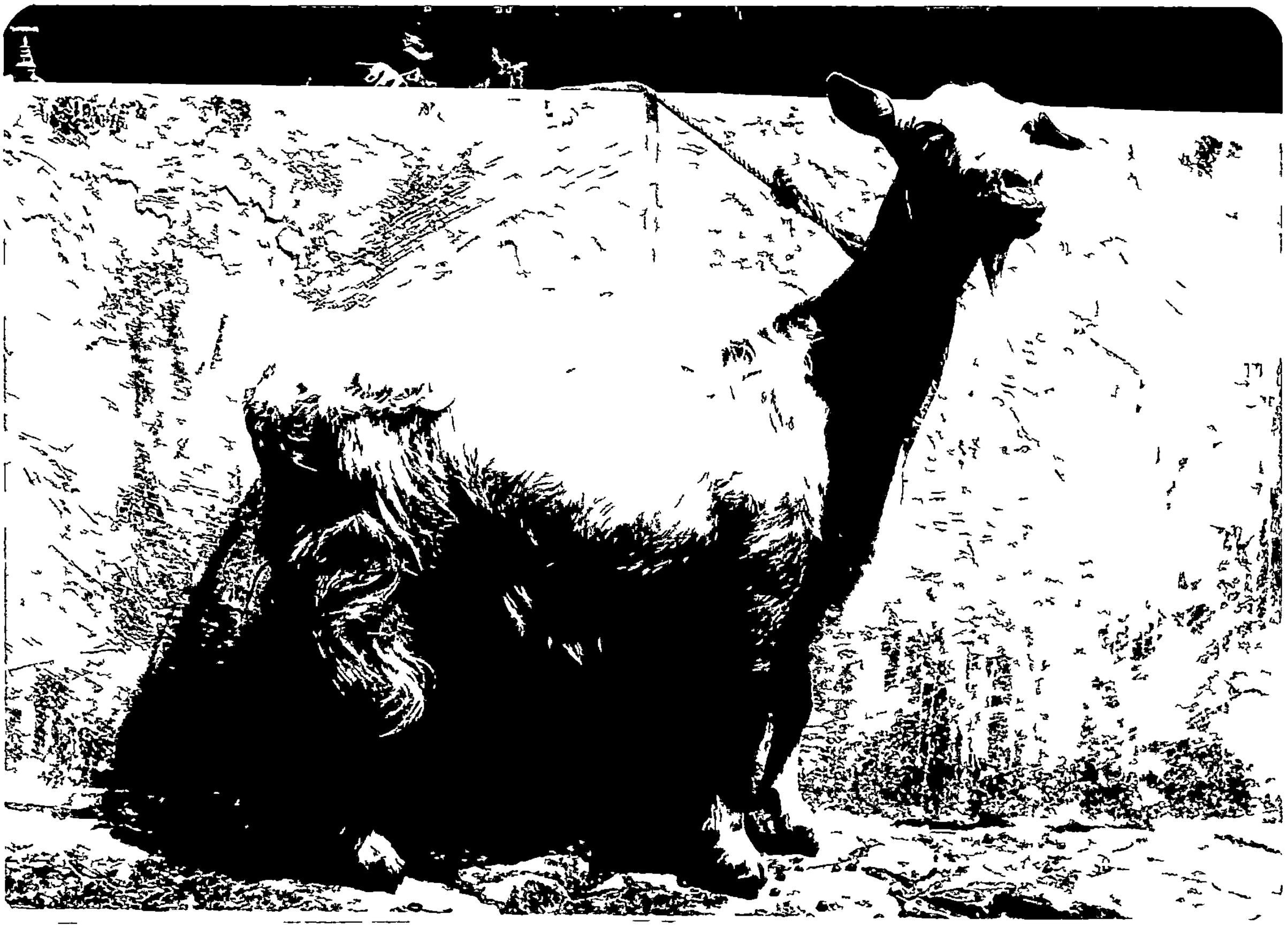


Fig.3 Alpine x Malabari

anticoagulant was: sodium citrate 20 g, sodium chloride 5 g, distilled water 1000 ml. Ten per cent of this anticoagulant was used for collection of the blood samples. For serum, the blood was collected in a test tube without anticoagulant.

The potassium concentration was estimated using 5 ml of whole blood collected in a test tube previously rinsed with a drop of heparin (5,000 iu/ml). The samples were analysed within 24 hours after the collection.

For estimating glutathione and packed cell volume, 5 ml of blood was collected in the test tube containing 1 ml of acid-citrate-dextrose (ACD) anticoagulant. The composition of the ACD anticoagulant used was:

sodium citrate	- 2.20 g
citric acid	- 0.73 g
dextrose	- 2.45 g
distilled water	- 100 ml

The samples were analysed within 24 hours after collection.

Blood groups

Nineteen goat polyvalent antisera obtained from the Institute for Animal Breeding, University of Bern, Bern, Switzerland were used for producing the blood group reagents. The experimental animals utilised for the preparation of blood typing reagents were drawn from the Malabari goats and its exotic crossbreds maintained at the AICRP on goats, Mannuthy. For distinguishing the blood group factors in goats, the immune haemolysis were used.

Haemolytic test.

Standard haemolytic test was employed to assess the antibody titre. Red blood cells from 20 goats were chosen for the haemolytic tests. 1 ml each of the goat blood was taken separately in glass tubes. The volumes were made upto 10 ml with normal saline. The tubes were shaken and centrifuged for 10 minutes at 2500 rpm in a refrigerated centrifuge. The supernatant fluid was removed and the process continued till the cells were free from the serum. A three per cent suspension of the cell samples were prepared by reducing the cell volume to 0.3 ml and then by adding normal saline upto 10 ml mark.

The haemolytic tests were arranged in special test tube racks. The number of test tube racks depend on the number of cells and the diluted sera available for test.

Two drops (0.1 ml) of serum of approximate dilution were placed in each tube in the vertical column. In the penultimate column, two drops of normal saline per tube and in the last column three drops of normal saline were added.

Red cell suspensions prepared from individual animals were dropped in horizontal rows at the rate of one drop (0.05 ml) per tube. Ultimately each serum in vertical column would contain all the blood cells used in separate tubes. The racks were shaken and left for 15 minutes. The one drop of complement (fresh rabbit serum absorbed with goat erythrocytes) was added in every tube except the tubes in the last vertical column. All the racks were shaken and the time was recorded on the haemolytic test sheets specially designed.

After half an hour, the racks were shaken and the extent of haemolysis was recorded with a lead pencil according to the following scale.

o - All cells were intact, no light passed through the suspensions.

± - About 50 per cent of the cells were lysed; much light passed through the fluid.

One hour after first reading the second reading was taken and recorded in blue ink. After the second reading the racks were shaken. The third reading was taken 90 minutes after second reading and recorded in red pencil.

The scale used for second and third readings were as follows:

o - All cells intact and settled at the bottom, supernatant was clear, with no trace of color.

tr - Nearly all cells were intact, and settled at bottom supernatant was slightly reddish colored.

1 - Most cells were intact and settled, supernatant was red.

2 - More than 50 per cent of cells were lysed, and the unlysed cells settled at the bottom in the form of a small button or ring.

3 - Nearly all cells were lysed, supernatant was bright red, when tube was shaken, the liquid became cloudy.

4 - All cells were lysed, liquid was sparkling red, and remained so even after the tube was shaken.

Absorption technique.

The goat polyvalent sera obtained from the Institute for Animal Breeding, University of Bern, Bern, Switzerland were subjected to absorption based on the results of haemolytic tests. It was seen that all the cells which possessed a particular antigenic factor had reacted. If one or more of such cells did not show any reaction, then it was decided that antibodies against that antigenic factor were not present in the serum. The reacting cells, one at the time, were used for absorption.

Absorptions were carried out with 5 ml of a properly diluted serum taken in a centrifuge tube. The dilution was calculated by multiplying the highest titre of the serum expressed as a faction by eight, as recommended by Lazear and Ferguson (1953). The cells chosen for absorption were washed thrice in saline. Suitable volume of packed cell to represent 20 per cent of serum taken, were pipetted out into the serum, shaken well and kept for 30 minutes. Then the contents were centrifuged and the supernatant was removed and kept. The cells used for absorption were discarded.

The results of the haemolytic tests of serum absorbed using blood cells from a single animal was carefully

scrutinised and any weak reactions when compared to unabsorbed serum test were noted. In addition to first cells used, the second series of cells showing weak reactions were added, and the entire process was repeated. Absorptions, testings and additions of next series of cells were done till the final absorbed serum was nonspecific and confirmed for its unitary behaviour. If after each absorption, the resulting serum showed no reaction with any of the cells in the haemolytic test, this was taken as evidence that the serum contained antibodies against only a particular antigenic factor and was considered to be monospecific and a blood group reagent.

If the absorptions were not successful, several combinations of cell concentrations and dilutions of serum and also different absorbing cells were tried until the serum containing a unit antibody was obtained. The blood group reagents were labelled conveniently.

Naturally occurring antibodies.

The naturally occurring antibodies were screened in animals having no history of previous blood transfusion by employing the standard haemolytic techniques as described earlier.

Estimation of gene frequency.

The presence of an antigen in an animal, as indicated by the haemolytic test, was taken to be dominant and its

absence as recessive. Based on the assumption that every single factor is controlled by a member of pair of alleles, the gene frequencies of blood factors were estimated as described below:

$$q^a = \sqrt{\frac{q}{N}}$$

where q^a = frequency of the recessive (non-reacting) gene

q = number of animals with non-reacting red cells

N = total number of individuals tested.

The gene frequency of dominant allele was calculated as $(1-q^a)$.

Starch gel electrophoresis for haemoglobin typing

Hydrolysis of starch.

The starch was hydrolysed by using the method of Smithies (1955). In the present study, potato starch of Loba Chemie Indoaustranal Co. was used.

600 g of potato starch was taken in Erlenmeyer flask. 1200 ml of acetone and 16 ml of concentrated

hydrochloric acid was taken in a separate flask. Both the flasks were kept in a waterbath for 2 hours at 40°C. Then the acetone acid mixture was mixed with starch and again kept in the water bath for one hour at 40°C. After the incubation, the supernatant was removed and 200 ml of 1 M sodium acetate solution was added. The starch was then filtered off in a Buchner funnel and washed thoroughly with running water for 3 to 4 hours. The starch was kept overnight with suction on. Next morning the starch was washed with 1000 ml of acetone and dried for 24 hours at 37°C.

Preparation of gel.

A continuous buffer system described by Gahne et al. (1960) was employed for the haemoglobin typing. The tris buffer contained the ingredients as given below:

Tris (hydroxymethyl) aminomethane	- 20.2 g
Ethylene diamine tetra acetic acid (EDTA)	- 2.0 g
Boric acid	- 1.5 g
Distilled water ad	- 1000 ml

pH 8.9

In the gel, the buffer was diluted ten fold with the distilled water.

The gels were prepared using 11 per cent hydrolysed potato starch in 250 ml of gel buffer in a 1000 ml filtering flask. To a required amount of hydrolysed starch, the gel buffer was added and the mixture was heated over a naked flame with constant and vigorous swirling. The heating was continued until the temperature of the gel reached 90°C, when the consistency of the gel was fluid and the gel fluid became transparent. The next step consisted of applying a vaccum for about 30 - 40 seconds to remove air bubbles from the gel. The hot gel was poured quickly into a glass plate (25 cm x 20 cm x 0.5 cm) which was edged by two pairs of removable glass bards (20 cm x 2 cm x 0.5 cm) and 21cm x 2 cm x 0.5 cm). The plate was filled until the gel came just above the top, then a glass plate of 25 cm x 20 cm x 0.5 cm size was gently placed over the surface of the gel. Care was taken to avoid trapping of air bubbles. The gel was kept for one hour at room temperature and then 1½ - 2 hours in the refrigerator.

The haemoglobin solution was made by haemolysing 0.25 ml of washed cells in 2.5 ml of distilled water. After removing the cover plate gently the gel was cut and the samples were inserted in the gel linearly after soaking in whatmann chromatography paper No.1 cut into

small bits of 1 x 0.5 cm size. The excess solution of the small paper bits was removed by placing it over a thick filter paper. The samples were inserted in the gel at a distance of 3 cm from the cathode bridge. The interspace between the samples were 5 mm. The gel was placed on an electrolyte vessel having potassium electrodes. Connections between the gel and the vessel buffer were made by wicks made of whatmann filter paper No.1. The gel was covered with plastic sheet to prevent evaporation.

Electrophoresis was done at 15 m A. After 2 minutes, the paper bits were removed. Care was taken to avoide air bubbles in the place of insertion of the samples. The electrophoresis was continued for 1½ hours at 15 m A. After completion of the electrophoresis, the gels were sliced horizontally using a thick nylon thread. The lower half was stained with benzedine stain of the following composition.

Benzedine	- 250 mg
Hydrogen peroxide	- 0.4 ml
Glacial acetic acid	- 1.5 ml
Distilled water	- 100 ml

The stain was allowed to act on the gels for 3 minutes and then the excess stain was removed by washing

the gel with tap water. The destaining and fixation of the gel was done in methanol-water-acetic acid (5:5:1).

Animals were typed for haemoglobin based on the movement of bands in the gel.

Estimation of blood constituents

Potassium concentration.

Potassium concentration in whole blood was determined by using EEL flamephotometer as per the method of Oser (1965). The whole blood samples were diluted 1:100 with deionised water.

A stock standard solution containing 10 meq of potassium/l was prepared by dissolving 0.746 g of Kcl and making up the volume to one litre in a volumetric flask with deionished water. Working standards equivalent to 5.0, 10.0, 20.0, 40.0 and 60.0 meq of potassium/l at a dilution of 1:100 were prepared by diluting 0.5, 1.0, 2.0, 4.0 and 6.0 ml of stock solutionto 100 ml respectively.

Flamephotometer reading was initially adjusted to zero by spraying deionised water. Then potassium standard solution were atomised and the readings of the flame

photometer were obtained separately for each batch of blood samples. An average of these readings were calculated and a test fit line was arrived at and this formed the standard graph. The dilutes of whole blood samples for each batch were then sprayed separately and the readings were recorded. The concentration of potassium in the blood samples were estimated by using the standard graph.

Glutathione (GSH) concentration.

Glutathione (GSH) level in whole blood was estimated as per the method of Beutler et al. (1963) using a spectrophotometer at a wave length of 412 mm. The concentration of GSH per 100 ml packed red blood cells were calculated from the whole blood haematocrit values.

Reagents used in the method were as follows:

1. Precipitating solution - Dissolved 1.67 g of glacial metaphosphoric acid (a mixture of HPO_3 and $NaPO_3$), 0.2 g disodium or dipotassium ethylene diamine tetra acetic acid (EDTA) and 30 g of sodium chloride in 100 ml of distilled water.

2. Phosphate solution. A solution of 0.3 M Na_2HPO_4 was prepared in distilled water (53.4 g of $Na_2HPO_4 . 2H_2$ per litre of distilled water).

3. DTNB reagent. Dissolved 40 mg 5.5' - dithiobis (2-nitrobenzoic acid) in 100 ml of one per cent sodium citrate solution.

A reagent blank was prepared with 8 ml of the phosphate solution, 2 ml of the diluted precipitating solution (3 parts to 2 parts of distilled water) and one ml of DTNB reagent. The reagent blank was used to set the optical density of the spectrophotometer to zero before reading the optical densities of the samples.

0.2 ml of whole blood was added to 1.8 ml of distilled water. 3 ml of the precipitating solution was mixed with the haemolysate. The mixture was allowed to stand for about 5 minutes to precipitate all the proteins and then filtered. 2 ml of filtrate was added to 8 ml of the phosphate solution in the cuvette. To this, 1 ml of the DTNB solution was added. The optical density was then measured in the spectrophotometer after setting the optical density to zero with the reagent blank.

Glutathione (GSH) level was calculated on the basis of molar extinction coefficient of 13,600 and molecular weight of 307. The glutathione content of blood in mg per 100 ml red blood cells were calculated by the following formula when 0.2 ml of blood sample was used.

GSH mg/100 ml RBC:

$$\frac{OD}{13,600} \times \frac{5}{0.2} \times \frac{11}{2} \times 307 \times 100 \times \frac{100}{PCV}$$

$$= OD \times 310.4 \times \frac{100}{PCV}$$

OD = optical density of the spectrophotometer

PCV = Packed cell volume.

The classification of goats into two distinct glutathione types as suggested by Agar et al. (1974) was followed. Goats with GSH values below 60 mg/100 ml RBC was classified as low glutathione type (GSH low type) and those with values of 60 mg/100 ml RBC and above as high glutathione type (GSH high type).

Packed cell volume (haematocrit).

Wintrobe haematocrit method described by Benjamin (1978) was followed for determining the packed cell volume. The samples were filled in the haematocrit tubes using the special pipette and were centrifuged at 3000 rpm for one hour. The packed cell volume percentage was calculated by multiplying the cell volume by ten.

Economic traits considered for the present study were (a) growth traits viz. body weight at birth and at the

ages of three months, six months, nine months and one year and at kidding and (b) production traits viz. first lactation yield and first lactation length.

The gene frequencies at different loci and phenotype frequencies were calculated by direct counting method.

Comparison of the gene frequencies at different loci, the association among the different phenotypes and their association with economic traits were estimated using statistical methods as described by Snedecor and Cochran(1967).

Results

RESULTS

Blood groups

Naturally occurring antibodies.

The naturally occuring antibodies were screened in animals having no history of previous blood transfusion. Naturally occurring antibodies could not be observed in any of the 150 goats screened during the present study.

Blood group reagents.

Twelve blood group reagents were produced in this laboratory during the course of study from the antisera obtained from Switzerland. They were designated as M1, M2, M3, M4, M5, M6, M7, M8, M9, M10, M11 and M12 in order of production. Comparison of the above reagents could not be made as standard International reagents were not available. The test for monospecificity being carried out before typing the animals showed that these reagents were monospecific.

One hundred and fifty animals, belonging to the three genetic groups viz. 35 Malabari (MM),

42 Saanen x Malabari (SM) and 73 Alpine x Malabari (AM) were blood typed with the aid of the above twelve reagents. The number of animals (genetic group wise) which reacted to these reagents is presented in table 1.

The percentage of various blood group factors in the animals studied have been shown in table 2. Of the twelve blood grouping reagents, M4, M10 and M12 have not reacted with any of the red blood cells of MM goats, whereas all the reagents were positive in SM and AM crossbreds. In MM goats the M2 blood group factor had the highest frequency percentage of 37.14 followed by M3 (34.29) M1 and M11 (31.43), M7 (28.57), M6 (25.71), M5 (22.86), M9 (11.43) and M8 (5.71). In SM crossbreds, M2 had the highest frequency percentage of 92.86 and was followed by M3 (80.95), M7 (78.57), M6 (76.19), M11 (73.81), M5 (57.14), M1 (54.76), M10 (47.62), M9 and M12 (30.95), M4 (23.81) and M8 (21.43). In AM goats, the highest frequency percentage of 86.30 was obtained for M1 followed by M3 (73.97), M6 (72.60), M11 (65.75), M7 (63.01), M2 (57.53), M5 (54.79), M9 (27.40), M4 (24.66), M8 (20.55), M10 (13.70) and M12 (12.33).

In the pooled population, the M3 had the highest frequency of 66.67 per cent and M12 had the lowest frequency of 14.67 per cent.

Table 1. Number of goats observed under different blood group factors

Genetic group	No.of animals	Blood group factors											
		M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
Malabari	35	11	13	12	-	8	9	10	2	4	-	11	-
Saanen x Malabari	42	23	39	34	10	24	32	33	9	13	20	31	13
Alpine x Malabari	73	63	42	54	18	40	53	46	15	20	10	48	9
Pooled Population	150	97	94	100	28	72	94	89	26	47	30	90	22

Table 2. Frequencies of various blood group factors (in percentage)

Genetic groups	No.of animals	Blood group factors											
		M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
Malabari	35	31.43	37.14	34.29	-	22.86	25.71	28.57	5.71	11.43	-	31.43	-
Saanen x Malabari	42	54.76	92.86	80.95	23.81	57.14	76.19	78.57	21.43	30.95	47.62	73.81	30.95
Alpine x Malabari	73	86.30	57.53	73.97	24.66	54.79	72.60	63.01	20.55	27.40	13.70	65.75	12.33
Pooled Population	150	64.67	62.67	66.67	18.67	48.00	62.67	59.33	17.33	31.33	20.00	60.00	14.67

Gene frequencies of blood group factors.

The gene frequencies estimated for various blood group factors in the three genetic groups and for the pooled population are presented in table 3.

Haemoglobin

Employing horizontal starch gel electrophoresis, 305 goats belonging to three genetic groups viz. 45 Malabari (MM), 95 Saanen x Malabari crossbreds (SM) and 165 Alpine x Malabari crossbreds (AM) were typed for haemoglobin types.

On electrophoresis, the haemoglobin bands showed distinct movement towards anodic end of the electrophoretogram and two electrophoretically distinct haemoglobin were identified. The fast moving one was designated as Hb^A whereas the slow moving designated as Hb^B. Individual animals possessed either one or both the haemoglobins.

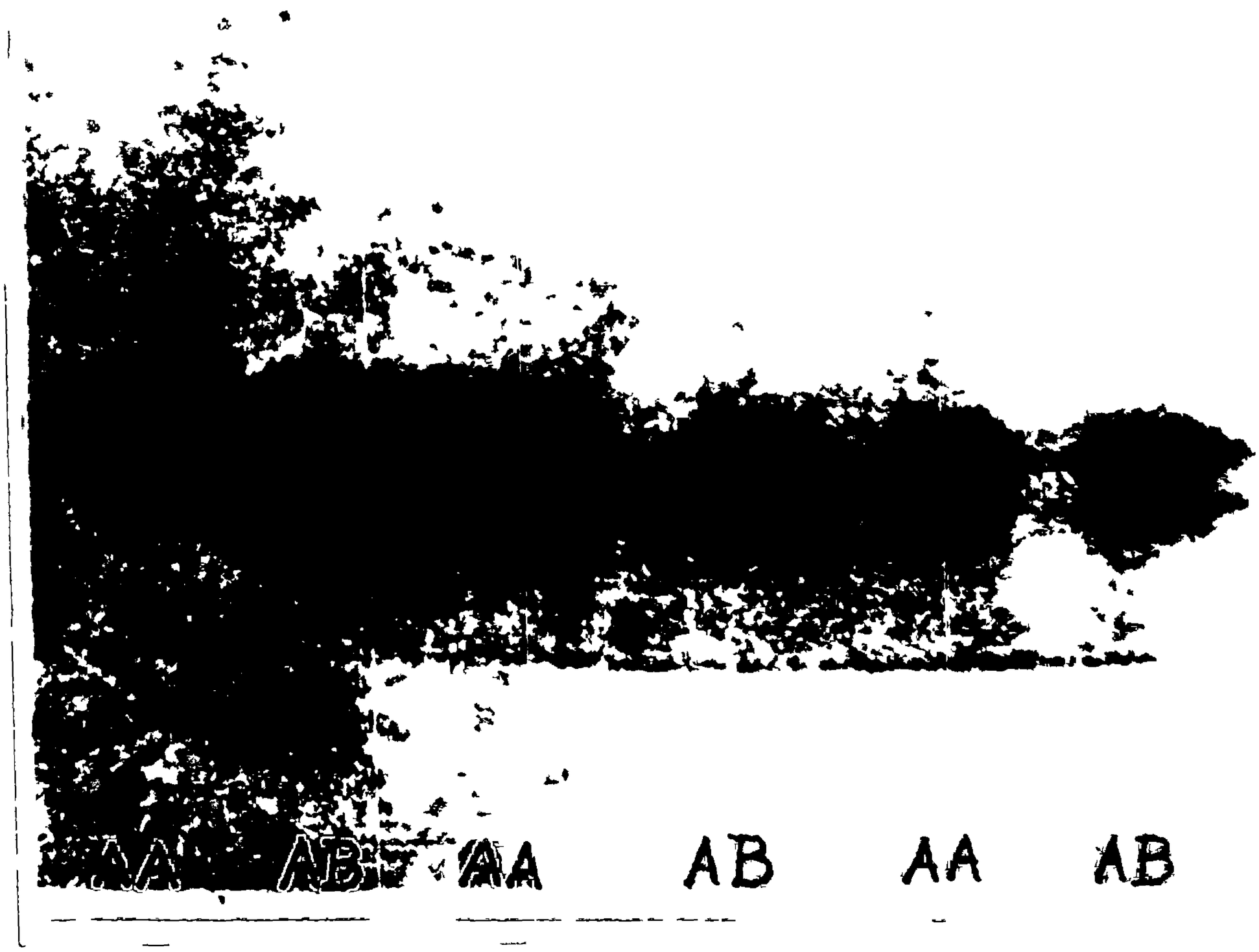
Distribution of haemoglobin type.

Two haemoglobin phenotypes HbAA and HbAB were observed in the present study (Fig. 4). Of the three possible phenotypes HbBB was not observed in any of the genetic groups. The phenotype HbAA had only one fast moving band whereas HbAB had one fast moving and one slow moving band.

Table 3. Gene frequencies of various blood group factors in different goat populations

Genetic group	No.of animals	Blood group factors											
		M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
Malabari	35	0.2	0.2	0.2	-	0.1	0.1	0.1	0.02	0.06	-	0.2	-
Saanen x Malabari	42	0.3	0.7	0.6	0.1	0.3	0.5	0.5	0.1	0.2	0.3	0.5	0.2
Alpine x Malabari	73	0.6	0.3	0.5	0.1	0.3	0.5	0.4	0.1	0.1	0.07	0.4	0.06
Pooled Population	150	0.4	0.4	0.4	0.1	0.3	0.4	0.4	0.1	0.2	0.1	0.4	0.1

Fig.4 Stained starch gel showing different haemoglobin phenotypes in goats


AA
AB
AA
AB
AA
AB

The phenotype frequencies of haemoglobin types in different genetic groups are presented in Table 4. A diagramatic representation of the phenotype frequencies of haemoglobin types are given in Fig.5.

The frequency of HbAA was 0.96 in MM, 0.96 in SM and 0.93 in AM. The frequency of HbAB was 0.04, 0.04 and 0.07 in MM, SM and AM respectively.

Inheritance of haemoglobin types.

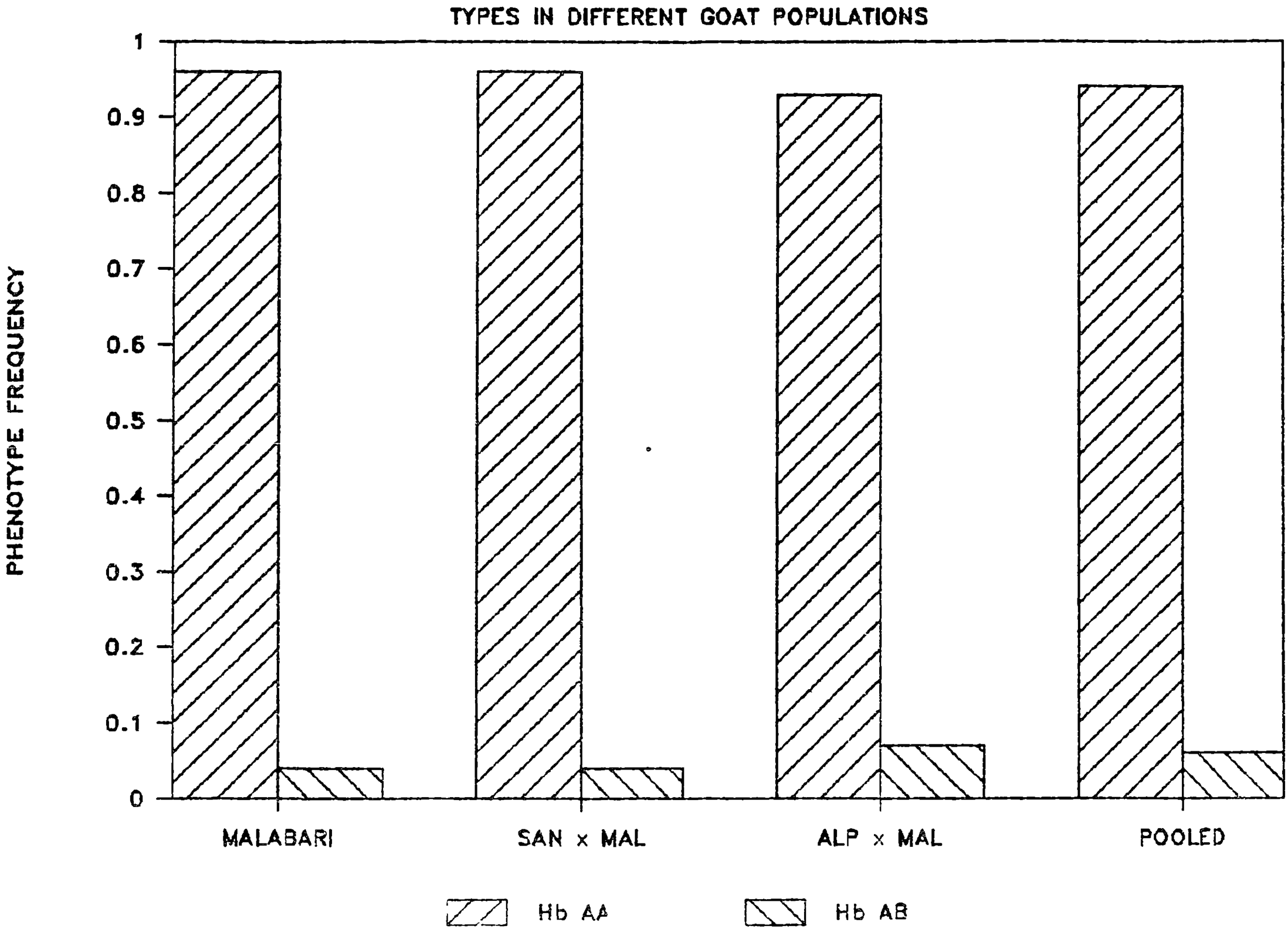
The frequency of Hb types among the offspring born of different HbAA and HbAB matings are furnished in table 5. It is seen that HbAA x HbAA matings always resulted in HbAA offspring. Mating of HbAA x HbAB resulted in HbAA and HbAB offsprings in equal proportion. The observed number of offspring in different matings did not differ significantly from those of the expected number.

Gene frequencies of Hb allele.

The gene frequencies of Hb alleles in the three genetic groups are also given in table 4. The frequency of Hb^A allele was 0.98, 0.98, 0.97 and 0.97 in MM, SM, AM and pooled population respectively.

The gene frequency of Hb^B allele was 0.02 in MM, 0.02 in SM, 0.03 in AM and 0.03 in pooled population.

FIG-5. PHENOTYPE FREQUENCIES OF HAEMOGLOBIN



61 (1)

The diagrammatic representation of the Hb gene frequencies in different genetic groups are given in Fig.6.

Variation between genetic groups.

A comparison of the Hb^A and Hb^B gene frequencies among different genetic groups was carried out by employing χ^2 test. (Table 6). It is seen that the gene frequencies of Hb^A and Hb^B observed in different genetic groups did not differ significantly.

Test of genetic equilibrium.

Assuming random mating, the expected number of the different haemoglobin phenotypes in all the genetic groups were calculated and compared with the observed number (Table 7). It may be seen that the χ^2 values did not reach the level of significance in any genetic group.

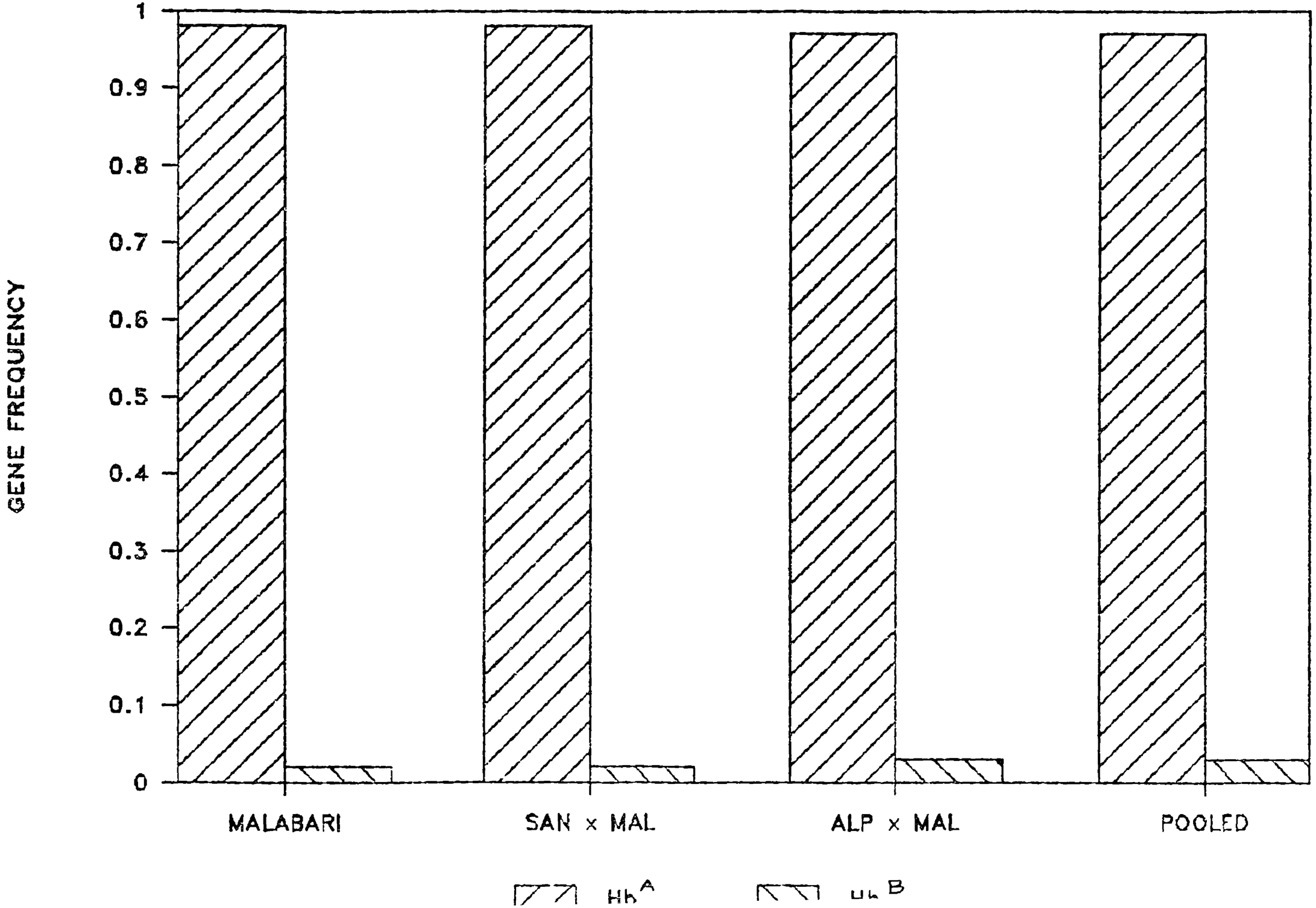
Potassium

Distribution of potassium types.

The concentration of potassium in whole blood (meq/l) was estimated to find out polymorphism, if any, at this locus.

Fig — 6. HAEMOGLOBIN GENE FREQUENCIES

IN DIFFERENT GOAT POPULATIONS



63(1)

Table 6. Comparison of gene frequencies of Hb^A and Hb^B in Malabari goats and their exotic crossbreds

Allele	Genetic group			χ^2
	Malabari	Saanen x Malabari	Alpine x Malabari	df=2
Hb^A	0.98	0.98	0.97	0.84 NS
Hb^B	0.02	0.02	0.03	0.84 NS

NS - Not significant

Table 4. Phenotype frequencies and gene frequencies of haemoglobin types in Malabari goats and their exotic crossbreds.

Genetic group	No.of animal	Phenotype frequencies			Gene frequencies	
		HbAA	HbAB	HbBB	Hb^A	Hb^B
Malabari	45	0.96 (43)	0.04 (2)	-	0.98	0.02
Saanen x Malabari	95	0.96 (91)	0.04 (4)	-	0.98	0.02
Alpine x Malabari	165	0.93 (154)	0.07 (11)	-	0.97	0.03
Pooled population	305	0.94 (288)	0.06 (17)	-	0.97	0.03

Number in parenthesis indicates number of animals.

Table 5. Results of mating between goats of different haemoglobin types.

Parents		No.of mating	No.of kids	Phenotype of offspring						χ^2 df=1
Sire	Dam			HbAA		HbAB		HbBB		
				Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	
AA (6)	x AA (36)	36	42	42	42	-	-	-	-	0.00
AA (1)	x AB (1)	1	2	1	1	1	1	-	-	0.00

Table 7. Observed and expected number of goats with different haemoglobin variants according to Hardy-Weinberg law.

Genetic group	No.of animals	Haemoglobin phenotypes						χ^2 df=2
		HbAA		HbAB		HbBB		
		Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	
Malabari	45	43	43.04	2	1.94	-	0.02	0.03 NS
Saanen x Malabari	95	91	91.05	4	3.91	-	0.04	0.05 NS
Alpine x Malabari	165	154	154.29	11	10.53	-	0.18	0.24 NS
Pooled population	305	288	286.97	17	17.75	-	0.28	0.31 NS

NS - Not significant

The mean whole blood potassium concentration (meq/l) in the three genetic groups, viz. MM, SM and AM are presented in Table 8. The mean values were 16.96±1.12 in MM, 15.96±0.80 in SM and 15.91±0.58 in AM. In pooled population, the mean potassium value was 16.08±0.42.

Table 9 shows that the mean potassium concentration in whole blood obtained from the three genetic groups was not significantly different.

Since the whole blood potassium concentration in the three genetic groups did not differ significantly, a frequency curve of potassium concentration was plotted for the whole population (Fig. 7). It was possible from the bimodal nature of the curve to divide the goats into two subpopulation, viz. low potassium (LK) and high potassium (HK) types. The cut off point for the two types was fixed as 22.0 meq/l. Goats having whole blood potassium concentration below 22 meq/l were grouped as LK types and those with above 22 meq/l were grouped as HK types.

The frequency distribution of LK and HK phenotypes in different genetic groups are presented in table 10. A diagrammatic representation of the phenotype frequencies of the potassium types is given in Fig. 8. The LK and HK phenotypes were observed in all the genetic groups.

Table 8. Mean, standard error (SE) and co-efficient of variation (CV%) of whole blood potassium concentration (meq/l) in Malabari goats and their exotic crossbreds

Genetic group	No.of animals	Mean	SE	CV%
Malabari	45	16.96	1.12	46.64
Saanen x Malabari	95	15.96	0.80	49.05
Alpine x Malabari	165	15.91	0.58	47.01
Pooled population	305	16.08	0.42	46.64

Table 9. Analysis of variance for potassium level in different genetic groups of goats.

Source	d.f	SS	M.S.S.	F
Between genetic groups	2	37.52	18.76	0.33 NS
Error	302	17401.33	57.62	
Total	304	17438.85		

NS - Not significant

FIG-7. FREQUENCY DISTRIBUTION OF POTASSIUM

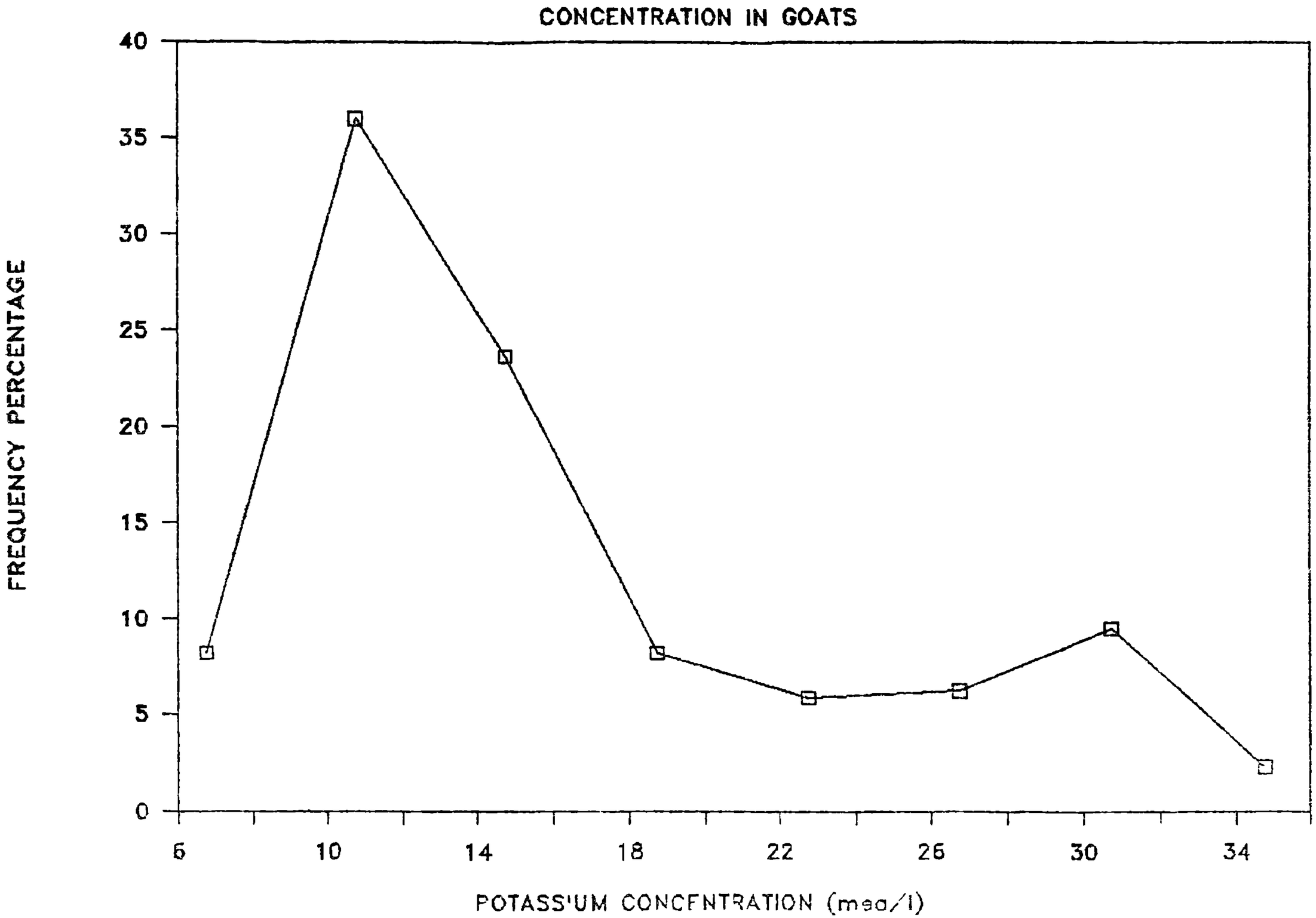


Table 10. Frequency distribution of LK and HK phenotypes and their gene frequencies in Malabari goats and their exotic crossbreds.

Genetic group	No.of animals	Observed no.of potassium phenotypes		Phenotype percentage		Gene frequency	
		LK	HK	LK	HK	K^L	K^H
Malabari	45	35	10	77.78	22.22	0.53	0.47
Saanen x Malabari	95	71	24	74.74	25.26	0.50	0.50
Alpine x Malabari	165	127	38	76.97	23.03	0.52	0.48
Pooled population	305	233	72	76.39	23.61	0.51	0.49

FIG-8. PHENOTYPE FREQUENCIES OF POTASSIUM

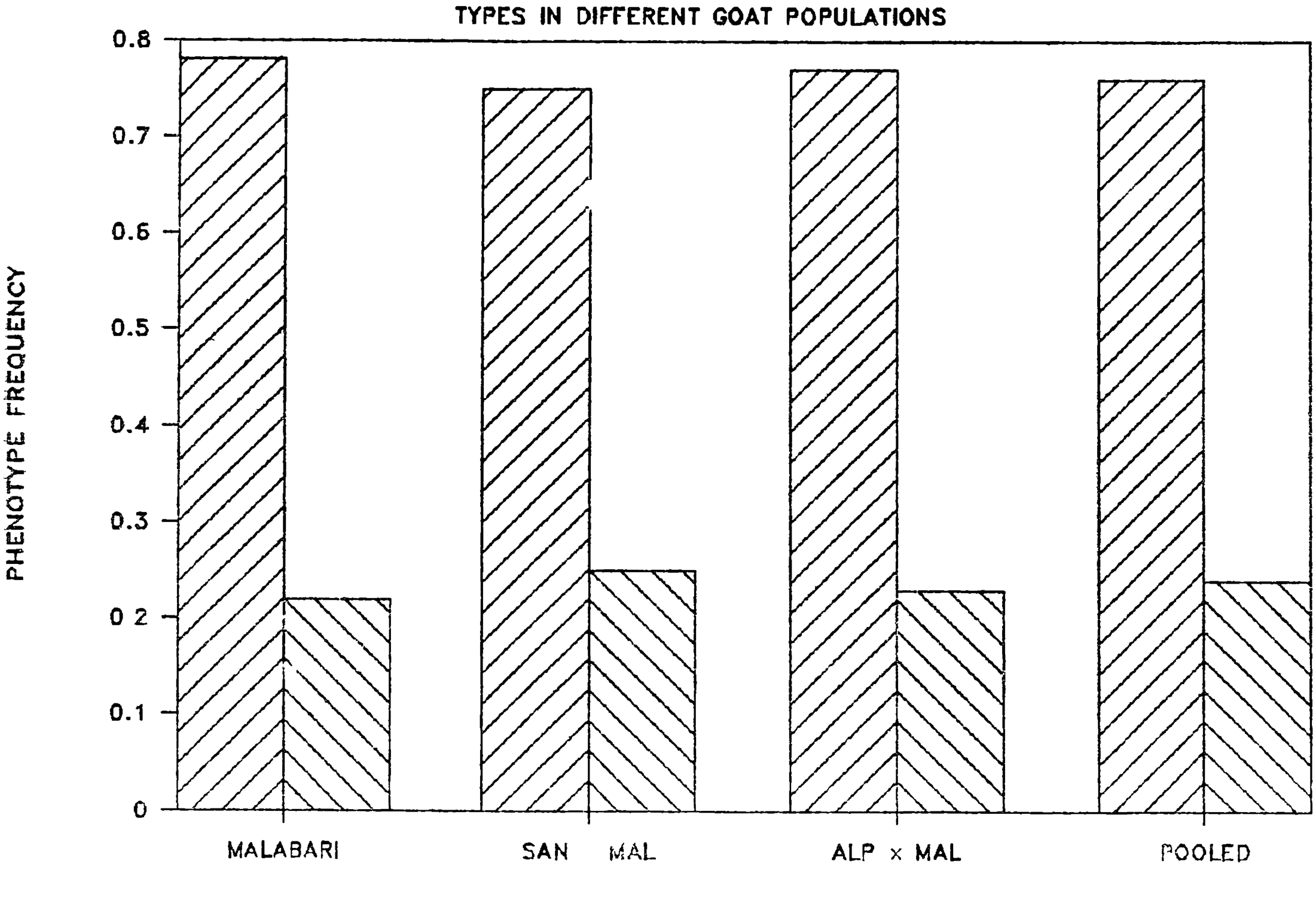


Table 11. Segregation of potassium phenotypes from various mating types in goats.

Type of mating and number	No.of progeny	Progeny: Observed number LK	Observed number HK	Expected ratio LK		Expected ratio HK	Expected number LK	Expected number HK	χ^2 df=1
LK x LK (5) (25)	30	24	6	0.89	:	0.11	26.70	3.30	2.48 NS
LK x HK (3) (6)	7	6	1	0.67	:	0.33	4.69	2.31	1.11 NS
HK x LK (1) (5)	6	6	-	0.67	:	0.33	4.02	1.98	2.96 NS
Total	13	12	1	0.67	:	0.33	8.71	4.29	3.77 NS
HK x HK (1) (1)	1	0	1	0	:	1	0	1	0.00

NS - Not significant

0.48 respectively. In the pooled population K^L allele had a frequency of 0.51 and K^H allele of 0.49.

Diagramatic representation of the potassium alleles in different genetic groups are shown in Fig. 9.

A comparison of the gene frequencies of K^L allele in different population and K^H allele in different population showed that the differences were not significant (Table 12).

Potassium phenotypes in different generations.

The SM crossbreds and AM crossbreds included in the present study belonged to two generations - secord and third generations. The frequency distribution of LK and HK phenotypes and their gene frequencies in the two generations are presented in table 13. The phenotypic percentage of LK animals in the SM goats of second generation (F_2SM) was 71.05 and in its third generation (F_3SM) the same was 77.19. The percentage of occurrence of HK type in F_2SM and F_3SM was 28.95 and 22.81 respectively. In AM crossbreds, the goats of second generation (F_2AM) had the LK phenotypic percentage of 69.23 and HK of 30.77. In AM crossbreds of third generation (F_3AM) the phenotypic percentage of LK and HK were 83.91 and 16.09 respectively.

Table 12. Comparison of gene frequencies of K^L and K^H in Malabari goats and their exotic crossbreds.

Allele	Genetic group			χ^2
	Malabari	Saanen x Malabari	Alpine x Malabari	df=2
K^L	0.53	0.50	0.52	0.17 NS
K^H	0.47	0.50	0.48	0.17 NS

NS - Not significant

Table 13. Frequency distribution of LK and HK phenotypes and their gene frequencies in Malabari goats and their exotic crossbreds of two generations.

Genetic group	Generation	Observed number of potassium phenotypes		Phenotype percentage		Gene frequencies	
		LK	HK	LK	HK	K^L	K^H
Malabari (45)	45	35	10	77.78	22.22	0.53	0.47
Saanen x Malabari (95)	Second (38)	27	11	71.05	28.95	0.46	0.54
	Third (57)	44	13	77.19	22.81	0.52	0.48
Alpine x Malabari (165)	Second (78)	54	24	69.23	30.77	0.45	0.55
	Third (87)	73	14	83.91	16.09	0.60	0.40
Pooled population	305	233	72	76.39	23.61	0.51	0.49

The gene frequencies of K^L and K^H alleles in the two generation of goats are also presented in table 13. In F_2SM, the gene frequencies of K^L allele and K^H allele were 0.46 and 0.54 respectively. In F_3SM, it was 0.52 for K^L allele and 0.48 for K^H allele. In F_2AM, 0.45 and 0.55 were the gene frequencies of K^L and K^H alleles and in F_3AM, the values were 0.60 and 0.40 respectively.

Comparison of the gene frequencies among MM, F_2SM, F_3SM, F_2AM and F_3AM revealed no significant difference (Table 14).

Potassium concentration in LK and HK types

The mean potassium concentration (meq/l) in whole blood in different types of potassium phenotypes are given in table 15. The mean concentration of potassium (meq/l) in LK animals was 13.76±0.42 in MM, 11.84±0.37 in SM, 12.24±0.27 in AM and 12.35±0.20 in the pooled population. It is seen that the mean value obtained for MM was significantly higher to that of SM and AM. The difference in potassium concentration between SM and AM crossbreds was not significant. The mean concentration of potassium in the HK type animals was 28.20±1.61 in MM, 28.16±0.73 in SM, 28.19±0.64 in AM and 28.18±0.74 in pooled population, the differences being non significant.

Table 14. Comparison of gene frequencies of K^L and K^H in Malabari goats and their exotic crossbreds of two generations

Allele	Genetic group					χ^2 df=4
	Malabari	Saanen x Malabari		Alpine x Malabari		
		F_2	F_3	F_2	F_3	
K^L	0.53	0.46	0.52	0.45	0.60	4.80 NS
K^H	0.47	0.54	0.48	0.55	0.40	4.80 NS

NS - Not significant

Table 15. Mean, standard error and co-efficient of variation (CV%) of whole blood potassium concentration (meq/l) in LK and HK type goats.

Genetic group	No. of animal	LK				HK			
		No.	Mean	SE	CV(%)	No.	Mean	SE	CV(%)
Malabari	45	35	13.76[a]	0.42	18.02	10	28.20	1.61	18.12
Saanen x Malabari	95	71	11.84[b]	0.37	26.54	24	28.16	0.73	12.64
Alpine x Malabari	165	127	12.24[b]	0.27	25.13	38	28.19	0.64	14.01
Pooled population	305	233	12.35	0.20	24.86	72	28.18	0.74	14.23

Means with different superscripts differ significantly ($P < 0.01$)

The analysis of variance for potassium concentration in LK and HK type goats are presented in table 16 and table 17 respectively.

Potassium concentration and sex.

The mean values of potassium concentration (meq/l) in males and females of each genetic group are presented in table 18. The mean potassium concentration in LK type males and females was 13.34±1.29 and 13.80±0.45 in MM, 11.02±1.35 and 11.89±0.39 in SM and 10.26 and 12.26±0.27 in AM goats. The difference in mean values between males and females was not significant.

In HK type goats, the mean potassium concentration in males and females was 24.10 and 28.33±0.74 in SM and 29.74 and 28.15±0.66 in AM. In MM, the females had a mean potassium concentration of 28.20±1.61. There was no significant difference in the mean potassium concentration between males and females in any genetic group.

Potassium concentration and generation.

The mean values for potassium concentration in LK and HK type goats of different generation within a genetic group are presented in table 19.

In LK type goats, the mean potassium concentration (meq/l) was 12.15±0.50 and 11.64±0.51 in F_2SM and F_3SM

Table 16. Analysis of variance of whole blood potassium concentration in LK type goats of Malabari and their exotic crossbreds

Source	df	SS	MS	F
Between genetic group	2	89.58	44.79	5.01**
Error	230	2056.72	8.79	
Total	232	2146.30		

** ($P < 0.01$)

Table 17. Analysis of variance of whole blood potassium concentration in HK type goats of Malabari and their exotic crossbreds.

Source	df	SS	MS	F
Between genetic groups	2	0.03	0.02	0.001 NS
Error	69	1092.06	15.83	
Total	71	1092.09		

NS - Not significant

Table 18. Mean, standard error and coefficient of variation (CV%) of whole blood potassium concentration (meq/l) in male and female goats

Genetic group	Sex	LK				HK			
		No.	Mean	SE	CV (%)	No	Mean	SE	CV (%)
Malabari	Male	5	13.34	1.29	21.57	-	-	-	-
	Female	30	13.83	0.45	17.74	10	28.20	1.61	18.12
	Pooled	35	13.76	0.42	18.02	10	28.20	1.61	18.12
Saanen x Malabari	Male	4	11.02	1.35	24.42	1	24.10	-	-
	Female	67	11.89	0.39	26.71	23	28.33	0.74	12.45
	Pooled	71	11.84	0.37	26.54	24	28.16	0.73	12.64
Alpine x Malabari	Male	1	10.26	-	-	1	29.74	-	-
	Female	126	12.26	0.27	25.04	37	28.15	0.66	14.21
	Pooled	127	12.24	0.27	27.22	38	28.19	0.64	14.01
Total Population		233	12.35	0.20	24.86	72	28.18	0.47	14.23

Table 19. Mean, standard error and coefficient of variation of potassium concentration (meq/l) in LK and HK type goats of two generations

Generation	LK				HK			
	No.	Mean	SE	CV (%)	No.	Mean	SE	CV (%)
SM (Γ_2)	27	12.15	0.50	21.56	11	29.97[a]	0.72	10.18
SM (Γ_3)	44	11.64	0.51	29.20	13	26.62[b]	0.89	12.13
Total SM	71	11.84	0.37	26.54	24	28.16	0.73	12.64
AM (F_2)	54	11.51	0.39	24.67	24	27.95	0.61	10.70
AM (F_3)	73	12.78	0.36	24.33	14	28.60	1.43	18.78
Total AM	127	12.24	0.27	27.22	38	28.19	0.64	14.01

Mean values with different superscripts differ significantly ($P < 0.05$)

respectively. The difference was not significant. The mean value was 11.51±0.39 and 12.78±0.36 in F_2^{AM} and F_3^{AM} goats, the difference being non significant.

In HK type goats, the mean potassium concentration (meq/l) was 29.97±0.72 in F_2^{SM} and 26.62±0.89 in F_3^{SM}, the difference showing significance ($P < 0.05$). The mean values of 27.95±0.61 and 28.60±1.43 were observed for F_2^{AM} and F_3^{AM} goats respectively. The difference was not significant.

Effect of sire on potassium concentration.

The analysis of variance between sire potassium concentration in LK and HK type goats is presented in table 20 and 21 respectively. It was seen that significant effect ($P < 0.01$) of sire on the concentration of potassium in their offsprings exist in LK and HK types of AM crossbreds only. Sire had no effect on the concentration of potassium of their offsprings in LK and HK type goats of MM and SM.

Table 20. Analysis of variance between sire potassium concentration in LK type Malabari goats and their exotic crossbreds

Genetic group	Sources	df	SS	MS	F
Malabari	Between sire	6	50.50	8.42	1.59 NS
	Error	27	143.02	5.30	
	Total	33	193.52		
Saanen x Malabari	Between sire	8	38.90	4.86	0.51 NS
	Error	57	543.31	9.53	
	Total	65	582.21		
Alpine x Malabari	Between sire	9	232.61	95.18	11.55**
	Error	104	856.66	8.24	
	Total	113	1089.27		

** ($P < 0.01$) NS - Not significant

Table 21. Analysis of variance between sire potassium concentration in HK type Malabari goats and their exotic crossbreds

Genetic group	Sources	df	SS	MS	F
Malabari	Between sire	1	7.84	7.84	0.27 NS
	Error	6	171.74	28.62	
	Total	7	179.58		
Saanen x Malabari	Between sire	2	3.01	1.51	0.09 NS
	Error	11	189.58	17.23	
	Total	13	192.59		
Alpine x Malabari	Between sire	7	2630.14	357.73	9.85 **
	Error	25	953.20	38.13	
	Total	32	3583.34		

** ($P < 0.01$) NS - Not significant

Erythrocyte Glutathione (GSH)

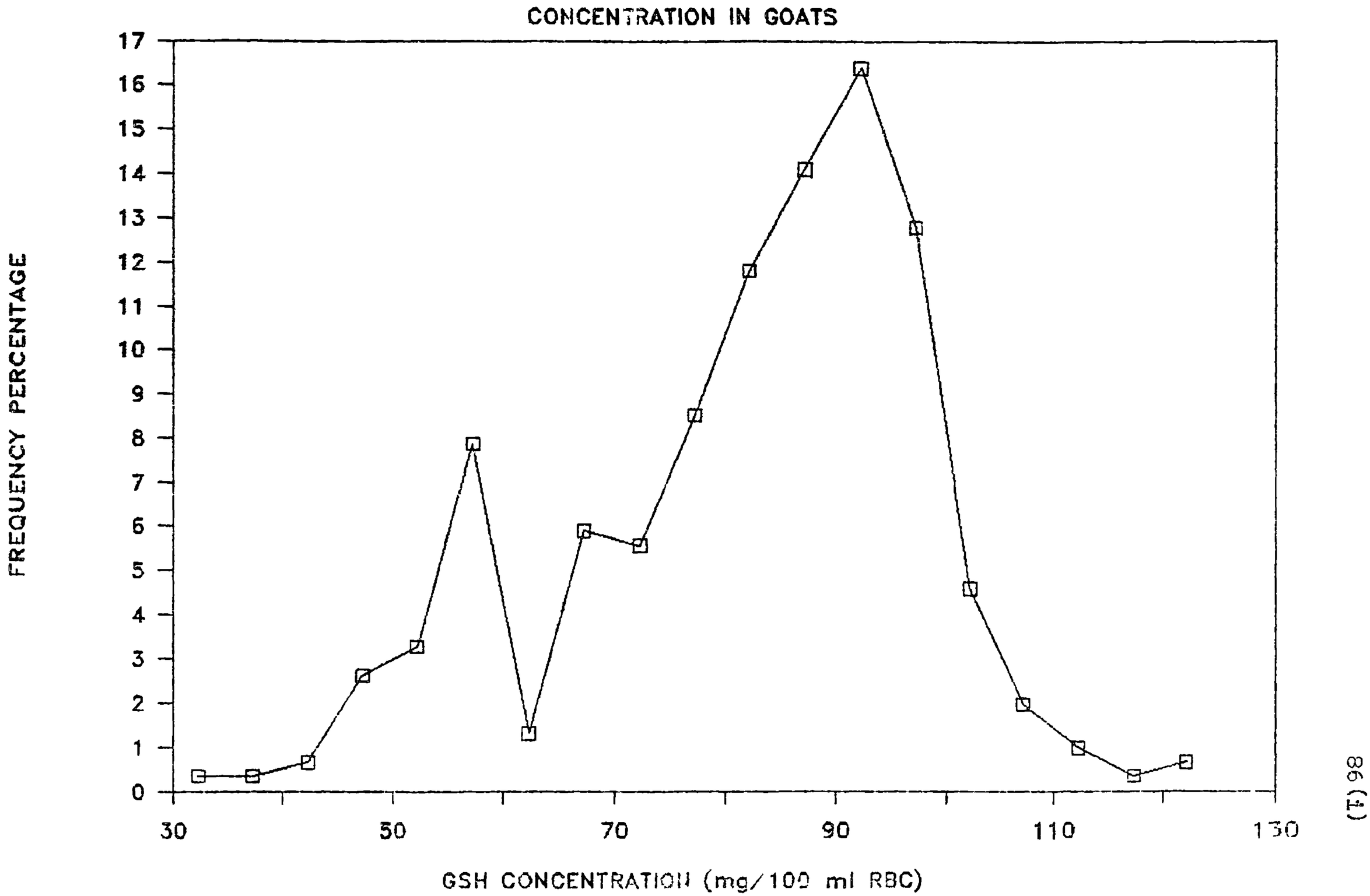
Distribution of GSH types.

The concentration of GSH (mg/100 ml red blood cell) was estimated in 305 adult goats belonging to Malabari (MM) and its exotic crossbreds viz. 95 Saanen x Malabari (SM) and 165 Alpine x Malabari (AM) to find out the existence, if any, of polymorphism at this locus.

The level of GSH varied from 33.5 to 121.4 mg/100 ml red blood cells and the distribution of GSH level in the population revealed a bimodality (Fig.10). However, there was no clear cut demarcation between the two GSH types. The tail ends of the two distribution were found to be merging. On the basis of classification made by Agar *et al.* (1974) goats with GSH level below 60 mg/100 ml red blood cells were classified as GSH-low type while those having 60 mg/100 ml red blood cells and above were classified as GSH-high type.

The mean GSH level in different genetic groups are presented in table 22. The mean GSH concentration was 74.95±2.48 in MM, 79.24±1.58 in SM and 86.03±1.19 mg/100 ml red blood cells in AM. In the pooled population, the mean GSH concentration was 82.28±0.93 mg/100 ml red blood cells.

FIG.10 FREQUENCY DISTRIBUTION OF GSH



(F) 98

Table 22. Mean, standard error (SE) and coefficient of variation (CV) of GSH concentration in Malabari goats and their exotic crossbreds

Genetic group	No.of animals	Mean GSH level (mg/100 ml RBC)	S.E.	C.V.%
Malabari	45	74.95^{a}	2.48	22.21
Saanen x Malabari	95	79.24^{ab}	1.58	19.63
Alpine x Malabari	165	86.03^{b}	1.19	17.80
Pooled population	305	82.28	0.93	19.71

Mean values with different superscript differ significantly. ($P < 0.01$)

Analysis of variance table (Table 23) shows that the mean GSH level in different genetic groups differ significantly ($P < 0.01$). Pairwise comparison of the mean GSH concentration revealed that the significant difference exists between MM and AM. The mean value of SM did not differ significantly from those of MM or AM.

The number and percentage of goats in each GSH type are given in table 24. In the pooled population the percentage of GSH-high type and GSH-low type animals was 85.26 and 14.74 respectively. The percentage of GSH-high types in different genetic groups was 75.56 in MM, 85.26 in SM and 88.48 in AM and that of GSH-low type was 24.44, 14.74 and 11.52 respectively in the three genetic groups. The diagrammatic representation of the frequency of GSH phenotypes are given in Fig.11.

Inheritance of GSH type.

The results of the mating of goats with different GSH types are presented in table 25. GSH-high x GSH-low matings produced GSH-high and GSH-low offspring. Of the 29 offsprings born out of the above mating 24 were of GSH-high type and five were of GSH-low type. In the mating between GSH-high x GSH-low and GSH-low x GSH-high types the offspring consisted of both GSH-high and GSH-low types.

Table 23. Analysis of variance of GSH level in different genetic groups of goats

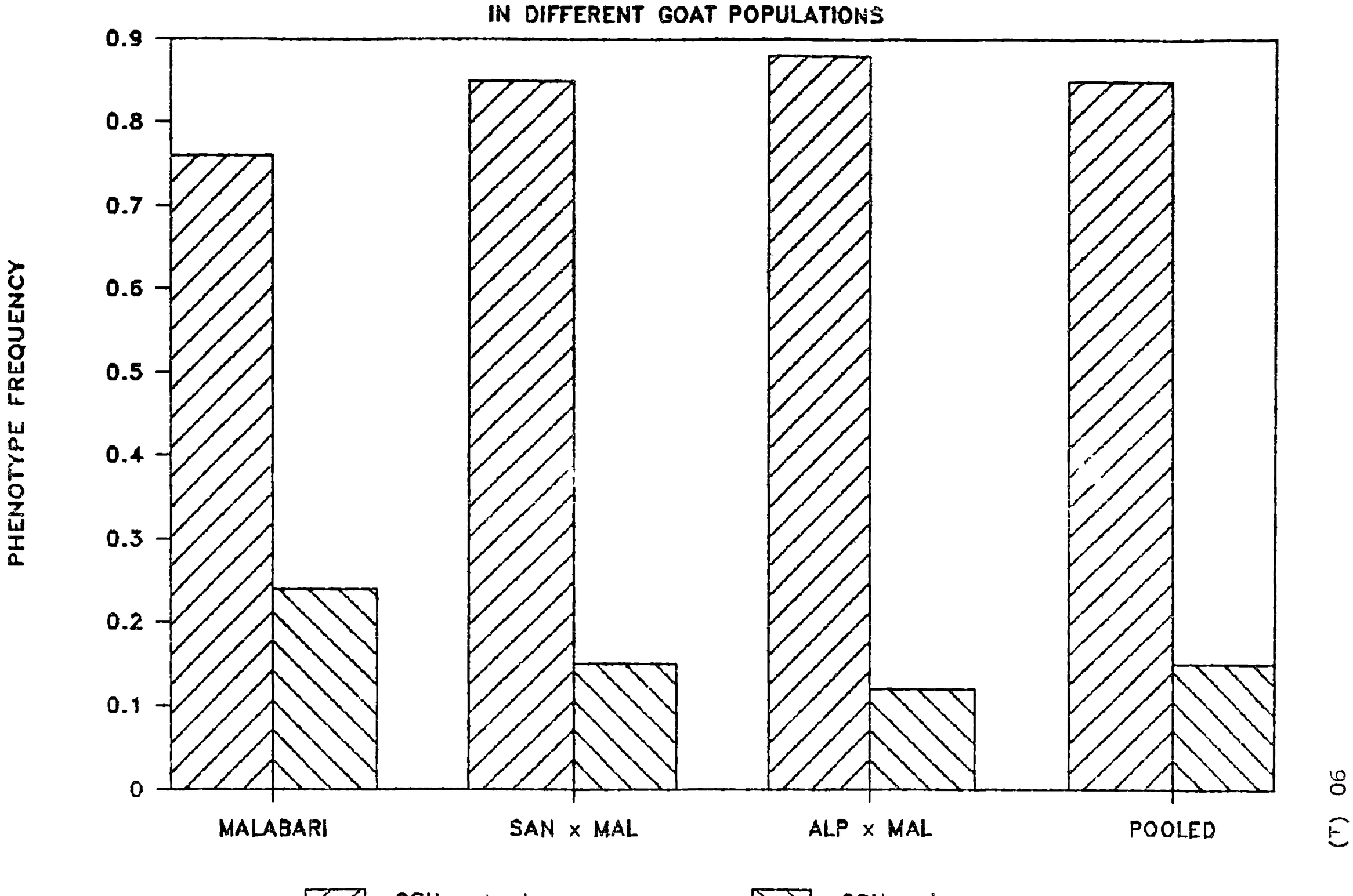
Source	df	SS	MS	F
Between genetic groups	2	5943.00	2971.50	11.36**
Error	302	73595.15	243.69	
Total	304	79538.15		

** ($P < 0.01$)

Table 24. Distribution of GSH and the gene frequencies of GSH^H and GSH^h in Malabari goats and their exotic crossbreds

Genetic group	No.of animals	No.of animals		Percentage of animals		Gene frequency	
		GSH-high	GSH-low	GSH-high	GSH-low	GSH^H	GSH^h
Malabari	45	34	11	75.56	24.44	0.51	0.49
Saanen x Malabari	95	81	14	85.26	14.74	0.62	0.38
Alpine x Malabari	165	146	19	88.48	11.52	0.66	0.34
Pooled population	305	261	44	85.26	14.74	0.62	0.38

FIG-11. PHENOTYPE FREQUENCIES OF GSH TYPES



(T) 06

Table 25. Segregation of GSH phenotype from various mating types in goats

Type of mating and number	No.of progeny	Progeny						χ^2 df=1
		Observed No.		Expected ratio		Expected No.		
		GSH-high	GSH-low	GSH-high	GSH-low	GSH-high	GSH-low	
GSH-high x GSH-high (4) (25)	29	29	5	0.92 :	0.08	26.68	2.32	3.37 NS
GSH-high x GSH-low (2) (5)	6	5	1	0.72 :	0.28	4.32	1.18	0.38 NS
GSH-low x GSH-high (2) (6)	8	7	1	0.72 :	0.28	5.76	2.24	0.95 NS
Total	14	12	2	0.72 :	0.28	10.08	3.92	0.86 NS
GSH-low x GSH-high (1) (1)	1	-	1	0 :	1	-	1	0.00

NS - Not significant

The observed number of offspring from different matings did not differ significantly from that of the expected number.

Gene frequency of GSH allele.

The gene frequencies of GSH^H (controlling GSH-high type) and GSH^h (controlling GSH-low type) alleles are also presented in table 24. The frequencies of GSH^H and GSH^h alleles in the different genetic groups were 0.51 and 0.49 in MM, 0.62 and 0.38 in SM and 0.66 and 0.34 in AM. In the pooled population the frequencies of GSH^H and GSH^h alleles were 0.62 and 0.38 respectively. A diagrammatic representation of the GSH gene frequencies are given in Fig. 12.

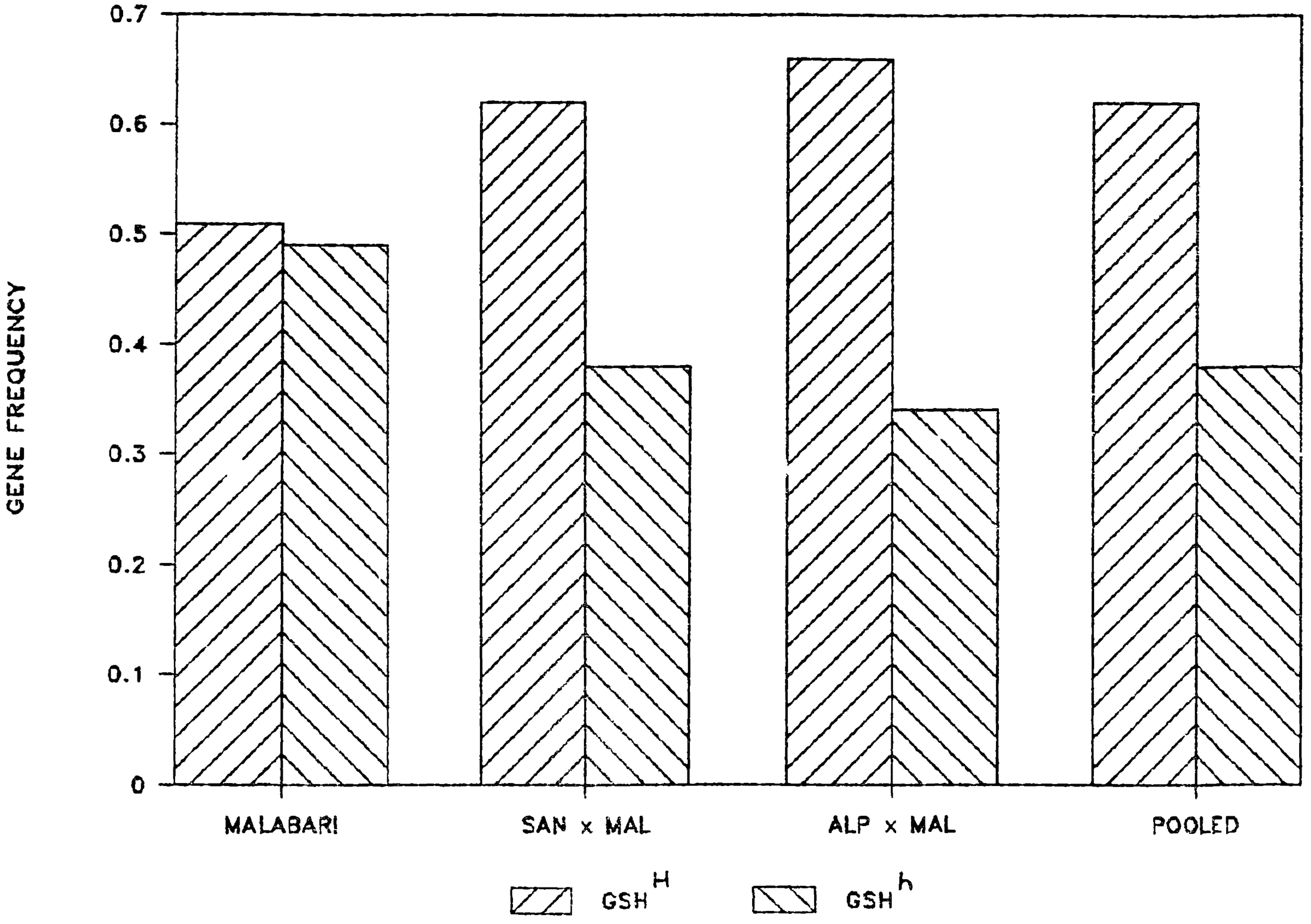
Comparison of the gene frequencies of GSH^H and GSH^h alleles in different genetic groups did not reveal any significant difference (Table 26).

GSH phenotypes in different generations.

The percentage of GSH phenotypes and frequency of GSH alleles in different generations within a genetic group are presented in table 27. It may be seen that the percentage of GSH-high type animals was 86.84 in F_2SM, 84.21 in F_3SM, 88.46 in F_2AM and 88.51 in F_3AM. The percentage

FIG–12. GSH GENE FREQUENCIES

IN DIFFERENT GOAT POPULATIONS



(T) 26 (F)

Table 26. Comparison of gene frequencies of GSH^H and GSH^h in Malabari goats and their exotic crossbreds

Allele	Genetic group			χ^2 df=2
	Malabari	Saanen x Malabari	Alpine x Malabari	
GSH^H	0.51	0.62	0.66	4.15 NS
GSH^h	0.49	0.38	0.34	4.15 NS

NS - Not significant

Table 27. Frequency distribution of GSH-high and GSH-low phenotypes and their gene frequencies in Malabari goats and their exotic crossbreds of two generations

Genetic group	Generation	Observed No.of GSH phenotypes		Phenotype percentage		Gene frequency	
		GSH-high	GSH-low	GSH-high	GSH-low	GSH^H	GSH^h
Malabari (45)	-	34 (45)	11	75.76	24.44	0.51	0.49
Saanen x Malabari (95)	Second (38)	33	5	86.84	13.16	0.64	0.36
	Third (57)	48	9	84.21	15.79	0.62	0.38
Alpine x Malabari (165)	Second (78)	69	9	88.46	11.54	0.66	0.34
	Third (87)	77	10	88.51	11.49	0.66	0.34
Pooled population	305	261	44	85.25	14.75	0.62	0.38

of GSH-low type animals was 13.16 in F_2SM, 15.79 in F_3SM, 11.54 in F_2AM and 11.49 in F_3AM.

The gene frequency of GSH^H allele was 0.64 in F_2SM, 0.62 in F_3SM, 0.66 in F_2AM and 0.66 in F_3AM, the difference among the groups were not significant (Table 28). The frequency of GSH^h allele was 0.36, 0.38, 0.34 and 0.34 in F_2SM, F_3SM, F_2AM and F_3AM respectively. The differences in the frequency of GSH^h allele among the groups were not significant.

<u>GSH concentration in high and low types</u>.

The mean values for GSH concentration in GSH-high and GSH-low type goats are presented in table 29. In the pooled population the mean GSH concentration in GSH-high type goats was 87.21±0.68. The mean GSH concentration in GSH-high type goats of different genetic groups was 82.46±1.90 in MM, 83.93±1.19 in SM and 90.11±0.91 in AM.

In the GSH-low type goats, the mean GSH concentration for the pooled population was 54.14±0.87. The mean GSH concentration for the different genetic groups was 51.73±1.92 in MM, 52.10±1.63 in SM and 54.72±0.67 in AM.

Table 28. Comparison of gene frequencies of GSH^H and GSH^h in Malabari goats and their exotic crossbreds of two generations

Allele	Genetic group				χ^2 df= 4
	Malabari	Saanen x Malabari		Alpine x Malabari	
		F_2	F_3	F_2	F_3	
GSH^H	0.51	0.64	0.62	0.66	0.66	3.50 NS
GSH^h	0.49	0.36	0.38	0.34	0.34	3.50 NS

NS - Not significant

Table 29. Mean, standard error (SE) and coefficient of variation (CV) of GSH concentration (mg/100 ml RBC) in GSH-high and GSH-low type goats

Genetic group	Number	GSH-high				GSH-low			
		No.of obs.	Mean	SE	CV %	No.of obs.	Mean	SE	CV %
Malabari	45	34	82.46[a]	1.90	13.44	11	51.73	1.92	12.33
Saanen x Malabari	95	81	83.93[a]	1.19	4.20	14	52.10	1.63	14.39
Alpine x Malabari	165	146	90.11[b]	0.91	12.14	19	54.72	0.67	5.35
Pooled population	305	261	87.21	0.68	12.53	44	54.14	0.87	11.12

Mean values with different superscript differ significantly ($P < 0.01$)

Analysis of variance of the GSH concentration (Table 30) in GSH-high type goats of different genetic groups revealed significant difference. Pairwise comparison showed that the mean GSH concentration of AM goats differ significantly from that of MM and SM. The difference in the mean values of MM and SM was not significant.

The mean concentration of GSH in GSH-low type goats of different genetic groups did not show any significant difference (Table 31).

GSH concentration and sex.

The mean GSH concentration (mg/100 ml red blood cells) of male and female goats within the genetic groups are presented in table 32. The mean concentration of GSH in males and females of GSH-high types was 88.03±0.73 and 81.92±2.06 in MM, 85.94±3.73 and 83.80±0.35 in SM and 91.20 and 90.10±0.91 in AM. The difference in the mean values of two sexes did not show any significant difference in any of the genetic groups.

The mean GSH concentration (mg/100 ml red blood cells) in males and females of GSH-low types in MM was 57.40±0.90 and 50.40±2.13. In SM, the females had a mean GSH concentration of 52.10±1.63. In AM, the mean GSH concentration was 55.30 and 54.69±0.70 in males and females

Table 30. Analysis of variance of GSH concentration in GSH-high type goats of Malabari and their exotic crossbreds

Source	df	SS	MS	F
Between genetic groups	2	2866.36	1433.18	16.38**
Error	258	22566.90	87.47	
Total	260	25433.26		

** ($P < 0.01$)

Table 31. Analysis of variance of GSH concentration in GSH-low type goats of Malabari and their exotic crossbreds.

Source	df	SS	MS	F
Between genetic groups	2	84.44	42.22	1.38 NS
Error	41	1251.09	26.62	
Total	43	1335.53		

NS - Not significant

Table 32. Mean, standard error (SE) and coefficient of variation (CV) of GSH concentration in male and female goats

Genetic group	Sex	GSH-high				GSH-low			
		No.of obs.	Mean	SE	CV %	No.of obs.	Mean	SE	CV %
Malabari	Male	3	88.03	0.73	1.43	2	57.40	0.90	2.21
	Female	31	81.92	2.06	14.60	9	50.40	2.13	12.70
	Pooled	34	82.46	1.90	13.44	11	51.73	1.92	12.33
Saanen x Malabari	Male	5	85.94	3.73	9.70	-	-	-	-
	Female	76	83.80	0.35	3.63	14	52.10	1.63	14.39
	Pooled	81	83.93	1.19	4.20	14	52.10	1.63	14.39
Alpine x Malabari	Male	1	91.20	-	-	1	55.30	-	-
	Female	145	90.10	0.91	12.19	18	54.69	0.70	5.46
	Pooled	146	90.11	0.91	12.14	19	54.72	0.67	5.35
Pooled population		261	87.21	0.68	12.53	44	53.14	0.87	11.12

respectively. The difference in the mean values of the two sexes in MM did not reveal any significant difference.

GSH concentration and generation.

The mean values for GSH concentration (mg/100 ml red blood cells) in goats belonging to different generations are presented in table 33. The mean GSH concentration in GSH-high type goat of different generation within genetic groups was 80.95±1.98 in F_2SM, 85.91±1.25 in F_3SM. The difference in mean values was significant. In AM crossbreds, the mean values were 89.86±1.23 in F_2AM and 90.32±1.79 in F_3AM, the differences being non significant.

The mean GSH concentration (mg/100 ml red blood cells) in GSH-low type goats of different generation was 53.03±2.70 in F_2SM, 51.41±2.00 in F_3SM, 54.77±1.11 in F_2AM and 54.67±0.79 in F_3AM. The differences in mean values between the generation within the genetic groups were not significant.

Effect of sire on GSH concentration.

It can be seen from the table 34 and 35 that the sire had significant effect in the concentration of GSH of their offspring in GSH-high type goats of SM ($P < 0.01$) and

Table 33. Mean, standard error (SE) and coefficient of variation (CV) of GSH concentration (mg/100 ml RBC) in GSH-high and GSH-low goats of two generations

Genetic group	Generation	GSH-high				GSH-low			
		No.	Mean	SE	CV %	No.	Mean	SE	CV %
Saanen x Malabari (95)	Second (38)	33	80.95[a]	1.98	13.84	5	53.03	2.70	11.41
	Third (57)	48	85.91[b]	1.25	10.06	9	51.41	2.00	11.67
	Pooled	81	83.93	1.19	11.97	14	52.10	1.63	14.05
Alpine x Malabari (165)	Second (78)	69	89.86	1.23	11.39	9	54.77	1.11	6.28
	Third	77	90.32	1.79	17.45	10	54.67	0.79	4.55
	Pooled	146	90.11	0.91	12.14	19	54.72	0.67	5.35

Mean values with different superscripts differ significantly ($P < 0.05$)

Table 34. Analysis of variance of between sire GSH concentration in GSH-high type goats of Malabari and their exotic crossbreds.

Genetic group	Source	df	SS	MS	F
Malabari	Between sire	4	193.88	48.77	0.33 NS
	Error	25	3653.74	146.15	
	Total	29	3847.62		
Saanen x Malabari	Between sire	6	27871.60	3981.60	50.28**
	Error	67	5306.05	79.19	
	Total	73	33177.65		
Alpine x Malabari	Between sire	10	2040.07	204.01	2.39 NS
	Error	117	9977.47	55.28	
	Total	127	12017.54		

NS - Not significant ** ($P < 0.01$)

Table 35. Analysis of variance of between sire GSH concentration in GSH-low type goats of Malabari and their exotic crossbreds

Genetic group	Source	df	SS	MS	F
Malabari	Between group	2	44.24	22.12	0.50 NS
	Error	7	312.52	44.65	
	Total	9	356.76		
Saanen x Malabari	Between group	3	72.11	24.09	0.26 NS
	Error	7	653.07	93.30	
	Total	10	725.18		
Alpine x Malabari	Beteen group	4	48.08	12.02	4.13 *
	Error	9	26.15	2.91	
	Total	13	74.23		

NS - Not significant * ($P < 0.05$)

GSH-low type goats of AM ($P < 0.05$). However, significant effect was not observed in GSH-high type goats of MM and AM and GSH-low type goats in MM and SM.

Frequency distribution of combination of haemoglobin potassium and Glutathione types.

The combination of haemoglobin, potassium and glutathione phenotypes and their frequencies are presented in table 36. AA LK GSH-high had the highest frequency in all the genetic groups with 0.49 in MM, 0.62 in SM and 0.63 in AM. The combination of AB HK GSH-low was not observed in any of the genetic groups, while AB LK GSH-low in MM and AM, AB HK GSH-high in MM and SM and AA HK GSH-low in MM were also not observed during the present study.

Genetic association among biochemical variants

Haemoglobin and potassium.

From the results detailed in tables 37 and 38, it is seen that no genetic association exists between haemoglobin and potassium.

Table 37 shows the observed and expected number of HK and LK animals in different haemoglobin types. The

Table 36. Frequency distribution of combinations of haemoglobin, potassium and glutathione types in Malabari goats and their exotic crossbreds

Genetic group%	Number of animals	AA LK GSH- high	AA HK GSH- high	AA LK GSH- low	AA HK GSH- low	AB LK GSH- high	AB HK GSH- high	AB LK GSH- low	AB HK GSH- low
Malabari	45	0.49 (22)	0.22 (10)	0.25 (11)	-	0.04 (2)	-	-	-
Saanen x Malabari	95	0.62 (59)	0.20 (19)	0.09 (8)	0.05 (5)	0.03 (3)	-	0.01 (1)	-
Alpine x Malabari	165	0.63 (105)	0.18 (30)	0.10 (16)	0.02 (3)	0.04 (6)	0.03 (5)	-	-
Pooled population	305	0.61 (186)	0.19 (59)	0.11 (35)	10.31 (8)	0.04 (11)	0.02 (5)	0.003 (1)	-

Number in parenthesis indicates number of animals

Table 37. Observed and expected number of LK and HK type goats in different haemoglobin types.

Genetic groups	Haemoglobin phenotypes		Potassium phenotypes HK	Potassium phenotypes LK	Total	χ^2 df=1
Malabari	AA	Obs.	10	33	43	0.03 NS
		Exp.	9.50	33.50		
	AB	Obs.	-	2	2	0.56 NS
		Exp.	0.44	1.56		
Saanen x Malabari	AA	Obs.	24	67	91	0.09 NS
		Exp.	22.75	68.25		
	AB	Obs.	-	4	4	1.33 NS
		Exp.	1.0	3.0		
Alpine x Malabari	AA	Obs.	35	119	154	0.01 NS
		Exp.	35.48	118.52		
	AB	Obs.	3	8	11	0.11 NS
		Exp.	2.53	8.47		

NS - Not significant

value did not reach the level of significance thereby establishing a good agreement between observed and expected numbers.

Table 38 shows the observed and expected number of goats with HbAA, HbAB and HbBB phenotypes in different potassium phenotypes. It is seen that the observed number of animals with different haemoglobin types in LK and HK types did not differ significantly.

Haemoglobin and GSH.

Genetic association could not be observed between haemoglobin and GSH (Tables 39 and 40).

Assuming that the haemoglobin and GSH are not associated the number of goats in GSH-high and GSH-low types were calculated based on the gene frequencies in different haemoglobin types (Table 39). It is seen that a good agreement exists between the observed and expected number in different GSH types.

Table 40 shows the expected number of goats with HbAA, HbAB and HbBB phenotypes in different GSH phenotypes. When these were compared with the observed numbers, the χ^2 test did not reveal any significance.

Table 38. Observed and expected number of HbAA, HbAB and HbBB type goats in different potassium types.

Genetic groups	Potassium phenotype		Haemoglobin phenotypes HbAA	HbAB	HbBB	Total	χ^2 df=2
Malabari	LK	Obs.	33	2	-	35	0.30 NS
		Exp.	33.61	1.38	0.01		
	HK	Obs.	10	-	-	10	0.42 NS
		Exp.	9.60	0.40	-		
Saanen x Malabari	LK	Obs.	67	4	-	71	0.59 NS
		Exp.	68.19	2.78	0.03		
	HK	Obs.	24	-	-	24	0.99 NS
		Exp.	23.05	0.94	0.01		
Alpine x Malabari	LK	Obs.	119	8	-	127	0.16 NS
		Exp.	119.50	7.39	0.11		
	HK	Obs.	35	3	-	38	0.34 NS
		Exp.	35.75	2.21	0.04		

NS - Not significant

Table 39. Observed and expected number of GSH-high and GSH-low type goats in different haemoglobin types

Genetic groups	Haemoglobin phenotypes		GSH phenotypes			χ^2 df=1
			GSH-high	GSH-low	Total	
Malabari	AA	Obs.	32	11	43	0.06 NS
		Exp.	32.68	10.32		
	AB	Obs.	2	-	2	0.63 NS
		Exp.	1.52	0.48		
Saanen x Malabari	AA	Obs.	78	13	91	0.001 NS
		Exp.	77.86	13.14		
	AB	Obs.	3	1	4	0.36 NS
		Exp.	3.42	0.58		
Alpine x Malabari	AA	Obs.	135	19	154	0.09 NS
		Exp.	136.2	17.80		
	AB	Obs.	11	-	11	1.44 NS
		Exp.	9.73	1.27		

NS - Not significant

Table 40. Observed and expected number of HbAA, HbAB and HbBB type goats in different GSH types

Genetic groups	GSH phenotypes		Haemoglobin types HbAA	HbAB	HbBB	Total	χ^2 df= 2
Malabari	GSH-high	Obs.	32	2	-	34	0.35 NS
		Exp.	32.65	1.34	0.01		
	GSH-low	Obs.	11	-	-	11	0.45 NS
		Exp.	10.56	0.44			
Saanen x Malabari	GSH-high	Obs.	78	3	-	81	0.04 NS
		Exp.	77.79	3.18	0.03		
	GSH-low	Obs.	13	1	-	14	0.38 NS
		Exp.	13.45	0.55	-		
Alpine x Malabari	GSH-high	Obs.	135	11	-	146	0.91 NS
		Exp.	137.37	8.50	0.13		
	GSH-low	Obs.	19	-	-	19	1.20 NS
		Exp.	17.88	1.10	0.02		

NS - Not significant

Potassium and GSH

It is seen that the potassium and GSH are not genetically associated (Tables 41 and 42).

Table 41 shows the expected number of GSH-high and GSH-low types in different potassium phenotypes. Table 42 shows the observed and expected number of LK and HK type goats in different GSH types. In both cases, it is seen that the observed numbers did not deviate significantly from the expected numbers.

Haemoglobin type and blood constituents

The mean, standard error and coefficient of variation of packed cell volume per cent(PCV per cent), potassium and glutathione concentration in different haemoglobin phenotypes are presented in table 43. The mean PCV per cent in HbAA and HbAB type goats were 30.86±1.06 and 32.50±1.50 in MM, 30.55±0.34 and 32.50±0.87 in SM and 30.69±0.17 and 29.36±0.94 in AM. The difference were not significant.

The mean potassium concentration (meq/1) in HbAA and HbAB type goats were 17.17±1.17 and12.56±0.77 in MM, 16.13±0.81 and 12.18±1.30 in SM and 15.85±0.60 and 16.88±2.45 in AM, the differences being non significant.

Table 41. Observed and expected number of GSH-high and GSH-low type goats in different potassium phenotypes.

Genetic group	Potassium phenotypes		Glutathione phenotype			χ^2 df=1
			GSH-high	GSH-low	Total	
Malabari	LK	Obs.	25	10	35	0.40 NS
		Exp.	26.6	8.40		
	HK	Obs.	9	1	10	1.07 NS
		Exp.	7.60	2.40		
Saanen x Malabari	LK	Obs.	63	8	71	0.58 NS
		Exp.	60.75	10.25		
	HK	Obs.	18	6	24	2.16 NS
		Exp.	20.53	3.47		
Alpine x Malabari	LK	Obs.	111	16	127	0.13 NS
		Exp.	112.32	14.68		
	HK	Obs.	35	3	38	0.50 NS
		Exp.	33.61	4.39		

NS - Not significant

Table 42. Observed and expected number of LK and HK type goats in different GSH phenotypes

Genetic Group	GSH phenotype		Potassium phenotype			χ^2 df=1
			LK	HK	Total	
Malabari	GSH-high	Obs.	25	9	34	0.38 NS
		Exp.	26.49	7.51		
	GSH-low	Obs.	10	1	11	1.08 NS
		Exp.	8.57	2.43		
Saanen x Malabari	GSH-high	Obs.	63	18	81	0.33 NS
		Exp.	60.75	20.25		
	GSH-low	Obs.	8	6	14	2.39 NS
		Exp.	10.50	3.50		
Alpine x Malabari	GSH-high	Obs.	111	35	146	0.07 NS
		Exp.	112.36	33.64		
	GSH-low	Obs.	16	3	19	0.57 NS
		Exp.	14.62	4.38		

NS - Not significant

Table 43. Influence of haemoglobin types on per cent packed cell volume and concentration of potassium and glutathione in Malabari goats and their exotic crossbreds.

Genetic Group	Hb type		PCV (Per cent)			Potassium (meq/l)			GSH (mg/100 ml RBC)		
			Mean	SE	CV %	Mean	SE	CV %	Mean	SE	CV %
Malabari (45)	AA	(43)	30.86	1.06	22.54	17.17	1.17	44.68	75.11	2.59	22.60
	AB	(2)	32.50	1.50	6.52	12.56	0.77	8.60	71.60	5.21	10.27
Saanen x Malabari (95)	AA	(91)	30.55	0.34	10.49	16.13	0.81	48.10	79.06	1.61	19.43
	AB	(4)	32.50	0.87	5.32	12.18	1.30	21.26	70.58	7.52	21.30
Alpine x Malabari (165)	AA	(154)	30.69	0.17	6.97	15.85	0.60	47.13	85.92	1.63	23.60
	AB	(11)	29.36	0.94	10.59	16.88	2.45	48.10	87.62	2.15	8.16

Number in parenthesis indicates number of animals

The glutathione (GSH) concentration (mg/100 ml red blood cells) in Hb^{A} type goats was 75.11_2.59 in MM, 79.06±1.61 in SM and 85.92±1.63 in AM and that of HbAB was 71.60±5.21 in MM, 70.58±7.52 in SM and 87.62±2.15 in AM. The differences in GSH concentration between HbAA and HbAB goats were not significant in any of the genetic groups.

Potassium level in different haemoglobin types within potassium types.

The mean potassium concentration in different haemoglobin types within LK and HK type goats are presented in table 44. In LK type goats of Malabari, the HbAA and HbAB animals had a mean potassium concentration of 13.83±0.44 and 12.56±0.77. The same values were 11.82±0.39 and 12.18±1.28 in SM and 12.24±0.29 and 12.31±0.66 in AM. The differences in the potassium concentration between the HbAA and HbAB goats of LK type were not significant in any of the genetic groups. Among the HK type goats, comparison could be made only in AM goats and it was found to be non significant.

GSH level in different haemoglobin types within GSH types.

The mean GSH concentration in HbAA and HbAB goats of GSH-high and GSH-low types are presented in table 45. In GSH-high type goats, the mean GSH concentration of 83.19±5.66 and 70.85±4.45 (in MM), 84.25±1.11 and 75.33±8.23 (in SM)

Table 44. Potassium level in different haemoglobin types within potassium types (meq/l)

Genetic group	Haemoglobin types		Potassium phenotypes			
			LK		HK	
			Mean	SE	Mean	SE
Malabari (45)	HbAA	(43)	13.83 (33)	0.44	22.20 (10)	1.62
	HbAB	(2)	12.56 (2)	0.77	-	
Saanen x Malabari (95)	HbAA	(91)	11.82 (67)	0.39	28.16 (24)	0.73
	HbAB	(4)	12.18 (4)	1.28	-	
Alpine x Malabari (165)	HbAA	(154)	12.24 (119)	0.29	28.11 (35)	0.68
	HbAB	(11)	12.31 (8)	0.66	20.06 (3)	1.97

Number in parenthesis indicates number of animals

Table 45. GSH level in different haemoglobin types within GSH types
(GSH mg/100 ml RBC)

Genetic group	Haemoglobin types	GSH phenotypes			
		GSH-high		GSH-low	
		Mean	SE	Mean	SE
Malabari (45)	HbAA (43)	83.19 (32)	5.66	51.73 (11)	1.92
	HbAB (2)	70.85 (2)	4.45	-	
Saanen x Malabari (95)	HbAA (91)	84.25 (78)	1.11	51.78 (13)	1.72
	HbAB (4)	75.33 (3)	8.23	56.30 (1)	
Alpine x Malabari (165)	HbAA (154)	90.30 (135)	0.96	54.72 (19)	0.67
	HbAB (11)	87.62 (11)	2.15	-	

Number in parenthesis indicates number of animals

and 90.30±0.96 and 87.62±2.15 (in AM) obtained for HbAA and HbAB goats were found to be non significant. The comparison could not be made in GSH-low type animals as number in certain group was negligible or absent.

Potassium types and blood constituents

The per cent packed cell volume (PCV per cent) and GSH concentration in different potassium types are presented in table 46. The mean PCV in LK and HK type goats were 31.97±0.31 and 27.08±0.51 in MM and 31.83±0.28 and 27.08±0.51 in SM and 31.19±0.16 and 28.63±0.38 in AM. The differences in the mean values of PCV between the LK and HK type goats were found to be significant ($P < 0.01$) in all the genetic groups.

The mean GSH concentration (mg/100 ml red blood cells) in different potassium types were 70.57±2.72 and 90.29±1.90 in LK and HK types respectively of MM, 79.49±1.79 and 76.38±3.33 in LK and HK types respectively of SM and 85.28±1.36 and 88.52±2.45 respectively in LK and HK type goats of AM. However, significant difference was observed only in MM goats ($P < 0.01$).

Table 46. Influence of potassium types on per cent packed cell volume and concentration of glutathione in Malabari and their exotic crossbreds

Genetic group	Potassium type	PCV (per cent)		GSH (mg/100 ml RBC)	
		Mean	SE	Mean	SE
Malabari (45)	LK (35)	31.97	0.31	70.57	2.72
	HK (10)	27.08	0.51	90.29	1.90
Saanen x Malabari (95)	LK (71)	31.83	0.28	79.49	1.79
	HK (24)	27.08	0.51	76.38	3.33
Alpine x Malabari (165)	LK (127)	31.19	0.16	85.28	1.36
	HK (38)	28.63	0.38	88.52	2.45

Number in parenthesis indicates number of animals.

Potassium types and GSH concentration within GSH types.

The GSH concentration in GSH-high and GSH-low type goats of different potassium types are presented in table 47.

The GSH concentration in GSH-high type goats of LK and HK phenotypes was 79.53±2.19 and 90.63±2.21 in MM, 83.81±0.44 and 84.34±2.31 in SM and 89.73±0.99 and 91.30±2.05 in AM. Significant difference was observed in MM only. The GSH concentration in GSH-low types of LK and HK goats was 51.38±1.99 and 55.20 in MM, 51.80±3.51 and 52.50±1.88 in SM and 54.46±0.89 and 56.10±0.57 in AM, the difference being non significant.

Glutathione type and blood constituents

The mean and standard error of packed cell volume (per cent) and concentration of potassium (meq/l) in different GSH phenotypes are presented in table 48. The mean packed cell volume in GSH-high and GSH-low type goats was 30.18±0.48 and 33.00±0.53 in MM, 30.78±0.35 and 29.87±0.83 in SM and 30.59±0.19 and 30.68±0.45 in AM. In all the genetic groups, the difference in packed cell volume between the GSH-high and GSH-low goats was not statistically significant.

Table 47. GSH level in different potassium types within GSH types (GSH mg/100 ml RBC)

Genetic group	Potassium types		GSH phenotypes			
			GSH-high		GSH-low	
			Mean	SE	Mean	SE
Malabari (45)	LK	(35)	79.53[a] (25)	2.19	51.38 (10)	1.99
	HK	(10)	90.63[b] (9)	2.21	55.20 (1)	
Saanen x Malabari (95)	LK	(71)	83.81 (63)	0.44	51.80 (8)	3.51
	HK	(24)	84.34 (18)	2.31	52.50 (6)	1.88
Alpine x Malabari (165)	LK	(127)	89.73 (111)	0.99	54.46 (16)	0.89
	HK	(38)	91.30 (35)	2.05	56.10 (3)	0.57

Mean values with different superscripts differ significantly ($P < 0.01$)

Number in parenthesis indicates number of animals

Table 48. Influence of glutathione type on per cent packed cell volume and concentration of potassium in Malabari and their exotic crossbreds

Genetic group	Glutathione type		PCV (per cent) Mean	PCV (per cent) Se	Potassium (meq/l whole blood) Mean	Potassium (meq/l whole blood) SE
Malabari (45)	GSH-high	(34)	30.18[a]	0.48	18.01	1.28
	GSH-low	(11)	33.00[b]	0.53	13.75	0.73
Saanen x Malabari (95)	GSH-high	(81)	30.78	0.35	15.49	0.83
	GSH-low	(14)	29.87	0.83	18.49	2.26
Alpine x Malabari (165)	GSH-high	(146)	30.59	0.19	16.00	0.62
	GSH-low	(19)	30.68	0.45	15.22	1.60

Mean values with different superscript differ significantly ($P < 0.01$)

Number in parenthesis indicate number of animals

The concentration of potassium (meq/l) in whole blood was 18.01±1.28 and 13.75±0.73 in GSH-high and GSH-low goats of MM, 15.49±0.83 and 18.49±2.26 in GSH-high and GSH-low goats of SM and 16.00±0.62 and 15.22±1.60 in GSH-high and GSH-low goats of AM. The difference between the GSH-high and GSH-low animals was not significant.

Association of biochemical variants with economic traits

Haemoglobin type, body weight and production traits.

The mean, standard error and coefficient of variation of body weights at birth, three months, six months, nine months, one year and at first kidding, first lactation milk yield and first lactation length in HbAA and HbAB type goats of Malabari (MM), Saanen-Malabari (SM) and Alpine-Malabari (AM) are presented in tables 49, 50 and 51. respectively. In MM, significant difference was observed between the mean body weight (kg) at one year. The HbAA type goats had significantly ($P < 0.05$) higher (16.95±0.69) body weight at one year to that of HbAB animals (13.00±0.35). In SM, the HbAA animals had significantly ($P < 0.05$) higher body weight at nine months (15.24±0.31) to that of HbAA

Table 49. Mean, standard error (SE) and coefficient of variation (CV) of body weight in HbAA and HbAB type Malabari goats.

Trait	HbAA				HbAB				t value
	No.	Mean	SE	CV %	No.	Mean	SE	CV %	
Birth weight (kg)	43	1.77	0.07	27.12	2	1.75	0.18	14.28	0.06 NS
Body weight at 3 months (kg)	43	5.57	0.18	20.65	2	5.25	0.04	0.95	0.38 NS
Body weight at 6 months age (kg)	43	9.28	0.33	23.49	2	8.00	0.72	12.5	0.81 NS
Body weight at 9 months (kg)	43	12.94	0.40	20.56	2	10.25	0.18	2.43	1.40 NS
Body weight at 1 year (kg)	43	16.95	0.69	26.49	2	13.00	0.35	3.85	2.52 *

NS - Not significant * ($P < 0.05$)

Table 50. Mean, standard error (SE) and coefficient of variation (CV) of body weight, first lactation yield and first lactation length in HbAA and HbAB type Saanen x Malabari goats.

Trait	HbAA				HbAB				t value
	No.	Mean	SE	CV %	No.	Mean	SE	CV %	
Birth weight (kg)	91	1.93	0.02	10.36	4	1.78	0.19	21.96	1.37 NS
Body weight at 3 months (kg)	91	5.98	0.18	28.34	4	5.93	0.29	9.72	0.05 NS
Body weight at 6 months (kg)	91	10.48	0.28	25.44	4	9.13	0.37	8.10	1.00 NS
Body weight at 9 months a(kg)	91	15.24	0.31	19.52	4	11.88	0.91	15.29	2.20 *
Body weight at 1 year (kg)	90	19.38	0.39	18.88	4	16.25	1.81	22.24	1.64 NS
Weight at first kidding (kg)	37	26.02	0.76	17.95	2	30.55	3.15	14.57	1.31 NS
First lactation yield (kg)	30	81.86	11.73	78.51	2	112.40	3.15	15.27	0.63 NS
First lactation length (days)	30	171.5	9.05	28.90	2	173.5	18.73	15.27	0.05 NS

NS - Not significant * ($P < 0.05$)

Table 51. Mean, standard error (SE) and coefficient of variation (CV) of body weight, first lactation yield and first lactation length in HbAA and HbAB type Alpine x Malabari goats.

Traits	HbAA				HbAB				t value
	No.	Mean	SE	CV %	No.	Mean	SE	CV %	
Birth weight (kg)	150	1.72	0.47	3.85	9	1.79	0.09	15.08	0.04 NS
Body weight at 3 months (kg)	150	5.93	0.10	21.42	9	5.52	0.31	16.66	0.95 NS
Body weight at 6 months (kg)	150	10.20	0.18	22.11	9	9.18	0.48	15.62	1.32 NS
Body weight at 9 months (kg)	150	13.78	0.23	20.03	9	11.45	0.57	14.80	2.45 *
Body weight at 1 year (kg)	150	17.84	0.25	17.08	9	14.93	0.85	17.17	2.77 **
Weight at first kidding (kg)	56	24.67	0.64	19.48	3	23.00	0.47	3.55	0.60 NS
First lactation yield (kg)	38	65.18	7.35	69.51	3	61.30	12.38	34.98	0.70 NS
First lactation length (days)	38	158.66	12.47	48.46	3	164.00	29.39	31.04	0.24 NS

NS - Not significant * ($P < 0.05$) ** ($P < 0.01$)

animals (11.88±0.91). In AM, a significant difference in the body weight was observed between the HbAA and HbAB animals at nine months and one year. The HbAA animals had body weight of 13.78±0.23 and 17.84±0.25 at nine months and one year respectively and the same for HbAB animals were 11.45±0.57 and 14.93±0.85 at nine months and one year respectively. Body weight at birth, three months, six months and at kidding, first lactation yield and first lactation length was not influenced by the haemoglobin types in any of the genetic groups presently studied.

Potassium type, body weight and production traits.

The mean, standard error and coefficient of variation of body weight at birth, three months, six months, nine months, one year and at first kidding, first lactation yield and first lactation length in LK and HK type goats of MM, SM and AM are presented in tables 52, 53 and 54 respectively. It can be seen that the difference in mean values for the above economic traits between the LK and HK animals were not significant in any of the genetic groups studied.

Glutathione type, body weight and production traits.

The mean, standard error and coefficient of variation of body weights and production traits in GSH-high and GSH-low type goats of MM, SM and AM are presented in tables 55,56 and 57 respectively. It can be seen that in MM, the

Table 52. Mean, standard error (SE) and coefficient of variation (CV) of body weights, first lactation yield and first lactation length in Low potassium (LK) and high potassium (HK) type Malabari goats.

Traits	LK				HK				t value
	No.	Mean	SE	CV %	No.	Mean	SE	CV %	
Birth weight (kg)	35	1.79	0.08	27.37	10	1.68	0.13	24.40	0.70 NS
Body weight at 3 months (kg)	35	5.59	0.19	20.04	10	5.43	0.38	22.29	0.38 NS
Body weight at 6 months (kg)	35	9.30	0.38	24.19	10	8.95	0.59	21.01	0.49 NS
Body weight at 9 months (kg)	35	12.87	0.47	21.75	10	12.67	0.70	17.37	0.24 NS
Body weight at 1 year (kg)	35	16.70	0.61	21.62	10	17.04	1.01	18.72	0.29 NS
Weight at first kidding (kg)	9	22.17	1.67	22.60	4	22.25	3.63	32.58	0.02 NS
First lactation yield (kg)	9	61.60	11.27	54.90	4	70.44	20.75	58.90	0.37 NS
First lactation length (days)	9	172.67	16.48	28.64	4	166.00	27.19	32.75	0.21 NS

NS - Not significant

Table 53. Mean, standard error (SE) and coefficient of variation (CV) of body weight, first lactation yield and first lactation length in low potassium (LK) and high potassium (HK) type Saanen x Malabari goats

Trait	LK				HK				t value
	No.	Mean	SE	CV %	No.	Mean	SE	CV %	
Birth weight (kg)	71	1.86	0.05	24.19	24	1.83	0.08	22.40	0.33 NS
Body weight at 3 months (kg)	71	6.13	0.13	18.27	24	5.55	0.21	18.38	1.34 NS
Body weight at 6 months (kg)	71	10.64	0.20	16.07	24	9.81	0.42	20.90	1.78 NS
Body weight at 9 months (kg)	71	15.36	0.35	19.08	24	14.37	0.66	22.34	1.33 NS
Body weight at 1 year (kg)	70	19.56	0.35	15.24	24	18.34	0.70	18.70	1.56 NS
Weight at first kidding (kg)	33	26.51	0.87	18.94	6	24.83	1.21	11.96	1.12 NS
First lactation yield (kg)	27	96.05	9.12	46.27	5	85.98	19.80	51.50	0.46 NS
First lactation length (days)	27	171.78	9.94	30.07	5	170.8	12.85	16.82	0.06 NS

NS - Not significant

Table 54. Mean, standard error (SE) and coefficient of variation (CV) of body weight, first lactation yield and first lactation length in low potassium (LK) and high potassium (HK) type Alpine x Malabari goats.

Trait	LK				HK				t value
	No.	Mean	SE	CV %	No.	Mean	SE	CV %	
Birth weight (kg)	122	1.69	0.04	28.40	37	1.84	0.07	21.74	1.83 NS
Body weight at 3 months (kg)	122	5.86	0.12	22.01	37	6.06	0.19	18.81	0.92 NS
Body weight at 6 months (kg)	122	10.00	0.20	22.30	37	10.61	0.36	20.64	1.49 NS
Body weight at 9 months (kg)	122	13.49	0.23	19.13	37	14.17	0.54	23.22	1.16 NS
Body weight at 1 year (kg)	122	17.73	0.27	16.58	37	17.51	0.59	20.50	0.34 NS
Weight at first kidding (kg)	43	24.28	0.61	16.55	16	25.36	1.56	24.65	0.63 NS
First lactation yield (kg)	29	62.17	6.10	52.81	12	71.49	18.75	90.88	0.47 NS
First lactation length (days)	29	171.96	13.25	40.04	12	156.50	19.08	42.24	0.66 NS

NS - Not significant

Table 55. Mean, standard error (SE) and coefficient of variation (CV) of body weight, first lactation yield and first lactation length in GSH-high and GSH-low type Malabari goats

Trait	GSH-high				GSH-low				t value
	No.	Mean	SE	CV %	No.	Mean	SE	CV %	
Birth weight (kg)	34	1.77	0.08	26.55	11	1.74	0.15	28.74	0.18 NS
Body weight at 3 months (kg)	34	5.53	0.19	20.07	11	5.65	0.37	21.77	0.29 NS
Body weight at 6 months (kg)	34	9.09	0.29	18.70	11	9.63	0.96	33.23	0.69 NS
Body weight at 9 months (kg)	34	12.57	0.35	16.39	11	13.63	1.18	28.33	1.21 NS
Body weight at 1 year (kg)	34	16.42	0.51	18.03	11	17.86	1.42	26.37	1.17 NS
Weight at first kidding (kg)	11	21.14	1.53	24.03	2	28.00	4.25	14.30	1.59 NS
First lactation yield (kg)	11	57.94	9.90	56.71	2	99.40	25.60	36.32	1.49 NS
First lactation length (days)	11	165.55	16.27	32.64	2	198.50	1.06	0.75	0.79 NS

NS - Not significant

Table 56. Mean, standard error (SE) and coefficient of variation (CV) of body weights, first lactation yield and first lactation length in GSH-high and GSH-low type Saanen x Malabari goats

Trait	CSH-high				GSH-low				t value
	No.	Mean	SE	CV %	No.	Mean	SL	CV %	
Birth weight (kg)	80	1.88	0.05	22.34	15	1.72	0.13	29.65	1.13 NS
Body weight at 3 months (kg)	80	6.03	0.12	17.41	15	5.74	0.38	25.43	0.73 NS
Body weight at 6 months (kg)	80	10.48	0.20	17.18	15	10.17	0.52	19.76	0.54 NS
Body weight at 9 months (kg)	80	15.15	0.34	19.87	15	14.89	0.81	21.09	0.28 NS
Body weight at 1 year (kg)	79	19.19	0.36	16.52	15	19.56	0.77	15.24	0.43 NS
Weight at first kidding (kg)	35	25.43	0.76	17.32	6	30.75	1.95	14.57	2.68 *
First lactation yield (kg)	26	84.21	8.31	50.30	6	138.47	16.45	29.00	2.97 **
First lactation length (days)	26	165.08	10.19	31.48	6	200.00	-	-	1.58 NS

NS - Not significant * ($P < 0.05$) ** ($P < 0.01$)

Discussion

Table 57. Mean, standard error (SE, coefficient of variation (CV) of body weight, first lactation yield and first lactation length in GSH-high and GSH-low type Alpine x Malabari goats.

Trait	GSH-high				GSH-low				t value
	No.	Mean	SE	CV %	No.	Mean	SE	CV %	
Birth weight (kg)	140	1.74	0.04	27.01	19	1.62	0.09	23.46	1.22 NS
Body weight at 3 months (kg)	140	5.89	0.11	21.90	19	6.06	0.22	16.01	0.68 NS
Body weight at 6 months (kg)	140	10.11	0.23	27.50	19	10.38	0.44	18.20	0.59 NS
Body weight at 9 months (kg)	140	13.62	0.24	20.48	19	13.82	0.61	19.25	0.31 NS
Body weight at 1 year (kg)	140	17.72	0.27	17.72	19	17.41	0.65	16.31	0.44 NS
Weight at first kidding (kg)	53	24.91	0.66	19.39	6	21.67	1.04	11.81	2.62 *
First lactation yield (kg)	37	63.54	7.48	61.61	4	77.45	18.28	47.19	0.70 NS
First lactation length (days)	37	162.66	9.23	34.53	4	207.00	63.72	61.35	0.68 NS

NS - Not significant * ($P < 0.05$)

difference in the mean values between GSH-high and GSH-low were not significant for any of the traits studied. In SM, the goats with GSH low types had significantly ($P < 0.05$) higher weight at first kidding (30.75±1.95) to that of GSH high types (25.43±0.76). Similarly, GSH-low type goats had significantly ($P < 0.01$) higher first lactation yield of 138.97±16.45 kg to that of 84.21±8.31 of GSH-high types.

The body weight at any age was not significantly different between GSH-high and GSH-low types. In AM, the GSH-high and GSH-low animals did not show any significant difference in the body weight at any age, first lactation yield and first lactation length except the weight at first kidding. The GSH-high type goats had a mean weight at kidding of 24.91±0.66 kg which was significantly higher compared to that of 21.67±1.04 kg of GSH-low type goats.

DISCUSSION

Blood groups

Naturally occurring antibodies.

An attempt was made to find out the presence of naturally occurring antibodies in goats as in the case of 'J' in cattle. The search for natural antibodies in goats was fruitless. This finding is in agreement with the earlier report of Ricordeu (1981) in goats.

Blood group reagents.

Perusal of the few literature available on blood group studies in goats revealed that few blood group reagents were prepared by iso and heteroimmunization. Twelve blood group factors, designated as M1, M2, M3, M4, M5, M6, M7, M8, M9, M10, M11 and M12 were produced during the present study from the polyvalent goat sera obtained from Institute for Animal Breeding, Bern, Switzerland.

The number of animals positive for different blood group factors and the percentage frequencies of different blood group factors were exhibiting differences among the genetic groups. The blood group factors M4, M10 and M12 were not observed in Malabari goats, while both

Saanen x Malabari and Alpine x Malabari crossbreds exhibited all the blood group factors.

The gene frequencies of blood group factors among the three genetic groups showed difference. The frequencies of all the blood group factors were lower in Malabari when compared to that of Saanen x Malabari and Alpine x Malabari crossbreds.

The above observation may be due to the fact that the blood group reagents were produced by immunising the exotic goats and the exotic and Indian goats may be differing significantly in the frequencies of certain blood group alleles.

The findings made in the present study could not be compared due to the non-availability of reference sera.

Haemoglobin

Distribution of haemoglobin type.

In the Malabari breed of goats and its exotic crossbreds with Saanen and Alpine, an investigation of gene determined electromorphs of haemoglobin using horizontal starch gel electrophoresis revealed the presence of two haemoglobin types Hb^{A} and Hb^{B}. Though five different haemoglobin types (HbA, HbB, HbD, HbD Malta and HbE) have

been reported in adult goats by electrophoretic and chromatographic techniques (Huisman, 1970), Hb^D, Hb^D Malta and Hb^E were not observed during the present study. The structural studies on haemoglobin of adult goats showed that Hb^A and HbB are alpha chain variants whereas others occur in the beta chain. The most common is Hb^A which is a mixture of two chemically different species that differs in the alpha chains. The latter are products of two non allelic alpha globin genes ($^{I}\alpha$ and $^{II}\alpha$). The $^{I}\alpha$ and $^{II}\alpha$ chain ratio is approximately 3:1 (Adams et al., 1969). These two components ($^{I}\alpha_2^A\beta_2^A$ and $^{II}\alpha_2^A\beta_2^A$) of Hb were not separated by conventional starch gel electrophoresis even though they differ in four aminoacid residues (Huisman, 1970). But, Braend et al. (1987) reported that they can be distinguished by isoelectric focussing in immobiline polyacrylamide gel and also that the Hb^A type in Norwegian goats, characterised after starch gel electrophoresis, could be resolved into a number of haplotypes of which four (A_2, A_4, A_6 and A_8) behaved as if controlled by multiple alleles, of the β^A globin gene.

Out of the three possible phenotypes viz. HbAA, HbAB and HbBB, HbBB was not observed in the present study. The frequency of HbAA was higher in all the genetic groups.

These findings are in agreement with those reported earlier in Indian goats by Naik (1975), Goel and Nair (1976), Singh et al. (1977), Baruah and Bhat (1980) and Bhat (1986).

However, the existence of HbBB phenotype in a very low frequency was reported by Khanolker et al. (1963) in some Indian breeds of goats. The findings of Khanolker et al. (1963) seems to be erroneous, when the results obtained from 100 goats were tested using Hardy-Weinberg formula. Joshi et al. (1975) could also observe HbBB type in both Barbari and Jamnapari goats at 2.6 and 1.4 per cent respectively; but the methodology used was paper electrophoresis.

Non existence of polymorphism at haemoglobin locus has been reported in some Indian and exotic breeds of goat (Efremov and Braend, 1964; Watanabe et al., 1965; Tjankov, 1972; Odermatt, 1973; Kunz, 1974; Baruah and Bhat, 1980; Bhat et al., 1983; Tucker et al., 1983; Bhat, 1986; Bhat, 1987). Perusal of the literature available on the haemoglobin polymorphism in Indian as well as exotic goat breeds showed that HbAA is the predominant type in almost all the goat breeds.

Inheritance of haemoglobin type.

Mating between HbAA x HbAB goats produced both HbAA and HbAB offspring. Mating between HbAA x HbAA produced

only Hb^{AA} offspring. Mode of inheritance of Hb allele drawn from the results of mating between goats of different haemoglobin types revealed that haemoglobin phenotypes are controlled by two autosomal co-dominant alleles Hb^{A} and Hb^{B}. This finding is in agreement with the earlier reports on inheritance of Hb alleles in goats (Naik, 1975; Goel and Nair, 1976; Singh et al., 1977; Watanabe et al., 1979; Sartore et al., 1984).

Gene frequency of Hb allele.

In the present study, the frequency of Hb^{A} allele was higher in Malabari (MM) goats (0.98). This finding is in agreement with the earlier reports of high frequency of Hb^{A} allele in some goat breeds in India (Khanolker et al., 1963 ; Joshi et al, 1975; Naik, 1975; Goel and Nair, 1976; Singh et al., 1977; Baruah and Bhat, 1980).

Watanabe et al. (1965) reported high frequency of Hb^{A} allele in Saanen goats (Japanese Saanen 0.915; Saanen from Switzerland 1.00). Goel and Nair (1976) reported higher frequency of Hb^{A} (0.88) in Alpine and its crosses. Values for tropical and temperate goats reported by Fesus et al. (1983) showed significantly higher frequency of Hb^{A} allele. Taking into account the higher frequency of Hb^{A} allele in Saanen, Alpine and Malabari goats, higher frequency of Hb^{A}

allele was expected in Saanen x Malabari (SM) and Alpine x Malabari (AM) crossbreds. The results of the present study in the crossbreds agreed with the above assumption. The absence or negligible presence of Hb^B allele in goats, indigenous as well as exotic, may be indicative of either adaptive preference of Hb^A allele to Hb^B allele or species characteristic.

Variation between genetic groups.

Comparison of the frequencies of Hb^A and Hb^B alleles among the three genetic groups viz. MM, SM and AM revealed significant similarity in allelic frequencies at haemoglobin locus. This may be attributed to the non-existence of difference of Hb^A and Hb^B frequencies between exotic and Indian breeds.

Test of genetic equilibrium.

Failure to observe significant difference between the observed and expected haemoglobin phenotypes in all the genetic groups was indicative of the population presently studied in Hardy-Weinberg equilibrium with respect to the gene frequency and phenotype frequency. This was expected as the criteria for selection of goats did not include haemoglobin types of the animals.

Potassium

Distribution of potassium types.

The whole blood potassium concentration (meq/l) varied from 5.89 to 35.89. The mean potassium concentration in the pooled population was 16.08±0.42. Among the three genetic groups, Malabari (MM) had the highest concentration of 16.96±1.12 followed by 15.96±0.80 in Saanen x Malabari (SM) and 15.91±0.58 in Alpine x Malabari (AM). These values were less than those reported in some Indian breeds of goat. Bhat *et al.* (1983) reported a mean potassium concentration of 18.50±0.45 in Barbari and 20.47±0.38 in Jamnapari. Bhat (1986) reported a higher mean value of 21.10±0.20 in Jamnapari. Higher potassium concentration of 29.05±0.39 in the whole blood was observed in Pashmina goats viz.Cheghu and Changthangi by Bhat and Singh (1987). These higher values reported may be due to the fact that the above workers could not observe potassium polymorphism in the above mentioned breeds. All the goats were belonging to high potassium type.

From the bimodal nature of the frequency distribution of whole blood potassium concentration obtained in the present study, the goats could be grouped into two distinct types viz. high potassium (HK) and low potassium (LK).

This bimodal nature of the frequency distribution agreed with the earlier reports made by few workers in exotic and Indian goats (Evans and Phillipson, 1957; Tucker and Ellory, 1972; Dev *et al.*, 1979; Mostaghni, 1979; Komatsu *et al.*,1980; Khan and Taneja, 1983 and Tunon *et al.*, 1987). However, Bhat *et al.* (1983), Bhat (1986) and Bhat and Singh (1987) could not observe polymorphism at potassium locus in Jamnapari, Sirohi and Pashmina goats.

The cut off point for LK and HK types in the present study, based on the bimodal curve was taken as 22 meq/l. This value was different from that of earlier reports. The cut off point in bimodal distribution of potassium types has been reported by Mostaghni (1979) as 21.2±2.3 meq/l in Iranian goats and by Dev *et al.* (1979) as 27.50±0.95 meq/l in Barbari goats.

The frequency distribution of potassium phenotypes revealed the predominance of LK in all the genetic groups. The percentage of goats with LK phenotype in the pooled population was 76.39 and that of HK was 23.61. Among the three genetic groups MM had the highest LK percentage of 77.78 followed by 76.97 per cent in AM and 74.74 per cent in SM. The HK percentage of 25.26 was highest in SM followed by 23.03 in AM and 22.22 in MM.

Perusal of the available literature which were few on the potassium polymorphism in Indian goats revealed either absence of polymorphism or higher incidence of HK type. Dev et al. (1979) reported 68 percentage of HK type and 32 percentage of LK type goats in Barbari. Khan and Taneja (1983) observed 53.42 percentage of HK type and 46.58 percentage of LK type in Rajastan desert (Marwari) goats. Bhat et al. (1983), Bhat (1986) and Bhat and Singh (1987) could not observe LK type goats in Jamnapari, Barbari and Pashmina goats.

Most of the goat breeds of the world showed predominance of HK type as observed in Indian goats. Interestingly, the reverse trend noticed in the present study is in agreement with the findings of Evans and Phillipson (1957) reporting that the concentration of electrolytes in the whole blood in the four middle east breeds of goats viz. Damascus, Maltese, Nigeve and Syrian mountain showed distinct bimodal distribution of concentration with predominant low potassium type. Erkoc et al. (1987) observed similar finding in Angora goats in Turkey with LK type, being predominant. According to Kaura (1952), centuries ago, Arab merchants who came to Kerala for trade brought with them Mesopotamian goats which were crossed to local and Kutch strain in large

numbers along the Malabar sea cost and thus it can be seen that the Malabari goats owes its origin to Arabian and Mesopotamian goats. The predominance of low potassium type in the present study substantiates the historical view expressed by Kaura (1952) on the evolution of Malabari goats from Arab and Mesopotamian goats.

Inheritance of potassium types.

In the present study, HK X HK mating produced only HK progeny and the mating between HK x LK or LK x HK and LK x LK type goats produced both HK and LK type progenies. The gene responsible for the expression of HK phenotype (K^H) thus appears to be recessive. The HK phenotype animals can therefore be regarded as homozygous for the recessive allele (K^HK^H) whereas the phenotypically LK animals represent the heterozygous (K^LK^H) as well as the homozygous (K^LK^L) for the dominant allele K^L. The expected number of segregants of the different mating pairs has been calculated on the assumption that potassium polymorphism in goats is primarily due to a single gene pair, that the HK gene (K^H) is recessive and mating at random. The χ^2 analysis showed that the observed and expected numbers were in good agreement and the deviation was statistically insignificant.

The mode of inheritance that can therefore be proposed for the potassium type in goats is a pair of autosomal alleles, K^L and K^H, with K^L being dominant over K^H. This finding is in agreement with the report of Tunon et al. (1987) who proposed similar mode of inheritance of potassium alleles in their studies on 14 Spanish goats.

Gene frequencies of potassium allele.

Among the three genetic groups, the frequency of K^L allele was highest in MM (0.53) followed by 0.52 in AM and 0.50 in SM. On the other hand, the frequency of K^H allele was 0.47 in MM, 0.48 in AM and 0.50 in SM. In the pooled population, the frequency of K^L and K^H alleles were 0.51 and 0.49 respectively. The difference in the frequency of K^L allele among different genetic groups and that of K^H allele among the three genetic groups were non significant.

Higher frequency of K^H allele was reported earlier in British Saanen goats (Evans and Phillipson, 1957). Perusal of the literature did not reveal any data on the frequency of K^L and K^H alleles in Alpine breed.

Potassium phenotype in different generations.

On going through the frequency of K^H allele in SM and AM crossbreds of two generations it can be seen that the

differences in frequencies between second and third generation were not significant. However, there was a decreasing trend in the frequency of K^H allele from second to third generation, reaching approximately nearer to the value obtained for Malabari. The trend of increase in K^H allele observed in the second generation may be due to the higher frequency of K^H allele reported for European breeds (Evans and Phillipson, 1957; Tunon et al., 1987). The inter-se mating in the second generation might have resulted in the decline of the gene frequency of K^H allele in the third generation.

Potassium concentration in LK and HK type of goats.

Among the LK animals the concentration of whole blood potassium (meq/l) was highest in MM (13.76±0.42) followed by 12.24±0.27 in AM and 11.84±0.37 in SM. In the pooled population, the mean value was 12.35±0.20. Analysis of variance of the potassium concentration in LK animals of different genetic groups revealed significant difference ($P < 0.01$) between MM and SM and MM and AM. But the difference between SM and AM was not significant.

The mean concentration of potassium in the HK type animals was 28.20±1.61 in MM, 28.16±0.73 in SM and

28.19±0.64 in AM. In the pooled population the value was 28.18±0.76. The differences in the mean value were not significant.

The values obtained in the present study were more or less similar to those reported by Dev et al. (1979) in Barbari goats (12.54±0.481 in LK and 27.48±0.951 in HK type) and by Khan and Taneja (1983) in Marwari goats (13.73±0.81 in LK and 27.08±0.22 in HK). But, Bhat et al. (1983) and Bhat (1986) reported lesser potassium concentration in HK type goats. The mean potassium concentration reported by the above workers was 18.50±0.45 in Barbari and 20.47±0.38 in Jamnapari (Bhat et al., 1983), 21.1±0.2 in Jamnapari (Bhat, 1986). Comparatively higher concentration of potassium was reported in Pashmina goats (Bhat and Singh, 1987). The low values obtained by Bhat et al. (1983) and Bhat (1986) might be due to the fact that these authors did not observe potassium polymorphism.

Potassium concentration and sex.

It was observed that the sex of the animal had no effect on potassium concentration in any of the genetic groups presently studied. This agreed with the earlier report of Bhat and Singh (1987) in Pashmina goats.

Potassium concentration and generation.

It can be seen that the generations of goats had no effect on the potassium concentration in LK type goats belonging to SM and AM. But the difference in the potassium concentration in HK type goats of SM showed significant difference ($P < 0.05$). The SM goats belonging to the second generation had higher concentration of potassium (29.97±0.72) than that of third generation goats (26.62±0.89). But similar significant difference was not noticed in AM crossbreds The significant difference in SM goats may be due to chance fluctuations.

Effect of sire on potassium concentration.

Analysis of variance on the effect of sire on the potassium concentration revealed significant difference between the sire groups in both LK and HK type goats of AM. However, the same was not observed in MM and SM goats. Similar trend was noticed by Krishnamurthy and Rathnasabapathy (1977) in Nilagiri, Merino and their crossbred sheep, as regard to the influence of sire on the concentration of potassium in its offspring.

Erythrocyte glutathione (GSH)

Distribution of GSH types.

The glutathione (GSH) concentration in the pooled population varied from 33.5 to 121.4 mg/100 ml red blood cells. The distribution of glutathione level in the population showed a bimodality. Goats could be divided into two populations based on the glutathione concentration. Goats with glutathione level of below 60 mg/100 ml red blood cells were classified as GSH-low type while those having 60 mg/100 ml red blood cells and above were classified as GSH-high type. This classification was based on the earlier work of Agar et al. (1974) in some exotic breeds of goats, such as Saanen, Angora, British-Alpine, Toggenburg and Anglo-Nubian and of More (1983) in Jamnapari, Barbari, Beetal, Black Bengal and their crosses.

From the mean values of GSH level in different genetic groups, it can be seen that the concentration of glutathione (mg/100 ml RBC) of 86.03±1.19 was highest in AM followed by 79.24±1.58 in SM and 74.95±2.48 in MM. In the pooled population, the concentration was 82.28±0.93.

The analysis of variance showed that the genetic groups had a significant effect on the concentration of glutathione in goats irrespective of its glutathione types. Pairwise comparison between genetic groups revealed that Alpine inheritance contributed to significant difference. The high concentration of glutathione in AM is expected since Alpine was reported to be having highest concentration of glutathione among the exotic breeds viz. Saanen, Angora, Toggenburg and Anglo-Nubian (Agar et al.,1974).

All the three genetic groups examined were mostly of GSH-high type. However, the Malabari goats were found to have relatively more number of GSH-low type. Percentage of GSH-high type in different genetic groups was 75.56 in MM, 85.26 in SM and 88.48 in AM and that of GSH-low type was 24.44 in MM, 14.74 in SM and 11.52 in AM. High incidence of GSH-high type has been earlier reported in some exotic goat breeds (Agar et al., 1974) as 91 per cent in Saanen, 74 per cent in Angora and 93 per cent in British Alpine. All the animals of Anglo-Nubian and Toggenburg were of GSH-high type.

More (1983) reported high percentage of GSH-high type as 74.5 in Jamnapari, 96.0 in Barbari and 94.0 in Beetal breeds and could observe only GSH-high type in Black Bengal goats.

The observations on the incidence of GSH-high type in the present study are found to agree with the findings on exotic and Indian breeds. It can thus be concluded that the incidence of GSH-high type in higher frequency may be species specific. In view of the important metabolic role played by glutathione, the goats could be more efficient in resisting stressful conditions without being detrimental to optimum productivity in adverse situations.

Inheritance of GSH types.

The inheritance of GSH type was studied from the available data on mating of two GSH types. It is seen that GSH-high x GSH-high, CSH-high x GSH-low, GSH-low x GSH-high mating produced both the types of offspring. But GSH-low x GSH-low mating produced only GSH-low offspring. Since the observed numbers did not deviate significantly from the expected numbers of offspring in different mating, the breeding data support the hypothesis that GSH types are controlled by a pair of autosomal alleles, the gene for GSH-high (GSH^H) being dominant to the gene for GSH-low (GSH^h

Though no earlier reports are available on the inheritance of glutathione type in goats, the results obtain in the present study agrees with the reports on inheritance of GSH types in sheep by Tucker and Kilgour (1970), Board et al. (1974), Bhaskar and Krishnamurthy (1979) and Murugaraj et al. (1980).

Gene frequency of GSH allele.

Perusal of the literature available on glutathione polymorphism in goats did not reveal any information on the frequency distribution of GSH alleles. The frequency distribution of GSH alleles obtained during the present study showed that the GSH^H was predominant in all the genetic groups. The frequency of GSH^H allele was 0.51 in MM, 0.62 in SM and 0.66 in AM. Though there was difference in gene frequency among the genetic groups, it was not significant.

GSH phenotype in different generations.

It is seen that the generation has not altered the GSH allelic frequencies in the SM and AM crossbreds.

GSH concentration in GSH-high and GSH-low types.

The concentration of GSH in GSH-high type goats of different genetic groups showed significant difference. The AM crossbreds had significantly higher GSH concentration than that of MM and SM. This indicates that of the genetic groups or breed can be a source of variation. However, similar effect of genetic group on the concentration of GSH was not observed in GSH-low type goats of any genetic groups.

Effect of sex on GSH concentration.

It is seen that there was no significant sex difference in glutathione level in both the GSH types in any of the genetic groups. Similar findings were observed by Kandasamy et al. (1976) in Nilagiri sheep and Murugaraj et al. (1980) in Merino sheep.

GSH concentration and generation.

The goats belonging to different generations did not differ significantly in the GSH concentration in any of the genetic groups presently studied, except in the case of GSH-high animals of SaanenxMalabari goats. Among the GSH-high animals, SM goats of second generation had significantly lower (80.95±1.98 mg/100 ml RBC) GSH concentration than that of third generation (88.91±1.25 mg/100 ml RBC).

Effect of sire on GSH concentration.

The effect of sire on GSH concentration did not show any definite trend to draw any meaningful conclusion.

Frequency distribution of combination of different types of haemoglobin, potassium and GSH

The frequency distribution of combination of different types of haemoglobin, potassium and GSH in different genetic

group shows that the native breed Malabari and the crossbreds did not differ significantly in the allelic frequencies of haemoglobin, potassium and GSH types.

Genetic association among biochemical variants

Haemoglobin and potassium.

An attempt was made to find out genetic association, if any, between haemoglobin and potassium loci in Malabari breed of goat and its exotic crosses with Saanen and Alpine. In the present study, the observed number of HK and LK animals in the two haemoglobin types HbAA and HbBB did not deviate significantly from the expected numbers calculated on the assumption that these two loci are independent. The observed number of HbAA, HbAB and HbBB animals in LK and HK phenotypeswere not significantly different from that of the expected numbers. From these results, it can be inferred that the loci controlling haemoglobin and potassium are not genetically associated.

No studies on genetic association between haemoglobin and potassium seems to have been carried out in goats. However, the results obtained in the present study are

comparable with those of the sheep studies reported by Agar (1968), Arora et al.(1970), Bhaskar et al. (1976) and Bhat et al. (1981).

Haemoglobin and GSH.

The observed number of animals with GSH-high and GSH-low types in different haemoglobin types did not deviate significantly from the expected numbers in each types, calculated on the assumption that the haemoglobin and GSH are not genetically associated. The expected number of goats with HbAA, HbAB and HbBB phenotypes in different GSH types were also not significantly different from those of expected, thereby showing that haemoglobin types and GSH types are not genetically associated.

Potassium and GSH.

No genetic association could be observed between potassium and GSH. It is seen that the observed and expected number of goats in different phenotypes were not significantly different.

Haemoglobin type and blood constituents

No relationship exists between haemoglobin types and the blood constituents such as packed cell volume (PCV),

potassium and GSH concentration in all the three genetic groups studied. It can thus be inferred that HbAA and HbAB have no influence over PCV and concentration of potassium and GSH. However, in Tibetan sheep, Zhang et al. (1984) reported significantly higher PCV in HbBB animals than that of HbAA animals.

Potassium types and blood constituents

It was observed that the potassium type had a significant effect ($P < 0.01$) on the packed cell volume in all the genetic groups viz. MM, SM and AM. In all the genetic groups, the mean packed cell volume was significantly higher in LK type goats to that of HK type goats. The mean packed cell volume (per cent) in LK and HK type goats was 31.97±0.31 and 27.08±0.51 in MM, 31.83±0.28 and 27.08±0.51 in SM and 31.19±0.16 and 28.63±0.38 in AM. The above findings concur with the earlier report of Khan and Taneja (1983) in Marwari goats. The mean packed cell volume (per cent) in goats belonging to LK and HK types was reported to be 28.98±0.27 and 26.74±0.23 respectively, the difference being significant. The mean GSH concentration in LK and HK type goats did not show any significant difference in SM and AM cross breds. However, in Malabari goats the HK type animals had significantly ($P < 0.01$) higher concentration of GSH (90.29±1.90) than that of LK type goats which had 70.57±2.72 mg/100 RBC.

GSH types and blood constituents

The mean PCV in GSH-high type and GSH-low type did not show any significant difference in any of the genetic groups except in Malabari, in which the animals of GSH-low type had significantly higher PCV (33.00±0.53 per cent) than that of GSH-high type (30.18±0.48 per cent). The difference in the potassium concentration between the GSH-high and GSH-low type goats was not significant.

The results of the present study is comparable to that of sheep reported earlier by Agar *et al.* (1972), Tucker and Kilgour (1970, 1972) and Kandasamy *et al.* (1976).

Association of biochemical variants with economic traits

Haemoglobin type, body weight and production traits.

The mean body weight at birth and at three months, six months, nine months and at one year of age for the two haemoglobin types in MM, SM and AM goats showed that the HbAA animals were heavier in body weight at different ages in all the genetic groups. However, the difference was significant only for body weight at one year in MM, body

weight at nine months in SM and body weight at nine months and at one year in AM. Gopinathan and Nair (1976) also reported the superiority of HbAA to that of HbAB type in goats. They could observe significantly lower age at first kidding in females of HbAA type than females of other Hb phenotypes. However, Antova and Mkrtchyan (1977) and Bhuvanendran et al. (1981) reported the superiority of haemoglobin heterozygotes over the homozygotes in body weight and helminth egg counts respectively.

The first lactation yield and first lactation length were found to be not influenced by the haemoglobin type in SM and AM crossbred goats. Fesus et al. (1983) could not observe any significant difference between the reproductive performance of the female having different haemoglobin types in the Hungarian native breed of goat.

Potassium type, body weight and production traits.

The differences in the mean values of body weight at different ages, first lactation yield and first lactation length between LK and HK type goats were not statistically significant. It can be inferred that the potassium type had no significant effect on the body weight at different ages, first lactation yield and on first lactation length

in any of the genetic groups presently studied. This finding is in agreement with those of Dev et al. (1979) and Erkoc et al. (1987).

In sheep, King et al. (1958), Arora and Acharya (1972), Bhaskar et al. (1978), Singh et al. (1978), Khan and Bhat (1982) and Kumar (1983) could not observe any effect of potassium on the body weight.

GSH type, body weight and production traits.

The GSH types did not exert any significant effect on the body weight at different ages in any of the genetic groups presently studied. The first lactation yield and first lactation length of GSH-high and GSH-low type goats of MM, SM and AM did not differ significantly except in the case of first lactation yield in SM crossbreds. The goats of GSH-low type had significantly higher first lactation yield than that of GSH-high type goats. This difference may be due to the sampling fluctuation. However, Atroshi et al. (1985) reported that goats with high GSH content had significantly higher milk yield than goats with low GSH content. In sheep, Kandasamy et al. (1976) could not find any association between GSH type, body weight and production traits.

Summary

SUMMARY

Role of blood groups and biochemical polymorphism in animal improvement is gaining more and more importance as effective tools to maintain accurate breeding records of livestock species and to identify the path of evolution of a species. Very little information is available on the immunogenetics and biochemical genetics of goats although it has now been realised that goat plays a substantial role in the economy of the tropical countries as a provider of milk, meat, mohair and pashmina. With this in view research studies were taken up on the blood groups and biochemical polymorphism. 305 goats belonging to three genetic groups, viz. Malabari, Saanen x Malabari and Alpine x Malabari formed the materials for the study.

Twelve blood grouping reagents were produced during the course of the study from the polyvalent goat sera obtained from the Institute for Animal Breeding, University of Bern, Bern, Switzerland and they were tentatively designated as M1, M2, M3, M4, M5, M6, M7, M8, M9, M10, M11 and M12. The blood group factors M4, M10 and M12 were not observed in Malabari goats. The blood group factor M2 was the most frequent in Malabari and

Saanen x Malabari and M1 in Alpine x Malabari. The lower gene frequencies of the blood group factors and absence of some of the factors in Malabari may be indicative of the differences between the breeds of two regions.

Naturally occurring antibodies was not detected in the goats during the present study.

The goat haemoglobin displayed a fair degree of uniformity. 94 per cent of the samples showed only one fast moving component (Hb^A) in electrophoretic separation, the rest being slow moving (Hb^B). The gene Hb^A and Hb^B were located on the autosomes and were co-dominant alleles. Of the three possible phenotypes viz. HbAA, HbAB and HbBB, HbBB was not observed in any of the genetic groups. The gene frequency of Hb^A varied from 0.97 in Alpine x Malabari to 0.98 in Malabari and Saanen x Malabari. It was observed that the goat population was in genetic equilibrium with respect to the haemoglobin locus.

Estimation of potassium concentration in whole blood showed that the genetic groups did not differ significantly. The frequency distribution of potassium concentration revealed a bimodality and on the basis of the bimodal distribution the goats were classified into low potassium (LK) with concentration of less than 22 meq/l and high potassium (HK) with concentration of more than 22 meq/l. It was

interesting to observe that the LK type predominated in Malabari as well as its crossbreds with exotic breeds and 76.39 per cent of the pooled population were of LK type which resembles a situation found in Middle East goats substanting the historical belief that the Malabari breed owes its origin to Arabian and Mesopotamian breeds.

Studies on the inheritance of the potassium alleles revealed that the potassium locus was controlled by two autosomal alleles K^L (determining LK) and K^H (determining HK) the former being dominant to the latter. The three genetic groups did not show any difference in the frequency of potassium alleles, the frequencies of K^L and K^H being 0.53 and 0.47 and in Malabari 0.50 and 0.50 in Saanen x Malabari 0.52 and 0.48 in Alpine x Malabari respectively.

Among the LK type goats, the Malabari had significantly higher potassium concentration (meq/l) of 13.76±0.42 to that of 11.84±0.37 in Saanen x Malabari and 12.24±0.27 in Alpine x Malabari. The HK type goats did not show any significant genetic group difference in potassium concentration.

The mean erythrocyte glutathione (GSH) concentration was estimated in the three genetic groups and was found to be exhibiting significant difference among the genetic groups. The mean GSH concentration (mg/100 ml red blood cells) of 86.03±1.19 in Alpine x Malabari was significantly higher than that of 74.95±2.48 in Malabari but the mean value of 79.24±1.58 observed in Saanen x Malabari did not show any significant difference from that of Malabari and Alpine x Malabari.

The frequency distribution of GSH concentration revealed a bimodality and the goats with GSH concentration of 60 mg/100 ml red blood cells were classified as GSH-high type and those with below 60 mg/100 ml red blood cells were classified as GSH-low type. More than 75 per cent of the goats belonged to the GSH-high type. Highest percentage of 88.48 was observed in Alpine x Malabari and lowest of 76.56 was observed in Malabari. Higher incidence of GSH-high type in goats may be indicative of the efficiency which the goats exhibit in resisting stressful conditions.

The results of mating among different GSH phenotypes showed that GSH locus was controlled by two autosomal alleles GSH^H (determining GSH-high type) and GSH^h (determining GSH-low type), the GSH^H being dominant over GSH^h.

The frequency of GSH^H allele varied from 0.51 in Malabari to 0.66 in Alpine x Malabari and the difference in frequencies among the genetic groups was not significant.

The inter-se mating in second generation did not affect the gene frequencies of potassium and GSH alleles and their concentration in any of the genetic groups except in the case of Saanen x Malabari wherein the mean GSH concentration in GSH-high type goats of third generation was significantly higher than that of second generation.

Potassium and GSH concentrations were not found to be influenced by the sex in any of the genetic groups.

The effect of sire on potassium and GSH concentration in different genetic groups did not show any definite trend in the present study.

Studies on the genetic association revealed that haemoglobin, potassium and GSH were not genetically associated and each one inherited independent of the other, thereby revealing that there exists no linkage among the alleles of the three polymorphic systems.

Haemoglobin types had no influence on the packed cell volume in any of the genetic groups studied while potassium had a significant effect on the packed cell volume in all the genetic groups. The LK type goats had

significantly higher packed cell volume than that of HK type goats in all the genetic groups. The GSH concentration did not differ significantly between LK and HK animals in crossbreds but in Malabari, the HK type goats had significantly higher concentration of GSH than that of LK type goats.

In Malabari, the GSH-low type goats had significantly higher packed cell volume compared to that of GSH-high type goats. In other genetic groups, no influence of GSH type on packed cell volume was noticed.

Studies on the association between haemoglobin types and economic traits revealed a tendency for superiority of Hb^{AA} type over that of HbAB type in body weight at different ages. However, significant difference between haemoglobin types was seen in body weight at the age of one year in Malabari and at the age of nine months in crossbreds. Haemoglobin type had no effect on the first lactation milk yield and the first lactation length in any of the genetic groups. In general, growth and production traits were not seen influenced by the potassium and GSH types.

In the absence of large volume of information on the genetics of goats unlike other livestock, the findings of the present study are of paramount importance in filling up the gap in genetic studies on goats. The evidence that accrued during the present study on the origin of Malabari breed of goat from Arabian and Mesopotamian goats, the similarity of the Hb^A allele frequency in the indigenous and exotic goats, higher incidence of GSH-high types indicative of the remarkable vitality exhibited by goats are the salient findings of the present study.

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BLOOD GROUPS AND BIOCHEMICAL POLYMORPHISM IN THE MALABARI BREED OF GOAT AND ITS EXOTIC CROSSES

By

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ABSTRACT OF A THESIS

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ABSTRACT

Realising the importance of blood groups and biochemical polymorphism in livestock improvement a study was undertaken in 305 adult goats of Malabari breed and its exotic crosses viz. Saanen x Malabari and Alpine x Malabari, to identify the blood group factors and polymorphism, if any, at haemoglobin, potassium and erythrocyte glutathione (GSH) loci and their utility as genetic markers for selection. Standard haemolytic test and absorption technique were performed to produce monovalent reagents and to type the goats. The different haemoglobin types were detected employing horizontal starch gel electrophoresis. The potassium concentration in whole blood and the GSH concentration in erythrocytes were estimated by Flamephotometry and Spectrophotometry respectively.

Twelve blood group reagents M1, M2, M3, M4, M5, M6, M7, M8, M9, M10, M11 and M12 were produced during the present study from the nineteen polyvalent goat sera obtained from Switzerland. The phenotypic frequencies of different blood group factors were different from each other among the three genetic groups. The blood group factors M4, M10 and M12 were not observed in the Malabari goats.

In electrophoretic separation, 94 per cent of the goats showed only one haemoglobin band (HbAA) and six per cent showed two bands (HbAB). HbBB was not observed in any of the genetic groups. Inheritance pattern of Hb alleles revealed that they inherit as autosomal co-dominant alleles. The frequency of Hb^A allele was 0.98 in Malabari and Saanen x Malabari and 0.97 in Alpine x Malabari, the difference being non significant. It was observed that the goat populations were in Hardy-Weinberg equilibrium with respect to the haemoglobin locus.

The genetic group had no effect on the concentration of whole blood potassium. The frequency distribution of potassium concentration in the pooled population showed a distinct bimodality, on the basis of which the goats were classified into two distinct types viz. LK (< 22 meq/l) and HK (> 22 meq/l). 76.39 per cent of the pooled population were of LK type, a situation not reported in Indian goats.

The potassium phenotypes are controlled by two autosomal alleles, K^L (determining LK) and K^H (determining HK), the K^L being dominant over K^H. The gene frequencies of K^L and K^H were 0.53 and 0.47 in Malabari, 0.50 and 0.50 in Saanen x Malabari and 0.52 and 0.48 in Alpine x Malabari, the difference among the three genetic groups being non significant. The genetic groups had significant effect on the potassium concentration in LK type goats, but such effect was not noticed in HK type goats.

The genetic groups had significant effect on the erythrocyte glutathione (GSH) concentration. The frequency distribution of GSH concentration in the pooled population revealed a bimodality. Goats with GSH concentration of $>$ 60 mg/100 ml RBC were classified as GSH-high type and those with $<$ 60 mg/100 ml RBC were classified as GSH-low type. The frequency percentage of GSH-high type in the pooled population was 85.26. Among the three genetic groups, Alpine x Malabari had the highest frequency of 88.48 per cent and Malabari had the lowest frequency of 76.56 per cent. Inheritance pattern of GSH phenotypes showed that in goats GSH types are controlled by two autosomal alleles GSH^H (determining GSH-high type) and GSH^h (determining GSH-low type), the GSH^H being dominant over GSH^h. The frequencies of GSH^H and GSH^h were 0.51 and 0.49 in Malabari, 0.62 and 0.38 in Saanen x Malabari and 0.66 and 0.34 in Alpine x Malabari, without any significant differences among the genetic groups.

The frequencies of potassium and GSH alleles and also their concentration did not change over the two generation in any of the genetic groups except in Saanen x Malabari, wherein the mean GSH concentration GSH-high type goats of third generation was significantly higher than that of the second generation. Sex did not influence the concentration of potassium and GSH.

A valid conclusion could not be drawn on the effect of sire on the potassium and GSH concentration in its offspring.

Studies revealed that haemoglobin, potassium and GSH were not genetically associated. Haemoglobin type had no effect on packed cell volume and concentration of potassium and GSH. The LK type goats had significantly higher packed cell volume in all the genetic groups. The potassium type had no effect on the concentration of GSH in the crossbred goats but in Malabari the HK types had significantly higher concentration in GSH than that of LK types.

Goats with HbAA phenotype had heavier body weight at different ages when compared to that of HbAB type. However, the differences was significantly only for the weight at one year in Malabari and weight at nine months in crossbreds. Haemoglobin type had no effect on the production traits. In general, the growth and production traits were not seen influenced by the potassium and GSH types.