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ANIMAL PRODUCTION

Pre-feedlot *in vivo* measurements to predict slaughter body traits in sheep

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ABSTRACT: This study investigated the relationships between pre-feedlot in vivo measurements body mass index (BMI), frame, and body compactness and body traits measured before and after slaughter in sheep. Twenty-four 16-month-old castrated male crossbred sheep were evaluated for BMI, frame, and body compactness prior to entering the feedlot. At slaughter, 18 animals representative of the mean body weight and body condition of the group were evaluated. Slaughter live weight (SLW) and shrunk body weight (SBW; after fasting) were recorded at slaughter. After slaughter, hot carcass weight (HCW) and non-carcass components were weighed, and carcasses were assessed for conformation as well as carcass and shrunk dressing percentages. Pearson correlation analysis was performed to determine linear associations among variables. When significant correlations were detected between pre-feedlot BMI and/or frame and/or body compactness and SLW, SBW, HCW, carcass dressing percentage or shrunk dressing percentage, regression equations were fitted to predict these traits. BMI showed weak correlations with SLW and SBW ($r \leq 0.54$; $R^2 \leq 0.29$), whereas frame and body compactness were strongly correlated with SLW, SBW, and HCW (frame: $r \geq 0.82$, $R^2 \geq 0.68$; compactness: $r \geq 0.73$, $R^2 \geq 0.54$). None of the pre-feedlot measurements were associated with carcass dressing percentages ($P \geq 0.05$). Overall, frame and body compactness measured before feedlot entry were positively associated with SLW, SBW, and HCW and can be used to predict these traits. Frame and body compactness values measured before animals enter the feedlot can predict body and carcass weights of sheep, and can be used as selection criteria for animals better suited to this finishing system.
Key words: body compactness, body mass index, frame, carcass dressing percentage.

Medidas *in vivo* pré-confinamento para estimativa das características corporais de ovinos ao abate

RESUMO: O estudo objetivou identificar as relações entre Índice de Massa Corporal (IMC), Frame e Compacidade Corporal de ovinos pré-confinamento e características corporais pré e pós-abate. Para identificar as relações foram utilizados 24 ovinos machos castrados de 16 meses de idade sem raça definida. Antes da entrada no confinamento, os ovinos foram avaliados quanto ao IMC, ao Frame e a Compacidade Corporal. Em relação ao abate foram determinados o peso vivo ao abate (PVA) e o peso vivo com jejum (PVJ), sendo abatidos 18 animais. Logo após, foi realizada a pesagem da carcaça quente (PCQ) e dos componentes não carcaça. As carcaças foram avaliadas quanto a conformação e rendimento propriamente dito e no frigorífico. Os resultados foram submetidos à análise de correlação de Pearson para a determinação da associação linear entre as variáveis. Quando a correlação entre o IMC, o Frame e/ou a Compacidade Corporal antes da entrada dos animais no confinamento, e as características PVA, PVJ, PCQ, rendimento propriamente dito e no frigorífico foi significativa, foram estimadas equações de regressão para predizer estas últimas. O IMC se correlacionou com PVA e PVJ com baixos coeficientes de correlação ($r \leq 0{,}54$) e de determinação ($R^2 \leq 0{,}29$). O Frame se correlacionou com PVA, PVJ e PCQ com $r \geq 0{,}82$ e $R^2 \geq 0{,}68$. A Compacidade se correlacionou com PVA, PVJ e PCQ, com $r \geq 0{,}73$ e $R^2 \geq 0{,}54$. Nenhuma das variáveis pré-confinamento se correlacionou com os rendimentos de carcaça ($P \geq 0{,}05$). Os valores de Frame e Compacidade mensurados antes da entrada dos animais no confinamento podem predizer pesos corporais e de carcaças de ovinos, podendo ser utilizados como critério de seleção para animais mais adequados a esse sistema de terminação.
Palavras-chave: compacidade, índice de massa corporal, frame, rendimento de carcaça.

INTRODUCTION

The expansion of meat sheep production has been driven by strong consumer-market potential and the growing acceptance of lamb meat. In Brazil, however, domestic production remains insufficient to meet demand, leading to increased imports of live sheep, carcasses, and frozen or chilled meat. In this scenario, several strategies have been adopted to improve productivity, carcass yield, and overall

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production efficiency. Feedlot finishing is one such approach, since it enables higher output within a shorter time frame and smaller land area.

In meat production systems, quantitative carcass traits are key because of their direct association with final product quality. These traits are strongly influenced by genetics, age, sex, nutritional management, and environmental conditions. *In vivo* measurements such as body mass index (BMI), which reflects body weight and body condition, frame (based on body structure), and body compactness (an indicator of conformation) may help classify sheep that are more suitable for feedlot finishing. However, the relationships between these measurements and pre- and post-slaughter body traits, non-carcass components, and carcass dressing percentage are still not well established.

Carcass dressing percentage expresses the relationship between carcass weight and live body weight, making it particularly important for assessing animal performance during growth. In sheep, dressing percentage typically ranges from 45 to 60% and is influenced by breed, slaughter weight, feeding system, chilling conditions, and age. Therefore, this study determined the relationships between pre-feedlot BMI, frame, and body compactness and pre- and post-slaughter body traits, thereby supporting the selection of animals best suited to this finishing system.

MATERIALS AND METHODS

The experiment was conducted at the Palma Agricultural Center, Universidade Federal de Pelotas (km 535, BR-116), in Capão do Leão, Rio Grande do Sul state, Brazil (31º52’00” S, 52º21’24” W; 13.24 m altitude), within the Litoral Sul physiographic region. The experimental period lasted 34 days (November 12 to December 16, 2019).

Twenty-four 16-month-old castrated male crossbred sheep, predominantly Corriedale, were used (initial body weight: 42.45 ± 4.45 kg; body condition score: 2.3 ± 0.256). Animals were finished in a barn divided into four 9.24 m² pens, each housing six sheep and equipped with a 130 × 30 cm feeder. Prior to feedlot entry, the sheep were sheared, dewormed, and vaccinated against clostridial diseases. A 7-day adaptation period was conducted before the experimental phase (starting on November 6, 2019). During adaptation, the diet contained 40% alfalfa hay (dry matter [DM]: 89.32%; ash: 9.11%; crude protein [CP]: 18.77%; ether extract [EE]: 2.85%; neutral detergent fiber [NDF]: 46.93%; acid detergent fiber [ADF]: 37.52%; gross energy [GE]: 4.22 cal/g DM) and 60% commercial concentrate (DM: 89.13%; ash: 10.19%; CP: 16.62%; EE: 2.61%; crude fiber [CF]: 7.37%; GE: 4,207.6 cal/g DM) on a dry matter basis. During the experimental period, the same commercial feed was offered once daily (8 a.m.), with feed available throughout the day. Feed allowance was adjusted based on refusals from the previous day, which were maintained at 10% of the amount offered to maximize voluntary intake. Water was provided ad libitum. The initial feed allowance and mean intake over the experimental period were 3.6% and 3.33% of body weight, respectively. The facility remained continuously illuminated (natural light during the day and artificial light at night).

Before feedlot entry, sheep were evaluated using the following in vivo indices: body mass index (BMI; COSTA et al., 2020), calculated as BMI = [body weight (kg) / withers height (m) / body length (m)] / 10; frame (SOUZA JÚNIOR et al., 2013), calculated as frame = [(fore height (cm) + hind height (cm) + body length (cm) + body weight (kg)) / 4]; and body compactness (MOTTA et al., 2016), calculated as compactness = body weight (kg) / body length (cm).

On December 19, 2019, 18 sheep representatives of the average body weight and body condition of the group were slaughtered. Slaughter live weight (SLW) and shrunk body weight (SBW; 12-h fasting) were recorded prior to slaughter. Slaughter procedures followed humane slaughter guidelines (BRASIL, 2021). Hot carcass weight (HCW) and non-carcass components were then weighed, including skin, feet, head, full gastrointestinal tract, lungs with trachea, heart, liver with full gallbladder, spleen, diaphragm, kidneys, bladder + penis, kidney fat, and internal fat. Carcasses were scored for conformation (visual scale: 1–5) and dressing percentage, calculated as HCW/SLW × 100, as well as shrunk dressing percentage, calculated as HCW/SBW × 100 (MOTTA et al., 2016).

Pearson correlation analysis ($P \leq 0.05$) was used to evaluate linear associations among variables. When significant correlations were detected between *in vivo* measurements and SLW, SBW, HCW, dressing percentage, and/or shrunk dressing percentage, regression equations were fitted to predict these outcomes from the in vivo measurements. All analyses were performed using PAST software (version 3.20; HAMMER et al., 2001).

RESULTS AND DISCUSSION

Descriptive statistics for the variables evaluated are presented in table 1. None of the *in*

Table 1 - Descriptive statistics for pre-feedlot *in vivo* measurements, pre-slaughter body traits, and post-slaughter carcass and non-carcass components.

Variable	Mean	Standard deviation	Minimum	Maximum	CV (%)
---Pre-feedlot in vivo measurements---					
Body compactness (unitless)	0.70	0.06	0.57	0.79	8.70
Frame (unitless)	57.83	2.47	51.57	62.42	4.26
Body mass index (unitless)	11.04	0.98	8.97	12.95	8.92
---Pre-slaughter body traits---					
Slaughter live weight (Kg) – SLW	46.52	6.62	36.80	59.80	14.24
Shrunk body weight (Kg) – SBW	45.08	5.87	36.40	56.30	13.03
---Post-slaughter traits and non-carcass components---					
Carcass conformation score (1-5)	3.17	0.48	2.50	4.00	15.32
Hot carcass weight (Kg) - HCW	20.19	2.95	15.08	25.36	14.62
Dressing percentage (%)	43.40	1.83	40.65	46.67	4.21
Shrunk dressing percentage (%)	44.75	2.55	40.08	48.76	5.69
Viscera (Kg)	9.48	2.28	1.79	12.48	24.03
Head (Kg)	1.71	0.19	1.44	2.01	11.13
Feet (Kg)	0.95	0.14	0.72	1.25	14.66
Skin (Kg)	6.02	1.67	3.79	9.69	27.74
Heart (Kg)	0.20	0.04	0.14	0.31	22.28
Kidneys (Kg)	0.16	0.11	0.09	0.53	64.63
Kidney fat (Kg)	0.23	0.08	0.11	0.47	36.80
Internal fat (Kg)	0.51	0.21	0.03	0.87	40.91
Spleen (Kg)	0.07	0.02	0.05	0.09	18.31
Diaphragm (Kg)	0.19	0.06	0.09	0.31	31.22
Lungs + trachea (Kg)	0.70	0.14	0.45	0.95	20.52
Liver + gallbladder (Kg)	0.90	0.20	0.62	1.20	21.93

vivo measurements were correlated with dressing percentage, and no significant correlations were observed with carcass conformation score ($P > 0.05$). Shrunk dressing percentage was positively correlated with HCW ($r = 0.49$; $P = 0.0397$) and showed a strong correlation with dressing percentage ($r = 0.86$; $P < 0.0001$) (Table 2 and Table 3). Accordingly, no regression equations were fitted between the in vivo measurements and carcass dressing percentages. According to MOTTA et al. (2016), dressing percentage is calculated as HCW/SLW, and shrunk dressing percentage as HCW/SBW.

Pearson correlation analysis (Table 2 and Table 3) indicated that BMI measured before feedlot entry was positively associated with SLW ($r = 0.49$; $P = 0.0383$) and SBW ($r = 0.54$; $P = 0.0209$). Although statistically significant, these coefficients were low, indicating limited association between BMI and these pre-slaughter traits. Consistent with the correlation results, linear regression equations between BMI and SLW and between BMI and SBW were significant but showed low coefficients of determination (Table 4), limiting the use of BMI as a predictor of pre-slaughter body weight.

COSTA et al. (2020) reported that BMI at slaughter was significantly associated with energy reserves and tissue composition of the shoulder and leg in Corriedale lambs, indicating that BMI can be used to estimate body energy reserve. In the present study; however, BMI was not associated with kidney fat or internal fat (Table 2 and Table 3). This suggested that sheep with low BMI at the beginning of feedlot finishing could still be finished without compromising fat deposition at slaughter. SALAZAR-CUYTUN et al. (2020) also demonstrated that BMI can be used to predict carcass chemical components in non-pregnant, non-lactating Pelibuey ewes. The predicted components included total body crude protein, total body fat, total body ash, total body energy, carcass crude protein, carcass fat, carcass ash, carcass energy, visceral crude protein, visceral fat, visceral ash, visceral energy. The authors further concluded that BMI provided greater accuracy for predicting SBW in adult ewes.

Table 2 - Pearson correlation coefficients among pre-feedlot *in vivo* measurements, pre- and post-slaughter body traits, and non-carcass components of feedlot-finished sheep.

	BC	Frame	BMI	SLW	SBW	HCW	Head	Feet	Skin	FGIT
BC		0.61	0.84	0.78	0.79	0.73	-0.22	0.65	0.28	-0.17
Frame	**		0.18	0.86	0.82	0.84	0.13	0.72	0.42	0.33
BMI	***	ns		0.49	0.54	0.41	-0.18	0.36	0.14	-0.32
SLW	***	***	*		0.98	0.96	0.22	0.88	0.54	0.19
SBW	***	***	*	***		0.92	0.25	0.85	0.53	0.18
HCW	***	***	ns	***	***		0.23	0.81	0.40	0.10
Head	ns	ns	ns	ns	ns	ns		0.22	0.27	0.30
Feet	**	***	ns	***	***	***	ns		0.69	0.20
Skin	ns	ns	ns	*	*	ns	ns	**		0.22
FGIT	ns	ns	ns	ns	ns	ns	ns	ns	ns	
Heart	*	***	ns	***	***	***	ns	**	ns	ns
Kidneys	ns	ns	*	ns	ns	ns	ns	ns	ns	ns
KF	ns	ns	ns	ns	ns	*	ns	ns	ns	ns
IF	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Spleen	ns	**	ns	**	**	**	ns	**	ns	ns
Diaph.	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
L+T	*	**	ns	***	***	***	ns	***	ns	ns
L+GB	**	***	*	***	***	***	ns	**	ns	ns
DP	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
SPD	ns	ns	ns	ns	ns	*	ns	ns	ns	ns
CC	*	*	ns	**	**	***	ns	**	ns	ns

ns: not significant ($P > 0.05$); *: $P \leq 0.05$; **: $P \leq 0.01$; ***: $P \leq 0.001$; BC: body compactness; BMI: body mass index; SLW: slaughter live weight; SBW: shrunk body weight; HCW: hot carcass weight; FGIT: full gastrointestinal tract (with contents); KF: kidney fat; IF: internal fat; Diaph.: diaphragm; L+T: lungs + trachea; L+GB: liver + gallbladder; DP: dressing percentage; SDP: shrunk dressing percentage; CC: carcass conformation score.

Frame measured at the beginning of feedlot finishing showed strong positive correlations with SLW ($r = 0.86$; $P < 0.0001$), SBW ($r = 0.82$; $P < 0.0001$), and HCW ($r = 0.84$; $P < 0.0001$) (Table 2 and Table 3). These high coefficients indicate a strong association between frame and key pre- and post-slaughter traits, and that SLW, SBW, and HCW were strongly intercorrelated ($r > 0.92$; $P < 0.0001$).

Regression models using frame to predict SLW, SBW, and HCW were significant and showed high R^2 values with low coefficients of variation (Table 4), supporting the use of frame as a predictor, particularly for SLW. These results are consistent with SOUZA et al. (2019), who evaluated fore height, hind height, and body length individually and obtained similarly significant equations with high R^2 values and low coefficients of variation. Despite its predictive ability, frame should be interpreted with caution as a practical tool, because it combines multiple measurements and may be difficult to obtain when working with large numbers of animals.

Body compactness measured at the beginning of feedlot finishing was also positively correlated with SLW ($r = 0.78$; $P = 0.0001$), SBW ($r = 0.79$; $P = 0.0001$), and HCW ($r = 0.73$; $P = 0.0005$) (Table 2 and Table 3). Regression models between compactness and SLW, SBW, and HCW were all statistically significant ($P \leq 0.0005$), with low coefficients of variation and intermediate coefficients of determination (Table 4). These results indicated that compactness can also be used as a predictor of key pre- and post-slaughter traits, particularly SLW and SBW, which showed the highest R^2 values.

Compared with frame, compactness was easier to measure because it is calculated using only live weight and body length. Conversely, frame incorporates four measurements (fore height, hind height, body length, and body weight), which likely contributed to its higher coefficient of determination

Table 3 - Pearson correlation coefficients among pre-feedlot *in vivo* measurements, pre- and post-slaughter body traits, and non-carcass components of feedlot-finished sheep.

	Heart	Kidneys	KF	IF	Spleen	Diaph.	L+T	L+GB	DP	SDP	CC
BC	0.57	0.41	0.35	-0.06	0.44	0.30	0.52	0.65	-0.09	0.10	0.48
Frame	0.83	0.21	0.18	-0.19	0.62	0.27	0.65	0.71	0.05	0.32	0.55
BMI	0.22	0.47	0.33	0.07	0.35	0.30	0.34	0.46	-0.26	-0.18	0.22
SLW	0.78	0.19	0.43	0.01	0.68	0.41	0.81	0.86	-0.01	0.25	0.64
SBW	0.71	0.30	0.42	0.01	0.68	0.33	0.81	0.87	-0.07	0.11	0.60
HCW	0.76	0.08	0.46	0.07	0.60	0.39	0.75	0.81	0.28	0.49	0.72
Head	0.09	-0.08	-0.17	0.16	0.39	-0.11	0.31	0.20	0.11	0.03	0.11
Feet	0.62	0.01	0.25	-0.19	0.59	0.23	0.76	0.67	-0.11	0.16	0.58
Skin	0.23	-0.27	0.10	-0.16	0.37	0.22	0.41	0.31	-0.39	-0.17	0.21
FGIT	0.30	-0.05	0.15	0.18	0.31	0.05	0.41	0.32	-0.24	-0.13	-0.11
Heart		0.08	0.33	-0.01	0.60	0.41	0.48	0.58	0.06	0.37	0.66
Kidneys	ns		-0.11	-0.15	0.15	-0.28	0.20	0.36	-0.34	-0.44	-0.04
KF	ns	ns		0.58	0.10	0.52	0.35	0.51	0.14	0.20	0.38
IF	ns	ns	**		-0.15	0.25	0.16	0.26	0.20	0.14	-0.13
Spleen	**	ns	ns	ns		0.35	0.58	0.57	-0.17	-0.005	0.32
Diaph.	ns	ns	*	ns	ns		0.31	0.46	-0.02	0.23	0.16
L+T	*	ns	ns	ns	**	ns		0.87	-0.05	0.12	0.33
L+GB	**	ns	*	ns	**	ns	***		-0.03	0.12	0.34
DP	ns	ns	ns	ns	ns	ns	ns	ns		0.86	0.36
SDP	ns	ns	ns	ns	ns	ns	ns	ns	***		0.48
CC	**	ns	ns	ns	ns	ns	ns	ns	ns	*	

ns: not significant ($P > 0.05$); *: $P \leq 0.05$; **: $P \leq 0.01$; ***: $P \leq 0.001$; BC: body compactness; BMI: body mass index; SLW: slaughter live weight; SBW: shrunk body weight; HCW: hot carcass weight; FGIT: full gastrointestinal tract (with contents); KF: kidney fat; IF: internal fat; Diaph.: diaphragm; L+T: lungs + trachea; L+GB: liver + gallbladder; DP: dressing percentage; SDP: shrunk dressing percentage; CC: carcass conformation score.

Table 4 - Linear regression equations for predicting slaughter and carcass traits from pre-feedlot body mass index (BMI), frame, and body compactness.

Equation	R²	P-value	CV (%)
---BMI---			
SLW=1005419+3.3036BMI	0.24	0.0383	12.78
SBW= 961023+3.2134xBMI	0.29	0.0209	11.31
---Frame---			
SLW=-87.79142+2.3225xFRAME	0.75	<0.0001	7.37
SBW=-68.57080+1.9653xFRAME	0.68	<0.0001	7.58
HCW=37.78720+1.0026xFRAME	0.70	<0.0001	8.24
---Body compactness---			
SLW=-12.48107+84.1685xCOMP.	0.61	0.0001	9.18
SBW= -7.67668+75.2616xCOMP.	0.62	0.0001	8.28
HCW=-4.52632+35.2597xCOMP.	0.54	0.0005	10.25

*SLW: slaughter live weight (kg); SBW: shrunk body weight (kg); HCW: hot carcass weight (kg).

and, consequently, greater predictive accuracy. According to SOUZA et al. (2009), equations based on morphometric measurements can be used to estimate live weight in meat sheep of both sexes, across breeds and ages. The authors also emphasized that predicting live weight and measuring body compactness may help estimate commercial yield and serve as an indicator of quantitative carcass traits.

CONCLUSION

Frame and body compactness measured before feedlot entry were positively correlated with SLW, SBW, and HCW. Frame showed correlations of $r = 0.86$ ($P < 0.0001$), $r = 0.82$ ($P < 0.0001$), and $r = 0.84$ ($P < 0.0001$) with SLW, SBW, and HCW, respectively, whereas body compactness showed correlations of $r = 0.78$ ($P = 0.0001$), $r = 0.79$ ($P = 0.0001$), and $r = 0.73$ ($P = 0.0005$).

Frame and body compactness measured prior to feedlot entry can be used as selection criteria for animals better suited to this finishing system.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflicts of interest.

AUTHORS' CONTRIBUTIONS

The authors contributed equally to the manuscript, critically reviewed the text, and approved the final version.

BIOETHICS AND BIOSECURITY COMMITTEE APPROVAL

The study was approved by the Animal Experimentation Ethics Committee of the Universidade Federal de Pelotas (protocol no. 6730), in accordance with established guidelines for the use of animals and GMOs.

DATA AVAILABILITY STATEMENT

Research data is only available upon request.

DECLARATION OF USE OF ARTIFICIAL INTELLIGENCE

The authors declare that no gen AI was used in the creation of this manuscript.

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