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Influence of Supplemental Feeding on Body Condition Score and Reproductive Performance Dynamics in Botosani Karakul Sheep

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Abstract: The aim of this research was to study the impact of supplementary feeding on reproductive traits in sheep. Two groups, L1 (control) and L2 (experimental treatment), of adult females aged between two and six years belonging to the Botosani Karakul sheep breed were formed. The experimental treatment group (L2) received supplementary feeding 25 days prior to mating. Improvements in body condition and significant increases in live weight occurred by the time of mating in those ewes that had been flushed (L2) ($p < 0.01$ vs. L1). The number of lambs per individual parturition was influenced by the body condition score (BCS), especially in females with a BCS of 2.0. The total number of weaned lambs in females with a BCS of 2.0 differed in comparison to that of females with a BCS of 2.5 or 3.0. All results highlighted that supplementary feeding applied to ewes prior to mating affected their reproductive and economic performance, translating to an increased live weight of the litter at weaning in the L2 group ($p < 0.01$ in lambs from BCS 2.0 ewes and $p < 0.001$ in lambs from BCS 2.5 to 3.5 ewes).

Keywords: body condition score; ewes; reproductive traits; flushing

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1. Introduction

Northeastern Romania is a geographical region in which traditional sheep farming technologies are mostly applied and the rearing of the Botosani Karakul sheep breed represents a priority activity. The breed flock comprises more than 250,000 heads, of which 65% represent reproductive females [1]. Climate change, in the form of drought and high temperatures, induces alterations in the botanical composition and nutritional value of pastures, affecting the body conditions of ewes before the reproductive season and, subsequently, their level of productivity. The research aim was to evaluate the impact of supplementary feeding on the main reproductive and productive features of the Botosani Karakul sheep breed.

To establish the research objectives, we started from the idea that the management of sheep farms cannot be competitive without the satisfaction of certain minimal demands related to the biological state of flocks, i.e., their body condition and live weight throughout the essential periods of reproduction and production [2]. Bringing the breeders to an optimal body condition is important, due to the strong and complex connection between their metabolic functioning and their reproductive control system [3].

In reproductive ewes, an appropriate body condition is important. Hence, metabolic factors have intense manifestations and exercise variable effects, from yield increases to reproductive performance improvements, when the conditions become favourable or could induce the total inhibition of reproduction when the circumstances are adverse [4–6]. Supplementary feeding could be an efficient means for improvement in this regard when correctly applied and must comprise nutrient-rich feedstuffs. Intake and digestibility can be reduced or unaffected by supplementation with energy, while, in some cases, it has been proven that lower levels of energetic supplements increase the intake of grazed fodders [7]. Supplementary feeding is also useful because it covers ewes' nutritional demands throughout the developmental stages, providing a solution to the scarcity of specific nutrients and contributing to the formation of body reserves and the improvement of the growth rate and fertility, as well as meat, milk, and wool yields and quality [8]. Ewes' nutritional needs vary by age, body development, gestational status, gestation phase, and suckling period. The application of supplementary feeding is beneficial, preventing live weight losses in ewes and facilitating body weight maintenance at optimal levels [9].

The nutritional status of ewes can affect both their reproductive performance and their main productive functions, with yields decreasing below their genetic potential due to many limiting factors, such as malnutrition throughout critical physiological stages (i.e., gestation and lactation) [10].

Scoring the body development of sheep highlights quite well the general body condition of the herd, and farmers can intervene to correct nutritional uptake in relation to demand, which in the grazing period is very high, depending on the quality and quantity of the consumed grass [11]. Continuously updating the procedures and criteria used in the body condition score (BCS) calculation offers efficient technical support for the use of this tool in informing important farming decisions, with direct effects on the level of future production, as well as on the fodder management mode [12]. Body condition is determined by growth peculiarities and by farm management activities [13]. Evaluation based on point-scoring the body condition represents a valuable instrument for the assessment and management of ewes' welfare in farms [13,14].

Body condition assessment is highly relevant, along with live weight and size measurements, and could mitigate the errors that appear during certain periods (gestation or lactation) [15,16]. The results of the body condition scoring method are not affected by temporary mass variations caused by digestive tract filling or by wool length and moisture content [16–21]. The evaluation technique of the BCS was proposed by Jefferies (1961), in order to obtain accurate information on aspects affecting ewes' body development state and nutrition so that the available nutritional resources could be utilised more efficiently [17]. This technique allows the evaluation of the body condition in the absence of certain concrete aspects that are not visible through the analysis of the body's appearance (external traits). When correctly applied, the farmer can observe whether a major decline in body condition has occurred and can intervene to eliminate/prevent the apparition of certain negative effects [22].

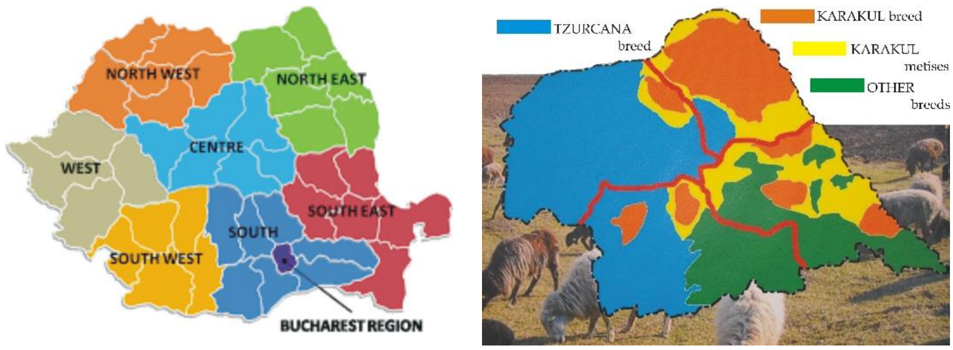
The achievement of favourable economic results is determined by the provision of appropriate welfare conditions, including supplemental feeding for the restoration or improvement of body condition, especially during certain critical periods of the production cycle, due to external factors (the poor nutritional value of feed, drought, etc.) or internal factors (special physiological statuses and metabolic conditions of animals) [23]. The application of stimulating feeding has a positive influence on static characteristics (live weight at mating) as well as on dynamic traits, such as variations in body weight across different periods [20,23].

Within the context of natural feed resource depletion and degradation due to climate change, i.e., the deterioration of the floristic composition and nutritional value of pastures, it is important to study the supplemental feeding of ewes prior to mating in order to assess the direct effect of nutritional boosting on their productive and reproductive performance. Many farmers rear Botosani Karakul sheep using inherited traditions and facilities, and such findings could be of substantial benefit by offering an example of effective practices for improving farm management. Additionally, this study could provide a technical example to other research facilities, based on which they might modify their fodder resources and nutritional optimisation process in order to use locally available feedstuffs and raise the economic performance of their herds.

2. Materials and Methods

2.1. Study Area

The rearing area of the Botosani Karakul sheep breed is situated in the North-east part of Romania (Figure 1) between 25°02′ and 28°07′ Eastern longitude and between 46°37′ and 48°15′ Northern latitude.



(**a**) (**b**)

Figure 1. Distribution map of Romania's regions (**a**) and representation of rearing area of Botosani Karakul sheep breed (**b**).

Temperatures have continued to increase throughout the last decades, progressively till July and August, and sometimes during September. Drought lasts more than 60 days. When higher temperatures are associated with less rainfall, the pastures' floristic composition modifies, and drought-resistant plants increase as proportion. They have poor nutritional value, unable to provide the optimal nutrients for ewes' body development prior to the reproduction season.

2.2. Animals and Data Management

The research was carried out within the Research and Development Station for Sheep and Goat Rearing Popauti-Botosani and took place on a complete reproduction-production cycle. Biological material was represented by adult females belonging to the Botosani Karakul sheep breed, representative of the Northeast Region of Romania (it counts up to 30% of the whole area sheep population) [24].

To study the impact of supplementary feeding on body condition (BC), reproductive and productive traits, two groups (L1 and L2) were formed, each comprising 100 adult females, aged 2 and 6 years (Figure 2). Each group benefited from the same experimental conditions, maintained throughout the whole research period in a local traditional system, i.e. indoors (barn) throughout the cold season (December–May) and on pasture during the warm season (May–November).

(**a**) (**b**)

Figure 2. Females exclusively grazed (**a**) and females which benefited from supplementary feeding (**b**).

During the cold season, a diet composed of a unique mix of gramineae (grasses) hay, alfalfa hay, and rough fodders was fed to ewes, and they were grazed exclusively on natural pasture, in the warm season.

The experimental factor that differentiated the Groups was the supplementary feeding provided to Group L2: 25 days prior to mating season onset, a mix of concentrated feedstuffs (cracked corn, sunflower meal, grains of barley, and oat). Their nutritional values and usage rates are presented in Table 1. Supplementary feeding in Group L2 aimed to improve the females' BC prior to reproduction season onset (150 g of the supplemental mixture was fed daily to each female), thanks to the 15% higher dietary energy, in comparison with the regular diet, fed to Group L1.

Table 1. Structure of diet throughout experimental period.

Feedstuffs Assortment	MU	Diet Provided before Mating and during the 1st Part of Gestation (First 3 Months)	Flushing Diet	Diet during the 2nd Part of Gestation		Diet during the Lactation Period		
				4th Gestational Month	5th Gestational Month	1st–2nd Lactation Months	3rd Lactation Month	4th Lactation Month
Pasture	Kg	7.5	6	7.5	-	-	-	5.833
Alfalfa hay	Kg	-	-	-	0.2	0.44	0.711	-
Grasses hay	Kg	-	-	-	0.5	0.5	0.915	-
Wheat straw	Kg	-	-	-	0.33	0.611	0.3	-
Barley	Kg	-	0.04	-	0.36	0.05	-	-
Oat	Kg	-	0.03	-		0.05	-	-
Corn	Kg	-	0.05	-		0.1	-	-
Sunflower meal	Kg	-	0.03	-	0.113	0.2	-	-
Salt	Kg	-	-	-	0.001	0.001	0.001	-
Nutritional value								
Dry matter	G	1077	1200	1200	1300	1687	1657	1225
Crude protein	G	199.81	225	225	160	215	195	175
NEM (Net energy for milk production)	MJ	7.47	8.59	8.23	7.0	8.2	7.71	7.65
Gross fibre	G	225	177	225	304	481	537	292
Ca	G	6.09	7.5	7.5	8.137	12.662	18.746	8.167
P	G	3.65	3.75	3.75	4.348	5.215	4.0	4.083
Ca/P Ratio		1.67:1	2:1	2:1	1.87:1	2.43:1	4.69:1	2:1
Na	g	1.18	1.42	1.425	1500	1.5	1.5	1.458
Mg	g	1.5	1.5	1.5	2.716	3.862	3.551	1.75

Water and salt were provided *ad libitum*. Reproduction season began in September and ended in October. Conducted natural mating was used, providing a ratio of 1 male to 25 females. Lambing season lasted between March and April and lambs were weaned 70 days post-partum.

To assess the economic efficacy of the supplemental feeding, average daily costs generated by the diets have been calculated for each experimental version, using the real pricing for producing or procuring the feedstuffs at the moment of the experiment.

2.3. Traits

The research aimed to highlight the impact of supplementary feeding on body condition (BC) dynamics, reported as body condition score (BCS), and on certain reproductive and productive traits of the Botosani Karakul sheep breed.

Body development condition was evaluated by palpation of muscular masses and fat deposits on the episome (topside trunk, loin, and rump) and was graded from 1 (slim ewes) to 5 (very fat ewes) with subrankings of 0.5 using a method developed by Russel [17]. BC was evaluated by two experienced graders who scored the ewes consensually. Live weight (LW) was measured with an electronic scale, with an accuracy of ±100 g.

The impact of supplementary feeding on reproduction performances was evaluated through certain specific parameters, in accordance with a pattern presented by Landais and Sissoko, 1986 [25]:

$$\text{Lambing rate (\%)} = (\text{number of lambing ewes}/\text{number of mated ewes}) \times 100;$$

$$\text{Fertility rate (\%)} = (\text{number of pregnant ewes}/\text{number of mated ewes}) \times 100;$$

$$\text{Litter size (prolificacy)} = (\text{number of lambs}/\text{number of lambing ewes}) \times 100;$$

$$\text{Weaned rate (\%)} = (\text{number of weaned lambs}/\text{number of born lambs}) \times 100;$$

$$\text{Fecundity rate (\%)} = (\text{number of live births}/\text{number of mated ewes}) \times 100;$$

$$\text{Abortion rate (\%)} = (\text{number of abortions}/\text{number of mated ewes}) \times 100;$$

$$\text{Pregnancy rate (\%)} = (\text{number of pregnant ewes}/\text{total mated ewes}) \times 100.$$

Other specific investigated traits were:
LLW-lambs live weight at birth (kg);
WLW-lambs live weight at weaning (kg);
LLW/LE-lambs live weight at birth(kg)/LE-number of lambing ewes (n);
WLW/LE-lambs live weight at weaning (kg)/LE-number of lambing ewes (n);
WLW/MWE-lambs live weight at weaning (kg)/MWE-metabolic weight of ewes ($kg^{-0.75}$).

2.4. Statistical Data Processing

Data have been assembled in a database using Microsoft Excel 2016 software and statistically processed via the GraphPad Prism 9.4.1., software (manufacturer, GraphPad Ltd., Palo Alto, CA, USA), to obtain the statistical descriptors (mean, standard error of the mean—SEM, coefficient of variation). Analysis of variance for the difference of average performances between studied groups was performed, using the ANOVA single factor algorithm followed by Tukey post-hoc for multiple comparisons correction using the statistical hypothesis testing.

In the quantifiable studied traits, such as LW at lambing and weaning moments (both for ewes and lambs), there were run comparisons between groups when at least three individual different values were present on the data class. Each data table displays the number of individuals that were compared.

Those traits with single output values, such as the reproduction indices, i.e., fecundity, prolificacy, fertility, abortion, pregnancy, lambing, and weaning rates, were expressed as percentages out of the main group and they were not compared statistically, because no repeated data were available.

3. Results

3.1. Impact of Supplementary Feeding on Body Condition and Live Weight

The obtained results show the effect of supplementary feeding, due to the 15% energetic dietary surplus, on the BC, through the restoration of body reserves as well as through depositing nutritional reserves that animals are supposed to metabolise further. The ewes BCS increased by 12% in L2 vs. L1 at mating and by 16% at weaning, while the LW values were 5.1 to 5.2% higher in L2 vs. L1, due to supplementary feeding usage ($p < 0.01$) (Table 2).

Table 2. Descriptive statistics for BCS (points) and ewe live weight (kg).

Assessment Moment	Trait	L1		L2		*p*-Value
		Mean	±St. Dev	Mean	±St. Dev	
Mating	BCS (points)	2.48	0.059	2.79	0.054	0.1960
	LW (kg)	46.61 [a]	5.484	49.02 [c]	5.049	0.0014
Weaning	BCS (points)	2.21	0.054	2.57	0.063	0.7713
	LW (kg)	45.09 [a]	5.666	47.44 [c]	5.514	0.0032

BCS = Body Condition Score; LW = Live Weight. ANOVA: means with different superscripts per row are statistically different: [ac] for $p < 0.01$.

Supplementary feeding determined more ewes to achieve better BCS categories in group L2 (Figure 3) due to LW increasing, due to muscular masses restoration, and due to adipose tissue deposition.

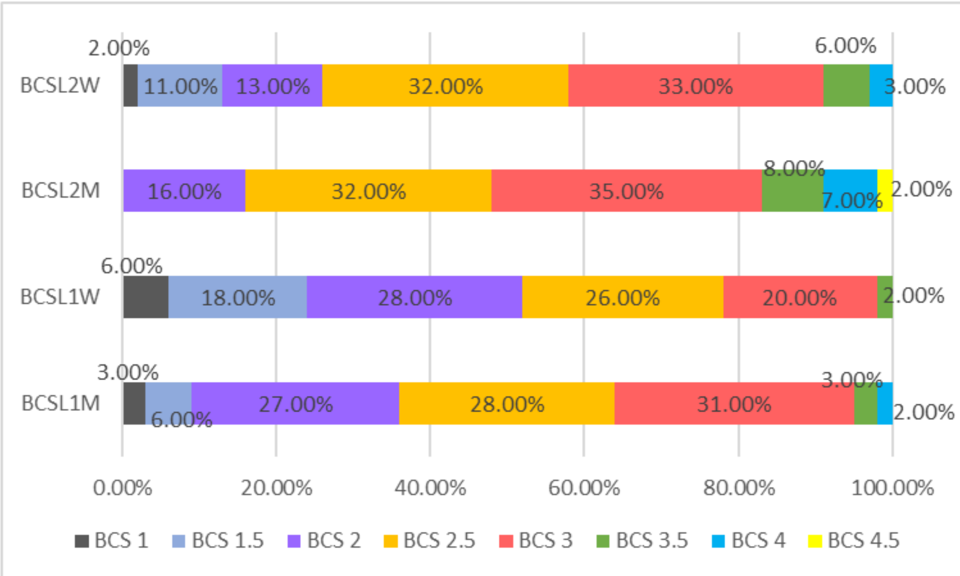


Figure 3. Females' rate (%) in relation to BCS (points) assessed at the mating moment and lambs' weaning moment. Notes: BCSL1M and BCSL2M: body condition score at the mating moment; BCSL1W and BCSL2W: body condition score at lambs weaning moment. ABWL1M and ABWL2M; average body weight at mating moment; ABWL1W and ABWL2W average body weight at lambs weaning moment.

3.2. Impact of Supplementary Feeding on Ovulation Rate and on Some Reproduction Characters

In the L1 group, ewes presented a narrow body frame and observable bone angles. After finishing mating in L1, 55.55% of females with BCS $\leq$ 1.5 did not become pregnant even if heats were observable. Female fertility was affected in a direct way by both BC and LW.

The positive impact of supplementary feeding is highlighted by the reproduction performances in L2 ewes, where just 7% of all ewes needed the third mating service, and less than 2% experienced abortions, in comparison with L1 ewes which had worse BC and, consequently poorer reproductive performance (12% of females with third mating service and 5% abortion rate) (Table 3).

After finalizing all lambing, better reproductive performances were recorded in the group that was supplementarily fed prior to mating. The number of lambs/ewes was influenced by ewes BC and LW at mating time.

Table 3. Effect of body condition on reproduction and production performances.

BCS	Pregnancy Rate, Lambing, and Weaning (n)						
	Total (%)	1st Service	2nd Service	3nd Service and More	Abortion	Lambing	Weaning
				Group L1			
1	3	1	1	1	2	1	0
1.5	6	2	2	2	3	3	2
2	27	19	5	3	0	30	22
2.5	28	23	3	2	0	32	27
3	31	20	8	3	0	35	28
3.5	3	1	1	1	0	2	2
4	2	1	1	0	0	2	0
4.5	0	0	0	0	0	0	0
Total (n)	100	67	21	12	5	103	97
				Group L2			
1	0	0	0	0	0	0	0
1.5	0	0	0	0	0	0	0
2	16	12	2	2	1	20	17
2.5	33	28	3	2	0	41	38
3	36	32	3	1	0	43	43
3.5	8	5	2	1	0	12	12
4	7	5	1	1	1	6	5
4.5	2	1	1	0	0	1	1
Total (n)	100	82	11	7	2	123	116

Impact of Supplementary Feeding on Reproduction Traits

Supplementary feeding had a positive impact on prolificacy (Table 4); in L2 group, there were 15.47% more lambs obtained in comparison with L1. The nutritional surplus meant not only energy intake but higher quantities of digestible proteins prior to mating, stimulating, most likely, the ovulatory rate.

Table 4. Effect of supplementary feeding on reproduction indices.

Groups	Fecundity, %	Prolificacy, %	Fertility Rate, %	Lambing Rate, %	Weaning Rate, %	Abortion, %	Pregnancy, %
L1	95	104	95	96	94.1	3	97
L2	97	123	97	98	94.3	2	98

Reduced differences were recorded for fecundity and fertility rates, due to the fact that those characters are genetically well consolidated and their different manifestation is relatively low even when ewes did not have an optimal BC or LW at mating.

When traditional rearing technologies are applied under the influence of climatic changes or of the quantity and quality of grazed forage, supplementary feeding prior to the mating period could improve reproduction traits and it is advisable to become a current technique for all farmers rearing Botosani Karakul sheep.

3.3. Evaluation of Relation between Ewes' Body Condition and Live Weight of Lambs at Lambing and Weaning

Even if weight at lambing was close among groups and no significant differences occurred (Table 5), by reporting the total LW of lambs to the total number of females which carried out the gestation till the end (LLW/LE), higher values were achieved by females L2 with favourable BCS (3.0 and 3.5).

Table 5. Descriptive statistics (mean ± SEM) and the ratio between the lambs' weight at lambing and at weaning in relation to the mothers' BCS.

Group	Characters	Body Condition Score (Points)				
		2	**2.5**	**3**	**3.5**	**4**
L1	LLW	4.57 ± 0.06	4.80 ± 0.07	5.08 ± 0.06	4.90 ± 0.10	0
	WLW	20.78 ^{a} ± 0.26	21.09 ^{a} ± 0.20	21.53 ^{a} ± 0.17 ^{a}	21.77 ^{a} ± 0.12	0
	LLW/LE	5.13	5.53	5.89	4.90	0
	WLW/LE	16.93	20.33	19.44	21.77	0
	WLW/MWE	1.30	1.23	1.24	1.22	0
L2	LLW	4.62 ± 0.06	4.84 ± 0.06	5.21 ± 0.06	5.03 ± 0.09	5.10 ± 0.13
	WLW	22.28 ^{c} ± 0.14 $p = 0.0051$	22.53 ^{d} ± 0.08 $p = 2.7 \times 10^{-5}$	23.06 ^{d} ± 0.07 $p = 0.0001$	23.37 ^{d} ± 0.15 $p = 0.0099$	22.66 ± 0.13
	LLW/LE	5.71	5.96	6.22	7.54	4.37
	WLW/LE	23.67	25.94	27.54	35.05	16.18
	WLW/MWE	1.36	1.30	1.32	1.25	1.19

ANOVA: statistical significance of differences between live weights of lambs at weaning, per classes of ewes Body Condition Scores (means with different superscripts per column are statistically different: ^{ac} for $p < 0.01$; ^{ad} for $p < 0.001$). LLW—lambing live weight (kg); WLW—weaning live weight (kg); LLW/LE—lambing live weight (kg)/LE—lambing ewes (n); WLW/LE—weaning live weight (kg)/LE—lambing ewes(n); WLW/MWE—weaning live weight (kg)/MWE—metabolic weight of ewes ($kg^{-0.75}$).

Supplementary feeding applied to group L2 prior to mating did not have a relevant effect on lamb weight at lambing because the resulting differences were not significant, and the lambs obtained from ewes with a mediocre BC had a reduced survival rate. Neonatal mortality exceeded 6% in ewes with BCS below 2.0. Lambs obtained from ewes in group L2 had a better survival rate and greater LW at weaning ($p < 0.001$). In group L2, ewes with BCS 2.0 and BCS 3.5 had better body development, higher prolificacy, and a better rate between lambs LW at weaning and the number of ewes that lambed (WLW/LE).

L2 ewes with BCS = 2.0 and BCS = 2.5 during mating raised the lambs easier till weaning, but the tendency was to have lower LW values, compared with the ewes with BCS $\geq$ 3.0. The ratio between the lambs' mean total weight at weaning and metabolic weight of ewes indicates certain variations, with higher values in females with BCS = 2.

3.4. Effect of Supplementary Feeding on the Economical Results

Supplementary feeding contributed to achieving differentiation in economic results, between groups (Table 6).

Thus, in the L2 group, the daily supplementary feeding costs exceeded by 1.3% the regular feeding in L1. At birth, the value of the lambs' LW was 23.1% higher in L2, compared to L1, while after weaning, the value gap became more intense, reaching 27.4%, in the favour of lambs issued from supplementary fed mothers (L2). Therefore, supplementary feeding probably generated higher ovulation rates, with positive effects on prolificacy, leading to better reproduction and higher economical performances.

Table 6. Economical outcomes generated by supplementary feeding.

Economical Item	n	Live Weight /Lamb (kg)	Live Weight /Group (kg)	Total Value/Group (Euro)
		L1		
Total born lambs (n)	103	4.81	495.43	1694.37
Total weaned lambs (n)	97	21.37	2072.89	7089.28
Feeding costs (euro/group/day)			189.21	
		L2		
Total born lambs (n)	123	4.96	610.08	2086.47
Total weaned lambs (n)	116	22.76	2640.16	9029.35
Feeding costs (euro/group/day)			191.72	

4. Discussions

4.1. Effect of Supplementary Feeding on Ewes' Body Condition and Live Weight

Supplementary feeding should be a common practice in farms, especially in arid areas where climate negatively affects the floral composition of pastures. It would be ideal that female breeders have fulfilled their nutritional requirements, in order to reach the appropriate BC and LW prior to mating, and to become able to express well the production and reproduction characteristics. Close and positive relations are between BCS and ewes' LW (LW) at mating and weaning, which improve many basic features. Additionally, stimulating feeding applied to Group L2 improved both BC and LW. The 25 days of stimulating feeding in L2 ewes produced moderate improvement of BCS and a significant increase of LW ($p < 0.01$), compared to L1, in mating and weaning moments. Supplementary feeding had a positive influence on the L2 group. More than 84% of ewes achieved a BCS $\geq$ 2.5 points, out of which 20.23% with a BCS between 3.5 and 4.0 points. In Group L1 (no supplementarily fed), around 9% of females achieved a BCS $\leq$ 1.5 (palpation revealed weakly developed muscle masses and lack of fat layer).

According to our results, the existence of quite a high proportion of females with BCS $\leq$ 2 could due to the extremely high temperatures and poor rainfalls throughout the months preceding mating (July and August), which affected not only pastures' productivity but also the grass quality and its nutritional value. From all climatic variables, fluctuations of ambient temperatures had the highest impact on animals' yields and welfare [26] but also on reproductive characteristics [2], and compromise the productivity of ewes with suckling lambs [27]. The combined effects of low feed intake and of higher energy demands, under conditions of thermal stress, induce the mobilisation of body-stored fats and of labile protein reserves to provide amino acids for protein neo-synthesis and carbon sources for gluconeogenesis [28]. Longer periods of exposure of animals to thermal stress are not desirable due to the generated negative effects: compromised growth, decreased milk and meat yields, and disrupted reproductive capacity [29].

The relation between BC and LW is dynamic due to the oscillations occurring throughout a production cycle. BCS values were consistent with ewes LW, and influenced ewes' reproductive function and yields. The impact of supplementary feeding was positive, and the BC was improved, in accordance with other studies (LW increases by 3.1 kg for each BCS unit) [30]. When nutritional requirements cannot be covered by grazing alone, decreasing in ewes' LW can occur, due to the demobilisation of body nutrients stored reserves. One study reported LW significant decrease throughout ewes' physiological stages, in relation to fodder availability, with the gestation stage ($p < 0.05$), but not with the pregnancy rank ($p > 0.05$) [31]. Experimental data suggest a linear relationship between LW and BCS. A study on the Aragonesa sheep breed [32] reported a curvilinear relation between LW and BCS, i.e., increasing in LW by 7, 10, 12, and 16 kg is necessary to improve BCS with 1.0 units within the BCS ranges of 1.0–2.0, 2.0–3.0, 3.0–4.0, and 4.0–5.0, respectively. The correlation between LW and BCS could be influenced by breed, age, or physiological status. A Turkish study indicated different regression equations that could be used to predict LW on the BCS basis and in accordance with ewes' physiological status: LW = 28.716 + 6.962 $\times$ BCS (reproduction period); LW = 39.977 + 6.771 $\times$ BCS (lambing period); LW = 33.444 + 7.074 $\times$ BCS (weaning period) [11]. Other authors [33] stated that the absence of a feed stimulating program (throughout gestation and milking) can induce metabolic dysfunctions, translating to some variations of LW, depreciation of BC, and modifications of certain blood serum parameters.

4.2. Effect of Supplementary Feeding on Sexual Cycle and Ovulation Rate

Ewes' mating period was placed during the regular—natural season for mating in the study area (September and October), to eliminate any abnormal seasonal interference on reproduction function. The results revealed the beneficial influence of the appropriate body condition on the manifestation of the sexual cycle and ovulation rate. Ewes in group L2 performed better till the end of mating season, suggesting that supplementary feeding improved the ovulatory rate. These females had a 93% ovulation rate and better fecundity values after two heats cycles. Ewes in group L1 needed the 3rd mating in quite high proportion because poor body condition at mating influences the number of sexual cycles required for pregnancy onset, inducing economic loss as well. Scottish ewes, Blackface, with lower BCS, had a late onset of the mating season [34], while at the end of the reproduction season, Masham females with higher BCS had a higher probability to manifest oestrus [35]. Aragonesa sheep with higher BCS had longer reproduction season, due to a tardive onset of seasonal anoestrus [36] and to a shorter total seasonal anoestrus [37]. Therefore, higher BCS could induce longer reproductive seasons. However, BCS effects on the duration of the reproduction season are not relevant in the majority of studies and are less probable to significantly change the moment or lastingness of the reproduction season, by improving the BCS of breeder ewes [38].

Static and dynamic effects of nutrition on ovulation rate are very well defined in sheep; ewes with higher LW and fed supplementary prior to mating could produce more lambs [39,40]. The relation between LW and ovulation rate is curvilinear. Each LW supplementary kg corresponds to a relative increase in ovulation rates, but to a point. After a certain level, exceeding LW does not lead to ovulation rate improvement, even if supplementary feeding is provided prior to mating [39]. Above a certain BCS threshold (3.5 points), the ovulation rate can decrease and ewes respond less to supplementary feeding, in comparison with ewes with average BCS values (2.0–3.0). Covering the nutritional requirements of ewes leads to positive effects in achieving a favourable BCS, an appropriate LW, and in reaching better values for reproduction indices, suggesting that a flushing diet has a positive impact on reproductive function [41,42].

The management of sheep reproductive activity influences farm economics and artificial selection activity. The number of lambs per lambing or weaned from each ewe, as well as their LW in both moments, affect profitability [43,44]. Therefore, breeder ewes must benefit from adequate feeding, knowing that the metabolic energy balance of one ewe represents an important factor in determining how many lambs are weaned and their LW [40]. Ewes with low BCS can have diminished reproductive performances in comparison with the ones with higher BCS; a study carried out on Lori-Bakhtiari sheep [30] reported that BCS values up to three at mating exert positive effects on the number of lambs weaned/ewe. Individual ovulatory rate establishes the potential for the number of lambs weaned per ewe and per year.

4.3. Effect of Supplementary Feeding on Reproductive Indices

BCS effect on the reproductive performance of ewes reared in Romania was not studied till now, and the current research brings new findings in this respect.

All reproductive traits were improved in the L2 group, probably due to stimulating feeding, compared to L1 (−33% abortion rate; +2.1% fecundity, fertility and lambing rates; +18.3% prolificacy rate; +0.21% weaning rate). In group L1, some females manifested signs of sub-nutrition, because grazed-only ewes did not have the ability to cover their daily nutritional needs (36% of the group achieved a BCS ≤ 2.0). After a long-lasting period of poor feeding, the miscarriage rate reached 5% in this group. A daily decrease in nutrient uptake induces sub-nutrition, diminishing the endometrial sensitivity to progesterone and affecting embryo survival [45].

Studies on other sheep breeds revealed that the rate of oocyte loss could be higher and reproductive performances lower even if ewes have good levels of body condition [41,46,47]. It is recommended to score the ewes for body condition 6–8 weeks prior to mating, to allow the farmer to take adequate measures to bring the breeding stock to an optimal state (BCS of 2.5–3) at the moment of mating. Other studies recommend to assess the BCS of adult ewes at least once a trimester [48], to keep it within the optimal range while, on the contrary, other authors [49] reported insignificant effects of BCS on ovulation rate, pregnancy rate, and oocyte loss. On the other hand, in ewes with poor BC at the onset of reproductive activity, deletion or attenuation of oestrus can occur [50]. Effects of supplementary feeding on prolificacy are positive and relevant, knowing this trait has a reduced heritability, hence a longer time needed for improvement via artificial selection. Genetic control of ovulation rates at many breeds, even at the prolific ones, is hard to manage, because litter size is a trait subjected to polygenic influence, implying a great number of genes with small individual effects [51].

Botosani Karakul sheep breed was formed and selected for pelts production. Therefore, among the selection criteria included in the breeding synthesis program, technical activities to support prolificacy improvement were not included. Obtaining more products per lambing led to less developed new born lambs, and to decreased individual pelts surface. However, in the current research, it was noticed that supplementary feeding led to an increase in litter size, with better values in L2 ewes presenting BCS between 2.0 and 2.5 prior to mating.

Ewes in the L2 group deposited body reserves efficiently when their BCS was between 2 and 2.5 and, subsequently, it can be hypothesised that the concentration of hormones and metabolites which appear during chronological modifications was optimal. In pregnant ewes, prolongation of the sub-nutrition state induces certain modifications and increasing of endometrial sensitivity to steroid hormones throughout the gestational beginning stages, with a negative impact on the intrauterine environment and on embryo survival, as well [52,53]. This can explain why L1 ewes with BCS ≤ 1.5 points were not fertile or why they experienced abortions.

4.4. Effect of Body Condition on Lambs Weight at Lambing and Weaning

Ewes' LW and BC influence the postpartum lambs' survival rate. Providing balanced diets prior to mating is essential to allow ewes to reach a BC that will guarantee reproductive performance. Additionally, it is recommended to provide well-balanced feeding throughout the whole gestation period. The current research confirms that next to reproductive performance, ewes in L2 with higher BCS (2, 2.5, and 3) produced more lambs, with better LW in both lambing and weaning moments.

Weight at birth is a determinant of the lambs' immediate and further survival rate. Usually, lambs born below 3 kg LW have a higher risk of sudden death, regardless of the ranking received at birth or the age and BC of the mother. Litter weight was higher in ewes with better BSC values at mating (Table 5). Ewes with BCS ≥ 3.0 produced lambs above 5.0 kg LW. Ewes with BCS ≤ 2.5 gave birth to lambs with close mean LW, with very small differences between groups ($p > 0.05$). Both LW and BCS of mothers had a great influence on the postpartum adaptation of lambs to the extra-uterine environment. Supplementary feeding aimed to build up ewes' energy reserves, used during gestation to positively influence the foetal development and lambs' LW at birth. In both groups, ewes with BCS $\geq$ 3.0 produced lambs with LW values between close limits (4.90 $\pm$ 0.10 kg till 5.21 $\pm$ 0.06 kg).

Statistically significant differences appeared between groups, on the lambs' LW at weaning: for $p < 0.01$ in females with BCS 2; for $p < 0.001$ in those having BCS $\geq$ 2.5. The ratio between lambs' total weight at weaning (WLW) and the total number of females which lambed (LE) indicated better values in the flushed group (25.94 in ewes with BCS 2.5 and in 35.05 in ewes with BCS 3.5).

For the same BC, the LW of ewes was different, therefore we considered that the assessment of the ratio between lambs' LW at weaning (WLW) and metabolic weight of ewes (MWE) will be more relevant. Maximal values of 1.30 were calculated in group L1 and higher in group L2, except the value of this ratio in group L2 ewes with BCS 3.5. In this case, the value was lower, influenced by lower litter size and by higher LW of the ewes.

The performance related to lambs' total weight at lambing, lambs' weight at weaning moment (WLW) and litter size was considered the most representative evaluation, because it mixed multiple traits, such as conception rate, fecundity, prolificacy, lambs survival rate till weaning, weight at weaning, suckle capacity, and maintenance conditions provided to ewes and lambs during suckle period. The ratio between lambs' LW and the number of ewes that lambed (LLW/LE) had higher values in females with BCS 3.0 (6.22 kg/ewe) and in ewes with BCS 3.5 (7.54 kg/ewe). This rate can be improved only in two situations: when the litter size is greater, or when lambs' LW is higher at lambing. A study carried out on the Afshari breed [54] confirmed that BCS had a significant effect on litter size. Females with BCS 3 had better reproductive performances and bore heavier lambs, while the lambing rate at ewes with BCS > 3.5 decreased. Other research [55] has shown that ewes' BCS at the lambing moment did not have any effect on the LW of lambs at birth or at the age of 30, 60, 90, and 120 days. On the contrary, Sezenler et al. [56] noticed that ewes with higher BCS values at lambing had lambs with better LW. Other studies reported the direct impact of ewes' BCS on reproductive performances [56,57], on colostrum production [58], with a direct and significant impact on lambs' mortality reduction throughout the incipient neonatal period [59]. According to other authors, flushing diet and BCS value at mating did not have any effect on lambs' LW or on apparent colostrum intake [21]. When ewes are malnourished throughout gestation, negative effects can occur, especially on Maternal Behaviour Score (MBS) and on the postpartum moment when lambs make their first suckling [60] with further negative consequences on their development.

In accordance with BCS and by reporting the lambs' LW at weaning (WLW) to the total numbers of females which lambed (LE), better values were observed in group L2. Ewes' BCS had a significant effect on productivity and on some features with high economic relevance (number of lambs at lambing, lambs' total weight at lambing and at weaning). In both groups, females with BCS $\leq$ 3.0 had lower performances for the same parameters, proving that in advanced gestation, ewes' nutritional requirements were not covered at an optimal level. The current study results are in concordance with other published data on other breeds from semi-arid zones, such as the Ossimi ewes [50] and Malpura breed [61] which proved that ewes' BCS has a curvilinear correlation with productive traits.

The tendency of decreasing performance (lambs' LW at birth and weaning) in females with BCS lower than 3–3.5 could be attributed to poor feeding of mothers throughout the advanced gestation stage [49]. The decreasing tendency of performance in ewes' with BCS above 3.5 can probably be attributed to higher requirements for maintenance because ewes with BCS 4 were heavier than the ones with a BCS 3–3.5. On the other hand, the litter size and the number of weaned lambs in ewes with BCS 3.0 was higher, compared to ewes with lower BCS values.

Better rates between lambs' LW at weaning (WLW) and ewes' metabolic weight (MW) in Group L2 can be due to the supplementary feeding, that facilitated the achievement of a better body condition and induced the constitution of some energetic deposits as backup for the increased nutritional requirements throughout both advanced gestation stage and whole suckling period. Reaching an optimal BC has a positive effect on milk yield [62,63], knowing that approx. 33% of the yielded milk is based on the mobilization of fat and proteins previously deposited by females [64,65].

Besides these, reproductive performances depend on the ewes' age. Studies of other sheep reared in drought areas, indicate that the older the ewes were, the higher were prolificacy and weaning rates [66]. When adequately fed, ewes can cover the metabolic demands for gestation and milk secretion, regardless of their age and litter size.

5. Conclusions

All the original results highlight the positive effect of a supplementary diet on breeder ewes, prior to mating.

Botosani Karakul sheep provide better performances in ewes having a BCS between 2.5 and 3.5, therefore it advisable for farmers to identify those technical-economic ways to bring and keep their female breeders within this BCS interval.

Supplementary feeding positively influenced the reproductive performance and, generated better economical results (23–27% better live weight in lambs from flushed ewes, with only 1.3% supplemental dietary costs), supporting thus the idea of its applicability into farm conditions.

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