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Pedigree analysis of Ile de France sheep breed in Bulgaria

Zhivko Duchev*and Evgeniya Achkakanova

Agricultural Academy, Institute of Animal Science, 2232 Kostinbrod, Bulgaria
**Corresponding author:* zhivko.duchev@agriacad.bg

Abstract

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The objective of this study was to assess the pedigree information of the Ile de France sheep population in Bulgaria, and determine its structure and inbreeding status. The pedigree was compiled from the herdbook data of the established in 2006 breeding association, the breeding certificates of imported animals and other data about the imports. The pedigree included animals born between 2001 and 2022, lambs born during 2019–2022 were considered as reference population. Starting from 2020, the completeness of the first generation of pedigree exceeded 98% and that of the second generation – 80%. The equivalent complete generations for the reference population are 2.2, the fully traced generations – 1.8 and the maximum number of traced generations – 7. The generation interval is 3.8 years for the whole population, but higher in the reference one – from 4.3 to 4.5 years. The rate of inbreeding is increasing in the last years, reaching 0.0147 in 2022. There is a proportion of animals with high inbreeding coefficient level, which should be considered in the management of the breeding programme.

Keywords: population; data completeness; herdbook; generation interval; inbreeding

Introduction

Due to its specific qualities, the Ile de France sheep breed is becoming popular among the farmers in Bulgaria. The stock flocks are also increasing in number, with increasing demand for quality rams. All that makes Ile de France „a breed of increasing importance for Bulgaria“ (Annual report of the Association for breeding of Ile de France sheep in Bulgaria, 2023). The increased demand requires also the production of breeding animals of high genetic value. Since 2006, the Association for breeding of Ile de France sheep in Bulgaria (AILFB) is running the approved breeding programme for this breed in the country (Dimitrov et al., 2016). In 2023, there are 58 farms, all around Bulgaria, keeping more than 8000 purebred animals. The regular import of high quality animals from France also contributes to the population improvement (Duchev & Achkakanova, 2023).

An Electronic herdbook for the Ile de France breed was developed and put into operation at the end of 2017. The Electronic herdbook enabled the addition, modification and archiving of information about farmers, farms, herds, animals and events related to them, allowing for tracing the logical connections between the various data items.

In breeds selected for economically important traits, loss of genetic diversity is observed, mainly due to increased inbreeding and loss of founder alleles (Vozzi et al., 2007). It has been demonstrated that the inbreeding has statistically significant effect on some of the meat production traits, e.g. for Dorper (Kiya et al., 2019), Zwartbles (Filipčík et al., 2023), Texel, Shropshire, and Oxford Down (Norberg & Sorensen, 2007). A good quality pedigree information proves useful for maintenance of the genetic diversity (Fernández et al., 2005). Tsiokos & Ligda (2021) also demonstrate the importance of complete pedigree data in their study of the effects of scrapie resistance selection on the genetic variability of Florina sheep. They conclude, “ a nucleus flock with solid genealogical and performance data could provide the potential to dynamically maintain and evolve the population”.

Pedigree analysis was done both for small (Danchin-Burge et al., 2010; Oravcova & Krupa, 2011; Rochus & Johansson, 2017; Mokhtari et al., 2013; Gowane et al., 2014; Mokhtari et al., 2014) and large sheep breeds (Vyas et al., 2022; Borges Barbosa et al., 2020; Huby et al., 2003; Nilson et al., 2023; Ghafouri-Kesbi, 2010).

The objective of this study was to assess the pedigree information of the Ile de France sheep population in Bulgaria, and determine its structure and inbreeding status.

Material and Methods

The data from the herdbook of the Ile de France sheep in Bulgaria, provided by the AILFB was used to compile a pedigree of the breed. This data contained information about 11292 animals born between 2001 and 2022. It was complimented by data from the breeding certificates of the imported in Bulgaria animals from France, some of which were only available on paper. The pedigree was cleaned from loops. Discrepancies in the data, e.g. animals occurring in either sexes, or offspring born before its parent were resolved where possible, otherwise conflicting data was erased. The reference population were the animals born 2019-2022. Data was analysed with the software PopReport (Groeneveld et al., 2009), except for the additional assessment of the pedigree completeness of the reference population, where the R package optiSel (Wellmann, 2019) was used.

Pedigree completeness

The pedigree quality was assessed by the pedigree completeness index (PCI) following the algorithm described in MacCluer et al. (1983):

$$I_d = \frac{4I_{d_{pat}}I_{d_{mat}}}{I_{d_{pat}}+I_{d_{mat}}}, \qquad I_{d_k} = \frac{1}{d}\sum_{i=1}^{d} a_i \quad k = pat, mat,$$

where k is the paternal or maternal line of an individual, a_i is proportion of known ancestors in generation i and d is the number of generations.

The pedigree of the reference population was assessed additionally by the equivalent complete generations (ECG) – the sum of the proportions of known ancestors of an individual over all generations traced (Maignel et al., 1996); by the number of fully traced generations (FTG), and by the number of maximum generations traced (MGT). The number of fully traced generations was defined as the furthest generation from the progeny where all its ancestors were known, and the number of maximum generations traced, as the number of generations separating the individual from its furthest ancestor.

Inbreeding coefficient (F) and rate of inbreeding (ΔF)

The inbred animals (animals with an inbreeding coefficient greater than zero) were grouped into six classes according to their level of inbreeding: $0 < F \leq 5.0$; $5.0 < F \leq 10.0$; $10.0 < F \leq 15.0$; $15.0 < F \leq 20.0$; $20.0 < F \leq 25.0$; $F > 25.0$.

The rate of inbreeding (ΔF) per generation (t) was estimated using the Falconer and Mackay (1996) formula:

$$\Delta F = \frac{F_t - F_{t-1}}{1 - F_{t-1}},$$

where F_t and F_{t-1} are the average inbreeding of the offspring and their parents. In this case, the generation t was considered all animals born in a given year.

Generation interval

Generation interval (GI) is the mean age of parents at the birth of their offspring held for reproduction (Falconer & Mackay, 1996). This parameter was calculated in the four possible pathways: sire-son, sire-daughter, dam-son, and dam-daughter.

Results and Discussion

Pedigree completeness

The compiled pedigree consisted of 25 404 animals, of which 8407 in the reference population (Table 1). The introduction of software for Electronic herdbook in 2017, and the work done in the following years for correcting records with inconsistent genealogy and births data, shows its positive effect in the reference population, where 98% of the animals are with both known parents.

From year 2011, the pedigree completeness index is improving in time (Figure 1), reaching in 2019 100% in first generation (parents) and more than 80% in second gener-

Table 1. Summary of the pedigree of Ile de France sheep breed in Bulgaria

	Male	Female	Total
Whole population			
Number of animals	2090	23 314	25 404
Number of animals with both known parents	1256	15 253	16 509
Number of animals with one known parent	51	359	410
Reference population (2019–2022)			
Number of animals	762	7645	8407
Number of animals with both known parents	709	7510	8219
Number of animals with one known parent	48	52	100

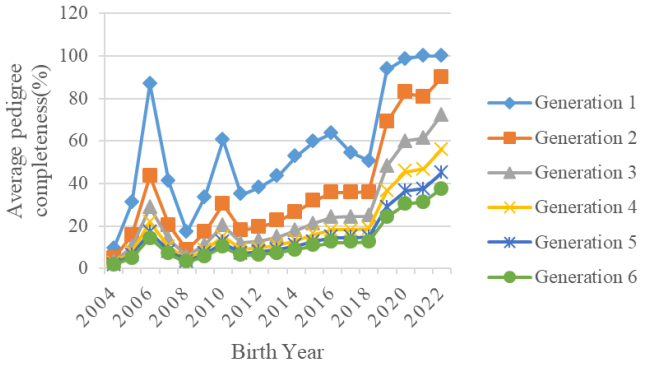

Fig. 1. Average pedigree completeness of Ile de France sheep breed in Bulgaria

ation (grandparents). The peaks in the early years – 2006, 2010 can be explained by the information added from the breed certificates of the imported animals. A gap in the data is observed in years 2017–2018, where the average completeness of first generation is 54.6% and 50.8%, respectively, which has impact on the completeness of the next years.

The other indicators of the pedigree quality – ECG, FTG and MGT, applied to the reference population (Table 2), confirm the above gap, average ECG increasing from 1.8 in 2019 to 2.6 in 2022 and average FTG – from 1.5 to 2.1. The average ECG for the whole reference population was 2.2, and the FTG – 1.8. Compared to the pedigree analysis of a single flock of Valachian sheep in Slovakia (Oravcova & Krupa, 2011), where they report FTG 2.19 and ECG 3.71 for their reference population, our numbers are lower. Vyas et al. (2022), estimated the mean of FTG and ECG for the Marwari sheep in India to 2.75 and 5.35, respectively. Their dataset was covering 40 years and almost 12 000 animals. Danchin-Burge et al. (2010) reported even higher number of ECG (4.6–10.5) for seven small populations of French sheep breeds with more than 30 years of data. It should be noted that the history of the breed in Bulgaria since the establishment of breeding association is relatively short, which is reflected in the lower values of these parameters. Our results

Table 2. Mean number of Equivalent complete generations (ECG) and Fully traced generations (FTG), and the Maximum generations traced (MGT) for the reference population

Year	ECG	FTG	MaxG
2019	1.8	1.5	6
2020	2.1	1.7	6
2021	2.5	1.9	7
2022	2.6	2.1	7

are similar to the reported by Goyache et al. (2003) number of equivalent generations of 1.09 for the Xalda sheep. In the case of Ile de France, the mean ECG for the whole population was 1.28. In Bulgaria (Zhelyazkova et al., 2023) estimated for the pedigree of 1937 White Maritza sheep animals, 2.05 average known generations which is similar to our results for year 2022.

Population structure

There is a general trend of increase in numbers of animals born in the last 10 years (Figure 2). The animals born in the reference years vary between 1637 and 2664, and the number of used sires is approximately in 1:10 ratio with them. The average age of sires in these years, was 3.1–3.4 years, slightly higher for dams – 3.1–3.8 years. Most of the sires and dams of animals in the reference population – 92%, were between one and six years of age at the time of birth of their progeny.

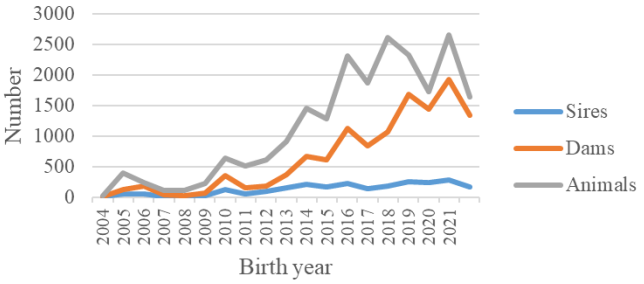

Fig. 2. Number of Ile de France sires and dams in reproduction by the birth year of their offspring

Inbreeding

The calculated inbreeding coefficient for 88% of the reference population was under 5%. The completeness of the pedigree of the ancestors has its impact on the estimation of the inbreeding coefficient of their offspring (Groeneveld et al., 2009). The ECG of the reference population is under three, which means that the inbreeding is probably underes-

Table 3. Distribution of the reference population by the inbreeding coefficient

Inbreeding coefficient (F) levels, %	Number of animals	Proportion, %
F = 0	52	0.62
0 < F ≤ 5.0	7398	88.00
5.0 < F ≤ 10.0	206	2.45
10.0 < F ≤ 15.0	344	4.09
15.0 < F ≤ 20.0	107	1.27
20.0 < F ≤ 25.0	227	2.70
F > 25.0	73	0.87

timated. The PCI of the reference population is also low for forth and above generations, and this index that quantifies the chance of detecting inbreeding in the pedigree (Sørensen et al., 2005). There is a proportion of animals with high inbreeding coefficient level, which should be considered in the management of the breeding programme (Table 3).

The rate of inbreeding in the reference population went up from 0.0053 in 2019 to 0.0147 in 2022. The system of the Food and Agriculture Organization of the United Nations for categorizing the risk status of the breeds, considers the inbreeding rate of more than 1% as indication for risk of extinction (FAO, 2013). This should be taken into account in management of the breed.

Generation interval

The GI for the population born in years 2019-2021 is between 4.3 and 4.5. For the total population, the GI was 3.8, which is similar to the reported by Justinski et al. (2023), for the population of Il-de-France sheep in Germany, GI of 3.94 years. The GI of the other sheep meat breeds in the study of Justinski et al. (2023) is between 3.03 and 3.92 years, with one exception – the Texel sheep, which has much higher GI – 6.42 years.

The GI of the sire-son and sire-daughter pathways were shorter than the dam-progeny pathways, which is explained by the longer use of breeding females for reproduction. In the recent years, there are ewes in their fifth parity and even few ones in parity six and beyond (Figure 3).

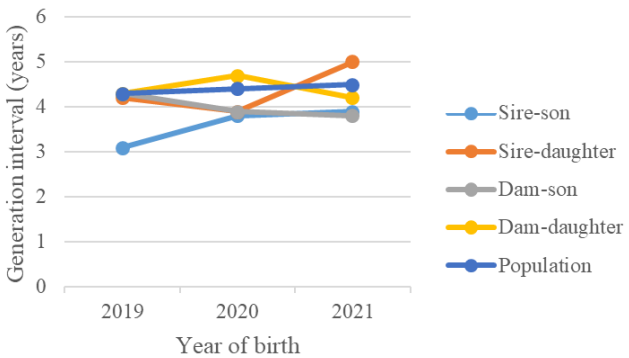

Fig. 3. Generation interval by year of birth

Conclusion

The utilisation of a software for keeping the herdbook records have improved the completeness of the pedigree data. The results of this study do not raise immediate concerns for the genetic variation of the breed; however, some of the findings need to be taken into account when implementing the breeding programme. For better understanding of the diversity of Il de France breed in Bulgaria, utilisation of molecular data analysis might prove useful.

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