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Analysis of multivariate relations among birth weight, survivability traits, growth performance, and some important factors in Suffolk lambs

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Abstract. The aim of this study was to describe the relationships among lambs' birth weight, survivability traits, growth performance, and selected factors in Suffolk lambs kept under a specified extensive management system. Data were collected regarding 1012 Suffolk lambs born during a 3-year period (2012–2014) in one flock. Statistical analyses were conducted using the SAS and CANOCO program software. Birth weight was found to be an important factor influencing survivability and growth performance traits. Lambs with too low a birth weight (< 2.9 kg) had the worst results of practically all the survivability and growth performance traits. A significantly lower percentage of live-born lambs (5.2 to 6.1 %; $P < 0.05$) was also observed amongst overweight lambs at birth (> 6.0 kg) compared to lambs with a birth weight of 4–5.9 kg. Generally, the highest results of growth performance traits were detected in groups of lambs with a birth weight of 5.0–5.9 and 6.0–9.0 kg. Therefore, the optimal birth weight of Suffolk lambs was in the range of 5.0 to 5.9 kg in the evaluated flock management system. Litter size was found to be the dominant factor influencing birth weight, survivability, and growth performance traits, such that singles tended to have the highest birth weight and growth performance traits, while higher survivability traits were found in twins. The results of multivariate relations also clearly indicated that the selection of lambs should be focused on twins with regard to the monitoring of mature ewes' live weight at mating, which helped to improve the lambs' survivability traits, in particular. The monitoring of ewes' mature live weight at mating should also serve as a tool for flock management to shorten the lambing period in the flock and to improve the birth weight and growth performance traits of lambs. The mature ewe body condition score at mating should be monitored to ensure that lambs are adequately meaty and fatty. This study confirmed the importance of keeping records of birth weight and suggested practical implications of some important factors when improving flock profitability.

1 Introduction

The Suffolk sheep is the most widespread meat sheep breed in the Czech Republic, with approx. 6000 ewes in official statistics (Bucek et al., 2015). The Suffolk sheep is popular, due to its adaptability, good maternal abilities, and the lamb's growth parameters (Dwyer and Lawrence, 2005). Therefore, it is used in management systems which aim for maximal independence of sheep and lambs from additional help, such as systems in which sheep are kept outside year-round or an easy-care lambing system.

Birth weight is the first attribute when evaluating growth performance traits. However, in the Czech Republic, it is more common for this attribute to be assessed subjectively than it is for birth weight to actually be measured. Birth weight has a close connection with a lamb's survivability (Hatcher et al., 2009) and with subsequent growth performance traits (Hinch et al., 1985; Thomson et al., 2004; Caro

Petrovic et al., 2013). Generally, lambs that are too light have decreased survivability and subsequent growth performance traits. By contrast, Dalton et al. (1980) and Morris et al. (2000) pointed out the negative influence of too great a body weight in lambs on their survivability shortly after birth. The moderate heritability (in the range $h^2 = 0.33$–0.77) of birth weight (Assan et al., 2002; Everett-Hincks et al., 2014) has been detected, and thus its importance in the selection process as one of the criteria employed has been confirmed. Birth weight is also influenced by external or internal factors, such as the year of birth (Gardner et al., 2007), the ewe's age (Thomson et al., 2004), the mature ewe's nutritional status (Kenyon et al., 2004, 2014), litter size, or the sex of the lamb (Morris et al., 2003; Gootwine and Rozov, 2006; Schiller et al., 2015; Fazio et al., 2016). All of these factors also affect subsequent survivability traits and lambs' growth performance, as referred to by the abovementioned authors.

The aim of this study was to describe relationships among birth weight, survivability traits, growth performance, and evaluated factors in Suffolk lambs under a year-round outdoor management system.

2 Material and methods

2.1 Animals and flock management

The monitoring was performed in a semi-extensive Suffolk sheep flock located in the Central Bohemian Region (Příbram district). The flock is located at an altitude of 310 m a.s.l. (above the sea level), with an average annual rainfall of 900 mm and an average annual temperature of 8 °C. The feed ration during the grazing season (from mid April to mid October) consisted of grassland pasture and hay (ad libitum) as a potential food supply. The stocking rate was 2–5 ewes per hectare in specific years and grazing pasture areas. No flushing was applied before the mating season. The sheep had free access to mineral lick and to drinking water throughout the whole year. In the non-grazing period (from mid October to mid April), the ewes' feed ration consisted of haylage (3–5 kg per head per day) and hay (ad libitum). The feed ration of lambs consisted of ewe's milk, pasture, unlimited meadow hay, and concentrate supplement (alfalfa granules for lambs; Mikrop Čebín, a.s., Czech Republic; 2×200 g per head per day).

More than 98 % of all ewes lambed during a period of 40 days (from 14 April to 23 May). Only 20 lambs were born after this period during the 3 years (form 24 May to 23 June), and therefore they are excluded from further evaluation. Temperature and precipitation were obtained from the weather station Nedrahovice–Rudolec (15 km distance from the flock location). The average daily temperature (with minimal and maximal values) during the lambing season in the particular years of observation was 12.7 °C in 2012 (min.: −4.6 °C; max.: 30.5 °C), 12.1 °C in 2013 (min.: 1.0 °C; max.: 26.7 °C), and 11.2 °C in 2014 (min.: −5.1 °C; max.: 29.2 °C). Precipitation in April ranged from 30 mm (2014) to 52 mm (2012). May precipitation was in the range of 25 mm (2012) to 105 mm in 2013.

2.2 Data collection and evaluated traits

The data were collected from 1012 lambs born during a 3-year period (2012–2014). Prior to mating (during the period of 7 days before the introduction of the ram), all ewes were weighed (LW) and their body condition score (BCS) was assessed. Immediately after birth, all lambs (born live and dead) were weighed (BW, kg). Information about number of live-born lambs and their survival abilities until 48 h and at 100 days of age were recorded. These traits were expressed as a percentage of live-born lambs (LB, %), a percentage of lambs reared until 48 h (R48, %), and a percentage of lambs reared until 100 days of age (R100, %) in further statistical evaluation.

Lambs' growth performance traits were provided by officially published data of the Sheep and Goat Breeders Association of the Czech Republic. The lambs were weighed at 100 days of age (LW100, kg) (Milerski, 2005). Ultrasound measurements of musculus longissimus lumborum et thoracis depth (MLLT100, mm) and back fat thickness (BT100, mm) were recorded in the area of the last thoracic vertebra at the same age (Milerski, 2007). Finally, the average daily gain from birth until 100 days of age (DG100, g) was computed; DG100 = ((LW100 − BW) / 100). The information about the year of lambing (2012, 2013, 2014), the sex of lambs (males, females), the age of dams (2–11 years), the date of lambing (14 April until 23 June), and litter size (singles, twins, triplets) was also noted from the farm's records.

2.3 Statistical analysis

The REG procedure (STEPWISE method; SAS/STAT® 9.3., 2011) was used to select appropriate factors in the model. The influence of birth weight on survivability and subsequent growth traits was assessed using SAS 9.3. (SAS/STAT® 9.3., 2011; general linear model – GLM – procedure). Lambs' BW was grouped according to its number distribution in particular groups and according to its physiological distribution (Thomson et al., 2004; Hatcher et al., 2009) in the dataset: BW – 6.0–9.0 kg ($n = 144$); BW – 5.0–5.9 kg ($n = 320$); BW – 4.0–4.9 kg ($n = 384$); BW – 3.0–3.9 kg ($n = 130$); BW – 1.0–2.9 kg ($n = 34$). Due to the low numbers of lambs born to ewes with an age of 6 to 11 years, all these lambs were combined to create a group of 6-year and older dams. The season of lambing was divided as follows: (a) lambs born from the 1st to the 20th day of the lambing season (14 April–3 May, SEA1), (b) lambs born from the 21st to the 40th day of the lambing season (4–23 May, SEA2). Lambs ($n = 20$) born after the 40-day period were excluded from the trial.

The model for evaluating the survivability and growth performance contained the fixed effects of year (2011,

$n = 349$; 2012, $n = 286$; 2013, $n = 377$), the dam's age (2 years, $n = 242$; 3 years, $n = 218$; 4 years, $n = 223$; 5 years, $n = 120$; 6 years and older, $n = 209$), the sex of lambs (males, $n = 510$; females, $n = 502$), the season of lambing (1–20 days, $n = 879$; 21-40 days, $n = 133$), the litter size (singles, $n = 123$; twins, $n = 792$; triplets, $n = 97$), and the lamb's birth weight (see above). Effects of LW (from 28.4 to 107.5 kg) and BCS (from 2 to 5 points) were evaluated as covariates in the model. The differences between the variables estimated were tested by the Tukey–Kramer method at the level of significance $P < 0.05$.

Redundancy analysis (RDA) was used to investigate the multivariate relationships between factors considered to be independent (season of lambing, sex of lambs, litter size, body condition score at mating, ewe live weight at mating) and birth weight, survivability, and growth performance traits (dependent variables). Centering and standardization by dependent variables was used because of the different units of tested variables. The effects of year and the dam's age at lambing were considered as covariates. The statistical significance of the first and of all the other constrained canonical axes was determined by a Monte Carlo permutation test (499 permutations). All ordination analyses were performed in the CANOCO program (ter Braak and Smilauer, 2002). An ordination diagram was created in CanoDraw in order to graphically visualize the results.

3 Results

3.1 Basic database structure

The lamb's birth weight was observed for a total of 1012 lambs. The arithmetic mean of BW was 4.8 kg, with a range from 1.0 kg (minimal value) to 9.0 kg (maximal value). The average value of R48 was 79.2 %, while R100 was 16.7 % lower. Growth performance traits were observed for a total of 634 lambs. The average LW100 was 39.1 kg (13.8–60.1 kg), DG100 was 342.2 g (91.0–536.0 g), MLLT100 was 30.2 mm (11.4–38.4 mm), and BT100 was 4.8 mm (2.1–7.2 mm).

3.2 Influence of lambs' birth weight on survivability and growth performance traits

The model used to explain the variation in lambs' survivability and growth traits was significant ($P < 0.001$). The particular values of R^2 were 6.2 % for LB, 7.7 % for R48, 6.5 % for R100, 21.8 % for DG100, 26.9 % for LW100, 9.7 % for MLLT100, and 8.6 % for BT100.

3.2.1 Survivability traits

The influence of lambs' birth weight on their survivability is presented in Table 1. Generally, the lowest BW of lambs (group from 1.0–2.9 kg) negatively influenced the percentage of live-born lambs and other survival ability traits. This type of lamb was frequently born dead (24.8 to 30.9 %); in this regard, it significantly differed from all the other evaluated groups. The worst results were also clearly marked in R48 (28.1 to 45.4 %; $P < 0.05$) and subsequently at R100 (27.2 to 41.8 %; $P < 0.05$). A lower percentage of live-born lambs was also detected in the group of the heaviest lambs (BW: 6.0–9.0) compared to BW 4.0–4.9 kg (6.1 %; $P < 0.05$) or BW 5.0–5.9 kg (5.2 %; $P < 0.05$). However, no differences were marked in the subsequent rearing period (R48 and R100) among lambs with BW 4.0–9.0 kg. On the other hand, decreasing values of R48 (reaching up to 17.3 %; $P < 0.05$) and R100 (reaching up to 14.6 %; $P < 0.05$) traits were observed in the group of lambs with BW 3.0–3.9 kg compared to heavier lambs (BW > 3.9 kg). Generally, lambs' BW in the range of 4.0 to 5.9 kg showed a higher percentage of live-born lambs, and their survivability traits (R48, R100) did not significantly decrease compared to others groups.

Table 1. Effect of lambs' live birth weight on their survivability abilities.

BW	LB (%)	R48 (%)	R100 (%)
6.0–9.0 kg	89.0 ± 2.55^{a}	75.5 ± 3.99^{a}	64.3 ± 4.80^{a}
5.0–5.9 kg	94.2 ± 1.92^{b}	80.1 ± 3.00^{a}	62.6 ± 3.60^{a}
4.0–4.9 kg	95.1 ± 1.85^{b}	77.0 ± 2.89^{a}	$56.5 \pm 3.47^{a, b}$
3.0–3.9 kg	$92.7 \pm 2.50^{a, b}$	62.8 ± 3.91^{b}	49.7 ± 4.70^{b}
1.0–2.9 kg	64.2 ± 4.46^{c}	34.7 ± 6.97^{c}	22.5 ± 8.38^{c}

BW: lambs' birth weight; LB: percentage of live-born lambs; R48: percentage number of lambs weaned until 48 h after birth; R100: percentage number of lambs reared until 100 days of age. [a, b, c] Means within columns with different letters differed significantly (= $P < 0.05$).

3.2.2 Growth performance traits

There was a positive effect of lambs' birth weight on their growth traits, as presented in Table 2. The lambs with BW 5.0–5.9 and 6.0–9.0 kg grew faster than those of the BW 1.0–2.9 and 3.0–3.9 kg groups. This situation was demonstrated especially by significant differences in DG100 (reaching up to +26.1 g; $P < 0.05$) and LW100 (reaching up to +5.2 kg; $P < 0.05$) traits. Lambs with BW 4.0–4.9 kg did not significantly differ from heavier ones, except for lower results in LW100 (−1.38 to −2.16 kg; $P < 0.05$). The positive influence of a higher birth weight was also observed in MLLT100 and BT100 traits; however, it was not as obvious as in the DG100 or LW100 traits. Nevertheless, significant differences between BW 6.0 and 9.0 vs. BW 3.0 and 3.9 kg in MLLT100 (1.6 mm; $P < 0.05$) or BW 5.0–5.9 kg vs. BW 3.0–3.9 kg in BT100 (0.3 mm; $P < 0.05$) were detected in this study.

3.3 Factors affecting lambs' birth weight, survivability, and growth performance traits

Information presented in Figs. 1 and 2 provide a comprehensive overview of the complex relationships among important factors affecting lambs' birth weight, their surviv-

Table 2. Effect of lambs' live birth weight on their growth traits.

BW	DG100 (g)	LW100 (kg)	MLLT100 (mm)	BT100 (mm)
6.0–9.0 kg	347.6 ± 7.55^{a}	41.2 ± 0.76^{a}	30.5 ± 0.50^{a}	$4.8 \pm 0.11^{a, b}$
5.0–5.9 kg	350.7 ± 5.91^{a}	40.4 ± 0.59^{a}	30.3 ± 0.39^{a}	4.9 ± 0.09^{a}
4.0–4.9 kg	344.7 ± 5.97^{a}	38.9 ± 0.60^{b}	$29.7 \pm 0.39^{a, b}$	$4.8 \pm 0.09^{a, b}$
3.0–3.9 kg	324.6 ± 8.01^{b}	36.0 ± 0.80^{c}	28.9 ± 0.53^{b}	4.6 ± 0.12^{b}
1.0–2.9 kg	$333.4 \pm 21.73^{a, b}$	$36.0 \pm 2.18^{b, c}$	$29.0 \pm 1.43^{a, b}$	$4.7 \pm 0.31^{a, b}$

BW: lambs' birth weight; DG100: average daily gains of lambs from birth until 100 days of age; LW100: live weight of lambs at 100 days of age; MLLT100: musculus longissimus lumborum et thoracis depth of lambs at 100 days of age; BT100: back fat thickness of lambs at 100 days of age. $^{a, b, c}$ Means within columns with different letters differed significantly ($= P < 0.05$).

ability, and growth performance traits. Regarding lambs' survivability traits, independent variables had a significant influence ($P < 0.002$) but only contributed 6.7 % to total variability. Lambs' growth performance traits were significantly affected by independent variables ($P < 0.002$); these factors (see Fig. 2) explained 12.6 % of total variability. The dam's age was considered to be a fixed factor in the GLM or a covariate in RDA analysis. The results indicated that the factor of the dam's age was significant only for BT100, and therefore the results are not shown in detail. Nevertheless, a significantly reduced value of BT100 was demonstrated in lambs born to 6-year-old and older mothers (−0.1 to −0.4 mm; $P < 0.05$) in comparison with all the others dam age groups. Also, other lamb survivability or growth performance traits tended to show the lowest results in the group of 6-year-old and older ewes.

3.3.1 Survivability traits

Figure 1 shows that the most important driving factor was litter size, with the BW continually decreasing with increasing litter size. Singles had a higher birth weight, but higher survivability traits tended to be found in twins. By contrast, triplets showed the lowest BW and survivability traits (R48, R100). Of all other factors, LW showed the highest relation to lamb survivability, such that lambs from mothers with higher LW had higher survivability traits. This tendency was obvious especially in twin lambs, where the effect of LW obviously improved survivability traits. On the other hand, singles had the highest BW and survivability traits regardless of LW, in a similar way to triplets having the lowest. Ewe LW had the opposite tendency with SEA2 on the second canonical axis (vertical), indicating that heavier ewes give birth earlier than lighter ones. Males had a higher birth weight, while survivability traits were clearer in females. Only a minor effect of BCS on birth weight and survivability traits was detected.

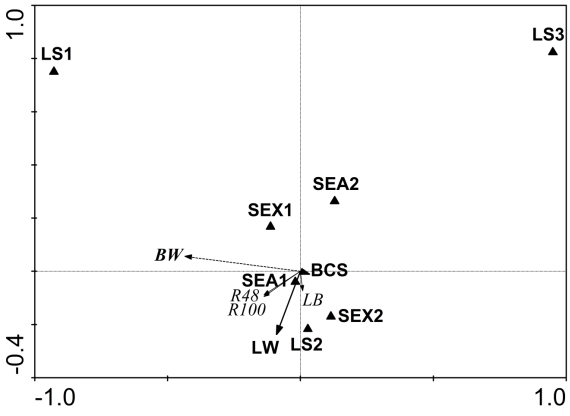

Figure 1. Ordination biplot describing the relationship between lambs' survivability (dependent variables, bold lines) and the evaluated factors (explanatory variables, triangles or broken line). The first and all canonical axes, respectively, explained 5.7 and 6.7 % of variability ($P < 0.002$; 499 permutations). LS1: litter size – singles; LS2: litter size – twins; LS3: litter size – triplets; SEX1: sex of lambs – males; SEX2: sex of lambs – females; SEA1: first season of lambing; SEA2: second season of lambing; BCS: ewe's body condition score at mating; LW: ewe's live weight at mating; BW: lambs' birth weight (kg); LB: percentage of live-born lambs (%); R48: lambs weaned during 48 h after birth (%); R100: lambs reared until 100 days of age (%).

3.3.2 Growth performance traits

Similarly to survivability, litter size was the most important factor regarding the first canonical axis (horizontal), where singles were related to higher birth weight and all growth performance traits. Higher BW, DG100, and LW100 traits were obvious in males, while higher MLLT100 and BT100 tended to occur in females. There were also different relationships between mature LW or BCS and growth performance traits. Higher mature LW improved LW100 and DG100 traits, while increased BCS was positively oriented to MLLT100 and BT100 attributes. The effect of the season of lambing on BW or growth performance traits was ambiguous; however, lambs born during SEA2 showed a slightly negative tendency with regard to BW and all other evaluated

growth performance traits. Briefly, the results of Figs. 1 and 2 clearly indicated a positive relation of birth weight with survivability abilities as well as growth performance traits.

4 Discussion

4.1 Influence of lambs' birth weight on survivability and growth performance traits

The aim of this study was to evaluate the influence of lambs' BW on their survival abilities and growth performance traits. Hinch et al. (1985) found that Booroola crossbred lambs with the lowest birth weight had the highest percentage of mortality (39.6 to 56.7 %). These results corresponded to ours, as we found that lambs with too light a birth weight had a significantly lower LB parameter and other survivability traits. Dalton et al. (1980), Hinch et al. (1985), and Morris et al. (2000) pointed out that the survivability immediately after birth also decreased significantly in overweight lambs. The curvilinear relationship between lambs' birth weight and survival abilities was observed in our study especially in the LB parameter but not in other survivability traits. Moreover, the decrease in LB parameter in overweight lambs was not as considerable as documented by previous authors, who described a significant decrease reaching up to 50 %. Overweight lambs were frequently prone to dystocia due to their excessive size, which therefore resulted in smothering. However, if they were born successfully they seemed to have no problems with viability, as documented by the high percentage numbers of survivability traits during the rearing period (up until 100 days of age). Very similar results to ours were found by Thomson et al. (2004) for Romney sheep and their crossbreeds. They explained the differences in the above-mentioned studies as being due to different genotypes or selection for easy-care lambing. This assumption is very suitable in our study as well, where the easy-care lambing system of Suffolk sheep is largely preferred in the evaluated flock. The optimal birth weight of Suffolk lambs kept in a defined management system was 4 to 6 kg from the viewpoint of their survival ability. These results are approx. 1 kg higher than those published by Hatcher et al. (2009) in Australian Merino sheep regardless of birth type.

Generally, lambs that had too low a birth weight did not have enough viability to survive after birth. This fact could be connected with a higher loss of body temperature in combination with lower fetal lipid reserves (Casellas et al., 2007) and therefore a lower colostrum intake, i.e., the starvation of the lamb shortly after birth (Christley et al., 2003). As Gama et al. (1991) adds, lighter lambs are at a disadvantage with regard to competition for resources compared to heavier siblings. Inadequate colostrum, milk, or food supply in later age meant that these lambs achieved lower growth abilities from birth until 100 days of age. Conversely, our results indicated that overweight lambs are at a greater advantage if they are born successfully. This was also observed by Thomson et al. (2004) when evaluating the influence of birth weight on lambs' weaning weight at 12 weeks of age.

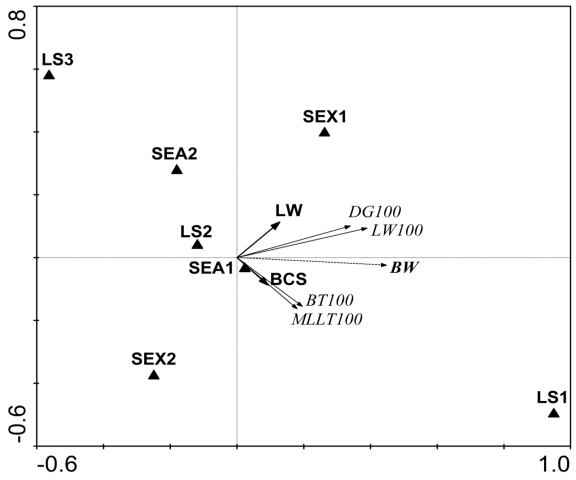

Figure 2. Ordination biplot describing the relationship between lambs' growth traits (dependent variables, solid lines) and evaluated factors (explanatory variables, triangle labels). First and all canonical axes, respectively, explained 10.8 and 12.6 % of variability ($P < 0.002$; 499 permutations). LS1: litter size – singles; LS2: litter size – twins; LS3: litter size – triplets; SEX1: sex of lambs – males; SEX2: sex of lambs – females; SEA1: first season of lambing; SEA2: second season of lambing; BCS: ewe's body condition score at mating; LW: ewe's live weight at mating; BW: lambs' birth weight (kg); DG100: average daily gains of lambs from birth until 100 days of age (g); LW100: live weight of lambs at 100 days of age (kg); MLLT100: musculus longissimus lumborum et thoracis depth of lambs at 100 days of age (mm); BT100: back fat thickness of lambs at 100 days of age (mm).

Birth weight is the first indicator that could help with the early selection of animals. Heavier lambs were more viable and grew faster than those with too light a weight. The moderate heritability of birth weight ($h^2 = 0.38$–0.77) confirmed this selection with the aim of improving survivability traits and growth performance in the flock (Assan et al., 2002; Everett-Hincks et al., 2014). Careful recording of birth weight is important especially in flock management systems in which sheep are kept outside year-round or in easy-care lambing systems, where the independence of sheep and their lambs from additional help is necessary.

4.2 Factors affecting lambs' birth weight, survivability, and growth performance traits

The aim of this study was to evaluate relationships among lambs' BW, survivability traits, growth performance, and other evaluated factors. Litter size was the major effect influencing either survivability traits or, in particular, growth performance traits; this is in accordance with previously published studies of Gootwine and Rozov (2006), Kuchtík and Dobeš (2006), and Milerski et al. (2006). Wolfová et

al. (2009) estimated costs of EUR 88.1 per Suffolk ewe per year in the Czech Republic. Average lambs' slaughter weight was 32.8 kg, while their average worth was EUR 1.71 per kg (EUR 1 = CZK 27.05) as published by Bucek et al. (2015). It is evident that long-time profit – without governmental subsidies – is ensured only by ewes giving birth to multiple litters. Our results clearly confirmed the lowest survivability and growth performance traits in triplets. Therefore, litters of twins are most favorable from the viewpoint of economic efficiency in meat breed flocks in the Czech Republic, which is also suggested by Ptáček et al. (2015). It is also important that our results clearly confirmed the relevance of the monitoring of LW, especially in twin lambs, whose survivability traits were obviously improved by increased LW. The positive influence of LW on survivability traits was also demonstrated more generally by Kenyon et al. (2004), regardless of litter size. In practice, only a minor effect of BCS on survivability traits was marked. Our results indicated that ewes' LW was related to the LW100 and DG100 of lambs, while ewes' BCS was related to lambs' MLLT100 and BT100 in an evaluation of lambs' growth performance traits (see Fig. 2). These results can be connected with the heritability of individual growth performance traits described by Fogarty (1995) or Safari et al. (2005). The positive selection of LW can thus improve the growth performance traits of the offspring. Animals that are too thin could produce lambs with lower MLLT100 or BT100. Similarly, low BCS was negatively associated with animal welfare (Kenyon et al., 2014). On the other hand, overly fat ewes were detected to have problems with decreased reproductive and productive traits (Kenyon et al., 2014; Ptáček et al., 2017), which is negative as well. Culling sheep with regard to the published results should help to improve lambs' birth weight, their survivability, and growth performance traits. An interesting negative relation between LW and SEA2 was detected in Fig. 1. A possible interpretation of results is that ewes with the higher LW conceived earlier within the mating period and lambed in a shorter time than those with a lower LW. In a practical sense, the monitoring of LW could shorten the lambing period in the flock. Nevertheless, the relatively ambiguous effect of the season of lambing in this study could be connected with the short period of lambing in the evaluated flock (the lambing season was spread across only two periods). The sex of lambs had exactly the same influence as follows from studies of De Siqueira et al. (2001), Stanford et al. (2001), and Milerski et al. (2006). A comparable or higher live weight or daily gains were observed in males, while mainly nonsignificantly higher meatiness or fattiness were detected in females. Significantly decreased values of lambs' survivability or growth performance traits were detected in dams aged 2 or 6 years and older (Morris et al., 2000; Thomson et al., 2004; Hatcher et al., 2009). The effect of dams' age was nonsignificant in this study except with regard to BT100. However, mainly nonsignificantly decreased values of practically all the evaluated traits were noticed, especially in lambs born to the group of 6-year-old and older ewes.

5 Conclusion

RDA analysis showed that survivability and growth performance traits were significantly influenced by the observed factors. However, the variability explained by the model was about 10 % only. Also, ANOVA evaluation did not exceed 27 %, while survivability traits were explained maximally by 7.7 %. Therefore, these traits are influenced by other undefined factors. Nevertheless, the proposed measures can contribute to improving partial survivability or growth performance traits on the overall scale of approx. 10 to 15 %. Birth weight was found to be the important factor influencing survivability and growth performance traits. Lambs with too low a birth weight (< 2.9 kg) were detected to have the worst results in practically all the survivability and growth performance traits. A significantly lower percentage value of live-born lambs (5.2 to 6.1 %; $P < 0.05$) was also monitored in overweight lambs at birth (> 6.0 kg) compared to lambs with a birth weight of 4–5.9 kg. Generally, the highest results regarding growth performance traits were detected in the groups of lambs with a birth weight of 5.0–5.9 and 6.0–9.0 kg. Therefore, the optimal birth weight of Suffolk lambs was in the range of 5.0 to 5.9 kg in the evaluated flock management system. Litter size was found to be the dominant factor influencing birth weight, survivability, and growth performance traits. The selection of lambs should be focused on twins with regard to the monitoring of mature live weight at mating, which particularly helped to improve the lambs' survivability traits. The monitoring of ewes' mature live weight at mating should also serve as a tool for flock management to improve birth weight and growth performance traits. The mature ewe body condition score at mating should be monitored to ensure the adequate back body tissue development of lambs. This study confirmed the importance of keeping records of birth weight and suggested practical implications of some important factors when improving flock profitability.

Data availability. The original data of the paper will be available upon request to the corresponding author.

Competing interests. The authors declare that they have no conflict of interest.

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