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Effect of inbred on reproduction and body weight of sheep in a closed Booroola flock

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Results of the analysis are presented of the effect of inbreeding on selected reproduction traits and body weight in a Booroola flock kept closed for 14 years at the Institute of Genetics and Animal Breeding, Jastrzębiec. The mean inbred in lambs rose linearly until 2002, when it reached the level of 9.81%, ranging from 0 to 31.7%. No inbred effect was observed on ovulation rate, fertility, litter size, frequency of stillbirths and results of rearing lambs (lambs survival rate) until week 4 of age. Negative effect of inbred was identified on body weight at birth and on week 4 and 8 of age.

KEY WORDS: Booroola sheep / inbred / lamb body weight / reproduction

The importation of Booroola embryos from New Zealand in 1988 has provided the basis for development of Booroola sheep population in Poland. The flock was located at the Institute of Genetics and Animal Breeding in Jastrzębiec, and its beginnings were described by Klewiec *et al*. [1991] and Członkowska *et al*. [1991]. In spite of the high foecundity of Booroola sheep [Davis *et al*. [1982], Polish farmers were not attracted by the breed due to its poor meat performance and small body size. The lack of demand for breeding material resulted in abandonment of the breed use after 14 years of managing it in a closed flock in Jastrzębiec.

As a rule, any small closed population is exposed to inbreeding on a rate which inreases continuously from generation to generation and depends on the mating strategy and selection applied [Boujenene and Chami 1997]. The majority of studies indicate negative

inbred effect both on production and reproduction traits in sheep. The definite conclusions regarding this issue come from research of Wiener *et al*. [1992abc], where inbred effect was estimated in systematic inbreeding experiment leading to the development of four lines ($I_1 - I_4$) with a mean inbred level of 0.25, 0.38, 0.50 and 0.59, respectively. In their study [Wiener *et al*. 1992a] conception rate in the first oestrus cycle was 71% in outbred ewes and only 44 % in ewes from the line with highest inbred level. On the average, with an increase of inbred level by 1 per cent point (pp), conception rate in the first cycle decreased by 0.42 pp. Similar results were obtained by Ercanbrack and Knight [1991], where fertility decreased by 0.23 pp in Rambouillet ewes and by 0.31 pp in Targhee ewes with 1 pp rise of inbred. Many studies confirmed negative impact of lamb and ewe inbred level on litter size and litter weight, although the effects were not always linear. According to Wiener *et al*. [1992a] the litter size of 1.73 in outbreed ewes decreased to 1.37 in ewes with 0.25% inbred and to 1.24 in ewes with 0.59% inbred. Their study also confirmed inbred effect on the litter weight.

Many studies have reported the negative effect of inbred on body weight of sheep at birth. Examples include its decrease by 0.0061 kg in Beni Guil sheep [Boujenene and Chami 1997], 0.013 kg in Australian Merino [Analla *et al*. [1999] and 0.016 kg in Blackface, Cheviot and Welsh Mountain [Wiener *et al*. [1992b] with the rise of individual inbred by 1 pp. The inbred negative effect increases during the rearing period, the most pronounced being observed by Analla *et al*. [1999] in Australian Merino lambs at day 90 of age: -0.076 kg per 1 pp increase of inbred. Moreover, lambs born in multiple litters were found less sensitive to inbred increase than singles. The differences in body weight between inbred and outbreed lambs were found increasing with age by Wiener *et al*. [1992b] and Analla *et al*. [1999]. According to Ercanbrack and Knight [1991], the combined impact of lamb and ewe inbred increase by 1% led to decrease in the litter weight at 120 days on average by 0.5 kg. Moreover, the survival of inbred lambs was lower by 0.241 pp in Rambouillet, 0.444 pp in Columbia and 0.458 pp in Targhee sheep.

Material and methods

Included were all Booroola individuals born in Poland from embryo transfer in 1989, as well as in successive lambings in 1991-2001. A total of 742 Booroola lambs were studied, the progeny of 52 sires and 128 dams. Figure 1 shows the number of animals in successive years. In order to minimize inbreeding, the number of sires used every year was very high, reaching its maximum in 1994. In 1997 the number of sires decreased, and then stabilized.

The inbred coefficient was calculated on the basis of pedigree analysis using SPIN software developed by Olech [2003] based on the tabular Quass-Henderson method. On the basis of the inbred coefficient the animals were divided into inbred classes, five in case of lambs and three in case of ewes, as presented in Table 1. The individual inbred effect was analysed for the following traits: maximum ovulation rate recorded

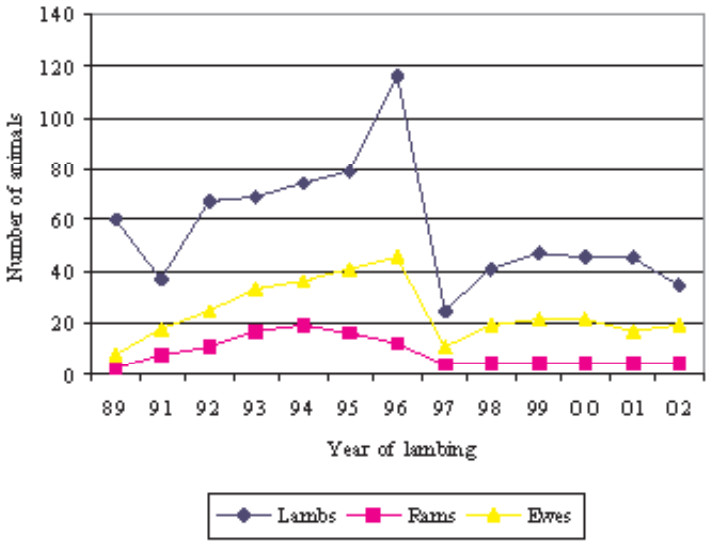

Figure 1. Experimental material: number of lambs born in successive years and number of ewes and rams giving progeny in successive lambings.

Table 1. Inbred classes for lambs and ewes

Lambs		Ewes	
class	inbred coefficient	class	inbred coefficient
1	0.0-0.050	1	0.0-0.050
2	0.051-0.100	2	0.051-0.100
3	0.101-0.150	3	over 0.100
4	0.151-0.200		
5	over 0.200		

by laparoscopy as the number of *corpora lutea*; fertility in the first, in remaining, and in the total of reproduction seasons; litter size; litter weight; lamb body weight at birth and at week 4, 8 and 12 of age; body weight at the age of one year; frequency of stillbirths, and lamb rearing results (lamb survival rate) up to 4 weeks of age. The impact of dam inbred on frequency of stillbirths was also analysed. The inbred effect was estimated with the following models:

For ovulation rate: $\mathbf{y_{ik}} = \mu + \gamma_i + \alpha_k + \mathbf{e_{ik}}$

where:

γ_i – effect of year of recording (i=1992...2001);
α_k – effect of inbred class (k=1, 2, 3).

For litter size: $\mathbf{y_{ikm} = \mu + \gamma_i + \alpha_k + \varepsilon_m + e_{ikm}}$

where:
μ_i – effect of year of lambing (i=1992...2001);
α_k – effect of inbred class (k=1, 2, 3).
ε_m – effect of successive reproduction season (m=1...8 for analysis including barren ewes and m=1...6 for analysis including only born litters)

For litter weight: $\mathbf{y_{iklm} = \mu + \gamma_i + \alpha_k + \delta_l + \varepsilon_m + e_{iklm} + b(x\text{-}x)}$

where:
γ_i – effect of year of lambing (i=1992...2001);
α_k – effect of inbred class of dam (k=1, 2, 3);
δ_l – effect of litter size (l=1...4);
ε_m – effect of successive reproduction season (m=1...6);
b – regression for ewe body weight at the age of one year.

For body weight: $\mathbf{y_{ijkl} = \mu + \gamma_i + \beta_j + \alpha_k + \delta_l + e_{ijkl}}$

where:
γ_i – effect of year of birth (i=1991...2002);
β_j – effect of sex (j=1, 2);
α_k – effect of inbred class (k=1...5 for body weight at birth and at week 4 and 8 of age;
δ_l – effect of the type of birth (l=1...5).

The *chi*^{2} test was used to analyse inbred effect on ewe fertility and frequency of stillbirths and results of lamb rearing (lamb survival) until week 4 of age.

Results and discussion

The mean inbred coefficients of ewes and rams – parents of lambs born in the successive years – are shown in Figure 2. The rapid increase of inbred between 1996 and 1997 resulted from the decrease in the number of sires. The total inbred increase was similar in ewes and rams, and reached a mean of about 10%. Figure 3 shows that lamb inbred increased almost linearly from 1992 to 2000, when it reached a level of 10.54%. Since 1997, all lambs showed some level of inbreeding, and as expected, their inbred

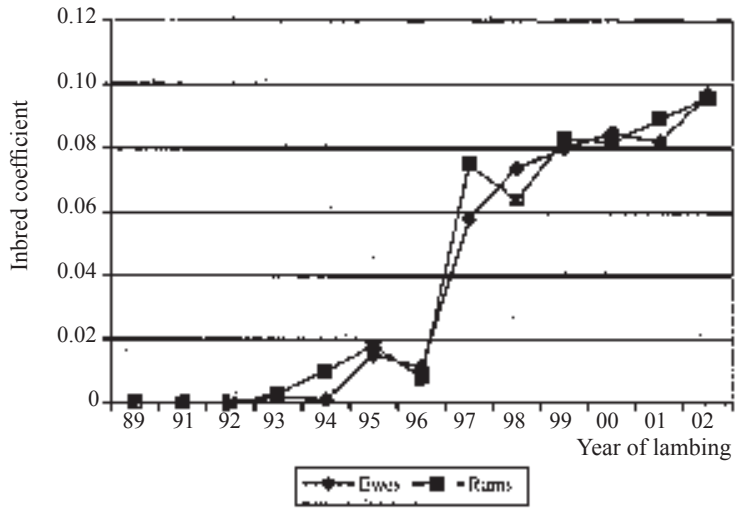

Figure 2. Mean inbred level in ewes and rams giving progeny in successive reproduction seasons.

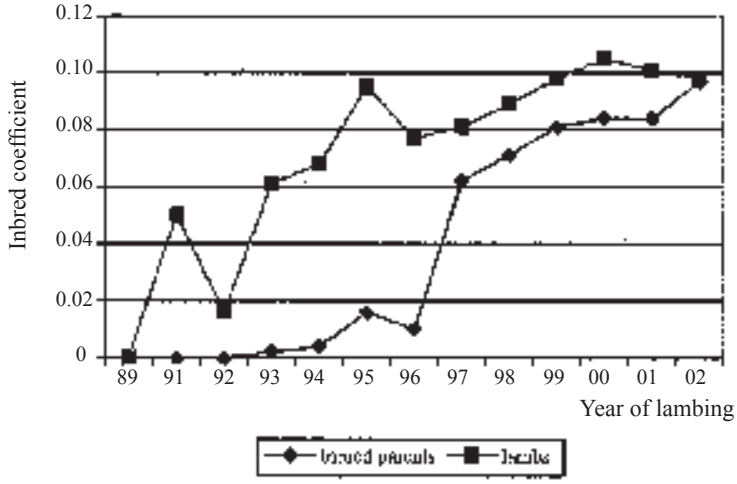

Figure 3. Mean inbred in lambs born in successive years as compared to that of their parents.

coefficient was higher than in their parents. The distribution of inbred coefficient in all lambs, all rams and all ewes is presented in Figures 4, 5 and 6, respectively. The range of inbred coefficient was similar in ewes and lambs – from 0.02 to 0.30 and over – while in rams was narrower and reached only 0.14. The average inbred coefficient values in all lambs, all ewes and all rams were 6.0, 4.07, and 3.53%, respectively,

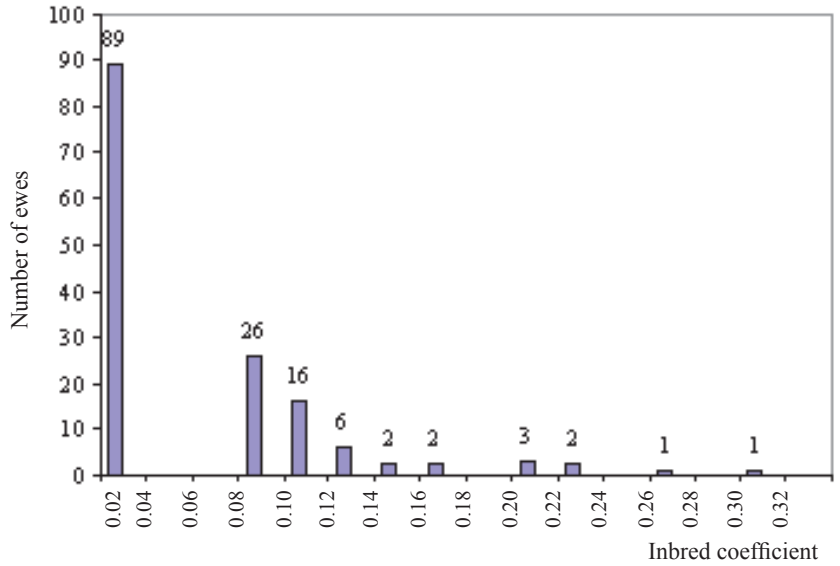

Figure 4. Distribution of inbred level in ewes.

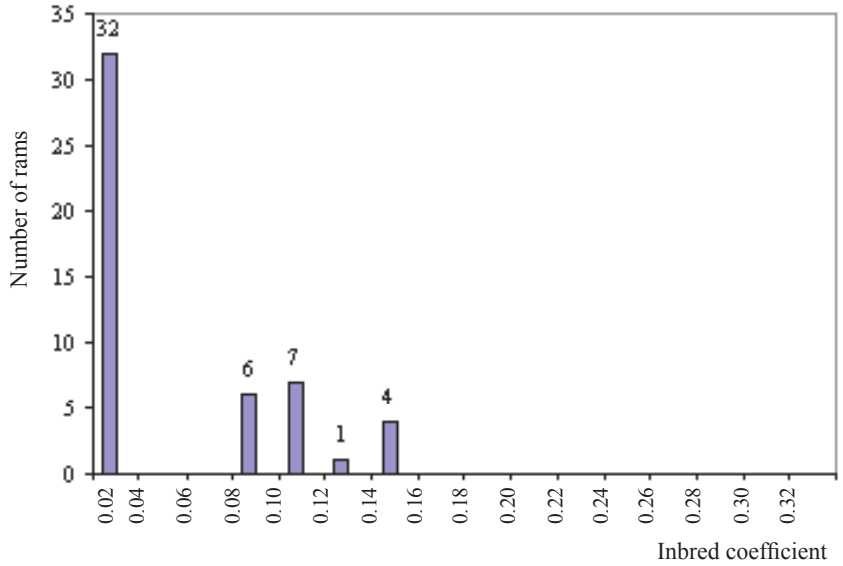

Figure 5. Distribution of inbred level in rams.

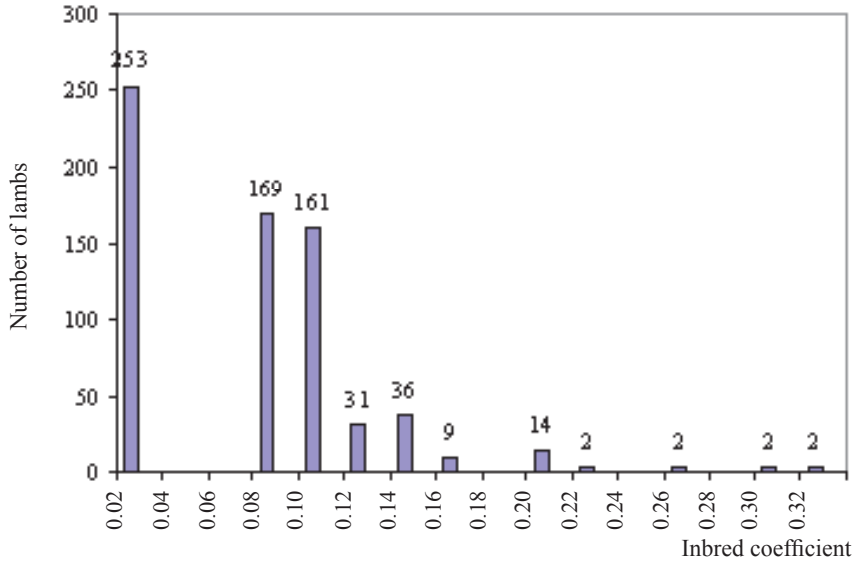

Figure 6. Distribution of inbred level in lambs.

while when only inbred animals were considered, the respective values were 8.67, 8.58 and 7.67%.

In the flocks analysed by Boujenene and Chami [1997] the mean inbred levels in lambs, ewes and rams were much lower than in the present study. In Sardi sheep they rached 2.82, 1.04 and 1.44%, respectively, while 0.48, 0.53 and 0.04% in Beni Guil sheep. However, when only inbred animals were considered, the mean inbred value in Beni Guil flock was 18.4% in lambs, 17.9% in ewes and 25.0% in rams. In Sardi flock the respective values were 32.8, 31.3 and 12.5%. It has to be noted that both flocks were much bigger in size that the Booroola flock in this study. It can be concluded, that well-planned mating in the Booroola flock reduced the rate of inbreeding.

Many authors have reported negative effects of inbreeding on fertility and other reproduction traits. Lamberson *et al*. [1982] found a 1.2 pp decrease in ewe fertility per 1 pp of inbred increase in Hampshire sheep, while Wiener *et al*. [1992a] reported that the decrease was smaller, averaging 0.28 pp. However, the results of the present study do not support negative effects of inbreeding to impact on fertility and other reproduction traits. Analysis of variance showed no effect of ewe inbred class on any of reproduction traits analysed, including fertility, ovulation rate and litter size. Table 2 presents the summary of ewe fertility data in three inbred classes. The analysis of variance only confirmed the highly significant effect of the number of reproduction seasons on litter size. In Booroola sheep, the ovulation rate is determined by a single gene $FecB^B$. As a result, neither inbred class nor year of birth, or the number of breeding

Table 2. Mean fertility in the first reproduction season and in all reproduction seasons of ewes belonging to three inbred classes

Trait	Inbred class		
	1	2	3
	First reproduction season		
Lambed (No.)	54	32	11
Barren (No.)	34	8	5
Fertility (%)	61.4	80.0	68.8
	Later reproduction seasons		
Lambed (No.)	75	37	12
Barren (No.)	59	14	8
Fertility (%)	56.0	72.5	60.0
	All reproduction seasons		
Lambed (No.)	129	69	23
Barren (No.)	93	22	13
Fertility (%)	58.1	75.8	63.9

seasons, have any impact on the mean or maximum ovulation rate of the ewe.

In the analysis of frequency of stillbirths and of lamb survival rate during the rearing period, inbred class 3, 4 and 5 were combined into one class to increase the number of observations for statistical purposes. The statistical analysis did not confirm any effect of individual lamb inbred or dam inbred on frequency of stillborn lambs. In studies carried out by Ercanbark and Knight [1991] this inbred effect was breed-dependent, not significantly in Rambuillet and Targhee, but significantly in Columbia sheep. As shown in Table 3, the rearing success till week 4 of age was not related to inbred level. Similar conclusions were withdrawn by Boujenene and Chami [1997], both in Sardi and Beni Guil lambs that were reared till day 90 of age. This contradicts the results shown in Hampshire sheep, where the decrease in survival was 1.1 pp till 7 days of age, and 1.3 pp till 90 days of age per each pp of increasing inbred [Lamberson *et al*. 1982].

In the present study, the inbred effect was confirmed only in case of early lamb growth, expressed by body weight at birth, and on week 4 and 8 of age. In comparison with the flock mean at birth, lambs from class 1 had a body weight by 0.32 kg

Table 3. Number of lambs reared and per cent of lamb losses by week 4 of age in three inbred classes

Lambs	Inbred class of lambs		
	1	2	3
Reared by week 4 of age	177	223	53
Dead by week 4 of age	36	54	8
% of lamb losses	16.9	19.5	13.1

higher, while those from class 5 by 0.61 kg lower (Tab. 4). Effects of both year of birth and type of birth were highly significant, while sex had only a significant effect. For instance, lambs born in litters of five had the mean body weight by 0.7 kg lower than the flock mean value. At the age of 4 weeks, the inbred effect was still highly significant with a decrease of body weight in the class 5 reaching 1.3 kg. Other highly significant effects were year and type of birth; sex effect was significant, ram-lambs had a higher body weight than ewe-lambs by 0.48 kg. The inbred effect remained highly significant at the age of 8 weeks, with lambs from class 5 having a body weight lower by 2.01 kg, whereas those from class 1 by 1.18 kg heavier than the flock mean value. The impact of the remaining effects was consistent with analysis at the earlier age. Table 4 presents constant values of inbred classes for lamb body weight at birth, and on week 4 and week 8 of age. At the age of 12 weeks the inbred effect was not found significant. This resulted from selection taking place before this age, which limited the availability of animal material.

Many authors reported negative effect of inbred on body weight at birth and in early rearing periods – Boujenene and Chami [1997] in Beni Guil sheep, and Ercanbark and Knight [1991] in Rambouillet and Targhee sheep. In studies by Analla *et al*. [1998, 1999] the body weight at the age of 60 days of Spanish Merino lambs decreased by 0.033 kg and 0.041 kg respectively, per 1 pp of increasing inbred.

The present study confirmed that in a small closed flock, well planned mating with maximum avoidance of mating closely related animals may reduce inbred increase in successive crops of lambs. It is impossible to avoid the inbred growth in small flocks. It

Table 4. Effect of inbred class on lamb body weight at birth and on week 4 and 8 of age

Inbred class	Range of inbred coefficient	Body weight at birth			Body weight on week 4 of age			Body weight on week 8 of age		
		no. of lambs	constant	error of constant	no. of lambs	constant	error of constant	no. of lambs	constant	error of constant
1	0.0–0.050	209	0.3239	0.0966	177	0.9809	0.2519	174	1.1764	0.2785
2	0.051–0.100	277	0.0104	0.0716	223	0.0160	0.1902	214	0.1967	0.2841
3	0.101–0.150	61	0.0202	0.0966	57	-0.0225	0.2527	52	-0.0476	0.2761
4	0.151–0.200	22	0.2499	0.1780	20	0.3244	0.1591	18	0.6996	0.5515
5	over 0.200	8	-0.6144	0.2018	7	-1.2965	0.5196	7	-2.0149	0.7971
LSM overall (kg)		–	2.42	–	–	6.67	–	–	10.75	–

could, however, be controlled to reduce negative impacts. The negative inbred effect was highly significant in the case of body weight at birth, and at the age of 4 and 8 weeks. No inbred impact was observed on ewe reproductive traits, *i.e*. fertility, litter size, frequency of stillbirths and lambs rearing success. Ovulation rate was not related to inbreeding level, as the trait is determined by the single gene of major effect.

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Wpływ inbredu na rozród i masę ciała owiec rasy booroola utrzymywanych w stadzie zamkniętym

S t r e s z c z e n i e

Analizowano wzrost współczynnika inbredu w zamkniętym stadzie owiec Booroola utrzymywanym przez 14 lat w Instytucie Genetyki i Hodowli Zwierząt PAN w Jastrzębcu. Średni inbred jagniąt rósł liniowo do roku 2002, w którym osiągnął poziom 9,81% (zakres od 0 do 31,7%). Nie stwierdzono wpływu inbredu na stopień owulacji, płodność, wielkość miotu, częstość martwych urodzeń i odchów jagniąt do 4 tygodnia życia. Ujemny wpływ inbredu obserwowano jedynie na masę ciała przy urodzeniu oraz w 4 i 8 tygodniu życia.