42. Studies on the Transferrin of Goat. II

Inheritance Mode of Serum Transferrin Types

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The polymorphic biochemical system inherited with the simple mode has been studied by many investigators by using the electrophoresis of starch gel method introduced by Smithies and particularly modified by Poulik.

Variable serum β -globulins have genetically been demonstrated to be transferrin, the specific iron-binding proteins of serum, in cattle by Giblett *et al.* (1959), in pigs by Kristjanson (1960), and in deer by McDougall (1961).

β -globulins polymorphs in goats were classified into three phenotypes by Ashton and McDougall (1958), Millson and Pattison (1961). It had not been clarified whether the variable β -globulins in goats are the iron-binding transferrins as those in sheep and horses or not. But the variable β -globulins in goats were identified with iron-binding transferrins by present authors from the facts that the variable β -globulins might be labelled with Fe^{59} , and the three phenotypes of transferrins in goats were classified.

The present experiments were carried out to clarify the inheritance mode of serum transferrin type in goats, and to research the differences in the gene frequencies of transferrins among a few breeds of goats.

Materials and Methods. The mating tests were carried out by Japanese Saanen goats being reared at the Institutes of Animal Industry of Nagano, Gunma, and Kanagawa Prefectures; and at the Institute of Animal Serology of Tokyo University of Agriculture.

The goats examined on the gene frequencies of transferrins amounted to 2058 heads of Japanese Saanen (J. G. for short), Tokara goats (Japanese natives, T.G. for short), Native goats and their hybrids in Rhukyu Islands (R.G. for short), Saanen goats in Switzerland (S.G. for short), German coloured goats (G.G. for short), Alpen goats in Italy (I.G. for short), and Saanen goats in Hungary (H.G. for short).

The vertical starch gel electrophoresis was employed by the method described in the previous paper by the present authors.

Results and Discussion. I) *Inheritance mode of transferrin type in goats.* In various species of animals, their serum transferrins have been studied to be genetically controlled by multiple autosomal alleles.

The distribution of offsprings obtained from four matings among three phenotypes of transferrins in goats is shown in Table I. Unfortunately, the other matings except four matings could not be obtained in the present experiments, because the presence of III type in Japanese Saanen goats was very few.

Table I. Distribution of offsprings from four matings among three phenotypes of transferrin in goats

Mating	Number of mating	Offsprings			Total offsprings
		I	II	III	
I×I	172	242	0	0	242
I×II	54	42	32	0	74
I×III	1	0	2	0	2
II×II	3	0	5	1	6
Total	230	284	39	1	324

As shown in table, no offsprings of I type were obtained from matings between I and III type, II and II type; II type from mating between I and I type; and III type from the other matings except the mating between II and II type, respectively.

If the transferrin types in goats are genetically controlled by two allelomorphs, the genotype of each transferrin type is to be follows;

Therefore, the gene frequencies of Tf^I and Tf^{II} are able to be calculated from the following formulas:

Phenotype	Genotype	$p^2 + 2pq + q^2 = 1$
I type	Tf^I/Tf^I	$\sqrt{I} = p$
II "	Tf^I/Tf^{II}	$1 - p = q$ or $\sqrt{III} = q$
III "	Tf^{II}/Tf^{II}	$\sqrt{II} = 2pq$

Where, p and q of the gene frequencies of three phenotype were calculated to be 0.9362 and 0.0638, respectively.

In this population, the probabilities of appearance of matings in phenotypes and expected values on offsprings from various matings

Table II. Probability of appearance of matings and expected values on offsprings from various matings

Matings		Offsprings		
Type	Frequency	I	II	III
I×I	p^4	p^4		
I×II	$4p^3q$	$2p^3q$	$2p^3q$	
I×III	$2p^2q^2$		$2p^2q^2$	
II×II	$4p^2q^2$	p^2q^2	$2p^2q^2$	p^2q^2
II×III	$4pq^3$		$2pq^3$	$2pq^3$
III×III	q^4			q^4

are calculated by the formulas shown in Table II. When $p=0.9362$ and $q=0.0638$ are substituted for the values of p and q , Table III is obtained.

The observed values and the expected ones of the appearance

Table III.

	I	II	III
I×I	76.819		
I×II	10.470	10.470	
I×III		0.714	
II×II	0.357	0.714	0.357
II×III		0.0484	0.0484
III×III			0.0016

Table IV.

Matings	I	II	III
I×I	242 248.871		
I×II	42 33.911	32 33.911	
I×III		2 2.310	
II×II	0 1.155	5 2.310	1 1.155
II×III		0 0.157	0 0.157
III×III			0 0.053
Total	284 283.937	39 38.698	1 1.365

The upper : Observed values.

The lower : Expected values.

Table V.

	I	II	III
Expected frequency	87.635%	11.944%	0.421%
Observed frequency	87.654%	12.037%	0.309%
Expected value	283.937	38.698	1.365
Observed value	284	39	1

$$X^2=0.0568 \quad D.f.=2 \quad 0.9$$

of the transferrin type in offsprings are calculated according to the values in Table III, as shown in Table IV.

The observed values in each mating except the matings of II×II, II×III, and III×III are almost similar to the expected ones.

When, the expected values in each transferrin type are calculated by the gene frequencies and compared with the observed ones, the

results obtained are as shown in Table V. The observed values seem to be the expected ones.

From these results and the facts in previous paper by the present authors that II type goat was considered to be the heterozygote between the I and III type goat, it was suggested that the transferrin types in goats are controlled by two allelomorphs Tf^I and Tf^{II} , giving three genotypes Tf^I/Tf^I , Tf^I/Tf^{II} , Tf^{II}/Tf^{II} and three phenotypes I, II, and III type.

The facts that the transferrin types of the offsprings obtained by back crossing the male of II type to two females of II type produced from the mating $II \times I$ type were segregated into three phenotypes I, II, and III type are recognized to certify accurately the above results.

Therefore, the three phenotypes I, II, and III must be expressed as Tf_{I-I} , Tf_{I-II} , and Tf_{II-II} , respectively.

II) *Frequencies of appearance of transferrin phenotype by sex.* The frequencies of appearance of transferrin phenotypes by sex were researched in J.G., T.G., and R.G. No sexual differences were recognized from the results shown in Table VI. Therefore, the serum transferrin phenotypes in goats were considered to be inherited and controlled by two alleles at an autosomal locus.

III) *Gene frequencies in a few breeds of goats.* The gene frequencies were calculated on the population of J.G. (Table VII). Despite of the slight differences due to each population, the frequency of q (gene of Tf^{II}) was very low in every population.

On the other hand, the differences of gene frequencies due to breeds of goats were observed greatly as shown in Table VIII.

The gene frequencies in J.G., T.G., and R.G. were almost similar to each other in the fact that q was very low. On the contrary, the frequency of q in I.G. and H.G. was observed to be slightly high than that of p in those breeds. However, the gene frequencies in S.G. were calculated to be $p=1.000$, $q=0$, owing to the phenotypes classified into I type. Therefore, it is considered that the transferrin types S.G. were homologous completely.

Summary. Recently, many studies on the polymorphic biochemical systems controlled by the simple inheritance mode have been reported. The polymorphism of transferrin in human, animals and poultry has been demonstrated by many investigators. But that in goats has never been reported satisfactorily. β -Globulin polymorphism in goats was classified into three phenotypes by Ashton and McDougall, Millson and Pattison.

The variable β -globulins in goats had been identified by the present authors to be iron-binding transferrins.

In order to clarify the inheritance mode of serum transferrin type in goats, and to consider the differences of gene frequencies of transferrins among a few breeds of goats, the experiments were performed by using 2058 goats. The results obtained are as follows:

Table VI. Frequency of appearance of phenotypes and gene frequencies by sex in J. G.

Population	Sex	Frequency of appearance of the phenotypes						Gene frequencies	
		I		II		III		<i>p</i>	<i>q</i>
		(No)	(%)	(No)	(%)	(No)	(%)		
K	M	8	38.095	13	61.905	0	0	0.617	0.383
	F	20	71.429	8	28.571	0	0	0.845	0.155
NK	M	16	76.190	5	23.810	0	0	0.873	0.127
	F	28	71.790	11	28.205	0	0	0.847	0.153
NN	M	36	90.000	4	10.000	0	0	0.949	0.051
	F	90	80.357	21	18.750	1	0.893	0.896	0.104
T	M	0	0	0	0	0	0	0	0
	F	43	58.108	31	41.892	0	0	0.762	0.238
R. G.	M	67	93.443	4	6.557	0	0	0.967	0.033
	F	474	96.146	19	3.854	0	0	0.981	0.019
Total	M	117	81.818	26	18.182	0	0	0.904	0.096
	F	655	87.919	90	12.080	1	0.001	0.938	0.062

M : Male

F : Female

Table VII. Gene frequencies on populations in J. G.

Population	Number of individuals	Gene frequencies	
		<i>p</i>	<i>q</i>
G	53	0.981	0.019
K	49	0.755	0.245
ND	21	0.654	0.346
NK	60	0.856	0.144
NN	408	0.911	0.089
NS	626	0.937	0.063
T	74	0.762	0.238
Total	1291	0.915	0.085

Table VIII. Gene frequencies on various breeds of goat

Breed	Number on Individuals	Gene frequencies	
		<i>p</i>	<i>q</i>
J. G.	1291	0.915	0.085
T. G.	15	0.966	0.034
R. G.	554	0.979	0.021
G. G.	54	0.882	0.118
I. G.	49	0.404	0.596
H. G.	56	0.462	0.538
S. G.	39	1.000	0
Total	2058	0.915	0.085

1) Three transferrin phenotypes in goats expressed as Tf_{I-I} , Tf_{I-II} , and Tf_{II-II} are genetically controlled by two autosomal alleles, Tf^I , Tf^{II} . The two alleles are co-dominant to each other. Therefore, the genotypes are expressed as terminology Tf^I/Tf^I , Tf^I/Tf^{II} , and Tf^{II}/Tf^{II} .

2) Gene frequencies of transferrin types in goats were as follows:

$$Tf^I \dots\dots p=0.915, \quad Tf^{II} \dots\dots q=0.085$$

3) The great differences recognized on the frequencies of appearance of the transferrin phenotypes were also observed on the gene frequencies of transferrins among J.G., T.G., R.G., S.G., G.G., I.G., and H.G..

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