BF-1851
[1-7]

RESEARCH ARTICLE Indian Journal of Animal Research

# Establishment of Prediction Equations for Tissue Weight and Chemical Composition of Gangba Sheep Based on Carcasses Weight

Basang Jiba[1], Pingcuo Bandan[1], Xiaoqing Zhang[2],
Luosang Cuicheng[1], Gesang Jiacuo[1], Danzeng Quzhen[1]

10.18805/IJAR.BF-1851

## ABSTRACT

**Background:** Gangba sheep are vital for Qinghai-Tibet Plateau sheep production, accurately predicting their carcass tissue weight and chemical composition is essential for optimizing production.

**Methods:** Eighteen male Gangba lambs, weighing between 23.7 and 33.3 kg, were slaughtered and analyzed to develop predictive equations based on slaughter body weight (SBW), empty body weight (EBW) and fleece-free empty body weight (FF-EBW).

**Result:** The findings demonstrated significant correlations between EBW and tissue weights for bone, muscle, fat and hide, with adjusted $r^2$ values of 0.59 or higher ($P<0.01$). Additionally, FF-EBW showed strong correlations with nutritional contents such as moisture, dry matter (DM), protein, fat and ash, with adjusted $r^2$ values of 0.55 or higher ($P<0.01$). These results underscore the potential of EBW and FF-EBW as reliable indicators for estimating tissue weight and chemical composition in Gangba sheep carcasses. This study provides valuable insights for optimizing meat production processes and enhancing economic efficiency in sheep farming, particularly on the Qinghai-Tibet Plateau.

**Key words:** Carcass characteristics, Carcass composition, Gangba sheep, Prediction equations, Tissue weight.

## INTRODUCTION

Gangba sheep, a pivotal breed in Qinghai-Tibet Plateau sheep production, are well-adapted to the harsh plateau environment, contributing to local ecological balance and serving as an important income source for farmers (Ding *et al.,* 2024). Accurate prediction of body and carcass traits is crucial for improving farming efficiency and meat production. Researchers worldwide continue to pursue this, studying breeds like Ouled Djellal and Hamra sheep in Algeria (Houssou *et al.,* 2024), Harnali sheep (Kumar *et al.,* 2017) and Hassan sheep (Kumar *et al.,* 2022) in India.

Various studies have explored various methods such as body measurements (*e.g.*, height at withers, body length) and ultrasound to predict sheep body composition. While body measurements are non-invasive and cost-effective, their accuracy can vary with breed and age (Salazar-Cuytún *et al.,* 2022). Ultrasound measurements can accurately assess fat and muscle depth but is limited by equipment and operator expertise (Van Der Merwe *et al.,* 2022). The most accurate method for predicting carcass composition is complete carcass separation into lean meat, bone and fat, but it is labor-intensive and impractical for commercial use. Recent studies suggest that tissue measurements (Hopkins *et al.,* 2008), joint dissection (Santos *et al.,* 2017) and neck traits Rivera-Alegria *et al.* (2022) can reliably indicate carcass composition. Thus, using carcass traits has become a more practical approach. Carcass traits such as slaughter body weight (SBW) and empty body weight (EBW) directly and accurately predict body composition (Barcelos *et al.,* 2021). SBW is the weight before slaughter, while EBW is the weight after removing gastrointestinal contents and non-carcass components, offering practical measurements less affected by age and breed (Owens *et al.,* 1995). Additionally, fleece-free empty body weight (FF-EBW) serves as a common baseline for evaluating carcass or organ conditions and was included as a key indicator in our regression equations (Aziz *et al.,* 1993).

Thus, this study aims to utilize carcass traits, including SBW, EBW and FF-EBW to precisely forecast the tissue

[1]Institute of Animal Science, Tibet Academy of Agricultural and Animal Husbandry Sciences, Lhasa 850009, China.
[2]Grassland Research Institute of China Academy of Agricultural Sciences, Hohhot 010010, China.

**Corresponding Author:** Basang Jiba, Institute of Animal Science, Tibet Academy of Agricultural and Animal Husbandry Sciences, Lhasa 850009, China. Email: lanana2024@126.com

Orcid id: https://orcid.org/0009-0001-7554-6046; https://orcid.org/0009-0006-8628-2433; https://orcid.org/0000-0002-3334-282; https://orcid.org/0009-0005-2974-1210; https://orcid.org/0009-0000-5631-7048; https://orcid.org/0009-0000-8938-2292.

**How to cite this article:** Jiba, B., Bandan, P., Zhang, X., Cuicheng, L., Jiacuo, G. and Quzhen, D. (2024). Establishment of Prediction Equations for Tissue Weight and Chemical Composition of Gangba Sheep Based on Carcasses Weight. Indian Journal of Animal Research. 1-7. doi: 10.18805/IJAR.BF-1851.

**Submitted:** 05-08-2024 **Accepted:** 18-10-2024 **Online:** 12-12-2024

weight and chemical composition of Gangba sheep carcasses. This approach has not been extensively explored in existing literature, particularly within the context of Gangba sheep, thereby offering new insights and potential applications in the field of animal nutrition and production.

## MATERIALS AND METHODS

### Ethics statement

This experiment was conducted from April to June 2024 at the Mende sheep raising professional cooperative (Tibet, China). All experimental procedures mentioned in the manuscript comply with the ethical guidelines and regulations for animal trials of Tibet Academy of Agricultural and Animal Husbandry Sciences (Approval code: TLRI-SEC-2024-031).

### Animal management and diet

Eighteen healthy male Gangba lambs (average initial body weight: 15.4±1.2 kg) were selected for the experiment. After a 10-day adaptation period, the lambs were randomly assigned to six groups (three lambs per group) with varying feeding levels to achieve different body weight gains. Groups I, II and III targeted nutritional levels at 0.8, 0.9 and 1.0 times the recommended average daily gain (ADG) of 100 g/d for a 20 kg sheep, respectively. Groups IV, V and VI targeted 0.8, 0.9 and 1.0 times the ADG for a 20 kg sheep gaining 200 g/d. Diets varied in metabolizable energy (ME) and crude protein (CP) levels, designed to meet the specific growth targets (Table 1). We intentionally varied ME and CP levels to examine their effects on tissue weight and chemical composition in Gangba sheep.

### Slaughter and sample collection

Lambs in Groups I -III were slaughtered at an average weight of 28.6 kg, while those in Groups IV-VI were slaughtered at 33.3 kg. After a 17-hour fasting period, the slaughter body weight (SBW) was recorded and lambs were slaughtered using standard commercial procedures after CO2 stunning. The empty body weight (EBW) was calculated by subtracting the gastrointestinal contents from the SBW and the fleece-free empty body weight (FF-EBW) was obtained by further subtracting the wool weight from the EBW. Carcasses were split along the dorsal midline and the right half, including hooves and head, was dissected to separate muscle, fat, bone and hide (Pereira *et al.,* 2014). Representative samples of bone, muscle, fat, blood plus viscera, hide and fleece were collected for further analysis.

### Chemical analysis

Samples were analysed for dry matter (method 934.01), crude protein (method 920.87), crude fat (method 920.85) and ash (method 924.05) according to Association of

**Table 1:** Composition and nutrient levels of the basal total-mixed ration (DM basis).

| Item | Treatment | | | | | |
|---|---|---|---|---|---|---|
| | Group I | Group II | Group III | Group IV | Group V | Group VI |
| **Ingredients, %** | | | | | | |
| Oat green hay | - | 5.00 | 20.0 | 20.0 | 20.0 | 30.0 |
| Highland barley straw | 20.0 | 20.0 | 20.0 | 20.0 | - | - |
| Corn | 70.0 | 55.0 | 30.0 | 30.0 | 20.0 | 30.8 |
| Soybean meal | 13.20 | 14.0 | 12.6 | 19.5 | 22.2 | 26.0 |
| Wheat | - | 4.00 | 9.20 | 7.00 | 11.0 | 1.60 |
| Wheat bran | 13.9 | 11.9 | 12.0 | 13.2 | 13.3 | 9.50 |
| Calcium bicarbonate | - | - | 0.10 | 0.10 | 0.20 | 0.80 |
| Stone powder | - | - | 0.20 | 0.30 | 0.60 | 0.40 |
| Salt | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |
| Premix[1] | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| **Nutrient levels, %** | | | | | | |
| DM | 87.8 | 87.8 | 87.7 | 87.6 | 87.2 | 87.2 |
| CP | 10.5 | 11.7 | 12.9 | 15.3 | 17.0 | 18.9 |
| NDF | 59.0 | 51.5 | 43.3 | 43.9 | 37.4 | 30.7 |
| ADF | 37.1 | 32.1 | 26.0 | 26.4 | 22.0 | 17.3 |
| Calcium | 0.52 | 0.46 | 0.46 | 0.51 | 0.59 | 0.62 |
| Tatal phosphorus | 0.27 | 0.27 | 0.31 | 0.36 | 0.39 | 0.41 |
| ME, MJ/kg[2] | 6.96 | 7.74 | 8.54 | 8.48 | 9.08 | 10.0 |

DM: Dry matter; CP: Crude protein; NDF: Neutral detergent fiber, ADF: Acid detergent fiber; ME: Metabolic energy.

[1]Nutrient composition per kilogram: Vitamin E: 200 IU, Vitamin $D_3$: $3\times10^5$ IU, Vitamin $A_1$: $4.5\times10^5$ IU, Biotin: 8mg, Se: 20-40mg, I: 10-25mg, Fe: 3000-6000mg, Mn: 2000-4000mg, Zn: 4000-7000mg, Cu: 1200-1800mg.

[2]The ME is calculated according to feed raw materials and ratio. (https://www.chinafeeddata.org.cn/admin/Zylist/index?type=feednutrientsheep).

Official Analytical Chemists (AOAC, 2000). Calcium and total phosphorus contents were determined using coupled plasma emission spectroscope and total energy was measured using an oxygen bomb calorimeter (Mitong Electromechanical Technology Co. Ltd., Shanghai, China).

**Establishment of prediction equations**

Simple linear regression models were employed to develop prediction equations for tissue weight and chemical composition, using SBW, EBW and FF-EBW as independent variables. The selection of these variables was based on their significant correlations with tissue traits. The models were evaluated by the coefficient of determination ($r^2$) and root mean square prediction error (RMSE).

**Statistical analysis**

Data were analysed using IBM SPSS Statistics (version 26.0; Chicago, IL, USA). Normality and variance homogeneity were assessed before conducting parametric tests. One-way ANOVA was used to identify significant differences among groups, while Pearson's correlation and t-tests assessed relationships between variables. Regression models were evaluated by $r^2$ and RMSE values, with coefficients greater than 0.70 indicating strong associations and those from 0.30 to 0.70 indicating moderate correlations Gomes *et al.* (2021). The significance level was set at $P<0.05$.

## RESULTS AND DISCUSSION

### Carcass measurements

Table 2 shows that carcass characteristics, including SBW, EBW, FF-BW and FF-EBW, increased linearly with feeding levels. Notably, the EBW/SBW ratio in Group I was lower than in the other groups ($P<0.05$). Similarly, carcass composition parameters, such as DM, protein, fat, ash and gross energy, also increased linearly with feeding levels ($P<0.05$). Table 3 reveals that the hide DM/body DM ratio in Group V was higher than in Groups II and IV and in Group VI, it was higher than in Group II ($P<0.05$). Both tissue fresh weight and DM weight increased linearly with feeding levels across all tissues, with the lowest values in Group I and the highest in Group VI ($P<0.05$).

As anticipated, carcass characteristics and components increased linearly with increasing feeding levels. This can be attributed to the elevated levels of crude protein and ME in the diets, resulting in optimal synchronization of carbohydrate and protein in the rumen and subsequently improved production performance (Costa *et al.,* 2013). However, the fat content, being the most variable component, raises question of whether its changes are primarily influenced by breed, sex, age, or body weight (Tedeschi *et al.,* 2013). Our results revealed that body fat content is mainly related to carcass weight, making body weight the key parameter. To further analyze changes in carcass components, we divided the sheep's carcass into five parts: bone, muscle, fat, blood and viscera (BV) and hide. As expected, the fresh weight and DM weight of different tissues in Gangba sheep carcasses were consistent with the aforementioned carcass characteristics. Specifically, they uniformly displayed the lowest values in Group I and the highest values in Group VI, indicating the accumulation of major body tissues during growth. It is noteworthy that carcass characteristics and components in Group III were consistent with those in Groups IV and V, despite Group III's lower crude protein content in the diet compared to the other two groups (12.88% versus 15.29% and 16.95%, respectively). This finding aligns with a previous experiment where the growth rate of young sheep was not affected, despite different crude protein levels being provided (110 g versus 160 g CP/kg of DM) (Hajji *et al.,* 2015). Furtherly Considering the consistent metabolic energy across the three groups, this finding underscores the pivotal role of dietary energy concentration in the growth process of Gangba sheep. The beneficial effects of higher energy density in the diet on sheep's growth performance and meat production have been well-documented (Jaborek *et al.,* 2018). Thus, our findings indicate that in Gangba sheep

**Table 2:** Effects of different feeding levels on carcass characteristics and fleece-free empty body carcass composition of Gangba male lambs.

| Item | Group I | Group II | Group III | Group IV | Group V | Group VI |
|---|---|---|---|---|---|---|
| **Carcass characteristics** | | | | | | |
| SBW, kg | 23.7±0.31$^{d}$ | 25.5±0.12$^{c}$ | 28.6±1.04$^{b}$ | 27.2±0.53$^{b}$ | 27.9±1.29$^{b}$ | 33.3±0.70$^{a}$ |
| EBW, kg | 18.2±0.93$^{d}$ | 21.2±0.06$^{c}$ | 24.5±0.15$^{bc}$ | 24.0±1.10$^{bc}$ | 24.5±0.87$^{b}$ | 28.7±1.32$^{a}$ |
| FF-EBW, kg | 17.8±0.61$^{d}$ | 20.8±0.15$^{c}$ | 23.9±0.21$^{b}$ | 23.3±1.16$^{b}$ | 24.0±0.95$^{b}$ | 28.4±1.63$^{a}$ |
| EBW/SBW, % | 0.77±0.05$^{b}$ | 0.83±0.00$^{ab}$ | 0.86±0.03$^{a}$ | 0.88±0.03$^{a}$ | 0.88±0.07$^{a}$ | 0.86±0.02$^{a}$ |
| **Carcass composition, based on fleece-free empty body** | | | | | | |
| DM, kg | 23.7±0.31$^{d}$ | 25.5±0.12$^{c}$ | 28.6±1.04$^{b}$ | 27.2±0.53$^{b}$ | 27.9±1.29$^{b}$ | 33.3±0.70$^{a}$ |
| Protein, kg | 18.2±0.93$^{d}$ | 21.2±0.06$^{c}$ | 24.5±0.15$^{bc}$ | 24.0±1.10$^{bc}$ | 24.5±0.87$^{b}$ | 28.7±1.32$^{a}$ |
| Fat, kg | 13.3±1.03$^{d}$ | 14.9±0.45$^{c}$ | 15.9±0.85$^{b}$ | 16.0±0.70$^{b}$ | 16.5±0.65$^{b}$ | 19.5±0.42$^{a}$ |
| Ash, kg | 17.8±0.61$^{d}$ | 20.8±0.15$^{c}$ | 23.9±0.21$^{b}$ | 23.3±1.16$^{b}$ | 24.0±0.95$^{b}$ | 28.4±1.63$^{a}$ |
| Gross energy, MJ | 0.77±0.05$^{b}$ | 0.83±0.00$^{ab}$ | 0.86±0.03$^{a}$ | 0.88±0.03$^{a}$ | 0.88±0.07$^{a}$ | 0.86S±0.02$^{a}$ |

SBW: Slaughter body weight; EBW: Empty body weight; FF-EBW: Fleece-free empty body weight; DM; Dry matter.

$^{a,b,c,d}$Means within a row with different superscripts differ ($P<0.05$).

production, a diet with higher energy density and relatively lower crude protein content could sustain favorable growth performance, thereby reducing the consumption of protein feeds.

**Correlation coefficients and prediction equations of carcass measurements**

Based on Fig 1, except for carcass blood and viscera (CBV), all tissue traits were highly correlated with SBW, EBW and FF-EBW ($0.73 \leq r \leq 0.92$; $P<0.01$). Regression equations for estimating tissue weight were developed (Table 4). While blood and viscera (BV) had a low correlation with the EBW ($r^2$adj = 0.23; $P$ = 0.03), other tissues, including bone, muscle, fat and hide, showed significant correlations with EBW ($r^2$adj $\geq$0.59; $P<0.01$). Table 5 presents the regression relationship between nutritional contents and FF-EBW, with significant correlations found for moisture, DM, protein, fat, ash ($r^2$adj $\geq$ 0.55; $P<0.01$) and gross energy ($r^2$adj = 0.92; $P<0.01$).

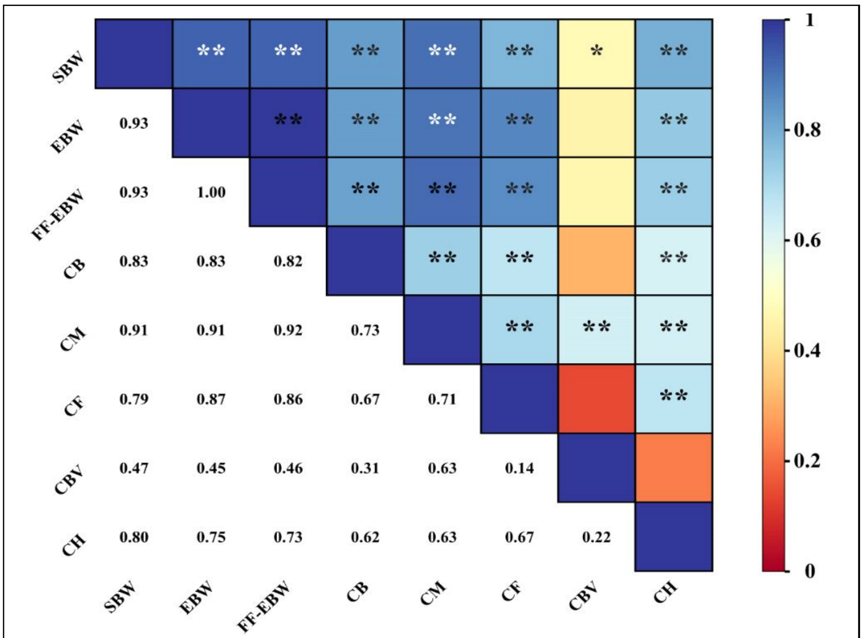
Many studies have demonstrated the feasibility of forecasting tissue weight and body chemical composition using carcass traits, which aids in managing feed strategy precisely (Santos *et al.*, 2017; Barcelos *et al.*, 2021). For instance, a previous study accurately predicted the carcass composition of Santa Inês sheep using cold carcass weight (CCW) as the predictor: muscle (kg) = 0.23671+0.5829 CCW ($r^2$ = 0.9768, $P$ < 0.0001); adipose (kg) = – 0.76543 + 0.20132 CCW ($r^2$ = 0.8615, $P$<0.0001) (Gomes *et al.*, 2021). Additionally, according to Morais *et al.* (2016), fasting body weight and withers height were the variables with the best results in predicting carcass fat and muscle content. Therefore, in the present experiment, we selected empty body weight (EBW) to predict the tissue weight of Gangba male lambs. While the blood and viscera (BV) had a low correlation with EBW ($r^2$adj = 0.23; $P$ = 0.03), the other tissues, including bone, muscle, fat and hide, were significantly correlated with EBW ($r^2$adj $\geq$0.59; $P<0.01$). Despite a lower $r^2$ compared to a previously mentioned muscle prediction equation (0.83 versus 0.98), our

**Table 3:** Fresh weight, DM content and DM weight of different tissues in fleece-free empty body of Gangba sheep.

| Tissue | Group | Fresh weight, g | Fresh weight/, FF-EBW g/kg | DM content, % | Weight of DM, g | Tissue DM/ Body DM,% |
|---|---|---|---|---|---|---|
| Bone | I | 2 637±42.1$^{C}$ | 180±9.42 | 60.5±2.68 | 1 595±55.3$^{C}$ | 30.5±2.35 |
| | II | 3 152±226$^{B}$ | 184±7.64 | 58.6±6.52 | 1 844±208$^{BC}$ | 27.6±1.61 |
| | III | 3 538±490$^{AB}$ | 189±22.5 | 58.7±2.83 | 2 073±284$^{AB}$ | 27.0±3.75 |
| | IV | 3 315±71.0$^{AB}$ | 181±8.17 | 56.9±3.85 | 1 888±169$^{BC}$ | 26.1±2.89 |
| | V | 3 397±58.1$^{AB}$ | 177±8.07 | 60.7±0.48 | 2 061±50.3$^{AB}$ | 26.1±0.60 |
| | VI | 3 793±270$^{A}$ | 162±14.7 | 60.6±3.97 | 2 297±181$^{A}$ | 23.9±3.38 |
| Muscle | I | 7 527±375$^{C}$ | 512±24.2 | 30.3±2.61 | 2 277±168$^{D}$ | 43.4±1.80 |
| | II | 9 100±505$^{B}$ | 532±14.4 | 33.2±1.16 | 3 025±269$^{C}$ | 45.4±2.94 |
| | III | 9 446±623$^{B}$ | 506±29.7 | 34.9±1.97 | 3 290±172$^{BC}$ | 42.8±2.35 |
| | IV | 9 609±571$^{B}$ | 523±14.7 | 33.1±2.27 | 3 182±240$^{BC}$ | 43.9±2.46 |
| | V | 9 829±577$^{B}$ | 511±11.8 | 35.6±2.00 | 3 497±203$^{B}$ | 44.2±2.62 |
| | VI | 12 271±667$^{A}$ | 523±20.0 | 33.8±0.85 | 4 154±306$^{A}$ | 43.1±2.58 |
| Fat | I | 834±408$^{C}$ | 56.4±25.9 | 75.5±6.15 | 631±304$^{C}$ | 11.7±4.48 |
| | II | 1 274± 77$^{BC}$ | 74.8±12.7 | 83.4±7.20 | 1 069±2159$^{BC}$ | 16.1±3.67 |
| | III | 1 613±258$^{B}$ | 86.6±15.4 | 87.2±3.03 | 1 411±266$^{AB}$ | 18.4±3.37 |
| | IV | 1 571± 1.7$^{B}$ | 85.6±3.16 | 80.6±9.01 | 1 267±148$^{B}$ | 17.5±2.23 |
| | V | 1 300±237$^{BC}$ | 67.7±13.0 | 86.4±6.15 | 1 130±261$^{BC}$ | 14.3±3.28 |
| | VI | 2 163±511$^{A}$ | 91.8±19.5 | 87.2±0.59 | 1 887±447$^{A}$ | 19.4±3.48 |
| Blood and Viscera | I | 1 341±388 | 90.7±23.3 | 24.4±0.74 | 329±103$^{BC}$ | 6.30±2.16 |
| | II | 1 343±157 | 78.4±7.13 | 22.5±1.09 | 304±48.9$^{C}$ | 4.54±0.56 |
| | III | 1 355±192 | 72.7±11.8 | 24.9±3.20 | 342±93.1$^{BC}$ | 4.45±1.22 |
| | IV | 1 436±371 | 77.9±17.9 | 27.4±2.21 | 400±136$^{ABC}$ | 5.50±1.79 |
| | V | 1 829±474 | 94.6±21.3 | 29.5±6.35 | 521±48.2$^{A}$ | 6.59±0.62 |
| | VI | 1 875±204 | 80.1±11.5 | 26.2±3.00 | 488±23.9$^{AB}$ | 5.06±0.41 |
| Hide | I | 2 379±320$^{BC}$ | 161±17.6 | 17.9±3.44 | 431±129$^{C}$ | 8.08±1.57$^{ABC}$ |
| | II | 2 237±231$^{C}$ | 131± 6. 8 | 19.0±2.28 | 422±35.6$^{C}$ | 6.34±0.68$^{C}$ |
| | III | 2 723±264$^{BC}$ | 146±12.2 | 21.1±3.84 | 567±54.6$^{BC}$ | 7.38±0.74$^{ABC}$ |
| | IV | 2 433±301$^{BC}$ | 133±19.8 | 21.1±4.41 | 504±41.7$^{C}$ | 6.95±0.44$^{BC}$ |
| | V | 2 883±325$^{B}$ | 150±21.9 | 24.4±2.28 | 699±56.0$^{AB}$ | 8.84±0.72$^{A}$ |
| | VI | 3 380±211$^{A}$ | 144±4.29 | 24.4±3.13 | 827±146$^{A}$ | 8.53±0.99$^{AB}$ |

FF-EBW: Fleece-free empty body weight; DM: Dry matter. $^{A, B, C, D}$Means within a column with different superscripts differ ($P$<0.05).

prediction equation showed promise for application in Gangba sheep production. To predict carcass composition more accurately, we chose fleece-free empty body weight (FF-EBW) as the indicator instead of EBW. Our results revealed that moisture, DM, protein and fat were highly correlated with FF-EBW ($r^2$adj ≥0.77; *P*< 0.01). However, ash showed a moderate correlation ($r^2$adj = 0.55; *P* <0.01), possibly due to the stable concentration of major elements in tissues across different feeding levels (Bellof *et al.,* 2006). Based on our results, both EBW and FF-EBW can serve as appropriate indicators to predict tissue weight and chemical composition of Gangba sheep carcasses. Notably, both EBW and FF-EBW can be estimated with high accuracy using the slaughter body weight (SBW) in the present experiment ($r^2$adj ≥0.86; *P*< 0.01). Therefore, our findings offer a new approach for estimating tissue weight and chemical composition in Gangba sheep. However, relying solely on weight parameters may lead to inaccuracies in predicting actual carcass composition. Future studies should incorporate additional biometric measurements for more accurate predictions (Gomes *et al.,* 2021). While our preliminary results are promising, we acknowledge the limitation posed by the small sample size. Further research with larger samples is needed to validate the reliability and robustness of these prediction equations.




SBW: Slaughter body weight (kg); EBW: Empty body weight (kg); FF-EBW: Fleece-free body weight (kg); CB: Carcass bone (kg); CM: Carcass muscle (kg); CF: Carcass fat (kg); CBV: Carcass blood and viscera (kg); CH: Carcass hide (kg).

**Fig 1:** Correlation coefficients among carcass and tissue traits.

**Table 4:** The regression equations to estimate tissue weight of Gangba sheep carcasses.

| Equations | $r^2_{adj}$ | RMSE | *P* |
|---|---|---|---|
| EBW, kg = - 4.53 (± 2.73) + [1.01 (± 0.10**) × SBW, kg] | 0.87 | 1.30 | < 0.01 |
| DM, kg = - 1.99 (± 0.56**) + [0.40 (± 0.02**) × EBW, kg] | 0.94 | 0.33 | < 0.01 |
| Bone, kg = 0.50 (± 0.29) + [0.06 (± 0.01**) × EBW, kg] | 0.59 | 0.17 | < 0.01 |
| Muscle, kg = - 0.60 (± 0.42) + [0.16 (± 0.02**) × EBW, kg] | 0.83 | 0.25 | < 0.01 |
| Fat, kg = - 1.51 (± 0.39**) + [0.12 (± 0.02**) × EBW, kg] | 0.74 | 0.23 | < 0.01 |
| Blood and viscera, kg = - 0.004 (± 0.16) + [0.02 (± 0.01*) × EBW, kg] | 0.23 | 0.10 | 0.03 |
| Hide, kg = - 0.38 (± 0.16*) + [0.04 (± 0.01**) × EBW, kg] | 0.67 | 0.10 | < 0.01 |
| Gross energy, MJ = - 82.50 (± 22.29**) + [12.55 (± 0.94**) × EBW, kg] | 0.91 | 13.23 | < 0.01 |

Adj. $r^2$, determination coefficient adjusted to parameter numbers of models; RMSE: Root mean square error; EBW: Empty body weight; SBW: Slaughter body weight; DM: Dry matter.

* *P*<0.05; ** *P*<0.01.

**Table 5:** The regression relationship between nutrition contents and fleece-free empty body weight of Gangba sheep carcasses.

| Equations | $r^2_{adj}$ | RMSE | *P* |
|---|---|---|---|
| FF-EBW, kg = – 4.53 (± 2.73) + [1.01 (± 0.10**) × SBW, kg] | 0.86 | 1.27 | < 0.01 |
| Moisture, kg = 2.29 (± 1.09) + [0.38 (± 0.05**) × FF-EBW, kg] | 0.80 | 0.65 | < 0.01 |
| DM, kg = – 1.99 (± 0.56**) + [0.40 (± 0.02**) × FF-EBW, kg] | 0.94 | 0.33 | < 0.01 |
| Protein, kg = 0.36 (± 0.39) + [0.12 (± 0.02**) × FF-EBW, kg] | 0.77 | 0.23 | < 0.01 |
| Fat, kg = – 2.43 (± 0.56**) + [0.25 (± 0.02**) × FF-EBW, kg] | 0.86 | 0.33 | < 0.01 |
| Ash, kg = 0.08 (± 0.15) + [0.03 (± 0.01**) × FF-EBW, kg] | 0.55 | 0.09 | < 0.01 |
| Gross energy, MJ = – 87.23 (± 20.74**) + [12.38 (± 0.87**) × FF-EBW, kg] | 0.92 | 12.30 | < 0.01 |

Adj. $r^2$: Determination coefficient adjusted to parameter numbers of models; RMSE: Root mean square error; FF-EBW; Fleece-free empty body weight; SBW: Slaughter body weight; DM: Dry matter.
* $P<0.05$; ** $P<0.01$.

## CONCLUSION

Our findings indicate that Gangba lambs weighing between 23.7 and 33.3 kg are suitable candidates for moderate-intensity fattening. Significant correlations were observed between EBW and tissue weights ($r^2$adj ≥0.59; $P<0.01$) for bone, muscle, fat and hide. Additionally, FF-EBW showed significant correlations with nutritional contents such as moisture, DM, protein, fat and ash ($r^2$adj ≥0.55; $P<0.01$). These findings underscore the potential of EBW and FF-EBW as reliable indicators for estimating tissue weight and chemical composition of Gangba sheep carcasses. Our findings offer valuable insights into Gangba sheep nutrition and production, despite some limitations.

## ACKNOWLEDGEMENT

This work received funding from the Tibetan Major Science and Technology Projects (XZ2021ZD0001N); the National Key Research and Development Program of China (2022YFD1302102); and the National Wool Sheep Industry Technology System (CARS-39-33). The authors would like to thank the Mende sheep raising professional cooperative for animals handling.

### Data availability statement

Data will be made available on request.

### Informed consent

All experimental procedures mentioned in the manuscript in compliance with the ethical guidelines and regulations for animal trials of Tibet Academy of Agricultural and Animal Husbandry Sciences (Approval code: TLRI-SEC-2024-031).

### Conflict of interest

The authors declare no conflicts of interest.

## REFERENCES

AOAC- Association of Official Analytical Chemists. (2000). Official methods of analysis. 17th ed. Gaithersburg, USA: Association of Official Analytical Chemists.

Aziz, N., Murray, D., Ball, R. (1993). The effect of live weight gain and live weight loss on body composition of Merino wethers: noncarcass organs. Journal of Animal Science. 71: 400-407. doi: 10.2527/1993.712400x.

Barcelos, S., Vargas, J., Mezzomo, R., Gionbelli, M., Gomes, D., Oliveira, L., Luz, J., Maciel, D., Alves, K. (2021). Predicting the chemical composition of the body and the carcass of hair sheep using body parts and carcass measurements. Animal. 15: 100139. doi: 10.1016/j.animal.2020.100139.

Bellof, G., Most, E., Pallauf, J. (2006). Concentration of Ca, P, Mg, Na and K in muscle, fat and bone tissue of lambs of the breed German Merino Landsheep in the course of the growing period. Journal of Animal Physiology and Animal Nutrition. 90: 385-393. doi: 10.1111/j.1439-03 96 .20 06. 00 610.x.

Costa, M., Pereira, E., Silva, A., Paulino, P., Mizubuti, I., Pimentel, P., Pinto, A., Junior, J.R. (2013). Body composition and net energy and protein requirements of Morada Nova lambs. Small Ruminant Research. 114: 206-213. doi: 10.1016/j.smallrumres.2013.06.014.

Gomes, M.B., Neves, M.L.M.W., Barreto, L.M.G., Ferreira, M.D.A., Monnerat, J.P.I.D.S., Carone, G.M., Morais, J.S.D., Véras, A.S.C. (2021). Prediction of carcass composition through measurements in vivo and measurements of the carcass of growing Santa Inês sheep. PLoS ONE. 16: e0247950. doi: 10.1371/journal.pone.0247950.

Hajji, H., Smeti, S., Hamouda, M.B., Atti, N. (2015). Effect of protein level on growth performance, non-carcass components and carcass characteristics of young sheep from three breeds. Animal Production Science. 56: 2115-2121. doi: 10.1071/AN14917.

Hopkins, D., Ponnampalam, E., Warner, R. (2008). Predicting the composition of lamb carcases using alternative fat and muscle depth measures. Meat Science. 78: 400-405. doi: 10.1016/j.meatsci.2007.07.002.

Houssou, H., Djeffal, S. and Djebbari, D. (2024). Prediction of sheep carcass yield using combinations of ante-mortem and post-Mortem measurements. Asian Journal of Dairy and Food Research. doi: 10.18805/ajdfr.DRF-391.

Jaborek J., Zerby H., Moeller S., Fluharty F. (2018). Effect of energy source and level and sex on growth, performance and carcass characteristics of long-fed lambs. Small Ruminant Research. 167: 61-69. doi: 10.1016/j.smallrumres.2018.08.005.

Kumar, N.G.S., Inamdar, B.K., Gowda, H., Dodamani, S. (2022). Phenotypic and carcass characterization of Hassan sheep. Asian Journal of Dairy and Food Research. 41(2): 173-177. doi: 10.18805/ajdfr.DR-1741.

Kumar S., Dahiya, S.P., Malik, Z.S., Patil, C.S. (2017). Prediction of body weight from linear body measurements in sheep. Indian Journal of Animal Research. 52(9): 1263-1266. doi: 10.18805/ijar.B-3360.

Morais, M.d.G., Menezes, B.D., Ribeiro, C.B., Walker, C.C., Fernandes, H.J., Souza, A.D.L., Itavo, C.B.F., Feijo, G.D. (2016). Models predict the proportion of bone, muscle and fat in ewe lamb carcasses from *in vivo* measurements of the 9th to 11th rib section and of the 12th rib. Semina: Ciências Agrárias. 37: 1081-1090. doi: 10.5433/1679-0359. 2016v37n2p1081.

Owens, F.N., Gill, D.R., Secrist, D.S., Coleman, S. (1995). Review of some aspects of growth and development of feedlot cattle. Journal of Animal Science. 73: 3152-3172. doi: 10.2527/1995.73103152x.

Pereira, E.S., Fontenele, R.M., Silva, A.M., Oliveira, R.L., Ferreira, M.R., Mizubuti, I.Y., Carneiro, M.S., Campos, A.C. (2014). Body composition and net energy requirements of Brazilian Somali lambs. Italian Journal of Animal Science. 13: 3583. doi: 10.4081/ijas.2014.3583.

Rivera-Alegria, F.D.M., Ríos-Rincón, F.G., Macías-Cruz, U., Garcia-Herrera, R.A., Herrera-Camacho, J., Benaouda, M., Angeles-Hernandez, J.C., *et al*. (2022). Prediction of carcase characteristics using neck traits from hair-sheep ewes. Italian Journal of Animal Science. 21: 106-112. doi: 10.1080/1828051X.2021.2018363.

Salazar-Cuytún, E., Sarmiento-Franco, L., Aguilar-Caballero, A., Fonseca, M., Tedeschi, L. (2022). Predicting body composition of hair-lambs based on body mass index. Journal of Animal Feed Science. 31: 283-291. doi: 10.22358/jafs/150005/2022.

Santos, V.A., Silvestre, A.M., Azevedo, J.M., Silva, S.R. (2017). Estimation of carcase composition of goat kids from joint dissection and conformation measurements. Italian Journal of Animal Science. 16: 659-665. doi: 10.1080/1828051X.2017.1321472.

Tedeschi, L.O., Fox, D.G., Kononoff, P.J. (2013). A dynamic model to predict fat and protein fluxes and dry matter intake associated with body reserve changes in cattle. Journal of Dairy Science. 96: 2448-2463. doi: 10.3168/jds.2012-6070.

Van Der Merwe D., Brand T., Steyn S., Hoffman L. (2022). Using ultrasound to predict fat deposition in growing lambs of different South African sheep breed types. Small Ruminant Research. 210: 106670. doi: 10.1016/j. smallrumres. 2022.106670.