

Pedigree based analysis of population structure in Hungarian sheep (Racka sheep)

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Abstract

The Hungarian sheep (also known as Racka sheep) is the best known and most characteristic native sheep breed of Hungary, which has been bred in the Carpathian Basin for centuries. Regular pedigree data collection has been ongoing since 1994. The black and white colour variants are bred separately and registered in closed studbooks, and although they are similar in appearance, they are genetically distinct. Thanks to subsidies, the breed is currently flourishing, but the processing of studbook data and population genetic analysis are essential for its long-term, secure maintenance. The white Racka herd numbers 4,314 living animals currently, while the black Racka herd numbers 3,905 animals. The white Racka variant is kept by 48 breeders and the black one by 43 breeders, with an average number of 90 and 91 individuals per farm, respectively, with a very large variation. There are few large flocks (with more than 200 ewes), six for each colour. Therefore, it can be said that the stock is fragmented, which is favourable for preserving the genetic diversity of the breed, as more rams are used than in the case of modern breeds at large operations. The sex ratio is advantageous, 1:24 for white and 1:21 for black variant. The current breeding situation therefore appears favourable. However, we have found that despite the seemingly favourable data, genetic narrowing is occurring in both colours. In the white colour, this process is particularly noticeable in the male sex. Here, the number of lines has decreased from 103 to 42 in 30 years. In the black colour, this process is visible in both sexes. The number of lines has decreased from

88 to 41, and the number of families from 3,163 to 1,128. These data show that the long-term sustainability of the breed is at risk. The effective population size exceeds 2,200 individuals for both colour variants, but this seemingly favourable data alone is not sufficient for a correct assessment of the situation. Taking into account external factors (the high selection pressure applied to rams, the strong dependence of breeders on subsidies, the fragmentation of breeding farms, and the low willingness of breeders to cooperate), it can be said that new methods need to be developed to ensure the sustainability of the breed. Our main goal is to preserve the original characteristics of the Hungarian sheep, a breed that has defined Hungarian shepherding for centuries, and to maintain its original genetic diversity. To this end, we have processed the pedigree data of 110,000 individuals recorded over the past 30 years. As part of this, the ram lines and maternal families have been identified and coded. Going forward, we aim to use this knowledge to propose a breed maintenance program based on the within-family selection.

Keywords: Hungarian Racka sheep, within-family selection, maternal lineages

Introduction

In the case of breeds registered as native to Hungary, it is more accurate to speak of old historical breeds, since they arrived in the Carpathian Basin in the last two or three centuries and adapted to the natural-geographical, housing, and feeding conditions here. There is only one exception, the breed known today as the Hortobágyi Racka, which is unique to the Hungarians, developed in the Carpathian Basin, was shaped by the Hungarian soil and Hungarian breeding, and does not occur anywhere else in the world – so we can rightly call it the most Hungarian sheep breed. The name of the breed is also interesting, for centuries the Hungarians called only the Racka “juh” (sheep in Hungarian), all other breeds were called “birka” (a somewhat derogatory name for sheep brought from abroad). Thus, the name of the breed is actually Hungarian sheep, the name Hortobágyi Racka is more a product of the 20th century, when the place where the remnants of the herd were found stuck to the breed.

The origin of the breed is uncertain according to most authors (FÖLDI et al., 2016), but several significant figures in agricultural history consider it to be a breed that arrived with our ancestors migrating from its Uralic homeland (HANKÓ, 1937). The earliest finds of Racka-like horn bones in archaeological findings date back to the Middle Ages (16th century), but they became really common in the early modern period (17th-18th centuries) (VÖRÖS, 2003). The population at that time was by no means uniform, GÁSPÁRDY (2011) describes several Racka variants from these centuries that have since died out or disappeared. Until the middle of the 18th century, the Hungarian sheep was the dominant breed until Maria Theresa ordered

the crossing with fine wool breeds. HANKÓ (1941) already mourned the Hungarian sheep, as he put it, “ungrateful selfishness condemned it to death” – referring to the economic purpose of crossing. He was partly right, as between the two world wars the domestic sheep population numbered 1.1 million individuals, but only 1% of this was Hungarian sheep. HANKÓ also puts the number its white colour variant in 1941 at 2-3 thousand individuals, and the black one at 300 individuals. In 1975, at the beginning of the most recent registration of the breed, the registered population was 1370, and in 1985 it was 2100. In 1983, the *Rackajuh-tenyésztő Egyesület* (Racka Sheep Breeders Association) was founded with the participation of László Veress and Béla Dunka and the cooperation of farmers around Debrecen. Their goal was to register and maintain the individuals of the breed that were in private hands, and they did this with wise foresight, since by the 1990s the cooperative farms of the breed had been liquidated.

In 2008, at the initiative of breeders, breeders, representatives of the breeders' organization and experts from the specialized authority in Mátranovák reviewed the breeding guidelines for Hungarian sheep, updated and expanded the breed description - a document that is still in force today as part of the Breeding Program of the Hungarian Sheep and Goat Breeders' Association. From 2010, a new opportunity opened up for breeders of the breed, the “the support of native breed”, which brought breeders enthusiasm and brought a new golden age for the breed. According to our survey, in 2025 the registered mother stock of the White Hungarian sheep approached 4,500 individuals (4,485), that of the Black Hungarian sheep was 4,000 (3,979). Although centrally supported programs may have drawbacks, FÖLDI et al. (2016) state that no native breed can exist without state maintenance, where decisions are not dictated solely by the market.

The breed is known in two colours, SCHANDL, in 1953, mentions these two colour variants of the breed, however, considering that the shepherds grazed the black and white flocks separately and did not crossbreed, more and more opinions have come to light that they are separate breeds. ZSOLNAI et al. put an end to the debate in 2020, when they performed a genome analysis of 126 black and 128 white Racka sheep. The performance of the multidimensional scaling diagram showed that white and black Rackas represent well-separated groups among other sheep breeds and are also distinct from each other. It is suggested that the colour variants of Rackas be considered genetically distinct breeds. The fact that black and white Rackas are registered under the same name today is only a technical matter, the recording of data for the flock book is carried out separately. This also allows for data processing by colour.

KOMLÓSI (2012) mentions that in the case of small herds, herd structure studies are necessary to assess the vulnerability of the given breed and the vulnerability of their diversity. In the case of the Tsigai, Cikta and Gyimesi Racka sheep breeds, publications are already available that have explored the herd structure of the given

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breed in detail and assessed the mtDNA diversity (ANNUS et al., 2015; KOVÁCS, 2018; KÁRPÁTI et al., 2023).

There has been no publication describing the population structure of the Racka sheep in full. KUSZA et al. (2008) found that there was a potential risk of inbreeding in most of the populations they examined within the Racka breed group. Genetic distance estimates and cluster analysis showed that the main factor in genetic differences between populations is geographical distribution, namely that populations in given areas often show close genetic relationships. SÁFÁR (2017) performed calculations examining the inbreeding of native sheep breeds in Hungary. In his work, he found that the inbreeding coefficient was 0.029 and 0.036 in the White Hungarian sheep and in the Black Hungarian sheep, respectively.

According to the 2020 data of ZSOLNAI et al., the situation in this area has worsened, with the inbreeding coefficients (method-of-moments relatedness F coefficient) of black and white Rackas being 0.147 and 0.133, respectively. Genomic studies have only been carried out tangentially, examining the allele pairs determining scrapie resistance. According to our own studies, the proportion of individuals with R1 (ARR/ARR genotype) has increased from 5 to 18.5% over the past twenty years. BÁCSI et al. (2025) put the proportion of individuals with the same genotype at 17.62% but supplemented this data by stating that the ARR allele frequency increased by 42% across all genotypes. They note that despite the improvement, the potential impact of this change on other important traits remains uncertain.

Today, the Hungarian sheep follows the Hungarian Merino in second place in the list detailing the number of domestic sheep by breed. The EU and national support policy certainly plays a major role in the growth of the breed's population, which provides resources to breeders under several legal titles - expecting in return the additional work associated with maintaining native breeds. However, with a possible change in the support policy, an unpredictable situation may develop in terms of breed maintenance. In fact, the breed is not ideal for meat production, at least in terms of carcass characteristics of mutton type lambs. The muscle and body conformation is not as substantial in the Hungarian breed compared to a continental breed of sheep e.g. Charollais that has been selectively bred for a large, muscled carcass for slaughter. It would be a positive change if the breed could find its place in market conditions. Several authors highlight its role in landscape conservation, but this seems insufficient for sheep farms wishing to remain competitive in the market.

MUJITABA et al. (2024) found that in vitro techniques can play an important role in the genetic conservation of indigenous sheep breeds. To support this, sperm samples from indigenous sheep breeds were successfully collected, stored and used. They suggest the establishment of an indigenous in vitro gene bank. There are 3,378 frozen samples of the White Hungarian sheep, which were collected in 1990, but due to the low number of individuals, this would be worth expanding.

Material and methods

For the pedigree processing, we worked with Excel files provided by the Hungarian Sheep and Goat Breeders' Association, which contained data of White and Black Hungarian sheep from 1991 to 2024. In our processing, we assessed the size of the pedigree, the number of founding and living paternal lines and maternal lineages, the total and average number of offspring per lines and lineages, as well as per parents, respectively, furthermore the number of generations per founding ancestors. We calculated the effective herd size and, according to our own idea, we expanded this with the effective line and family number indicators. The statistical processing was performed with Pedigree Viewer (Kingham and Kinghorn, 2010), and the evaluations were performed with the Endog (Gutiérrez et al, 2005) and Poprep (Groneveld et al, 2009) programs.

Results and discussion

The number of White Hungarian sheep under herd book control is 4,485 individuals, of which 2,392 individuals are in the main herd book section. The same data are as follows for Black Hungarian sheep, the number of herds under herd book control is 3,979 individuals, of which 2,173 individuals are in the main herd book section. White Hungarian sheep are bred and registered in 48 farms, while Black Hungarian sheep are registered in 43 farms. The average herd size is 90 and 91 for White- and Black Hungarian sheep, respectively. The ratio of male and female breeding animals is 1:24 for White-, and 1:21 for Black Hungarian sheep. The herd structure data themselves paint a reassuring picture of both colour variants/breeds, and there is no significant difference in the comparison of them.

The processing of herd book data for individuals of White- and Black Hungarian sheep is detailed in Table 1.

Table 1: Flock book data of the White- and Black Hungarian sheep population

Indicator	White Hungarian sheep	Black Hungarian sheep
Total flock book stock (individual)	63,304	46,530
number of males	28,197	21,166
proportion of males	44.5%	45.5%
number of females	35,107	25,364
proportion of females	55.5%	54.5%
Number of individuals with a known date of birth	61,840	45,301
Number of individuals with an unknown date of birth	1464	1229
Number of founding sires (lines)	103	88
Number of descendants per line	506	451
Number of living lines	42	41
Total number of sires	591	498
Total number of sires' progeny	52,134	39,654
Average number of offspring per sire	88	80
Number of paternal generations	1 – 12	1 – 9
Number of founding dams (lineages)	3,175	3,163
Number of descendants per lineages	19	20
Number of living lineages	3,011	1,128
Total number of dams	14,859	11,395
Total number of dams' progeny	59,012	43,761
Average number of offspring per dam	4	4
Number of maternal generations	1 – 11	– 11

Processing of the White Hungarian sheep flock book data

The data in Table 1 show that unfavourable processes can be observed behind the seemingly reassuring herd structure data. It is striking that in the case of the White Hungarian sheep, the number of lines found has decreased from 103 to 42 (by 60%) in 23 years. The relatively large number of living sires (591) partially masks this change, but the above trend predicts the danger of genetic narrowing. The average number of offspring per sire (88) would provide ample opportunity to maintain an adequate number of rams representing the line, but due to the characteristics of the herd structure (low flock numbers, large harems, long-term use of rams), it is

difficult to imagine that the number of lines will not decrease further without effective intervention. The high number of paternal generations provides an opportunity to conduct molecular genetic studies that may enable effective selection. In the case of the White Hungarian White sheep, the number of families seems reassuring, with a 5.5% decrease in the number of living families compared to the founding families during the period under study. The average number of offspring per mother (4) may seem low from a management perspective, but it is sufficient from a gene conservation perspective. In the case of families, molecular genetic studies may also be of great help, based on which not only the maintenance of families could be ensured, but also the targeted development of mating plans could be improved annually. The effective population size, calculated according to the number of sires and dams, is 2,274, which is above the value estimated by the literature as sustainable populations without the risk of a decrease in genetic diversity and an increase in inbreeding. The effective population size calculated according to the number of lines and families is 399, which, compared to the number of living lines and families, also does not indicate a short-term threat to the sustainability of genetic diversity.

Processing of the Black Hungarian sheep flock book data

In the case of the Black Hungarian sheep, the number of lines found decreased from 88 to 41 (by 55%) during 23 years. The number of living sires is also relatively high here (451), but the trends are similar to those of the White Hungarian sheep. The average number of offspring per sire (80) is also relatively high here. Unfortunately, however, the number of families in the Black Hungarian sheep has drastically decreased from 3,163 to 1,128 (by 65%), i.e. almost two-thirds of the families have disappeared in just over two decades. Given that the average number of offspring here is also 4, the genetic mapping of families and their relationships is an urgent task. The effective herd size calculated according to the number of sires and dams is 2,273, and that is 344, calculated according to the number of living lines and families.

There are factors that are difficult to quantify in relation to the maintenance of the White- and Black Hungarian sheep, which may endanger the medium-term future of the breeds. These should definitely be taken into account when making strategic decisions:

- The Hungarian sheep are less suitable for producing broiler lamb in purebred form, buyers do not seek them out, and their alternative sales opportunities are also limited. Their maintenance under market conditions is currently unthinkable.
- Landscape conservation, agrotourism, and other alternative options do not offer sufficient space for the long-term maintenance of breeding stock.

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- Due to the above, breed maintenance is almost unthinkable without (EU and domestic) subsidies, and the current, relatively favourable situation could be fundamentally shaken by a possible change in the subsidy system.
- The herds are fragmented, there are only 4 farms where the herd size exceeds 200 mothers – and for this, they keep enough rams to keep the inbreeding level at around 0.05.
- Breeders keep a small number of large harems, and in addition, rams are used for a long time, even a decade. The majority of breeders have little tendency to cooperate, and the exchange of rams between themselves (which successfully stopped the decline in the Gyimesi Racka breed) is only conceivable to a limited extent.

For all these reasons, herd structure and pedigree data only serve to characterize the current situation and can be the basis for strategic planning for breed maintenance.

Conclusion and recommendation

The population structure of the White- and Black Hungarian sheep meets the requirements of breed maintenance, and the two breeds are very similar in their main characteristics. However, during the processing of the pedigree data, it was shown that the number of families and lines is changing in an unfavourable direction. The White Hungarian sheep is endangered on the paternal side, and the Black Hungarian sheep is endangered on both the paternal and maternal sides. It is important to provide a basis for effective breed maintenance using molecular biological methods (assessment of mtDNA and Y-chromosome diversity).

Based on the above, we consider it justified to continue our research. We planned to achieve the goal in the following steps: analysis of pedigree data, mtDNA sequence analysis in females, and Y-chromosome sequence analysis in males.

Currently, the first results of the analysis of the pedigree data are available. Sampling for the mtDNA analysis has been completed, and laboratory sequencing is currently underway. We plan to complete the tasks required for Y-chromosome testing by 2026.

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