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Genetic structure analysis of Tatra Shepherd dog population from Silesian Voivodeship

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The aim of the work was to analyze the genetic structure of the population of Tatra Shepherd dog, registered in Silesian Branches of Polish Kennel Club. Data consisted of four-generation pedigrees of 31 Tatra Shepherd dogs (11 males and 20 females) born between 1995 and 2010. Inbreeding and relationship coefficients, as well as effective number of founders and ancestors, were calculated. These statistics give the picture of genetic diversity of the population. Average inbreeding coefficient was 4.40%, whereas average relationship coefficient was 11.50%. Effective number of founders and ancestors was relatively high in relation both to the population size and to the results of studies of other authors on different dog breeds. However, only 5 ancestors explained 50% of gene pool and 20 ancestors were necessary to explain 90% of population gene pool. The population under study was only a small fragment of the population of Tatra Shepherd dogs; however, the results of the work give a general view on the whole population, in which mating of related animals should be avoided in order to prevent the increase of inbreeding level.

KEY WORDS: inbreeding / relationship / founders / ancestors / Tatra Shepherd dog

The Tatra shepherd dog, a breed of dogs belonging to the group originating from *Canis familiaris inostrancevi*, comprising many pastoral dogs and other Mollosers, was initially called liptok dogs. Its ancestors arrived to Europe in the 4th - 6th century AD with the Huns who settled in the present-day Hungary. In the 15th century the dogs were bred by Wallachian shepherds in the Tatra Mountains. The Tatra Shepherd dog, probably descending from the Tibetan mastiff, had very thick bones, long white coat and drooping ears. Many European shepherd breeds, e.g. Slovakian Chuvac or Italian Marremano-Abruzzese, closely resemble the Polish Tatra Shepherd dog. All these breeds are similar in appearance and also have white coats [23, 24].

In accordance with the present breed standard the Tatra Shepherd dog has been traditionally used as a pastoral dog to guard sheep flocks. This breed is strong, determined and wi-

lling to work. They are also very intelligent and alert, suitable to be guard dogs. This breed is also utilised as companion dogs and in dog-assisted therapy. The Tatra Shepherd dog is an excellent companion, thanks to its friendly attitude to children and pet animals [25].

The Tatra Shepherd dog is a native dog breed developed in the mountainous region in the vicinity of Zakopane. Since the Tatra Mountains constitute a natural geographical barrier, this breed was created in isolation from a similar breed in Slovakia. The first show for Tatra Shepherd dogs was organised in 1937 by the Polish Association of Pedigree Dog Breeders and the Society of Working Dog Breeders. The event was held in Zakopane and marked the beginning of regulated breeding for Tatra Shepherds. Since many representatives of this breed were kept in Zakopane throughout WWII, the breed managed to survive in that region. After the war the Polish Kennel Club (Związek Kynologiczny w Polsce) was reactivated and shows of Tatra Shepherd dogs were organised in Krakow by Prof. T. Marchlewski [3, 24].

In the Zakopane branch of the Polish Kennel Club Dr H. Dereziński searched for Tatra Shepherd type dogs; as a result, a show was organised in 1954 presenting 120 dogs of that breed. Thanks to the long-term efforts of Dr. Dereziński this breed was preserved and its representatives continue to be presented at dog shows. Tatra Shepherd dogs are also found in other branches of the Polish Kennel Club. In 1967 the Tatra Shepherd dog was recognised by FCI as a breed, registered under standard no. 252a. The standard was established by Prof. M. Trybulski. Since at present the population of this breed is limited in number, we may observe breeding problems typical of small populations [25]. For this reason the genetic structure of the Tatra Shepherd dog population needs to be constantly monitored.

The aim of this study was to estimate inbreeding coefficients and relationship coefficients as well as analyse the contributions of ancestors and founders to the active population of Tatra Shepherd dogs registered at the Silesian branches of the Polish Kennel Club.

Material and methods

The experimental material comprised four-generation pedigrees of 31 Tatra Shepherd dogs: 11 males and 20 females born in the years 1995-2010. Pedigrees were provided by three Silesian branches of the Polish Kennel Club: 10 from Katowice, 20 from Bytom and 1 from Będzin. Inbreeding coefficients (F_X) and relationship coefficients (R_{XY}) were estimated for all the animals and for each sex separately, while kinship between male and female dogs was determined using the algorithm proposed by Tier [26] with a recursive modification [7].

The reference population in the analyses of the contributions of founders and ancestors was an active population composed of 31 Tatra Shepherds. The total and effective numbers of founders and ancestors were estimated, while founders and ancestors with the highest contributions to the reference population were identified. The effective number of founders (f_e) and the effective number of ancestors (f_a) were estimated following a method proposed by Lacy [14, 15], as modified by Boichard et al. [1, 2].

Results and discussion

In the analysed population of 31 Tatra Shepherds a total of 24 animals (77.42%) were inbred. In the group of 11 male dogs there were 9 inbred animals (81.82%), while among 20 bitches 15 were inbred (75%). Mean inbreeding coefficients (F_X) amounted to 4.8% for all animals and 5.8% for inbred animals, respectively (Table 1). Male Tatra Shepherds were more inbred than bitches. Mean inbreeding coefficients for inbred animals ranged from 5.6% to 5.8% depending on the sex, but they did not exceed the critical value amounting to 12.5% [6].

Table 1
Average inbreeding coefficients (F_X) for TS dogs from Silesian Branches of PKC

Specification	Sex	
	dogs	bitches
Number of animals in active population	11	21
Number of animals in pedigrees	74	120
Number of inbred animals	9	15
Mean F_X (%) – all animals	4.80	4.20
Mean F_X (%) – inbred animals	5.80	5.60

The investigated Tatra Shepherd population comprised 465 pairs of animals, of which 351 pairs (75.5%) were related. Mean relationship coefficients (R_{XY}) for all pairs and related pairs amounted to 11.5% and 15.2%, respectively. Non-zero relationship coefficients were recorded for 45 (81.82%) out of 55 pairs of males and 136 (71.58%) out of 190 pairs of females. From the total number of 220 mixed dog-bitch pairs a total of 170 pairs were related (77.27%). Among the related pairs the highest R_{XY} values were recorded between females (Table 2).

Table 3 gives a list of 24 inbred Tatra Shepherds. The highest F_X values, exceeding the critical value of 12.5% [6], were found for two animals (a male PKR.I-58996 *Bystry z Siwej Polany* and a female PKR.I-59591 *Aurora Lodowa Sopla*). The two next animals, again a dog and a bitch, had very similar values of the inbreeding coefficient, amounting to 8-9%. Values of the inbreeding coefficient for the other Tatra Shepherds did not exceed 7%. That group included nine animals, which were full siblings born in different litters in the same breeding kennels. These were two bitches from the "Z Siwej Polany" kennel and from Silesia two bitches from "Z Dobieszowic", the next two bitches from the "Runo" breeding kennel and three animals from the "Nutrena" kennel.

The total and effective numbers of founders in the TS population were 55 and 28, respectively, while the total and effective numbers of ancestors in the analysed population

Table 2
Average relationship coefficients (R_{XY}) for TS dogs from Silesian Branches of PKC

Specification	Pairs of		
	dogs	bitches	mixed*
Number of all pairs	55	190	220
Number of related pairs	45	136	170
Mean R_{XY} (%) – all pairs	11.60	11.00	11.80
Mean R_{XY} (%) – related pairs	14.20	15.40	15.27
Maximum R_{XY} (%) value	30.83	55.71	54.90

*Male x female pairs

Table 3
List of 24 inbred TS dogs from active population

Animal ID	Name	Sex	F_X (%)
PKR.I-58996	Bystry z Siwej Polany	male	17.24
PKR.I-59591	Aurora Lodowa Sopla	female	16.48
PKR.I-38770	Murań z Psiej Parafii	male	8.94
PKR.I-58328	Rusita Biały Podhalan	female	8.45
PKR.I-66543	Kaprys znad Cichej Wody	female	6.29
PKR.I-55085	Hyrny z Butorowego Wierchu	male	6.25
PKR.I-55651	Grania z Siwej Polany	female	6.05
PKR.I-56109	Grań z Siwej Polany	female	6.05
KW.I-143/OP	Bajka Jasiowe Turnie	female	5.47
PKR.I-52771	Warka Strong z Psiej Parafii	female	5.32
PKR.I-60514	Asta z Dobieszowic	female	5.18
PKR.I-60515	Aida z Dobieszowic	female	5.18
PKR.I-37301	Rum z Wierchu Rolowego	male	5.08
PKR.I-63121	Nowina-Zbój z Zadymy	female	4.55
PKR.I-60229	Amant Kalong	male	3.71
PKR.I-61674	Atena Alpejskie Zauroczenie	female	3.71
KW.I-162/OP	Harnaś Niedźwiedzia Łapa	male	3.61
PKR.I-52443	Rady Spiska Warta	male	3.42
PKR.I-49766	Duna Runo	female	3.13
PKR.I-49864	Dukla Runo	female	3.13
PKR.I-57741	Sara Nutrena	female	2.29
PKR.I-57742	Saba Nutrena	female	2.29
PKR.I-58416	Singer Nutrena	male	2.29
PKR.I-54305	Harnaś Mała Dolina	male	1.86

amounted to 31 and 14, respectively. The joint contributions of as few as 5 ancestors were required to explain 50% gene pool in the reference population; however, to explain 90% of its gene pool joint contributions of 20 ancestors were needed (Table 4).

Table 4
Parameters of gene origin in the Silesian TS dogs' population

Parameter	
Number of animals in reference population	31
Maximum number of generation traced	8
Equivalent number of complete generations known per animal	4.19
Total number of	
founders	55
ancestors	31
Effective number of	
founders (f_e)	28
ancestors (f_a)	14
Explaining 50% of the genetic pool	
founders	11
ancestors	5
Explaining 90% of the genetic pool	
founders	31
ancestors	20

Table 5 presents a list of main founders, while Table 6 gives main ancestors, which gene shares in the Silesian population of Tatra Shepherds exceeded 1%. There were 29 main founders in the discussed population, with their total contribution amounting to 89% gene pool of that population (Table 5). The joint contributions of those 23 main ancestors explained approx. 95% genetic variation in that population (Table 6).

Eight animals, which names are given in italics in Tables 5 and 6, were both the main founders and the main ancestors.

In their study Drozd and Karpiński [5] estimated relationship coefficients and inbreeding coefficients for a population of 483 Rottweilers, 546 Boxers, 712 German Shepherds and 435 Great Danes. The F_X values for all animals included in this study were greater than those reported by the above-mentioned authors, ranging from 0.23% to 1.44%. The inbreeding coefficients for inbred animals were also much higher than in the cited study, in which F_X ranged from approx. 2% in German Shepherd females to almost 9% in Great Dane males.

In turn, Cole et al. [4] reported much greater inbreeding coefficient values, amounting to approx. 25% for German Shepherds and approx. 15% for Labrador Retrievers, which worked as guide dogs.

Table 5

Founders with more than 1% gene contribution to reference population (names of animals being both main founders and main ancestors are printed in italics)

Animal ID	Name	Sex	Contribution (%)
KW.T-I-306/XXVIII	Czort	dog	8.72
PKR.0-CXCII-47069	*Bujac od Dzioboni*	dog	6.50
KW.T-III-107/XXVIII	Siklawa ze Stoku Gubałówki	bitch	5.44
PKR.0-LXXII-19853	Bari z Kotelnicy	dog	5.44
KW.T-II-132/XXVIII	Brandzia	bitch	4.36
KW.T-III-119/XXVIII	Uroda	bitch	4.36
KW.TIV-63	*Zawrat*	dog	3.23
KW.I-218/OP	*Turnia*	bitch	3.23
KW.I-291/OP	*Urocza Nutrena*	bitch	3.23
KW.I-296/OP	*Mores Nutrena*	dog	3.23
KW.I-329/OP	*Zalotna Nutrena*	bitch	3.23
PKR.0-CLXXXV-45452	Hajduk z Liptoków	dog	3.18
PKR.I-XI-2090	Bidula z Polany Pod Jeziorem	bitch	3.18
PKR.0-CXCXI-48837	*Wiktoria*	bitch	3.02
KW.T-III-82/XXVIII	Dunajec	dog	2.70
PKR.0-CXXVIII-33046	Zorza	bitch	2.70
PKR.0-CCXII-51200	Brzana	bitch	2.47
PKR.0-CLXXIV-43334	Dujawica	bitch	2.17
PKR.0-CXCVIII-48213	*Hawrań ze Stoku Gubałówki*	dog	2.04
PKR.0-CXVII-30551	Morena	bitch	2.04
KW.T-IV/44	Zbójnik Powik	dog	1.87
KW.T-IV/45	Saba Pitnika	bitch	1.87
PKR.0-CCXXXII-55916	Limba z Roli Chowańcowej	bitch	1.87
KW.I-178/OP	Saba	bitch	1.61
PKR.0-CIV-27798	Grzmot	dog	1.61
PKR.0-CVI-28284	Buczyna z Budrysówki	bitch	1.61
PKR.0-CCXXXVII-57178	Berta ze Smytni	bitch	1.51
PKR.I-XIX-3676	Luśnia z Butorowego Wierchu	bitch	1.31
PKR.0-CCXIV-51717	Izaura Ślebodna z Butorowego Wierchu	bitch	1.01

In the small population of the Polish Hound investigated by Głażewska [10], the inbreeding level was also much higher than in the analysed Tatra Shepherd population, as it ranged from 7 to 40% and was increasing with time, leading to health and reproduction problems.

Ólafsdóttir and Kristjánsson [20] for a small population of the Icelandic Sheepdog, which is threatened with extinction, estimated mean F_X=21%, i.e. much higher than that in the presented study. Those authors were of an opinion that such an inbreeding level may cause a higher frequency of hip dysplasia in Icelandic Sheepdogs [20].

Table 6

Ancestors with more than 1% gene contribution to reference population (names of animals being both main founders and main ancestors are printed in italics)

Animal ID	Name	Sex	Contribution (%)
PKR.I-VIII-1460	a-Dunajek z Byrtusiowej Płazówki	dog	17.44
PKR.0-CXCVIII-48214	*Hawrań ze Stoku Gubałówk*i	dog	10.89
PKR.I-49864	Dukla Runo	bitch	8.47
PKR.I-32634	Ornak z Butorowego Wierchu	dog	7.06
PKR.I-16577	Krywań od Małkuchów	dog	6.05
PKR.I-XXIV-4662	Beskid spod Lawiny	dog	5.65
PKR.0-CXCII-47069	*Bujac od Dzioboni*	dog	4.28
KW.I-329/OP	*Zalotna Nutrena*	bitch	3.23
KW.I-296/OP	*Mores Nutrena*	dog	3.23
KW.I-291/OP	*Urocza Nutrena*	bitch	3.23
KW.I-218/OP	*Turnia*	bitch	3.23
KW.TIV-63	*Zawrat*	dog	3.23
PKR.I-29799	Gwiazdka Chluba Liliowej Przełęczy	bitch	2.87
PKR.I-16581	Miśka z Furkaski	bitch	2.52
KW.I-321/OP	Asza Dolina Małej Panwi	bitch	2.22
PKR.I-49766	Duna Runo	bitch	2.02
PKR.I-61674	Atena Alpejskie Zauroczenie	bitch	1.41
PKR.I-55085	Hyrny z Butorowego Wierchu	dog	1.41
PKR.I-XLII-8571	Bela ze Smytni	bitch	1.41
PKR.I-17247	Polana spod Krzesanych Skał	bitch	1.41
PKR.I-LVIII-11733	Bacuś z Bobakowej Dziedziny	dog	1.26
PKR.I-31058	Murka Reza	bitch	1.21
PKR.0-CXCXI-48837	*Wiktoria*	bitch	1.06

The inbreeding coefficients estimated by Leroy et al. [16] for nine French dog breeds fell within relatively broad ranges, from over 3% for French Bulldogs to 12.4% for Barbet dogs. They were comparable or higher than those estimated in this study for Tatra Shepherds from the Silesian breeding kennels.

Values of the inbreeding coefficients in the investigated Tatra Shepherd population fell within the range of values reported by Leroy et al. [17] for 61 dog breeds in France, which amounted to approx. 0.3% for Lagotto Romagnolo up to 8.8% for the Pyrenean Shepherd dogs.

In comparison to F_X values ranging from 12 to 17%, reported by Kania-Gierdziewicz et al. [13] for the Greman Shepherds from breeding kennels in Cracow, the results for the Tatra Shepherds from Silesia recorded in this study were lower. On the other hand, the analysed population was more closely related than the above-mentioned German Shepherds. However, the results concerning mean inbreeding coefficients and relationship coefficients in the investigated Tatra Shepherds were much higher for all the animals and they were

comparable for the inbred animals to those obtained for representatives of that breed from the Cracow breeding kennels estimated by Kalinowska et al. [11] and to those given by Gierdziewicz et al. [9] for the Beagle population from Cracow.

Mean inbreeding coefficients estimated by Martinez et al. [18] for Cimarrón Uruguayo dogs reached approx. 4-6% and they were comparable to the F_X values obtained in this study for Tatra Shepherds from the Silesian kennels; however, the latter were more closely related than dogs analysed in the cited study.

Values of the inbreeding coefficients in the Silesian population of Tatra Shepherds were generally lower than those given by Mäki [19], ranging from approx. 10% for Labrador Retrievers from Nova Scotia to approx. 25% for Lancashire Heelers.

In turn, Oliehoek et al. [21] for a small and threatened Icelandic Sheepdog population estimated mean F_X at approx. 20-30%, which was a much higher value than the figure obtained in this study for Tatra Shepherds from Silesia.

Mean F_X values recorded by Přibáňová eta l. [22] for the Czech population of Dachshunds ranged from approx. 1% to almost 3%, depending on the type, and they were lower than those given in this study. However, maximum inbreeding coefficients for individual animals were comparable or even higher for certain Dachshund types in comparison to the Tatra Shepherds from Silesia and amounted to over 20% for standard longhaired Dachshunds.

Voges and Distl [27] reported higher values of the inbreeding coefficient than those recorded in this study, since they ranged from approx. 4.5% for Bavarian Mountain Hounds to almost 9.5% for Tyrolean Hounds.

Estimates of the effective numbers of founders (f_e) and ancestors (f_a) for the Tatra Shepherd population calculated in this study were comparable to those reported by Cole et al. [4] for much larger populations of German Shepherds and Labrador Retrievers working as guide dogs.

In comparison to values estimated for Tatra Shepherds from Silesia the shares of genes of certain founders in the Polish Hound population obtained by Głażewska [10] were much higher.

In a study by Leroy et al. [17] the values of f_a and f_e for 61 dog breeds in France ranged rather markedly: f_e from 10 (in Barbet dogs) to 656 (in Poodles), whereas f_a ranged from 9 to 209, respectively. In turn, the size of the reference population amounted to 112 animals for Barbet dogs and 8808 for Poodles. Results recorded in this study fall within this range; however, the number of animals in the reference population, i.e. only 31 Tatra Shepherds, was much lower. In an earlier publication by Leroy et al. [16] concerning genetic variation of nine French dog breeds those authors obtained f_e and f_a values ranging from 7 to over 91 and from approx. 7 to over 40 depending on the breed. Results recorded in this study were comparable, although calculated for a smaller reference population.

For Bavarian, Hanover and Tyrolean Hounds Voges and Distl [27] cited similar f_a values, while for f_e they were higher. In that study covering much more numerous reference populations the contributions of 10 main founders to the gene pools of Bavarian, Hanover and Tyrolean Hounds ranged between 54% and 78% and they were comparable or lower than our results obtained for the 11 founders and 5 ancestors of the Silesian population of Tatra Shepherds.

Values of f_e and f_a in the Tatra Shepherd population in the Cracow branch of the Polish Kennel Club [8] were comparable to those recorded in this study for the Silesian population of this breed.

In a study by Mäki [19] the values of the effective number of ancestors (f_a) ranged from over 5 to approx. 14, while those for the effective number of founders (f_e) were from approx. 10 to over 15, respectively, for Labrador Retrievers from Nova Scotia and Lancashire Heelers. Our results were much higher, although obtained for a much smaller reference population (31 Tatra Shepherds), at much higher gene shares of the most important founders and ancestors.

Results concerning the effective number of founders (f_e) and ancestors (f_a) for the Silesian population of Tatra Shepherds obtained in the presented study were lower than those given by Gierdziewicz et al. [9] for a larger Beagle population. Values of f_e and f_a for the Cimarrón Uruguayo population in Urugway [18], much more numerous (1455 animals) than the investigated population of Tatra Shepherds, were higher than those recorded in this study. Also the f_e and f_a values estimated for the population of 60 German Shepherds from Cracow [12] were higher than those obtained in this study.

Summing up it may be stated that the mean values of the inbreeding and relationship coefficients obtained for the Silesian population of Tatra Shepherds were relatively low. However, in view of the considerable percentage of inbred animals (over 77%) and related animals (over 75%) in the analysed population we face a real threat of inbreeding depression. Values of the effective number of founders and the effective number of ancestors are relatively high in relation to the size of the reference population. However, the fact that contributions of as few as five ancestors account for a half of the gene pool in the investigated population may raise concern for its future prospects.

REFERENCES

1. BOICHARD D., MAIGNEL L., VERRIER E., 1996 – Analyse généalogique des races bovines laitières françaises. ***INRA Production Animalés*** 9(5), 323-335.
2. BOICHARD D., MAIGNEL L., VERRIER E., 1997 – The value of using probabilities of gene origin to measure genetic variability in a population. ***Genetics Selection Evolution*** 29, 5-23.
3. BUKŁAD E., 2006 – Owczarek podhalański. ***Pies*** – wydanie specjalne, 17-28.
4. COLE J.B., FRANKE D.E., LEIGHTON E.A., 2004 – Population structure of a colony of dog guides. ***Journal of Animal Science*** 82(10), 2906-2912.
5. DROZD L., KARPIŃSKI M., 1997 – Inbred wybranych ras psów wpisanych do Polskiej Księgi Rodowodowej. ***Annales Universitatis Mariae Curie-Skłodowska Lublin-Polonia***, vol. XV, 42, sectio EE, 293-297.
6. FALCONER D.S., 1984 – Einführung in die Quantitative Genetik. Eugen Ulmer Verlag, Stuttgart.
7. GIERDZIEWICZ M., KANIA-GIERDZIEWICZ J., 2007 – A study of efficiency of recursive algorithm for estimating relationship coefficients. ***Acta Scientiarum Polonorum, Sectio Zootechnica*** 6(4), 29-36.

8. GIERDZIEWICZ M., KALINOWSKA B., KANIA-GIERDZIEWICZ J., 2010 – Genetic structure analysis of Tatra Shepherd dog population in area of Krakow Branch of Polish Kennel Club. II. Contribution of founders and ancestors. ***Electronic Journal of Polish Agricultural Universities*** 13(3), #3 (http://www.ejpau.media.pl/volume13/issue3/art-03.html).
9. GIERDZIEWICZ M., KANIA-GIERDZIEWICZ J., KALINOWSKA B., 2011 – Analysis of genetic structure of the Beagle population in the area of Cracow Branch of the Polish Kennel Club. ***Animal Science Papers and Reports*** 29(4), 359-367.
10. GŁAŻEWSKA I., 2008 – Genetic diversity in Polish hounds estimated by pedigree analysis. ***Livestock Science*** 113, 296-301.
11. KALINOWSKA B., GIERDZIEWICZ M., KANIA-GIERDZIEWICZ J., 2010 – Genetic structure analysis of Tatra Shepherd dog population in area of Krakow Branch of Polish Kennel Club. I. Inbreeding and relationship coefficients. ***Electronic Journal of Polish Agricultural Universities*** 13(3),#2 (http://www.ejpau.media.pl/volume13/issue3/art-02.html).
12. KANIA-GIERDZIEWICZ J., KALINOWSKA B., GIERDZIEWICZ M., 2011 – Analiza udziałów założycieli i przodków w populacji aktywnej owczarka niemieckiego w rejonie działania Krakowskiego Oddziału Związku Kynologicznego w Polsce. ***Roczniki Naukowe Polskiego Towarzystwa Zootechnicznego*** 7(2), 9-17.
13. KANIA-GIERDZIEWICZ J., KALINOWSKA B., GIERDZIEWICZ M., 2011 – Inbreeding and relationship in the German Shepherd dog population in area of Cracow Branch of Polish Kennel Club. ***Roczniki Naukowe Polskiego Towarzystwa Zootechnicznego*** 7(3), 21-29.
14. LACY R.C., 1989 – Analysis of Founder representation in pedigrees. Founder Equivalents and Founder Genome Equivalents. ***Zoo Biology*** 8, 111-123.
15. LACY R.C., 1995 – Clarification of genetic terms and their use in the management of captive populations. ***Zoo Biology*** 14, 565-578.
16. LEROY G., ROGNON X., VARLET A., JOFFRIN C., VERRIER E., 2006 – Genetic variability in French dog breeds assessed by pedigree data. ***Journal of Animal Breeding and Genetics*** 123, 1-9.
17. LEROY G., VERRIER E., MERIAUX J.C., ROGNON X., 2009 – Genetic diversity of dog breeds: within-breed diversity comparing genealogical and molecular data. ***Animal Genetics*** 40(3), 323-332.
18. MARTINEZ M., ARMSTRONG E., GAGLIARDI R., Y LLAMBI S., 2011 – Estudio ógico del perro Cimarrón Urugayo (Pedigree analysis of the canine breed Cimarrón Uruguayo). ***Archivos de zootecnia*** 60(232), 1327-1330.
19. MÄKI K., 2010 – Population structure and genetic diversity of worldwide Nova Scotia Duck Tolling Retriever and Lancashire Heeler dog populations. ***Journal of Animal Breeding and Genetics*** 127, 318-326.
20. ÓLAFSDÓTTIR G.Á., KRISTJÁNSSON TH., 2008 – Correlated pedigree and molecular estimates of inbreeding and their ability to detect inbreeding depression in the Icelandic Sheepdog, a recently bottlenecked population of domestic dogs. ***Conservation Genetics*** 9, 1639-1641.
21. OLIEHOEK P.A., BIJMA P., VAN DER MEIJDEN A., 2009 – History and structure of the closed pedigreed population of Icelandic Sheepdogs. ***Genetics Selection Evolution*** 41, 39-51.

22. PŘIBAŇOVÁ M., HORÁK P., SCHRÖFFELOVÁ D., URBAN T., BECHYŇOVÁ R., MUSILOVÁ L., 2009 – Analysis of genetic variability in the Czech Dachshund population using microsatellite markers. ***Journal of Animal Breeding and Genetics*** 126, 311-318.
23. REDLICKA A, REDLICKI M., 2003 – Owczarek podhalański. Agencja Wyd. MAKO PRESS, Warszawa.
24. ŚCIESIŃSKI K., 2002 – Charakterystyka współczesnej populacji owczarka podhalańskiego (cz. I). ***Przegląd Hodowlany*** 6, 25-28.
25. ŚCIESIŃSKI K., 2002 – Charakterystyka współczesnej populacji owczarka podhalańskiego (cz. II). ***Przegląd Hodowlany*** 7, 20-25.
26. TIER B., 1990 – Computing inbreeding coefficients quickly. ***Genetics Selection Evolution*** 22, 419-430.
27. VOGES S., DISTL O., 2009 – Inbreeding trends and pedigree analysis of Bavarian mountain hounds, Hanoverian hounds and Tyrolean hounds. ***Journal of Animal Breeding and Genetics*** 126, 357-365.