Research Article

iMedPub Journals
http://www.imedpub.com

Journal of Animal Sciences and Livestock Production

2021
Vol. 5 No. 4: 001

Dynamics of Predictors of Body Reserves of Goats in Negative Energy Balance

Elvanio José Lopes Mozelli Filho[1], Raiany Resende Moura[1], Ismael Nacarati Silva[1], Michele Gabriel Camilo[1], Danielle Ferreira Baffa[1], Elon Souza Aniceto[1], Marcelo Teixeira Rodrigues[2], Alberto Magno Fernandes[1] and Tadeu Silva de Oliveira[1*]

[1]Department of Animal Science, State University of Norte Fluminense, Campos dos Goytacazes, RJ 28013-602, Brazil
[2]Department of Animal Science, Federal University of Vicosa, Vicosa, MG 36570900, Brazil

Corresponding author:
Oliveira TSD, Laboratory of Animal Science, State University of Northern of Rio de Janeiro, Campos dos Goytacazes, RJ 28013-602, Brazil, E-mail: tadeuzootecnista@gmail.com

Abstract

This study aimed to evaluate the relationship between body weight and body condition score with changes in protein and fat reserves in goats during the negative energy balance. Twenty-four goats were distributed in a completely randomized design, with four different Body Condition Scores (BCS): 3.5, 3.0, 2.5, and 2.0. Five experienced evaluators assessed the BCS by palpating two measurements (lumbar and sternal region). The animals' weight was determined every seven days to check weight loss or gain. The goats were slaughtered to assess body fat and protein contents. The BCS did not affect ($p>0.05$) the goats' performance. The BCS showed a lower precision (R2 0.34) to estimate the protein contents of the non-carcass components compared to the carcass (R2 0.61). The R2 values were better for fat in the carcass, empty body, and non-carcass, displaying values of 0.77, 0.75, and 0.72, respectively, BCS proved to be a good predictor. Body weight proved to be a good predictor for estimating protein in the carcass (R2=0.88), empty body (R2=0.86), and non-carcass (R2=0.99). Therefore, BCS and body weight proved to be good estimators for the body fat reserves in goats at the beginning of lactation. Body weight proved to be more accurate than BCS for determining body protein. BCS and body weight are very important and quick tools to evaluate the nutritional plans implemented in the production system, contributing to increase the efficiency in milk production and the animals' body condition recovery after the negative energy balance.

Keywords: Lactation; Mobilization; Milk synthesis; Calorimetric

Received: May 21, 2021; **Accepted:** June 04, 2021; **Published:** June 11, 2021

Citation: Filho EJLM, Silva NI, Moura RR, Camilo MG, Baffa DF, et al. (2021) Dynamics of Predictors of Body Reserves of Goats in Negative Energy Balance. J Anim Sci Livest Prod Vol. 5 No. 4: 001

Introduction

The extent of body mass loss in postpartum goats displays a high variation, and it is affected by several factors. However, the mobilization of energy and protein for goats during the Negative Energy Balance (NEB) is not fully understood. The AFRC (1998) considers a decrease of 4.6 MJ of ME/day and 30 g MP/day in the first month of lactation based on a constant value of the loss and 1 kg/week of body weight proposed by [1,2].

The constant value of energy and protein mobilization considered by does not reliably reflect the dynamics of fat and protein masses. Thus, it is essential to know the extent to which the negative energy balance influences the loss of fat and protein in goats [3]. It also should be considered that most of the data used for that inference were based on calorimetric studies, so a more accurate approach would be the comparative slaughter technique, which allows for long-term studies. Thus, it is essential to know the daily intensities in which this energy is transferred from the animal body to the milk synthesis [4]. The negative energy and protein balance influence the mass of internal fat and energy released from some specific organs, such as the liver and Gastro Intestinal Tract (GIT), which are metabolically active during this phase together with the mammary gland [5]. The Body Condition Score (BCS) is a widely used tool to assess the nutritional status of animals. Accurate knowledge about BCS is essential for determining the animals energy reserves, together with its speed, ease of use, and a high degree of accuracy. All these features make this method widely used to determine the body reserves of animals on commercial farms [6,7]. Like BCS, body weight is a simple and straightforward method to measure the animal's nutritional condition, but it varies during lactation. According to Body Weight (BW) follows a pattern with a rapid decrease in the parturition, coinciding with the expulsion of the

fetus, placenta, and other uterine contents, followed by a gradual decline in weight due to the mobilization of body reserves to supply the milk production [8]. After the beginning of lactation and new conception, there is a return to the initial weight due to the replacement of mobilized body tissues and fetal development. Therefore, this study aimed to evaluate the relationship between body weight and body condition score with changes in protein and fat reserves in goats during negative energy balance.

Materials and Methods

The experiment was carried out in the county of Viçosa, Minas Gerais State, Brazil (20°46'19'' S and 42 °51'12'' W, elv. 707 m a.s.l.). The climate is Cwa (tropical, high elevation) with rainy summers and dry winters according to the Koppen classification. The average annual temperature is 18.5°C, ranging from 8.2 to 28.5°C. The average annual rainfall is 1,203 mm, with an average relative humidity of 80%.

Animals and management

The ethics committee on animal use of the animal science department of the Universidad federal de Viçosa approved the experiment (Protocol 61/2013). We used 24 Multiparous Oberhasli Alpine goats selected according to the BCS. The animals were housed in individual metabolic cages with a trough for feed supply and drinker. The goats were chosen to provide homogeneity between the experimental units, so an initial group of 50 goats was necessary to select these animals. All animals received a single experimental diet described in **Table 1**. The feed was provided twice a day (7 am and 4 pm) after the goats were milked, and the diet was adjusted daily to around 20% orts. Before the morning offering, the orts of each experimental unit were collected, weighed, recorded, and sampled. They were stored frozen (-10°C) together with samples of corn silage and concentrate feed. Then, the orts samples formed a weekly composite sample per animal. At the end of the experimental period, those samples formed a total composite sample per animal/treatment to determine the chemical composition according to [9].

Table 1: Ingredients of the diet supplied during the lactation period.

Ingredients	Corn silage	Concentrate	DM diet (g/kg)	Diet
Corn silage	-	-	415	-
Ground corn	-	-	257.5	-
Soybean meal	-	-	156.1	-
Wheat bran	-	-	123.7	-
Oil	-	-	21.8	-
Limestone	-	-	11.5	-
Sodium bicarbonate	-	-	10.1	-
Salt	-	-	4.3	-
Dry matter	263.3	867.5	-	617
Crude protein	78.4	184.1	-	140
aNDFom	431.5	181.6	-	285
Acid detergent fiber	279.4	45.2	-	142
Lignin	36.1	4.8	-	18
NDICP (g.kg–1 CP)	29.4	99.8	-	71
ADICP (g.kg–1 CP)	28.5	97.3	-	69
Fat	37.6	74.6	-	59
Ash	50.6	63.6	-	58
NFC	291.3	616.9	-	482
Calcium	2.84	4.05	-	3.5
Phosphorus	0.56	2.82	-	1.9
Available-energy values	-	-	-	
Total digestible nutrients (g/kg)	-	-	-	828.8
Metabolizable energy (MJ/kg DM)	-	-	-	12.17
Net energy (MJ/kg DM)	-	-	-	7.91

Experimental design and body condition scoring

The 24 goats were distributed in a completely randomized design, in four different body conditions (BCS), and six goats were slaughtered every two weeks. The treatments were arranged as follows: BCS 3.5 (1-2 weeks; initial BCS 3.5 ± 0.0; initial Body Weight (BW) 62.31 ± 6.15 kg; mean ± standard deviation), BCS 3.0 (3-4 weeks; initial BCS 3.0 ± 0.26; initial BW 62.23 ± 2.20 kg), BCS 2.5 (5-6 weeks; initial BCS 2.5 ± 0, 5; initial BW 55.97 ± 6.02 kg), and BCS 2.0 (7-8 weeks; initial BCS 2.5 ± 0.5; initial BW 57.34 ± 5.28 kg). The animals were weighed weekly using a 50 g precision scale to monitor the variation in body weight, being one of the indicators of mobilization or retention of body reserves. The BCS was measured by five expert evaluators using the methodology described by every seven days together with the body weight [10]. The method originally described comprises palpation of two regions (lumbar and sternum) to check an animal's body condition quickly. Body condition is scored on a 6-point range from 0 to 5. It is based on an accurate description of the body region according to the amount of fat cover and thickness of the longissimus dorsi muscle and the sternal region, which guide the subjective scores.

Slaughter

The goats were slaughtered following humane slaughter procedures to measure the mass of fat and protein through chemical analysis of body tissues. First, the animals were rendered insensible by stunning, then the bleeding was performed through a section of the jugular and carotid veins, and all blood was collected and weighed. The mammary gland was removed, weighed, and dissected. Subsequently, we proceeded the skinning and separation of the hot carcass, internal organs, and viscera (liver with gallbladder, kidneys, heart, pancreas, spleen, tongue, lungs, diaphragm, esophagus, trachea, bladder, and uterus; bladder and gallbladder were weighed full and empty). The internal fat was separated into omental and visceral fat (mesenteric, perirenal, and pericardial fat). The gastrointestinal tract (rumen-reticulum, omasum, abomasum, small intestine, and large intestine were weighed full and empty), head/legs, and the skin. All parts were weighed, packed in identified plastic bags, and frozen at -15°C. Then, the carcass and head/legs set were sawn in an electric saw and ground separately in a cutter mill (30 HP; 1775 rpm). Viscera, organs, blood, and mammary gland were also ground separately in a cutter mill, and the skin was ground in a ball mill for further chemical analyses. The Empty Body Weight (EBW) was determined by the difference in the body weight at slaughter and GIT content. The composite samples of viscera/organs/blood, carcass, head/paws, and mammary gland were lyophilized to determine the Fat in Dry Matter (FDM). We used aluminum trays with a 500 mL capacity, and the lyophilization time varied between 48 and 72 hours. Subsequently, the samples were submitted to successive washes with petroleum ether for 24 hours, obtaining the Pre-Defatted Dry Matter (PFDM). The fat removed in the pre-degreasing was calculated by the difference between the FDM and PFDM to determine the total fat content. The result was added to those obtained for the residual ether extract in the PFDM. Then, the samples were ground in a ball mill for later analyses of dry matter, total nitrogen, and ether extract, according to [9].

Statistical analysis

The variables were analyzed according to the following statistical model,

$$yij=\mu+BCSi+eij$$

Where yij represents the natural logarithm of the value measured in the j-th animal in the i-th BCS, μ represents the overall mean, BCSi corresponds to the four different body conditions (i=3.5;3.0;2.5;and 2,0), and eij represents the random error. The data were submitted to regression analysis to identify the relationship between BCS and BW and their combination with the body parts through the PROC MIXED procedure from the SAS program (university edition version, SAS Institute Inc., Cary, NC, USA). We performed a correlation analysis using the PROC CORR procedure from the SAS program to relate the BCS, BW, carcass weight, non-carcass weight, internal organs, total internal fat, and weight of individual fat and protein deposits of goats.

Results and Discussion

The BCS did not affect statistically ($p>0.05$) the Dry Matter Intake (DMI) of the animals, and these variables did not present ($r=-0.04$; $p>0.05$) any correlation between them in **Table 2** These results corroborate the study by [11]. Although our study did not detect any correlation between BCS and DMI, there is a negative correlation between voluntary dry matter intake and postpartum body reserves in many studies with cattle, sheep and goats [12-14]. This negative correlation can be explained by metabolic changes such as the more intense use of Non-Esterified Fatty Acids (NEFA) in females with low BCS (e.g., 2.0) than females with a better body condition (e.g., 3.0 to 3.5). Because low plasma NEFA concentrations have a low impact on feed intake. Hormonal changes associated with the parturition and beginning of lactogenesis favor lipolysis over lipogenesis during the NEB. In addition, the lipolysis rate is accelerated by intense energy requirements, especially glucose, associated with parturition, early lactation, and reduced DMI. These observations support the glucostatic theory of appetite regulation proposed by Kennedy, in which the author verifies a relationship between plasma glucose concentration and appetite regulation [15].

Milk yield and milk protein and energy contents were not influenced by BCS ($p>0.05$). However, the goats' BCS affected the milk fat content in early lactation ($p<0.0001$) and presented a positive correlation ($r=0.45$; $p=0.0256$). Lactose was also influenced by BCS ($p<0.0001$), but we did not observe any correlation with BCS ($r=-0.26$; $p=0.2190$) **Table 2** . Goats with BCS 3.5 and 3.0 had a higher fat content than goats with BCS 2.5 and 2.0, which corroborates the study of [16]. They worked with lactating ewes and observed at the beginning of lactation, the milk fat content was higher in ewes with BCS above 2.5, whereas the lactose content was the opposite, as we found in our study. According to the decrease in milk fat content is related to at least two phenomena [17]. First, the dilution effect due to the increase in milk synthesis at the lactation peak, and second, the reduction of fat mobilization with advancement lactation. In this sense, reducing NEFA plasma concentrations can lead to a decrease in the milk fat synthesis, which probably occurred in our study.

Table 2: Dry matter intake, milk production, and composition of lactating goats with different BCS.

Variables	BCS				P-values		
-	3.5	3	2.5	2	SEM	Linear	Quadratic
DMI	1165	1313	1675	1112	115.1	NS	NS
MP	2236	2404	2849	2251	194.2	NS	NS
Fat	64.2	62.7	47.8	58.5	2.951	*	NS
CP	43.1	48.4	38.9	45	2.027	NS	NS
Lactose	32.5	41.5	44.1	38	1.709	NS	**

**p<0.0001; *p<0.01; NS=p>0.05; NS: Not Significant; SEM: Standard Error of the Means. DMI: Dry Matter Intake; MP: Milk Production; CP: Crude Protein all expressed as g/day. Fat, g/day=22.7 ± 1.42 × BCS; R2=0.91; root mean square error, RMSE=1.986; p<0.0001. However, the intercept of the equation did not differ from zero (p=0.4821) and Lactose, g/day=34.5 ± 3.26 × BCS–0.71 ± 0.10 × BCS2; R2=0.97; RMSE=0.754; p<0.0001. Consequently, it was removed from the model. However, the intercept of the equation did not differ from zero (p=0.1936) and consequently, it was removed from the model.

The body weight showed a change of ± 17.00 kg per unit of variation in the BCS, with an R2 value of 0.90. This change was ± 4.70 kg for each variation in the BCS unit for the carcass, with R2 0.81. These results prove the BCS can be a good predictor for estimating body weight and carcass weight in **Table 3**. The 17.00 kg variation found in this work is higher than the values found in other studies, e.g., with sheep 5.57 kg per BCS unit; 11.00 kg per BCS unit) [18,19]. But this difference can be explained because those authors worked with sheep and the animals were non-productive. On the other hand, the intercept value was 7.07 kg. It represents the body weight when the BCS is zero. This value is very close to who found a value of 6.42 kg for Sarda ewes [20]. This breed presents a maturity weight of 45 kg, similar to the maturity weight of the Alpine Oberhasli goats, between 45-50 kg. For the linear regression intercept between CP and BCS has a positive relationship with weight at maturity [21].

The correlation coefficient between BCS and body weight was r=0.84 (p<0.0001), close to who found r=0.90 for non-lactating Rasa Aragonesa ewes, and similar to who found r=0.83 for non-lactating Blanca Celtiberica goats and r=0.89, for Serra da Estrela ewes [19,22,23]. Animals with similar body weight may present different BCS, and it is probably due to the difference in the size, species, and gastrointestinal content. These are critical and difficult factors to interpret in ruminants for besides the subjectiveness of the BCS assessment. Although the distribution of body fat in goats is mostly internal, the carcass weight decreased (p<0.0001), in **Table 3** 4.70 kg with the variation of one unit in the BCS and r=0.82. Demonstrating at this stage of lactation, there is a significant loss in the carcass weight, so this weight loss in the carcass can be both fat and protein [3,24].

The BCS seemed to be a good predictor to determine the amount of protein, and the R2 values for the equations to estimate carcass protein deposits were 0.61 and 0.59 for the empty body, but for the non-carcass, it was 0.34 in **Table 3**. There are few studies on the use of BCS to estimate body protein, which means the BCS does not have a good precision about body protein. These authors worked with non-lactating churras ewes and found the BCS explained only 0.27 of the variation in the body protein content, whereas in our study the BCS was a good predictor of body protein, with carcass R2 values of 0.61, r=0.68, r=0.59 for non-carcass, and r=0.66 for the empty body. However, for non-carcass protein, BCS explained only 0.34 of the variation. Still, we observed in this lactation phase the animals lost around 1.39 kg of protein with the variation of a BCS unit, demonstrating the protein mobilization by these animals.

For the fat contents in the carcass, empty body, and non-carcass the R2 values were better, 0.77; 0.75; and 0.72; respectively. The fat deposits (omental and visceral fat) showed changes for the omental fat around ± 1.42 kg with the variation of a BCS unit and an R2 value of 0.57, whereas the visceral fat was ± 1.86 kg with a variation of a BCS unit and an R2 value of 0.67, and total fat was ± 3.38 kg with an R2 value of 0.71 in **Tables 3 and 4** Although the distribution of body fat in goats is different from sheep, even so, animals with dairy aptitude tend to deposit more internal fat than meat animals. So we can make some comparisons with dairy sheep about their internal fat deposits. In the present study, there was a decrease in the fat (p<0.0001) of the carcass (2.03 kg), empty body (5.64 kg), and non-carcass (3.75 kg) as expected due to the stage of the lactation of the goats. The BCS used in this study is a mean between the lumbar and sternal BCS, still, this was a good predictor for the fat determination, and the R2 values of the equations and their correlations were 0.77, r=0.68 for the carcass; 0.75, r=0.66 for the empty body; and 0.72, r=0.45 for the non-carcass in**Tables 3 and 5**These correlation values were below that found by for carcass r=0.96 (sternal BCS) and r=0.92 (lumbar BCS), for fat content in the empty body r=0.97(sternal BCS) and r=0.96(lumbar BCS). These higher values may be because the animals were non-lactating and non-pregnant, thus there may have been an accumulation of reserves in these animals and not mobilization as it happened in the present study.

According to the sternal region in goats has a large amount of fat, enabling a better estimate of body fat. There are two layers of fat in the sternum, the subcutaneous fat and a deeper called subcostal fat, which is thicker than subcutaneous fat and the main responsible for the sternal BCS. However, subcostal fat does not exist in the lumbar region this explains why the sternal BCS achieves a higher degree of precision than the lumbar region [25,26]. The fat deposits (omental and visceral fat) in the present study showed a linear decrease (p<0.0001) during this lactation phase. The omental fat decreased ± 1.42 kg with the variation

of a BCS unit, the visceral fat decreased ± 1.86 kg and total fat (omental+visceral) decreased ± 3.38 kg. However, the BCS accuracy to determine the amount of internal fat was below the literature, with the R2 values of 0.57, 0.67, and 0.71 for omental, visceral, and total fat, respectively **Table 3** . The R2 values of some experiments with goats omental fat was 0.94 (sternal BCS) and 0.86 (lumbar BCS), visceral fat was 0.83 (sternal BCS) and 0.80 (lumbar BCS); omental fat was 0.83 (sternal BCS) and 0.50 (lumbar BCS), visceral fat 0.78 (sternal BCS) and 0.47 (lumbar BCS), and total fat 0.90 (sternal ECC) and 0.59 (lumbar BCS)[6,23]. Sheep, omental fat was 0.15, visceral fat 0.34, and total fat 0.33; omental fat was 0.55, visceral fat 0.55, and total fat 0.73 [18,26]. Mendizabal et al. observed that the BCS accuracy obtained from the lumbar region is low, around 0.59, while in the sternal region it is 0.90. Thus, the low R2 values found in this study may be due to the mean calculated between the lumbar and sternal BCS or due to the subjectiveness of the BCS assessment.

We used body weight as a predictor and observed this can also be a good predictor to determine the amount of body protein, in which we obtained equations with good R2 values for the protein in the carcass of 0.88 and empty body weight of 0 .86, but as in the BCS, the R2 value was low for the non-carcass, because if we consider the intercept it was 0.50, without the 0.99 intercept **Table 4**.

Using body weight, the body protein behaved differently from the BCS, because when the independent variable was the BCS the body protein had a linear decrease. But when the independent variable was the body weight the decrease in body protein was curvilinear, i.e., at a certain moment (weeks of lactation) the mobilization slows down and tends to stability, which biologically makes sense, because according to the goats mobilize their reserves (energy and protein) with greater intensity during the first 40 days of lactation. For body weight was also a better predictor for body protein (R2 0.65) than BCS (R2 0.27) [18]. In the present study, the correlation coefficients of body weight were also better than the BCS; carcass (body weight, r=0.78; BCS, r=0.68), empty body (body weight, r=0.86; BCS, r=0.66) **Table 5** .

Carcass, empty body, and non-carcass fats also presented good R2 values such as 0.87, 0.83, and 0.81, respectively. omental fat decreased ± 0.09 kg with a variation of one BW unit and R2

Table 3: Regression equations to estimate the body weight, non-carcass and carcass content and fat deposits in goat's lactation using Body Condition Score (BCS).

	P-values					
	β0 ± SE	β1 ± SE	R2	SEM	Linear	Quadratic
Body weight (kg)	7.07 ± 3.90	17.07 ± 1.41	0.9	3.056	*	NS
Non-carcass (kg)	**	8.17 ± 0.18	0.99	2.188	*	NS
Crude protein	1.39 ± 0.46	0.50 ± 0.16	0.34	0.405	*	NS
Fat	-5.28 ± 1.47	3.75 ± 0.55	0.72	1.278	*	NS
Carcass (kg)	7.09 ± 1.45	4.70 ± 0.52	0.81	1.297	*	NS
Crude protein	1.64 ± 0.28	0.56 ± 0.10	0.61	0.254	*	NS
Fat	-2.57 ± 0.72	2.03 ± 0.25	0.77	0.614	*	NS
Empty body weight (kg)	***	15.56 ± 0.28	0.99	3.467	*	NS
Crude protein	2.32 ± 0.75	1.39 ± 0.27	0.59	0.671	*	NS
Fat	-7.87 ± 2.16	5.64 ± 0.76	0.75	1.83	*	NS
Omental fat (kg)	-2.12 ± 0.80	1.42 ± 0.28	0.57	0.742	*	NS
Visceral fat (kg)	-2.64 ± 0.86	1.86 ± 0.31	0.67	0.769	*	NS
Total fat (kg)	-5.19 ± 1.53	3.38 ± 0.54	0.71	1.351	*	NS

Total fat=Omental fat+Visceral fat. *p<0.0001; (p>0.05); NS: Not Significant; SEM: standard Error of the Means. SE:Standard error. **intercept (β0)=2.04, p=0.4811, R2=0.81; *** intercept=-0.23, p=0.9607, R2=0.84.

Table 4: Regression equations to estimate the body weight, non-carcass and carcass content, and fat deposits in goats lactation using Body Weight (BW).

Variables					P-values		
	β0 ± SE	β1 ± SE	β2 ± SE	R2	SEM	Linear	Quadratic
Non-carcass(kg)	-3.91 ± 1.96	0.48 ± 0.03	-	0.9	1.422	*	NS
Crude protein	**	0.05 ± 0.001	-	0.99	0.356	*	NS
Fat	-7.04 ± 1.34	0.22 ± 0.02	-	0.81	0.966	*	NS
Carcass (kg)	22.43 ± 6.99	-0.50 ± 0.26	0.008 ± 0.002	0.92	1.08	*	*
Crude protein	3.68 ± 1.42	-0.08 ± 0.05	0.001 ± 0.0004	0.88	0.217	*	*
Fat	-3.21 ± 0.59	0.12 ± 0.01	-	0.87	0.425	*	NS
Empty body weight (kg)	-5.42 ± 3.12	0.90 ± 0.05	-	0.92	2.265	*	NS

Crude protein	5.87 ± 2.56	-0.10 ± 0.009	0.002 ± 0.0008	0.86	0.394	*	*
Fat	-10.5 ± 1.99	0.35 ± 0.03	-	0.83	1.437	*	NS
Omental fat (kg)	-3.16 ± 0.88	0.09 ± 0.01	-	0.65	0.639	*	NS
Visceral fat (kg)	-3.66 ± 0.74	0.11 ± 0.01	-	0.78	0.519	*	NS
Total fat (kg)	-6.62 ± 1.37	0.20 ± 0.02	-	0.79	0.95	*	NS

Total fat: Omental fat+Visceral fat. *p<0.0001; (p>0.05); NS: Not Significant; SEM: Standard Error of the Means. SE: Standard Error. ** intercept (β0)=0.62, p=0.2068, R2=0.50.

Table 5: Pearson correlation between Body Condition Score (BCS) and Body Weight (BW) and non-carcass and carcass content, and fat deposits in goats lactation.

	ECC	BW	Car	Ncar	NcarCP	NcarCF	CarCP	CarCF	EBWCP	EBWCF	OCF	CVF
BCS	-	-	-	-	-	-	-	-	-	-	-	-
BW	0.838*	-	-	-	-	-	-	-	-	-	-	-
EBW	0.770*	0.943*	-	-	-	-	-	-	-	-	-	-
Car	0.824*	0.931*	-	-	-	-	-	-	-	-	-	-
Ncar	0.678*	0.894*	0.863*	-	-	-	-	-	-	-	-	-
NcarCP	0.450*	0.709*	0.700*	0.852*	-	-	-	-	-	-	-	-
NcarCF	0.759*	0.842*	0.863*	0.912*	0.729*	-	-	-	-	-	-	-
CarCP	0.683*	0.785*	0.864*	0.718*	0.524**	0.733*	-	-	-	-	-	-
Car	0.814*	0.873*	0.937*	0.881*	0.696*	0.910*	0.854*	-	-	-	-	-
EBWCP	0.663*	0.858*	0.905*	0.888*	0.839*	0.837*	0.902*	0.897*	-	-	-	-
EBWCF	0.793*	0.870*	0.906*	0.920*	0.733*	0.990*	0.789*	0.959*	0.874*	-	-	-
OCF	0.567*	0.591*	0.550*	0.696*	0.561**	0.662*	0.448**	0.635*	0.570**	0.667*	-	-
VCF	0.717*	0.785*	0.782*	0.861*	0.715*	0.881*	0.618*	0.855*	0.756*	0.891*	0.873*	-
Total fat	0.654*	0.698*	0.674*	0.794*	0.649*	0.784*	0.540*	0.756*	0.673*	0.790*	0.975*	0.959*

Total fat=Omental fat Visceral fat. *p<0.001; ** p<0.01. BCS: Body Condition Score; BW=Body Weight; EBW: Empty Body Weight; EBWCCP: Empty Body Weight Contents Crude Protein; EBWCF: Empty Body Weight Contents Crude Fat; NCar: Non-Carcass; NCarCP: Non-Carcass Contents of Crude Protein; NCarCF: Non-Carcass Contents of Crude Fat;Car: Carcass; CarCp: Carcass Contents of Crude Protein; CarCF: Carcass Contents of Crude Fat;OCF: Omental Crude Fat; VCF: Visceral Crude Fat

value of 0.65, visceral fat decreased ± 0.11 kg with a variation of one BW unit and R2 value of 0.78, and total fat decreased ± 0.20 kg with an R2 value of 0.79 **Table 4**. Body weight explains 0.87; 0.83; and 0.81 of the variation in the amount of fat in the carcass, empty body, and non-carcass, respectively. These results are very close to those found for sheep, described by in which they obtained R2 values for the carcass of 0.88, and empty body 0.92; 0.64 for the carcass, empty body 0.72, and non-carcass 0.62 [18,22].Goats for carcass 0.88 and empty body 0.90 [23].In our study, high correlation coefficients were obtained between body weight and carcass fat (r=0.87), empty body (r=0.87), and non-carcass (r=0.84) **Table 5** , however they were slightly lower than that described by r=0.94 for carcass; r=0.95 for empty body; but higher than those found by r=0.789 for carcass, r=0.766 or empty body, and r=0.625 for non-carcass[18,23]. For internal fats (omental and visceral), body weight was more accurate than BCS (R2 0.65, r=0.59 for omental fat; R2 0.78, r=0.78 for visceral fat; and R2 0.79, r=0.70 for total fat). Mendizabal et al.observed R2 values between 0.79 and 0.80. The present study corroborates the studies carried out by with Rasa Aragonese ewes and Mendizabal et al.with Blanca Celtiberica goats, in which they observed better estimates using body weight to determine fat reserves [26].

Conclusion

BCS and body weight proved to be good estimators for the body fat reserves in goats at the beginning of lactation. Body weight proved to be more accurate than BCS to determine body protein. BCS and body weight are very important and quick tools for the evaluation of the nutritional plans implemented in the production system, contributing to increase the efficiency in milk production and the animals' body condition recovery after the negative energy balance.

References

1. Institute National de la Recherche Agronomique (1988) Alimentation of bovines, ovins and caprins (Nutrition of cattle, sheep and goats)
2. Agricultural and Food Research Council (1998) The Nutrition of Goats. Technical Committee on Response to Nutrients. Cab. in
3. Oliveira TS, Rodrigues MT, Lima MC, Vieira RAM, Oliveira VS, et al. (2013) Variation of masses of body fat and protein and visceral organs of alpine goats in the first 60 days of lactation.R Bras Health Products Anim 14:672-683
4. Castagnino DS, Harter CJ, Rivera AR, Lima LD, Silva HGO, et al. (2015) Changes in maternal body composition and metabolism of dairy goats during pregnancy.R Bras Zootec 44:92-102
5. Wankhade PR, Manimaran A, Kumaresan A, Jeyakumar S, Ramesha KP, et al. (2017) Metabolic and immunological changes in transition dairy cows.Vet World 10:367-13776.

6. Mendizabal JA, Delfa R, Arana A, Purroy A (2011) Body condition score and fat mobilization as management tools for goats on native pastures.Small Rumin Res 98:121-127
7. Vieira A, Brandao S, Monteiro A, Ajuda I, Stiwell G (2015) Development and validation of a visual body condition scoring system for dairy goats with picture-based training. J Dairy Sci 98:6597-6608
8. Napso T, Yong HEJ, Tello LJ, Perri AS (2018) The Role of Placental Hormones in Mediating Maternal Adaptations to Support Pregnancy and Lactation. Front Physiol. 9:1-39
9. Association of Official Analytical Chemical (1990) Official methods of analysis
10. Fehr MP, Hervieu J (1999) Assessing the body condition of goats: interest and method. Reussir la Chevre 231:22-34
11. Barbosa LP, Rodrigues MT, Guimaraes JD, Maffili VV, Amorim LS, et al. (2009) Body condition and productive performance of Alpine goat in early lactation. R Bras Zootec 38:2137-2143
12. Poncheki JK, Canha MLS, Viechnieski SL, Almeida RD(2015) Analysis of daily body weight of dairy cows in early lactation and associations with productive and reproductive performance. R Bras Zootec 44:187-192
13. Santos MP, Godoy MM, Sousa CL, Assis RM, Sena CVB (2017) Productive and reproductive performances of Santa Inês ewes fed diets supplemented with protected fat in the postpartum. Pesq agropec bras 52:548-556
14. Rodrigues CAF, Rodrigues MT, Branco RH, Queiroz AC, Araújo CV (2006) Influence of body condition and energy concentration in peripartum diets on the performance of lactating goats. R Bras Zootec 35:1560-1567
15. Al-Mana NM, Robertson MD (2018) Acute Effect of Resistant Starch on Food Intake, Appetite and Satiety in Overweight/ Obese Males. Nutrients 10:1-11
16. Pulina G, Nudda A, Battacone G, Dimauro C, Mazzette A, et al. (2012) Effects of short-term feed restriction on milk yield and composition, and hormone and metabolite profiles in mid-lactation Sarda dairy sheep with different body condition score. Ital J Anim Sci 11:150-158
17. Menezes EB, Salles MG, Silva CMG, Fernandes CCL, Galeati G, et al. (2019) Milk production in Saanen goats treated with repeated low doses of intermediate-release insulin during early lactation. Cienc Rural 49:1-7
18. Frutos P, Mantecon A R, Giraldez F J (1997) Relationship of body condition score and live weight with body composition in mature Churra ewes. J Anim Sci 64:447-452
19. Caldeira RM, Portugal AV (2007) Relationships of Body Composition and Fat Partition with Body Condition Score in Serra da Estrela Ewes. Asian Australas J Anim Sci 20:1108-1114
20. Gaias G (2013) Body condition score and body composition of Sarda dairy ewes
21. Cannas A, Tedeschi LO, Fox DG, Pell AN, Van Soest PJ (2004) A mechanistic model for predicting the nutrient requirements and feed biological values for sheep.J Anim Sci 82:149-169
22. Teixeira A, Delfa R, Rocher FC (1989) Relationships between fat depots and body condition score or tail fatness in the rasa Aragonesa breed. J Anim Sci, 49:275-280
23. Delfa R, Teixeira A, Gonzalez C, Gosalvez LF, Tor M (1995) Relationships between body fat depots, carcass composition, live weight and body condition scores in Blanca Celtiberica goats. CHIEAM-Options Mediterraniennes.in 148
24. Oliveira TS, Rodrigues MT, Fernandes AM (2021) Energy requirements and efficiency of Alpine goats in early lactation. J Anim 15:1-8
25. Hervieu J, Morand-Fehr P, Schmidely P, Fedele V, Delfa R (1991) Body measurements explaining variations in scores for the sternal, lumbar, and caudal regions used to estimate body condition in dairy goats. CHIEAM-Options Mediterraniennes. in 43-56
26. Mendizabal JA, Delfa R, Arana A, Eguinoa P, Gonzalez C, et.al (2003) Estimating fat reserves in Rasa Aragonesa ewes: A comparison of different methods. CAN J ANIM SCI 83:695–701.