



The Ewe's Reproductive Performance, Growth Rate and Carcass Quality of Lambs Kept in a Barn vs Those Kept under an Overhead Shelter

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ABSTRACT: A herd of polish lowland local sheep was divided into two equal groups: the first group was kept under an overhead shelter, and the second group was kept in a warm barn. The effect of maintenance on ewe's reproductive performance, survival as well as the growth rate of lambs, and their carcasses quality was investigated. The lack of differences in fertility and prolificacy of ewes as well as in the survival and growth rate between the groups confirmed a good adaptation of Żelaźnieńska sheep to low temperature. Harsh environmental conditions did not cause a significant decrease of the body weight growth; however, they brought in an (insignificant) reduction of subcutaneous fat thickness and meatiness of the loin part of a lamb's body. The fat content of carcasses obtained from lambs reared under the overhead shelter was significantly lower, with no differences of meat and bones contribution between the groups. (**Key Words:** Reproductive Performance, Meat Quality, Harsh Environment)

INTRODUCTION

The new trend in livestock production in Poland and in other European Union countries is to move from intensive to extensive management systems. There are also incentives to utilize sheep for landscape conservation and waste land grazing, which is connected with extensive production. But the harsh environmental conditions will influence the reproductive performance of ewes as well as the rearing and fattening performance of their lambs. Moreover, a lamb's growth rate and carcass quality depends on the environmental conditions during the fattening period. Ram lambs kept in warm barn pens spend less energy on body warming, thus storing it up as a fat tissue (Symonds et al., 1991; Hocquette et al., 1998; Asakuma et al., 2003). On the other hand, cold environments increase the maintenance requirements (Young, 1983) and may reduce fat deposition in lambs fattening in pens situated in overhead shelters. Current trends show that the quality of animal products is of increasing importance to consumers and markets demanding lean meat.

Żelaźnieńska sheep are characterized by a high fecundity (Kuźnicka et al., 2005) and good meat

performance shown by live lambs (Kuźnicka and Rant, 2008). The observations so far have been carried out in warm barn conditions. In this context, the objective of the present study was to investigate whether the maintenance of ewes and their progeny under overhead shelters affects their reproductive performance as well as the survival, growth rate, and carcass quality of the lambs.

MATERIAL AND METHODS

The experiment was carried out in two successive years at the Sheep Experimental Station located in central Poland with the mean annual temperature of 7.9°C and the annual mean precipitation of 528 mm.

Animals

The Polish Lowland sheep is a breed of dual, meat and wool, purpose which since 1955 has been selected for reproductive and meat performance. That breed is characterized by high reproductive performance. The average lifetime fecundity expressed as the number of lambs weaned per ewe per year, approaches 1.5. That's why Żelaźnieńska sheep are considered a good maternal component for slaughter lamb production (Kuźnicka et al., 2005).

The reproductive performance of sheep from the

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Table 1. The number of animals in the barn and under the overhead shelter (heads)

Specification	Ewes	Singles	Twins	Ram lambs	Ewe lambs	Ram and ewe lambs
Barn	70	31	79	53	57	110
Overhead shelter	70	32	80	57	55	112

investigated flock was estimated based on 262 breeding records. The analysed ewes were between 2 and 9 yrs of age and descended from single or multiple (twin, triplet, quadruplet, and quintuplet) litters. On this basis, the flock was divided into two groups, experimental (1) and control (2), 70 ewes in each. In both groups there were ewes with a similar reproductive performance and age.

After lambing, the observations were carried out on ram and ewe lambs reared by mothers from each group. The observations included lambs reared in the barn and those from under the overhead shelter. In each group the number of ewe lambs and ram lambs, as well as singles and twins, was similar (Table 1).

Maintenance

During the entire period of the experiment, the treated group was kept under the overhead shelter, while the control group was kept in the barn.

The barn was made of bricks with a tin ridge roof, equipped with a usable loft and gravity ventilation, with the temperature never decreasing below 12°C at 75% relative humidity. The mean air temperature in the barn and under the overhead shelter at 6 am in the reproductive period and during the rearing is shown in Figure 1.

The overhead shelter was constructed of three wooden walls, with a wire-netting open-front on the southern side, and a tin uninsulated roof. Both groups were kept on deep litter.

The mating season was held at a typical term for that breed (September/October), implying parturition on the turn of February and March. All ewes were clipped to a coat depth of about 5 mm one month before the lambing season.

Feeding

The animals were fed standard diets recommended by

INRA (1988). The ewes were fed with farm produced fodder (grass hay, corn grain, rapeseed grind, wheat bran, red carrot). During the rearing period, to the age of 100 d, the lambs stayed with mothers, and milk was their basic food. From the second week of age they received additional concentrate (barley, oat, soya grind) and grass hay.

Reproductive performance

Two successive lambing seasons were taken into consideration. In each group the number of ewes lambing, the numbers of lambs born, as well as their mortality were recorded. On the base of this data the fertility, prolificacy and survival indices were calculated.

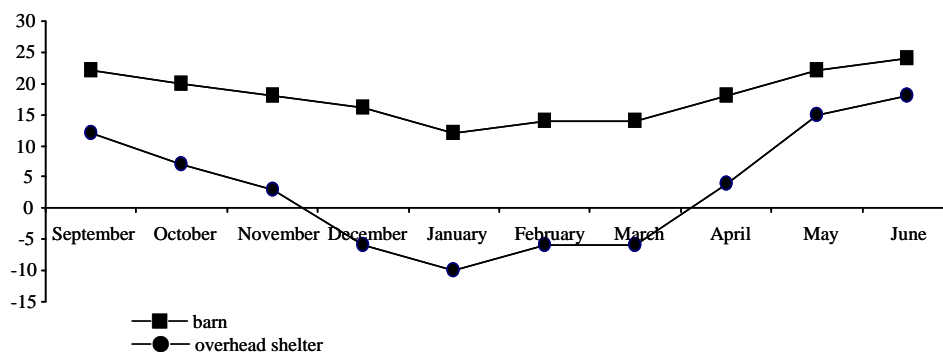
Growth rate of lambs

The lambs were weighed at birth and then every third week to estimate the body weight at birth and at 28, 56 and 100 d of age. Daily gains between 1 to 28, 1 to 56, 28 to 56, 28 to 100 and 56 to 100 d were evaluated as well.

At the 100th d of age the ultrasonic measurements of *musculus longissimus dorsi* (m.l.d.) on the last thoracic vertebrae were performed using a 5 MHz transducer. Both sexes of lambs were investigated. After the weaning (the 100th d of life) the lambs (in both groups) were kept in the same conditions as during the nursing period.

Carcass quality estimation

At the age of 120 d 20 ram lambs from each group were slaughtered for carcass quality estimation using the methodology recommended by the National Research Institute of Animal Production (Krupiński, 2009). After slaughter, carcasses were chilled at 4°C for 24 h. Objective measurements of carcasses were recorded: hind leg deepness, pelvic limb length, and hind leg circumference to calculate the hind leg tightness index. The carcass was split

**Figure 1.** The mean air temperature (°C) in the barn and under the overhead shelter at 6:00 in the reproductive period and during rearing.

longitudinally, and the two halves were weighed. Kidney with pelvic fat from the left carcass side was removed and weighed to obtain the contents of kidney knob and channel fat (KKCF). The left side was divided into shoulder, breast, pelvic limb (leg cut between the sixth and seventh lumbar vertebrae), neck (from the first to sixth cervical vertebrae), anterior-rib (from the seventh cervical vertebra to the fifth thoracic vertebra) and loin-rib (from the sixth thoracic vertebra to the sixth lumbar vertebra). Each joint was weighed. The joints: pelvic limb, loin-rib, anterior rib were classified as valuable cuts. The pelvic limbs were dissected into muscle, bone and fat. The percentage of each tissue in hind leg was calculated.

Statistical analysis

Data was estimated using the SPSS statistical package. The multi-way analysis of variance procedures was used to examine the effect of the chosen factors on the analyzed traits according to models:

For ewe’s fertility and prolificacy:

$$Y_{ijkl} = \mu + a_i + b_j + c_k + (ab)_{ij} + (ac)_{ik} + e_{ijkl}$$

For lamb’s survival:

$$Y_{ijkl} = \mu + a_i + b_j + c_k + d_l + (ab)_{ij} + (ac)_{ik} + (ad)_{il} + e_{ijklm}$$

For lamb’s growth rate:

$$Y_{ijkl} = \mu + a_i + b_j + d_l + f_m + (ab)_{ij} + (ad)_{il} + (af)_{im} + e_{ijlmn}$$

For lamb’s life ultrasonic measurements of m.l.d. muscle:

$$Y_{ijkl} = \mu + a_i + b_j + d_l + f_m + (ab)_{ij} + (ad)_{il} + (af)_{im} + e_{ijlmn}$$

For carcass characteristic of ram lambs:

$$Y_{ijkl} = \mu + a_i + b_j + d_l + f_m + (ab)_{ij} + (ad)_{il} + (af)_{im} + e_{ijlmn}$$

Where:

Y_{ijkl} = the value of observed trait; μ = overall mean; a_i = maintenance system; b_j = year of experiment; c_k = lambing number; d_l = litter size; f_m = the sex of lambs; $(ab)_{ij}$ - interaction maintenance system×year of experiment; $(ac)_{ik}$ - interaction maintenance system×lambing number; $(ad)_{il}$ - interaction maintenance system×litter size; $(af)_{im}$ - interaction maintenance system× sex of lambs; e_{ijlmn} = error.

The differences between treatments were tested using the Duncan test.

The figures have been compared in tables in the form of the least square means (LSM) and the standard error (S_E).

RESULTS AND DISCUSSION

Reproductive performance

The fertility and prolificacy of ewes as well as the lamb survival rate from both maintenance systems were very close, therefore, there were no differences of the reproductive performance between groups (Table 2). The ewes kept in the semi-open shed during the entire pregnancy period were exposed to low temperatures. Cold environmental stress is known to cause fetal death in certain species (Wentzel et al., 1979; Laburn et al., 2002). However, an increase or decrease in the umbilical and/or uterine blood flow would respectively increase or decrease the rate at which the fetus loses heat via the placental rout (Schröder and Power, 1997). Moreover, the pregnant ewes may have access to other means of maintaining thermal homeostasis of their progeny during maternal cold exposure, for example, vasoconstriction of uterine and in-skin vessels (Kawamura et al., 1986). Changes in the maternal metabolic environment may be important in enabling the newborn to effectively adapt to the extrauterine environment (Yakubu et al., 2007). The observed lack of differences in reproductive performance between the ewes kept in the barn and under the overhead shelter, as well as the survival rates of lambs reared in both maintenance systems, confirms a good ability of Żelaźnińska sheep to adapt to the cold environment.

Growth rate of lambs

The comparison of body weight and daily gains in the subsequent years of the experiment showed that during the first year of the study the lambs achieved a higher body weight in all the periods, but the differences were not statistically significant. Similarly, the rearing system×year of birth interaction did not show statistical significance. The differences in the lambs’ growth rate between the individual years of the experiment may have been caused by the variability of weather conditions. The lambing and the first stage of lamb rearing in the first year of study took place during lower temperatures. Other authors also indicated the influence of the experiment year on the growth rate of lambs (Rant and Niznikowski, 2003; Rant et al., 2005; Cloete et al., 2007).

The analysis of the body weight growth and daily gains showed no statistical differences with respect to the rearing

Table 2. Dependence of the reproductive performance on the maintenance system

Specification	Fertility		Prolificacy		Lambs survival	
	Mean	SD	Mean	SD	Mean	SD
Barn	0.96	0.04	1.78	0.10	0.91	0.06
Overhead shelter	0.95	0.03	1.80	0.07	0.93	0.05

system (Table 3). In both groups the distribution of lamb's sex and litter size was similar. Although the barn lambs were characterized by a higher birth weight, the animals kept under the overhead shelter achieved a higher growth rate in all the analyzed age periods, as confirmed by the equal body weight on the 100th d of age. According to Dwyer et al. (2006) there are breed differences in neonatal lamb vigor and in lamb thermoregulatory ability. Our results appear to confirm the good thermoregulatory ability of Żelaźnieńska ram lambs.

The ewes rearing their lambs in semi-open shed produced more milk, which may explain their smaller differences in body weight and daily gains compared to those reared in the barn. According to Sevi et al. (2002), sheep kept in buildings with a higher cubic capacity and better ventilation produced more milk. Also Świderek (1995) recorded a higher milk secretion in ewes maintained under an overhead shelter in comparison to those rearing lambs in a barn. Moreover, our previous experiment conducted on Żelaźnieńska sheep showed that mothers rearing their progeny in a harsh environment retain higher amounts of residual milk than those kept under warmer conditions (Kuźnicka and Rant, 2008). A faster growth rate of lambs from the overhead shelter might be also explained by seeking, due to the lower temperatures, a more frequent contact with the mother through suckling. The lamb growth rate is also influenced by the mothering ability of ewes, which has been stated by Nowak (1996) and Simm et al. (1996). According to them, ewes rearing lambs in harsh environmental conditions and at the same time having an appropriate feeding level are more careful mothers and rear heavier litters. Moreover, lambs reared in such conditions are more vital, which is manifested by more frequent suckling and supplementary feed consumption.

The sex of lambs showed no statistical differences in body weight and daily gains. The ram lambs were

characterized by a higher body weight at birth (4.87 kg) in comparison to the ewes (4.62 kg) and at 56 d of age (17.40 and 16.58 kg, respectively), but at 100 d the body weight in the ram and the ewe groups was almost identical (24.86 and 24.57 kg respectively). This was caused by higher daily gains between 28 and 100 d, and particularly between 56 and 100 d for the ewe lambs. These results are similar to those obtained in a previous study conducted on Żelaźnieńska type lambs reared in a barn (Rant and Niżnikowski, 2003). The rearing system×sex interaction indicates that the ewe lambs kept under the overhead shelter acquired a higher finishing weight in comparison to the ram lambs from the same rearing system, as well as to the ewe and ram lambs from the barn.

Birth type showed a highly significant effect on body weight and daily gains of the lambs reared as singles or twins. In all the analysed periods the single lambs surpassed the twins with regard to the body weight and daily gains ($p \leq 0.01$). These differences were observed both in the barn group and in the group kept under the overhead shelter. Although the rearing system×birth type interaction was not significant, the body weight of the twins from the barn (22.50 kg) and from the overhead shelter (22.56 kg) was similar. Generally, singles obtain greater body weight and daily gains than more numerous litters. It was observed in other experiments, where single-born lambs showed a significantly greater body weight growth in comparison to multiparous litters (Piwczyński et al., 1999; Yilmaza et al., 2007; Somavilla et al., 2012). According to Somavilla et al. (2012), the better daily gains of singletons may be related to the increased availability of milk.

Ultrasonically measured m.l.d muscle depth, width and area, as well as fat thickness over m.l.d muscle produced higher values in barn lambs, but the differences between the groups were not confirmed statistically (Table 4). Also, ultrasonic measurements of m.l.d muscle showed higher values for the ram lambs in comparison to the ewe lambs, but the differences were statistically insignificant.

The effect of litter size appeared to be significant for fat thickness over m.l.d. muscle ($p \leq 0.01$), muscle depth and area ($p \leq 0.01$) as well as muscle width ($p \leq 0.05$). Lambs born as singletons achieved higher values of measurements compared to those from multiple lambing. That was probably caused by the lower weight at birth and at 100th d of single reared lambs. Other authors also indicated the influence of the body weight on the *longissimus lumborum* muscle dimensions and fat thickness over m.l.d. muscle (Stanford et al., 2001; Wolf et al., 2006; Silva et al., 2007; Somavilla et al., 2012). According to Greenwood et al. (2002) low-birth-weight lambs are less mature than high-birth-weight ones in metabolic and endocrine development, which may enhance their capacity to utilize amino acids for energy production and to support gluconeogenesis during

Table 3. Body weight growth and daily gain of lambs depending on the rearing system

Specification	Lambs reared in barn		Lambs reared under overhead shelter	
	Mean	SD	Mean	SD
Body weight at birth (kg)	5.12	0.18	4.76	0.17
Body weight at 28 d (kg)	11.77	0.50	11.65	0.47
Body weight at 56 d (kg)	17.70	0.76	17.52	0.72
Body weight at 100 d (kg)	24.93	1.21	24.96	1.14
Daily gain (g/d) between				
1-28 d	246	15.33	254	14.44
1-56 d	227	12.79	231	12.04
1-100 d	200	11.97	204	11.27
28-56 d	206	13.92	204	13.11
28-100 d	183	12.73	185	11.99
56-100 d	164	15.41	171	14.51

Table 4. The dependence of a live lamb's ultrasonic measurements of m.l.d. muscle on the maintenance conditions, sex and birth type

Specification	Fat thickness over m.l.d. muscle (mm)		Muscle depth (mm)		Muscle width (mm)		Muscle area (cm ²)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Lambs reared at barn	1.23	0.04	19.74	0.45	43.17	0.68	8.63	0.23
Lambs reared under overhead shelter	1.27	0.04	19.69	0.47	42.36	0.72	8.29	0.24
Rams lambs	1.20	0.04	20.14	0.45	43.31	0.68	8.65	0.23
Ewes lambs	1.30	0.04	19.29	0.45	42.22	0.68	8.28	0.23
Singles	1.34 ^A	0.05	21.00 ^A	0.53	43.95 ^a	0.81	9.12 ^A	0.28
Twins	1.16 ^B	0.04	18.43 ^B	0.38	41.59 ^b	0.58	7.81 ^B	0.20

^{A,B} p≤0.01; ^{a,b} p≤0.05.

Table 5. Carcass measurements of ram lambs reared in different maintenance conditions

Specification	Lambs reared under overhead shelter		Lambs reared at barn	
	Mean	SD	Mean	SD
Pelvic limb length (cm)	24.27	0.31	24.51	0.29
Pelvic limb deepness (cm)	17.46	0.38	17.72	0.37
Pelvic limb circumference (cm)	34.29	0.64	35.01	0.61
Tightness index (%)	141.19	2.26	143.01	2.15
Fat thickness over m.l.d. muscle (mm)	0.70	0.09	0.84	0.09
M.l.d. muscle width (cm)	5.33	0.14	5.34	0.13
M.l.d. muscle depth (cm)	2.51	0.09	2.46	0.08

the immediate postpartum period.

The results regarding subcutaneous fat thickness and m.l.d. muscle area exhibit lower values compared to those reported by Rant and Niżnikowski (2003) where a 3.5 MHz transducer was used.

Although, the body weight of ram lambs at weaning was similar at 120 d of age, the ones kept in the overhead shelter were 1.55 kg heavier in comparison with the control group. Probably, the lambs reared in harsh environmental conditions started earlier into more supplementary food consumption, and the stress after weaning in that group was lower (Kuznicka and Rant, 2008). The results indicate that there are no significant differences for final live weights as well as for the carcass weight and its cuts.

Quality of carcasses

Significantly slighter carcasses were obtained from

twins (9.86 kg) compared to singles (12.09 kg) but the interaction of litter size with the maintenance system did not confirm the differences.

Carcass measurements of the overhead shelter group (Table 5), as well as the weight and contents of cuts in half carcasses (Table 6), showed no statistical differences between the groups. However, the fat content in the hind leg was higher for lambs kept in the warm barn. The difference was confirmed statistically (p≤0.05). At the same time, the hind leg dissection exhibited no significant differences in the meat and bone content between the groups (Table 7). Probably, the lambs kept in the overhead shelter had higher nutrient requirements and higher energy expenditure. That caused a lower fat tissue deposition and a higher lean content in the hind leg, which is a working muscle (Sormunen and Antila, 1987; Lawrence and Stibbards, 1990; Kuznicka, 2006). Moreover, the long term effects of

Table 6. Weight and contents of cuts in half carcass

Specification	Lambs reared under overhead shelter		Lambs reared at barn	
	Mean	SD	Mean	SD
Pelvic limb weight (kg)	1.71	0.09	1.76	0.09
Pelvic limb content (%)	32.14	0.69	32.97	0.66
Loin-rib weight (kg)	0.76	0.04	0.73	0.04
Loin-rib content (%)	14.14	0.22	13.57	0.22
Anterior-rib weight (kg)	0.36	0.02	0.38	0.02
Anterior-rib content (%)	6.99	0.14	6.70	0.15
Valuable cuts weight (kg)	2.47	0.13	2.54	0.13
Valuable cuts content (%)	46.30	0.42	47.10	0.43
Thoracic limb (kg)	1.04	0.05	1.06	0.05
Thoracic limb (%)	19.50	0.26	19.73	0.27

Table 7. Pelvic limb dissection

Specification	Lambs reared under overhead shelter		Lambs reared at barn	
	Mean	SD	Mean	SD
Fat weight (kg)	0.17	0.02	0.20	0.02
Fat content (%)	10.85 ^a	0.79	13.49 ^b	0.75
Meat weight (kg)	1.10	0.06	0.99	0.06
Meat content (%)	70.52	1.62	67.16	1.54
Bones weight (kg)	0.30	0.01	0.28	0.01
Bones content (%)	19.87	0.62	18.64	0.59

^{a,b} Statistical significance at ($p \leq 0.05$).

cold and acclimation include a complex of hormonal and physiological changes within the animal. These changes result in the increased energy requirement for maintenance (Young, 1981; Young, 1983) and affect the body composition. Cold exposure is associated with an increase in muscle oxidative metabolism (Symonds et al., 1992; Hocquette et al., 1998; Asakuma et al., 2003) which may cause a lower deposition of fat. Similar results were obtained by Sanza et al. (1995) who noted statistically low fat content in carcasses from lambs housed at cold temperature.

CONCLUSIONS

The lack of differences in fertility and prolificacy of ewes, as well as lambs survival and lamb's rearing performance, across the two maintenance systems confirms a good adaptation value of Żelaznieńska sheep to low temperature.

The harsher environmental conditions in the shelter did not translate into a decrease of body weight growth, although they did cause a slight reduction of subcutaneous fat thickness and meatiness of the loin part of the lamb's body.

The shelter environment had a positive impact on carcass quality as demonstrated by the significantly lower fat content in hind leg at the lack of meat content differences.

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