

INBREEDING AND ANCESTOR LOSS IN THE POPULATION OF TATRA SHEPHERD DOGS BASED ON THE SEX AND BREEDING SYSTEM

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ABSTRACT

The aim of the study was to analyse the structure of the population and inbreeding trend taking into account the sex, breeding system. The highest number of kennels, that was, 40 were registered in the Lesser Poland voivodeship, in the region of Podhale, which corresponded to 33.06%. For a 4-generation population, the inbreeding rate was 6.52% for male dogs and 6.79% for female dogs. The highest inbreeding rate was found in a nCH and PL groups consisting of both male and female dogs. The inbreeding rate was significantly higher in 2005–2014, amounting to 6.94% for male dogs and 8.22% for female dogs in comparison to the period 1994–2004 when it was 5.87% and 4.88%, respectively. An increasing ancestor loss coefficient (AVK) was found, which may result in an increased number of inbred animals. In particular, it referred to female dogs in the nCH, PL, and Z group, whereas a significant increase of AVK was observed in the group of male dogs from foreign kennels. Studies had shown that there was no risk of inbred depression yet; however, the gene pool of the Tatra Shepherd dog breed had become noticeably restricted.

Key words: *Canis familiaris*, Tatra Shepherd dog, champion, inbreeding, ancestor loss

INTRODUCTION

There are about 500 million dogs around the world, including more than 65.5 million living in the EU. The highest number of dogs in Europe live in Russia – more than 17.5 million, in Germany – 9.4 million, in United Kingdom – 9 million and in Poland – 7.6 million. In Poland and Romania, it is estimated that 42% of households have at least one dog, which puts Poland first in Europe. On the other hand, according to the American Veterinary Medical Association (AVMA), more than 70 million dogs live in the United States of America, while the American Pet Products Association (APPA) estimates their count as about 77.8 million. Both sources recount that smaller breeds are predominant in the USA. The World Canine Organization (Fédération Cynologique Internationale, FCI) classified 344 breeds, and Poland has currently 340 registered breeds split into hunting, guardian and shepherd dogs [Young et al. 2011,

The Humane Society of the United States 2016, FCI 2017, FEDIAF 2018].

The oldest canine organization in Poland is the Polish Kennel Club (ZKwP – founded in 1938) which keeps Stud Books (KW) for Polish breeds and maintains the longest pedigree lines for all world recognized breeds, verifies pairs of parents and registered litter, conducts mental health tests and organizes renowned shows of purebred dogs. ZKwP is a patron of 5 national breeds including: Polish Grey Hound, Polish Hunting Dog, Polish Hound, Polish Lowland Sheepdog and Tatra Shepherd Dog. In 1973 Fédération Cynologique Internationale (FCI), at the request of ZKwP, approved the Tatra Shepherd dog standard number 252 as a shepherd and guardian dog. In order to protect the exterior of dogs in Poland every year more than 120 purebred dog shows are organized, including 15 international ones with the participation of Tatra Shepherd Dogs [Redlicka and Redlicki 2003, Polish Kennel Club 2009]. Recently, dog shows have become increasingly popular, and the selection has

been more oriented at the phenotype and grooming of dogs [Lindblad-Toh et al. 2005]. Studies show that such breeding leads to a loss of genetic variability in some breeds in Europe [Leroy et al. 2006, Calboli et al. 2008, Jansson and Laikre 2018].

The Tatra Shepherd Dog breed has a number of relatives classified as separate breeds living along the Carpathians, Alps and Pyrenees. The territorial proximity between Tatra Shepherd Dog and Slovak Cuvac suggest a close relationship of these two breeds. However, based on the cross-population studies, on the grounds of DNA polymorphism a genetic distance dendrogram was designed for six breeds of white shepherd dogs: Pyrenean Mountain Dog (France), Maremma Sheepdog (Italy), Akbash Dog (Turkey), Tatra Shepherd Dog (Poland), Slovak Cuvac (Slovakia), and the Kuvasz (Hungary). Studies have shown that Tatra Shepherd dogs are the closest relatives of Akbash Dogs [Ściesiński 2002, Redlicka and Redlicki 2003, Yilmaz and Ertuğrul 2012]. Despite their unique guarding efficiency, Tatra Shepherd Dogs indirectly contribute to green grazing of sheep and are a tourist amenity to the numerous visitors in the region of Podhale [Radzik-Rant and Wojnarska 2008, Chodzeń 2014, Horoszewicz et al. 2017]. Despite many genetically valuable Tatra Shepherds having been taken abroad from Poland by their owners, the population seems to be reconstructed and quite even. However, it is still not sufficiently numerous, which prompts the monitoring of relationship in order to avoid inbreeding [Kalinowska et al. 2010, Kania-Gierdziewicz et al. 2015].

Inbreeding increases the level of homozygosity of an animal, which has positive and less positive effects. Creating homozygous animals can reveal latent defects in recessive genes. Many authors claim that the loss of genetic diversity and inbreeding contributes to the development of physical diseases, defects and disorders such as reduced fertility and prolificacy, the occurrence of lethal alleles in a litter, and lower offspring survival rate. In addition, anomalies may occur in the hip joint anatomy leading to dysplasia among house dogs, especially of large breeds [Ubbink et al. 1998, Ólafsdóttir and Kristjánsson 2008, Krzemińska et al. 2018]. The average inbreeding coefficients for a breed range from about 0.82% for Golden Retrievers, 2% for German Shepherd Dogs, 4.5% for Bullmastiff Dogs, through 9% for Great Danes to 26% for Nova Scotia Duck Tolling Retrievers and as much as 37% for Polish Hounds [Drozd and Karpiński 1997, Głazewska 2008, Mäki 2010, Kania-Gierdziewicz et al. 2014, Mortlock et al. 2016]. The F_x coefficient is supplemented by information about the content of a unique pool of genes revealed by the ancestor loss coefficient (AVK). AVK makes indicates a percentage ratio of unique ancestors to the total number of ancestors for a specific number of generations [Kruzińska et al. 2019]. The variations in the population

of Tatra Shepherd Dogs have been shown by Radko et al. [2018]. The DNA polymorphism analysis demonstrated a considerable genetic diversity of microsatellite markers and the lack of inbreeding in the analyzed population of Tatra Shepherd dogs. Other studies carried out in Poland [Kalinowska et al. 2010, Kania-Gierdziewicz et al. 2015, Świderek et al. 2015] confirm the differentiated level of inbreeding with an upward trend, depending on the sex and age as well as the region of occurrence of the Welsh Corgi breed and the Tatra Shepherd Dog breed.

The studies aimed at analyzing the structure of the population and the inbreeding trend based on pedigrees taking into account features such as: sex, breeding type (champions, non-champions) and origin (domestic and foreign) of Tatra Shepherd Dogs.

MATERIAL AND METHODS

Analyzed animal material

The first pedigree Tatra Shepherds in Poland were born in 1957 in Łeba, in the kennel run by Danuta Hryniewicz. They were the descendants of dogs she had owned since 1935, registered with the Polish Association of Pedigree Dog Breeders. During the first International Pedigree Dog Show in Poland, held in Poznań in 1962, only two Tatra Shepherds were shown, but in the following years the number of those dogs increased continuously. In 1973, the Fédération Cynologique Internationale (FCI), at the request of ZKwP (Polish Kennel Club) approved a breed standard of Tatra Shepherd dog under number 252. In 1979–1980 Tatra Shepherds were the most numerous Polish breed of dogs registered with ZKwP (in total 329 dogs) [Redlicka and Redlicki 2003]. After 1981 Clubs or sections associating Tatra Shepherd breeders were established abroad. The kennels comprised from several hundred (Netherlands, Belgium, Germany) to several dozen dogs (USA, France, Austria, Norway, Finland).

Research methods

The analysis of the structure of stocks of Tatra Shepherd Dogs in Poland covered the years 2009–2016. The Main Board of the Polish Kennel Club and its divisions in Poland provided figures such as the number of registered dogs, litter count (further split into male and female puppies) and dogs of unknown origin meeting the criteria of the breed standard entered into the stud book. The main focus was the statistics of the Polish Kennel Club in its capacity as the oldest and until recently the only organization associating the enthusiasts and breeders of purebred dogs that keeps reliable pedigree books. The material was supplemented during national and international purebred dog shows in Poland in the analyzed years. Analysis of the indicators of genetic diversity of the population covered dogs entered into the Stud Book

(non-pedigree parents) and dogs with 1 to 18-generation pedigrees within the same breed. A pedigree database containing data of 505 Tatra Shepherds (202 male dogs and 303 female dogs) born in 1964–2014 was developed and used to identify population with full 4-generation pedigrees totaling 194 dogs, including 82 males and 112 females born in 1994–2014. The Wright coefficients of inbreeding (F_x) and the ancestor loss coefficient (AVK) were estimated for all animals split according to: sex, having a champion title (CH) or not having a champion title (nCH), origin: from Polish kennels (POL) and from foreign kennels (Z).

The inbreeding coefficient (F_x) and the ancestor loss coefficient (AVK) were calculated according to relevant formulas [Tier 1990, Wright 1922, Boichard et al. 1997, Kania-Gierdziewicz 2008].

Statistical analysis

The results of research were subjected to the analysis of variance taking into account: sex, breeding system, and title according to the following models: for sex (gender):

$$y_{ik} = \mu + p_i + e_{ik}$$

for breeding system:

$$y_{jk} = \mu + h_j + e_{jk}$$

where:

y_{ik}, y_{jk} – trait level,

μ – population mean,

p_i – fixed effect of i for sexes ($i = 1, 2$),

h_j – fixed effect of j for breeding systems ($j = 1, 2, 3, 4$),

e_{ik}, e_{jk} – random error.

The significance of differences between discontinuous attributes for respective groups was verified by means of Tukey's test ($P \leq 0.001$) using Statistica 12.5 software [StatSoft Inc. 2016].

RESULTS AND DISCUSSION

The population of Tatra Shepherd Dogs has been growing both in domestic and foreign kennels. Since 2003 an increase has been observed in the number of Tatra Shepherd Dogs newly registered every year in the divisions of the Polish Kennel Club. Every year the number of registered female dogs is higher than that of male dogs. At the end of 2011, the number of registered Tatra Shepherds was 473 (184 males and 289 females), and 112 Shepherds, including 46 male dogs and 66 female dogs, were qualified for breeding (Table 1). As at 31 December 2016, out of 587 registered dogs (221 males and 366 females) as many as

246 (83 males and 163 females) were qualified for breeding, which corresponded to 41.9% of all the registered animals of this breed. Over five years only (2011–2016), 1961 puppies were born from 337 litters, which accounts for an average of about 5.8 puppies per litter. The analysis of the trend until 2021 shows a constant growth in the breed population both among male dogs (+8.30%) and female dogs (+17.93%). The largest growth was observed among breeding dogs. This is a positive symptom of recognizing the Tatra Shepherd Dog in the population. Among other things, it is due to its suitability as a shepherd and guard dog but also due to the decision of the authorities to open a stud book for the breed in order to extend the gene pool. In 2016 there were 121 registered Tatra Shepherd Dog kennels in Poland. The highest number, that is, 40 kennels are registered in Lesser Poland voivodeship – in the region of Podhale, which corresponds to 33.06%. Masovian voivodeship ranks second with 10.74% of all Tatra Shepherd Dog kennels. On the other hand, the least numerous population of Tatra Shepherds was recorded in northern Poland, including in Podlaskie voivodeship – it was only 0.83% (Fig. 1).

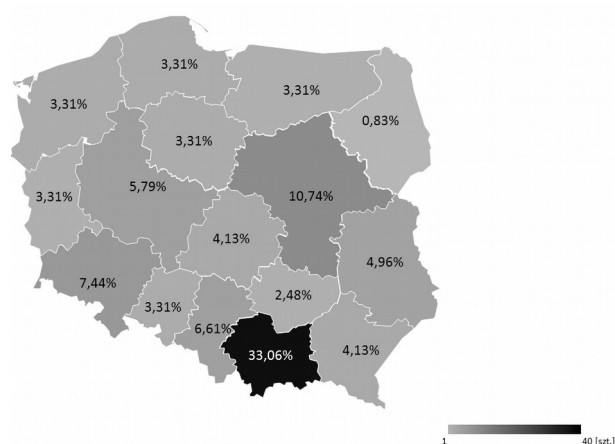


Fig. 1. Breeding of the Polish Sheepdog in individual provinces of Poland

Rys. 1. Hodowla polskiego owczarka podhalańskiego w poszczególnych województwach Polski

In 1999–2002, an average annual upward trend was noted in the number of Tatra Shepherds registered in Poland amounting to 7.4%, and in 2003 there was a downward trend of 36% in comparison to the previous year. In 2007, 21% of breeding female dogs were used for reproduction [Krzysztosek 2009].

The number of dogs shown at dog shows could be a measure of the breed's popularity. The groups of breeds that are popular in Poland such as Retrievers (Golden or Labrador) or Yorkshire Terriers during the shows often include more than 100 animals [Sell 2009].

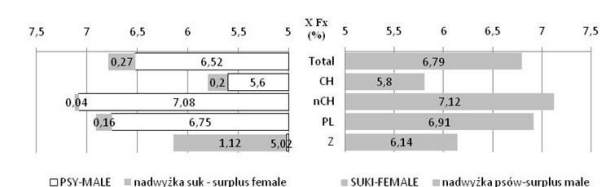
Table 1. The population of registered Tatra Shepherd dogs in all the branches of ZKwP within the time interval 2011–2016 (number of dogs) and the forecasted growth in 2017–2021

Tabela 1. Populacja zarejestrowanych owczarków podhalańskich we wszystkich oddziałach ZKwP w latach 2011–2016 (osobniki) oraz prognoza wzrostu na lata 2017–2021

Year – Rok	Adult dogs – Dorosłe osobniki				Puppies – Szczenięta	
	Male dogs in total Psy ogółem	Breeding Male dogs Psy reprodukcyjne	Female dogs in total Suki ogółem	Breeding female dogs Suki hodowlane	Male dogs Psy	Female dogs Suki
2011	184	46	289	66	136	150
2012 ¹	–	–	–	–	–	–
2013	218	81	309	152	190	201
2014	222	85	308	150	193	195
2015	220	89	337	152	205	224
2016	221	83	366	163	259	208
Trend until 2021 Trend do 2021 ²	+8.30	+47.80	+17.93	+56.18	+29.81	+19.23

¹No data available – Brak potwierdzonych danych. ²Trend values expressed in % – Trend wyrażony w %.

Thus, the Tatra Shepherd Dog cannot be classified as a popular breed, but it can be stated that the population size of Tatra Shepherds remained at a comparable level in 2005–2014, and the average number of dogs shown at dog shows was 21, with an average annual upward trend of 7.1%. Attendance at the most prestigious club dog shows was on average 56 dogs in 2005–2017, assuming the highest number, that is, 77 dogs in 2007 [Polish Kennel Club 2009].



CH – champion – czempion, nCH – non-champion – bez tytułu czempiona, PL – domestic kennel – wyhodowane w Polsce, Z – foreign kennel – wyhodowane za granicą

Fig. 2. Average values of the inbreeding rate (F_x) of the standardized population of Polish Tatra Shepherds by sex and group (%)

Rys. 2. Średnie wartości współczynnika inbredu (f_x) ustandaryzowanej populacji polski owczarek podhalański z uwzględnieniem płci i grupy (%)

The studies by Kania-Gierdziewicz and Gierdziewicz [2013] conducted for the Tatra Shepherd Dog breed in Silesian voivodeship showed that 77.42% was inbred (including 81.82% of males and 75% of females), and the average inbreeding coefficients (F_x) were respectively

4.8% for all and 5.8% for inbred animals, whereas the average kinship coefficient was 11.5%.

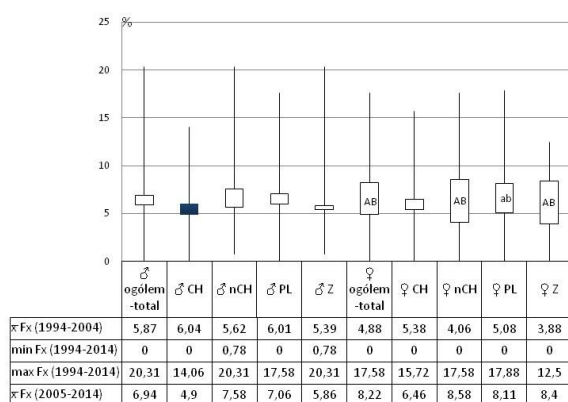
Studies carried out by this author demonstrated that the degree of inbreeding in the breed was determined by the sex of the animal and the breeding system (Fig. 2). The general inbreeding coefficient was 6.52% for male dogs and 6.79% for female dogs. For estimation purposes, the dogs with 4-generation pedigrees were divided into: champions (CH), non-champions (nCH) and dogs bred in Poland (PL) and abroad (Z). The average inbreeding value for Tatra Shepherds with full, 4-generation pedigrees, born in 1994–2014, amounted to 6.52% for males and 6.79% for females. The highest inbreeding rate was observed among male dogs (7.08%) and female dogs (7.12%) in the group of non-champions (nCH) as well as among male dogs (6.75%) and female dogs (6.91%) born in Polish kennels (PL). Similar F_x results at the level of 8.8% were obtained by Leroy et al. [2006] for Pyrenean Shepherds.

Kalinowska et al. [2010] demonstrated that half of the active population registered with the Krakow Division of ZKwP was inbred, whereas in the analyzed population more than 23% of dogs were inbred (about 27% males and 20% females). The average inbreeding coefficient was 1.37%, and the rate estimated only among inbred animals is 5.85%. The highest inbreeding coefficient was 14.06%.

In another experiment carried out in 2015 on the population of Tatra Shepherd Dogs living in the region of Podhale, Kania-Gierdziewicz et al. [2015] found that the average inbreeding coefficient for the breed was 7.17%, and the average kinship coefficient was 18.2%. In addition, the inbreeding coefficient showed an upward trend.

Similar F_x results at the level of 8.8% were obtained by Leroy et al. [2006] for Pyrenean Shepherds and by Cecchi et al. [2013] for Italian Pointers (Bracco Italiano) ($F_x = 6.7\%$).

Data in Fig. 2 reflects a dominance of females over males in each analyzed group. The largest dominance (by 1.12%) was characteristic of F_x of female dogs born abroad in comparison to male dogs from foreign kennels, and the smallest (0.04%) – of non-champion female dogs over dogs from the same group.



CH – champion – czempion, nCH – non-champion – bez tytułu czempiona, PL – domestic kennel – wyhodowane w Polsce, Z – foreign kennel – wyhodowane za granicą.

^{A, b} Sex means marked with different letters differ significantly at $P \leq 0.05$.

^{a, b} Średnie oznaczone różnymi literami różnią się istotnie przy $P \leq 0.05$.

^{A, B} Sex averages marked with different letters in columns differ significantly at $P \leq 0.001$.

^{A, B} Średnie oznaczone różnymi literami różnią się istotnie przy $P \leq 0.001$.

Fig. 3. Trend value of the inbred ratio (F_x) of the standardized population Polish Tatra Shepherds in the years 1994–2004 and 2005–2014 by sex and group (%)

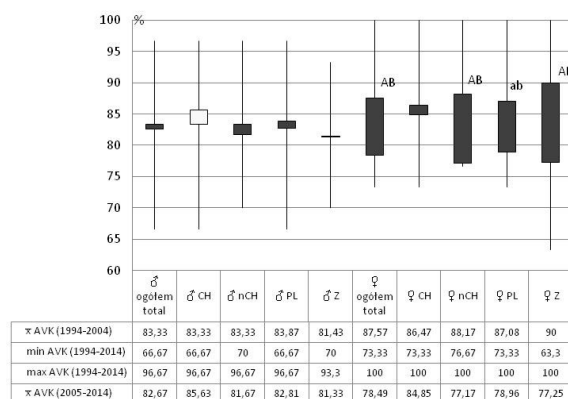
Rys. 3. Trend wartości współczynnika inbredu (F_x) populacji Polski Owczarek Podhalański w latach 1994–2004 i 2005–2014 (%)

Differences within the specific sex are supported by studies of the Norwegian Lundehund breed that has lost 38.8% of genetic diversity in the base population. The ancestor with the largest contribution to the pedigree is a female dog with 18 descendants born in the 1960s. Her contribution to the latest cohort is 41%. The only option of preserving this rare breed is presenting dogs of other breeds as candidates for breeding [Kettunen et al. 2017].

In order to get a full picture of changes in the breed's inbreeding rate, two time intervals of about ten years were selected: 1994–2004 and 2005–2014 (Fig. 3). Generally, the inbreeding coefficient increased with time regardless of the sex and group of dogs. It was lower only for CH dogs and amounted to 4.90%. The level of inbreeding among Tatra Shepherd Dogs born in 1994–2004 was 5.87% for males and 4.88% for females, whereas

in 2005–2014 it was 6.94% and 8.22%, respectively. Statistically significant differences were identified only for female dogs born in Poland, while they were highly significant for females born abroad and non-champion females, as well as all female dogs together. The significantly lowest ($P \leq 0.001$) inbreeding rate (3.88%) is found in female dogs born in 1994–2004 outside Poland as compared to female dogs born in 2005–2014. The highest inbreeding rate was recorded for nCH female dogs in 2005–2014. It was significantly ($P \leq 0.001$) higher than in the nCH group in 1994–2004. A decreased inbreeding coefficient among male dogs born in 2005–2014 in comparison to dogs born in 1994–2004 was observed only in the group of champion dogs. Other groups showed an upward but statistically insignificant trend.

In the group of protected Swedish dogs no relationship between the average inbreeding rate and the size of the dog population (correlation coefficients r fall within the range respectively from 0.00 to 0.53 and 0.15–0.60, at $0.07 < P < 1.00$). However, for dog breeds such as the Swedish Lapphund and Vallhund the average F was similar – 0.09 – despite their pedigrees comprised a few thousand dogs over the years [Jansson and Laikre 2018].



Explanations as in Fig. 3 – Objasnienia jak na rys. 3.

Fig. 4. Values of the ancestor loss coefficient of the standardized population of Tatra Shepherd dogs, taking into account their sex, group and years of study (%)

Rys. 4. Wartości współczynnika utraty przodków (AVK) ustandaryzowanej populacji polskich owczarków podhalańskich, z uwzględnieniem płci, grupy i lat badań (%)

A higher AVK means less inbreeding (Fig. 4). For dogs only from the champion group, AVK (85.63%) was slightly higher in 2005–2014 as compared to 83.33% in the group in 1994–2004. Similar results for AVK were obtained for Newfoundland dogs, i.e. above 85% [Kruzińska et al. 2019]. The AVK coefficient increased significantly ($P \leq 0.05$) in the group of dogs from foreign kennels to 93.30% in 2005–2014. AVK values were signi-

ificantly decreased over the analysed years in the groups nCH, PL, Z for female dogs to the following level, respectively: 77.17% ($P \leq 0.001$), 78.96% ($P \leq 0.05$), 77.25% ($P \leq 0.001$). With time, the overall AVK for female dogs was also significantly ($P < 0.001$) reduced to 78.49%. It can be concluded that the ancestor loss coefficient and the inbreeding rate were growing in the group of female dogs. The observed loss of genetic diversity is parallel to the contemporary society's growing requirement of dogs for many different purposes [Lindblad-Toh et al. 2005, Browne et al. 2006, Wells 2007, Horvath et al. 2008, Mostert et al. 2015, Jansson and Laikre 2018].

CONCLUSIONS

To sum up, in Poland there are about 121 registered kennels of Tatra Shepherd Dogs, most of them in Lesser Poland voivodeship, i.e. 33.06% on a national scale. In 2016, a record-breaking number of puppies of this breed were born (467), while for the first time in the second decade of the 21st century the number of male dogs born was 20% higher than the number of females. Taking into account the inbreeding coefficient in the breed, it was concluded that no risk of inbreeding depression occurs yet but there is a trend to reduce the pool of genes. Therefore, it is suggested that the stud book for the Tatra Shepherd Dog is left open because the breed has gained popularity year on year. Based on the results, it must be assumed that the maximum inbreeding coefficient (F_x) in the analyzed breed should not exceed 6.85%, whereas the ancestor loss coefficient (AVK) should not be lower than 76%.

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INBRED I UTRATA PRZODKÓW W POPULACJI POLSKIEGO OWCZARKA PODHALAŃSKIEGO W ZALEŻNOŚCI OD PŁCI I RODZAJU HODOWLI

STRESZCZENIE

Celem badań była analiza struktury populacji i trendu chowu wsobnego, z uwzględnieniem płci, rodzaju hodowli. Najwięcej (40 hodowli, 33,06%) zarejestrowanych było w województwie małopolskim (region Podhala). Inbred w rasie dla 4-pokoleniowej populacji wyniósł 6,52% dla psów i 6,79% dla suk. Największe zinbredowanie stwierdzono w grupach nCH i PL zarówno u psów, jak i suk. Wyższy istotnie inbred stwierdzono w latach 2005–2014, który wyniósł 6,94% dla psów i 8,22% dla suk, w odniesieniu do lat 1994–2004 odpowiednio 5,87% i 4,88%. Stwierdzono narastającą w badanych latach utratę przodków AVK, co może skutkować wzrostem inbredu. Dotyczyło to szczególnie suk w grupach nCH, PL, Z, natomiast w grupie psów z hodowli zagranicznych istotnie wzrastał AVK. Na podstawie przeprowadzonych badań stwierdzono, że nie występuje jeszcze zagrożenie depresji inbredowej, jednak można zauważyć zawężenie puli genowej u rasy owczarek podhalański.

Słowa kluczowe: owczarek podhalański, czempion, inbred, utrata przodków