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BLOOD GENETIC POLYMORPHISM OF ARAB HORSES BRED IN POLAND II. DISTRIBUTION OF GENOTYPES AT EIGHT LOCI OF POLYMORPHIC BLOOD PROTEINS WITHIN FEMALE BREEDING LINES[1]

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Summary. Genetic polymorphism of eight blood protein loci in 1049 Arab horses bred in Poland was detected by the method of starch electrophoresis. In serum: albumin (*Al*), transferrin (*Tf*), esterase (*Es*); in hemolysate: 6-phosphogluconate dehydrogenase (*6-PGD*), phosphoglucomutase (*PGM*), phosphohexose isomerase (*PHI*), carbonic anhydrase (*CA*), catalase (*Cat*). The female population comprising 726 individuals was compared with the whole population of Arab horses bred in Poland. Phenotypes of *DO* transferrin, *G* esterase and *FS* catalase occurred more frequently in the group of mares, while phenotypes of *DH* transferrin, *GI* esterase were less frequent when compared with the population as a whole. The seven most numerous female lines were compared with each other and significant differences in the allelic frequencies of all the protein systems studied were detected.

The present paper is a continuation of studies on the polymorphism of genetic markers in the blood of Polish-bred Arab horses. In the previous papers (Kaminski, Tomaszewska-Guszkiewicz 1978, Tomaszewska-Guszkiewicz et al. 1983) the whole population was analysed and male horses were compared with the whole population.

The aim of the present paper was to compare mares with the whole population of Arab horses and to find the differences in the frequency of separate alleles between the most numerous female lines.

MATERIAL AND METHODS

Blood samples were taken from 1049 Arab horses (726 mares) in the years 1974 - 1979 in studs at Janów Podlaski, Michałów and Kurozwęki.

Horizontal starch gel electrophoresis was used. The conditions under which the electrophoresis of the proteins studied was carried out are detailed in the pre-

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vious papers (Tomaszewska-Guszkiewicz 1971, Tomaszewska-Guszkiewicz, Kaminski 1980).

The following proteins were analysed —
in serum:
albumin (*Al*)
transferrin (*Tf*)
esterase (*Es*) at
in hemolysate:
6-phosphogluconate dehydrogenase (*6-PGD*)
phosphoglucomutase (*PGM*)
phosphohexose isomerase (*PHI*)
carbonic anhydrase (*CA*)
catalase (*Cat*).

RESULTS AND DISCUSSION

The frequency of alleles and phenotypes of proteins studied in the entire population is given in Table 1. The results were discussed in the previous paper (Tomaszewska-Guszkiewicz et al. 1983).

The present paper is concerned exclusively with the female part of the population. The mares were grouped in lines according to the classification of Rozwadowski (1975). Each line comprise from six to 112 individuals (Table 2). In a number of cases it was possible to determine the line far to 17 generations. The line of mare Milordka is given as an example (Table 3).

A comparison between mares and between horses in the entire population revealed differences in the frequency of phenotypes of the blood proteins studied (Table 1). The following are the most important recorded differences:

— higher number of horses with phenotype of *DO* transferrin, *G* esterase, *F 6-PGD* and *FS* catalase,

— smaller number of horses with phenotype of *DH* transferrin, *GI* esterase and *FS 6-PGD*
in the female population as compared with the entire population.

Seven most numerous lines have been selected out of the total fourteen female lines. They are the lines of Gazella [112], Milordka [87], Mlecha [85], Ukrainka [49], Szweykowska [48], Sahara [45], Wołoszka [41] (Table 2). Their female offspring amounts to 467 mares which makes up 64.3 per cent of the female population and 44.5 per cent of the entire population studied.

Considerable differences in the allelic frequency of a number of protein systems studied were recorded between the lines compared (Table 4). The results have been referred to the entire population.

In albumin system: the lines of Gazella and Szweykowska are characterized by a high frequency of Al^F, while the line of Ukrainka by a low frequency.

In transferrin system: a high frequency of Tf^D was recorded in the lines of Mlecha

Table 1. Comparison between the population of mares and entire population

Protein Phenotypes		Mares			Whole population		
		n	per cent of phenotypes	frequency of alleles	*n*	per cent of phenotypes	frequency of alleles
Al	*F*	135	19.8	0.450	190	18.9	0.443
	FS	343	50.4		509	50.7	
	S	203	29.8	0.550	305	30.4	0.557
Tf	*D*	50	7.4	0.292	79	7.9	0.310
	DF	261	38.4		398	39.7	
	DH	23	3.4		42	4.2	
	DG	13	1.9		16	1.6	
	F	250	36.9	0.616	352	35.1	0.600
	FH	42	6.2		62	6.2	
	FO	33	4.9		46	4.6	
	H	5	0.7	0.056	5	0.5	0.060
	HO	1	0.1		1	0.1	
	O	1	0.1	0.036	1	0.1	0.030
Es	*F*			0.026	1	0.1	0.024
	FG	3	0.4		4	0.4	
	FI	33	4.8		43	4.3	
	G	20	2.9	0.090	22	2.2	0.091
	GI	80	11.8		135	13.4	
	I	523	77.5	0.870	771	76.7	0.870
	IS	18	2.6		29	2.9	
	S			0.014			0.015
6-PGD	*F*	102	15.5	0.302	111	11.3	0.290
	FS	193	29.3		346	35.3	
	S	363	55.2	0.698	524	53.4	0.710
PGM	*F*	61	9.5	0.234	100	10.4	0.260
	FS	178	27.8		292	30.3	
	S	401	62.7	0.766	571	59.3	0.740
PHI	*F*			0.013			0.010
	FI	18	2.7		24	2.4	
	I	660	97.3	0.987	977	97.6	0.990
CA	*F*	1	0.2	0.042	2	0.2	0.040
	FI	54	8.1		81	8.1	
	I	618	91.7	0.958	913	91.7	0.960
Cat	*F*	1	0.3	0.075	1	0.2	0.060
	FS	50	14.5		68	10.8	
	S	294	85.2	0.925	559	89.0	0.940

and Milordka, while a low one in the lines of Ukrainka, Wołoszka and Sahara. A high frequency of Tf^F was recorded in the lines of Ukrainka, Szweykowska and Wołoszka, and a low one in the lines of Mlecha and Milordka. No Tf^O and Tf^H alleles were recorded in the line of Szweykowska.

In esterase system: considerable differences in the frequency of alleles were recorded between the compared lines. In a number of lines some alleles were not observed, while in others the frequency turned out to be several times higher as compared with the population average. No Es^F was recorded in the lines of Milordka and Ukrainka, no Es^G in the line of Sahara, and no Es^S in the lines of Gazella and Milordka. The frequency of Es^F is twice as high in the line of Gazella, and three times as high as in the line of Szweykowska. Es^G is twice as high as in the line of Szweykowska,

Table 2. More important female lines of Arab horses bred in Poland

Line number	Name of line	Number of female individuals
1	Gazella	112
2	Mlecha	85
3	Sahara	45
5	Milordka	87
6	Ukrainka	49
7	Szweykowska	48
10	Wołoszka	41
12	Szamrajówka	18
27	Semrje	15
28	Bent el Arab	6
29	Scherifa	21
30	Rodania	10
31	Solma	27
32	Cherifa	21

while Es^S is four and a half times as high as in the line of Sahara and two and a half times as high as in the line of Wołoszka as compared with the population average.

6-PGD: a high frequency of $6\text{-}PGD^F$ was recorded in the lines of Wołoszka, Milordka and Gazella, while a considerably lower frequency in the lines of Mlecha and Sahara.

PGM: a higher frequency of PGM^F was recorded in the lines of Sahara and Milordka, and a lower one in the line of Wołoszka. However, these differences here are much smaller than those in the systems discussed above.

In the remaining systems, *PHI*, *CA*, and *Cat*, one allele predominates (94 - - 100%) in all the lines. No PHI^F and CA^F alleles were recorded in the line of Milordka, no PHI^F allele in the lines of Ukrainka and Wołoszka.

It was observed that the frequency of PHI^F was 3-fold higher in the lines of Szweykowska and Sahara, and the frequency of Cat^F was 2-foldhigher in the line of Sahara and the frequency of Cat^F was 4-fold lower in the line of Ukrainka.

Summing it up, it should be pointed out that the mare population differs from the entire population of Arab horses bred in Poland in respect of frequencies of genetic variants recorded in the blood proteins studied. Differences between separate female lines were also recorded.

The population of Arab horses bred in Poland originates from a small number of individuals whose breeding was started in the XVIIIth century. The horses have already been cross-breed for twenty generation within a small population. In spite of that, both male and female lines (Tomaszewska-Guszkiewicz et al. 1983) have displayed considerable differences. This indicates that the population has been inbred only to a small extent. This seems to be the result of a proper and consistent policy in the field of breeding Arab horses in Poland, and a purposeful selection of individuals for mating based on a detailed genealogical and family analysis.

Table 3. Line of dam Milordka

MILORDKA 1810

Delfina, Zaira
Malikarda, Ostrouszka
Kraśna, Luba, Galicja
Lodoiska, Heraldyka, Sureka
Restauracja, Republika, Odyseja
Japonia, Malta, Amurath
Belgia, Siglavi, Hebda, Koalicja
Anielka, Bajka, Malaga, Federacja
Arabia, Jaga, Odra, Narada
Elsissa, Saga, Gałka, Walna
Lala, Canaria, Estokada, Galopada,
Ela, Czatanoga, Eskapada, Estebna, Estonia, Gejsza, Gilotyna, Pokaźnaja
Elokwercja, Eloe, Etola, Elstera, Elegia, Emilia, Emalia, Granica, Czarda, Cedzyna, Caryca,
Ekstaza, Epika, Espada, Esencja, Elwira, Epoka, Estera, Eskorta, Eskada, Errata, Gladiola, Parma
Elekcja, Elana, Etolia, Eroica, Egida, Emma, Erna, Eneida, Eufemia, Emka, Gwardia, Czeczuga, Cerkwia, Cukinia, Ekipa, Ekspansja, Espaniola,
Elegancja, Esmeraida, Esterka, Eulalia, Partita, Parodia
Elodia, Edda, Erta, Erotyka, Gwiazda, Głownia, Gwintówka, Gromada, Grusza, Groteska, Groza, Granda, Gromada, Catalina
Gwiazdka, Gozdawka, Catalonia

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

Table 4. Comparison of seven female line with the entire population

Protein Phenotypes		Gazella (born 1845)			Milordka (born 1845)			Mlecha (born 1845)			Ukrainka (born 1815)			Szweykowska (born 1800)			Sahara (born 1845)			Wołoszka (born 1810)			Whole population		
		n	%	allelic frequency	*n*	%	allelic frequency	*n*	%	allelic frequency	*n*	%	allelic frequency	*n*	%	allelic frequency	*n*	%	allelic frequency	*n*	%	allelic frequency	*n*	%	allelic frequency
	F	31	28.4	0.532	14	16.1	0.420	19	22.9	0.476	3	6.7	0.289	12	25.5	0.511	6	14.0	0.465	7	17.5	0.412	190	18.9	0.443
Alb	*FS*	54	49.5		45	51.7		41	49.4		20	44.4		24	51.1		28	65.1		19	47.5		509	50.7	
	S	24	22.0	0.468	28	32.2	0.580	23	27.7	0.524	22	48.9	0.711	11	23.4	0.489	9	20.9	0.535	14	35.0	0.588	305	30.4	0.557
	D	8	7.3	0.326	6	6.9	0.308	9	10.9	0.355	2	4.4	0.200	6	12.8	0.319	4	9.3	0.267	1	2.5	0.237	79	7.9	0.310
	DF	49	45.1		44	50.6		34	41.0		14	31.2		18	38.3		13	30.2		16	40.0		398	39.7	
	DH	5	4.6		7	8.2		3	3.6											1	2.5		42	4.2	
	DO	1	0.9		1	1.1		4	4.8								2	4.7					16	1.6	
	F	31	28.1	0.573	23	26.4	0.546	24	28.9	0.543	22	48.9	0.712	23	48.9	0.681	16	37.2	0.617	20	50.0	0.726	352	35.1	0.600
Tf	*FH*	8	7.3		4	4.6		5	6.0		2	4.4					3	7.0		1	2.5		62	6.2	
	FO	6	5.5		1	1.1		3	3.6		4	8.9					5	11.6		1	2.5		46	4.6	
	H	1	0.9	0.069	1	1.1	0.075			0.054	1	2.2	0.044						0.035			0.025	5	0.5	0.060
	HO							1	1.2														1	0.1	
	O			0.032			0.011			0.048			0.044						0.081			0.012	1	0.1	0.030
	F			0.049						0.024						0.073			0.011			0.012	1	0.1	0.024
	FG													3	6.3								4	0.4	
	Fl	11	9.8					4	4.8					4	8.3		1	2.3		1	2.4		43	4.3	
Es	*G*	2	1.8	0.067	2	2,3	0.007	2	2.4	0.113			0.041	2	4.2	0.187				1	2.4	0.061	22	2.2	0.091
	GI	11	9.8		13	14.8		15	17.8		4	8.2		11	22.9		1	2.3		3	7.3		135	13.4	
	I	88	78.6	0.884	73	82.0	0.903	61	72.6	0.851	45	89.8	0.949	27	56.2	0.729	37	94.1	0.920	33	80.5	0.890	771	76.7	0.870
	IS							2	2.4		1	2.0		1	2.1		6	13.6		3	7.3		29	2.9	
	S									0.011			0.010			0.010			0.069			0.036			0.015
	F	20	18.4	0.372	15	17.2	0.408	5	6.0	0.205	5	11.1	0.278	5	10.7	0.309	2	4.6	0.221	9	22.5	0.462	111	11.3	0.290
6-PGD	*FS*	41	37.6		40	46.0		24	28.9		15	33.3		19	40.4		15	34.9		19	47.5		346	35.3	
	S	48	44.0	0.628	32	36.8	0.592	54	65.1	0.705	25	55.6	0.722	23	48.9	0.691	26	60.5	0.779	12	30.0	0.538	524	53.4	0.710
	F	18	16.5	0.294	9	10.3	0.333	9	10.9	0.277	8	17.8	0.311	5	10.7	0.300	6	14.0	0.326	2	5.0	0.237	100	10.4	0.260
PGH	*FS*	28	25.7		40	46.0		28	33.7		12	26.7		19	40.4		16	37.2		15	37.5		292	30.3	0.740
	S	63	57.8	0.706	38	43.7	0.667	46	55.4	0.723	25	55.5	0.689	23	48.9	0.691	21	48.8	0.674	23	57.5	0.763	571	59.3	
	F			0.009						0.006						0.043			0.035						0.010
PHJ	*FI*	2	1.8					1	1.2					4	8.5		3	7.0					24	2.4	
	I	107	98.2	0.991	87	100.0	1.000	82	98.8	0.994	45	100.0	1.000	43	91.5	0.957	40	93.0	0.965	40	100.0	1.000	177	97.6	0.990
	F			0.055						0.024			0.022			0.053			0.035			0.038	2	0.2	0.040
CA	*FI*	12	11.0					4	4.8		2	4.4		5	10.4		3	7.9		3	7.5		81	8.1	
	I	97	89.0	0.945	87	100.0	1.000	79	95.2	0.976	43	95.6	0.978	42	89.6	0.947	40	93.0	0.965	37	92.5	0.962	113	91.7	0.960
	F			0.034			0.056			0.075			0.013	1	2.7	0.040	1	3.8	0.115			0.043	2	0.3	0.060
Cat	*FS*	4	6.8		10	13.2		6	15.0		1	2.6		1	2.7		4	15.4		2	8.7		68	10.8	
	S	55	93.2	0.966	66	86.8	0.934	34	85.0	0.925	37	97.4	0.987	35	94.0	0.960	21	80.8	0.885	21	91.3	0.957	558	88.9	0.940

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POLIMORFIZM GENETYCZNY KRWI KONI CZYSTEJ KRWI ARABSKIEJ HODOWANYCH W POLSCE
II. ROZKŁAD GENOTYPÓW W LINIACH ŻEŃSKICH DLA OŚMIU LOCI POLIMORFICZNYCH BIAŁEK I ENZYMÓW

Streszczenie

Metodą elektroforezy w żelu skrobiowym określono polimorfizm ośmiu układów białkowych krwi u 1049 koni arabskich hodowanych w Polsce. W surowicy: albuminę (*Alb*), transferynę (*Tf*), esterazę (*Es*); w krwinkach: dehydrogenazę 6-fosfoglukonianową (*6-PGD*), fosfoglukomutazę (*PGM*), izomerazę glukozofosforanową (*PHI*), anhydrazę węglanową (*CA*), katalazę (*Cat*). Porównano populację żeńską liczącą 726 osobników z całą populacją koni. W grupie klaczy stwierdzono większą częstość występowania fenotypów *DO* transferyny, *G* esterazy i *FS* katalazy oraz mniejszą częstość fenotypów *DH* transferyny, *GI* esterazy w stosunku do całej populacji. Porównano między sobą siedem najliczniej reprezentowanych linii żeńskich, wykazując istnienie znacznych różnic w częstościach alleli wszystkich badanych układów białek.

ГЕНЕТИЧЕСКИЙ ПОЛИМОРФИЗМ КРОВИ ЧИСТОКРОВНЫХ АРАБСКИХ КОНЕЙ, ВЫРАЩЕННЫХ В ПОЛЬШЕ
II. РАСПРЕДЕЛЕНИЕ ГЕНОТИПОВ В ЖЕНСКИХ ЛИНИЯХ ДЛЯ ВОСЬМИ ЛОКУСОВ ПОЛИМОРФИЧЕСКИХ БЕЛКОВ И ЭНЗИМОВ

Резюме

С помощью метода электрофореза в крахмальном геле был определен полиморфизм восьми белковых систем крови у 1049 арабских коней, выращенных в Польше. В сыворотке: альбумин (*Alb*), трансферин (*Tf*), эстераза (*Es*); в кровяных тельцах: 6-фосфорглюконовая дегидрогеназа (*6-PGD*), фосфоглюкомутаза (*PGM*), глюкозофосфатная изомераза (*PHI*), карбоангидраза (*CA*), каталаза (*Cat*). Женская популяция, насчитывающая 726 лошадей, была сравнена с целой популяцией коней. В группе кобыл была обнаружена высшая частота фенотипов *DO* трансферина, *G* эстеразы и *FS* каталазы, а также меньшая частота фенотипов *DH* трансферина, *GI* эстеразы относительно целой популяции. При сравнении семи наиболее многочисленных женских линий были обнаружены существенные разницы в частоте аллелей всех исследуемых систем белков.