

## Effect of body condition score and age on slaughter performance and carcass characteristics of Nellore brown rams

SANA D V SATYANARAYANA<sup>1✉</sup> and A KRISHNA MURTHY<sup>2</sup>

Kerala Agriculture University, Thrissur 608 656 Kerala India

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### ABSTRACT

The study investigated the influence of Body Condition Score (BCS), which serves as a practical indicator of nutritional status and fat reserves in sheep, on reproductive efficiency, health, and meat production, particularly in tropical regions like India, where Nellore Brown sheep contribute to rural economies. The experiment was conducted from January to April, 2023. Sixty rams were purposively selected and divided into two age groups: 1-year-old (n=30) and 2 to 3-year-old (n=30), further stratified by BCS (2.0, 3.0, 4.0, 5.0) on a 5-point scale with six rams per subcategory. Animals received a standard diet of 50% green fodder, 30% dry fodder, and 20% concentrate to preserve natural BCS variation. Pre-slaughter live weights were recorded after 12 hours of fasting. Different components were weighed post-slaughter. Data were analyzed via two-way ANOVA in SPSS 25.0, with Duncan's test ( $p < 0.05$ ) and Pearson correlations. Live weight increased with BCS and age, peaking at  $35.2 \pm 1.1$  kg in 2 to 3-year-olds at BCS 5.0. Drained blood averaged  $1.80 \pm 0.1$  kg in higher BCS groups, correlating positively with body mass ( $r = 0.72$ ,  $p < 0.01$ ). Skin weight was higher in older rams ( $3.5 \pm 0.2$  kg at BCS 5.0), reflecting hide development. GI tract contents showed age effects ( $4.20 \pm 0.3$  kg vs.  $3.20 \pm 0.2$  kg) but not BCS. Viscera weight increased with BCS, reaching  $3.70 \pm 0.2$  kg in mature rams at BCS 5.0. Average weight of head and legs was  $3.90 \pm 0.2$  kg in older groups. Hot carcass weight and dressing percentage correlated strongly with BCS ( $r = 0.85$ ,  $p < 0.01$ ), maximizing at  $17.1 \pm 0.7$  kg and  $48.5 \pm 1.2\%$  in 2 to 3-year-olds at BCS 5.0, comparable to reports in indigenous breeds (47-50%). Results confirmed BCS as a reliable predictor of slaughter performance, with optimal scores (4.0-5.0) enhancing yields, particularly in mature rams due to greater fat and muscle deposition. Age interactions were significant ( $p < 0.05$ ), underscoring nutritional management to mitigate low-BCS losses (15-20%). Integrating BCS assessment could optimize selective breeding and feeding in Indian sheep farming, though breed-specific extrapolations warrant caution due to genetic and environmental variations. Limitations included small subgroup sizes; future research might incorporate ultrasound for fat depth.

**Keywords:** Body condition score, Carcass yield, Dressing percentage, Nellore Brown rams, Slaughter traits

Slaughter performance and carcass characteristics are critical factors in the livestock industry, directly influencing meat production efficiency and profitability. The body condition score (BCS), a subjective measure of animal's fat and muscle reserves, plays a significant role in determining these outcomes across livestock species, including Nellore Brown rams (Satyanarayana and Murthy, 2023). Carcass characteristics, by contrast, encompass the qualitative and quantitative attributes of the carcass, including hot carcass weight, cold carcass weight, loin eye area (LEA), backfat thickness, and the proportions of lean meat, fat, and bone (Rangamma *et al.* 2025).

India has made significant contributions to the global livestock gene pool. Currently, India is home to 46 indigenous sheep breeds, which are well-adapted to diverse

agro-climatic conditions and are registered by the ICAR-National Bureau of Animal Genetic Resources (ICAR-NBAGR) (Bhateshwar *et al.* 2022). These sheep breeds are crucial for meeting the consumer's ever-growing demand for ethically sourced, nutritious, and high-quality meat (Liu *et al.* 2023). Nellore sheep, predominantly found in these states, is the preferred animal for commercial meat production because of their lean meat and rapid growth potential. On the other hand, Deccani sheep, found in the Deccan Plateau areas of Telangana, Karnataka, and Maharashtra, are dual-purpose, producing both meat and wool (Reddy *et al.* 2023).

BCS is a practical tool for assessing the nutritional status and fat reserves in sheep, directly impacting reproductive efficiency, health, and meat production (Kenyon *et al.* 2014). In tropical regions like India, where sheep farming contributes significantly to rural economies, optimizing carcass traits is crucial for enhancing profitability. Nellore Brown sheep, a native breed adapted to semi-arid conditions, are valued for their meat quality and resilience,

Present address: <sup>1</sup>PhD Scholar, Kerala Agriculture University, Thrissur, Kerala-680656, India. <sup>2</sup>Scientist (AH), Krishi Vigyan Kendra, Yagantipalle, Nandyal, Andhra Pradesh- 518124, India.  
\*Corresponding author email: sanasatya12345@gmail.com

but limited studies exist on how BCS influences their slaughter performance across age groups (Bhatta *et al.* 2019). Previous research has shown that BCS correlates positively with live weight and dressing percentage in various breeds, with under-conditioned animals yielding lower edible portions (Ermias *et al.* 2006; Gebreselassie *et al.* 2023). For rams, age plays a pivotal role, as younger animals (1-year-old) typically have leaner carcasses compared to mature ones (2–3-year-old), which accumulate more fat (Lambe *et al.* 2008). This variation can affect offal components like skin and viscera, influencing overall economic value (Mahgoub *et al.* 2005).

Recent studies on similar indigenous breeds report 40–50% dressing percentages with BCS 3.0–4.0 optimizing meat output without excessive fat (Nosso *et al.* 1999; Safari *et al.* 2005). Integrating BCS assessment in management practices could reduce production losses, as evidenced in Ethiopian sheep, where low BCS reduced carcass weight by 15–20% (Mengistie *et al.* 2010). The present objective was to evaluate the effects of BCS on drained blood, skin, gastrointestinal tract (GI tract), viscera, head and legs, and carcass weights in Nellore Brown rams of different ages, providing data to inform selective breeding and feeding strategies.

Overall, understanding the intricate relationships among body condition score, age, and genetic attributes is crucial for optimizing slaughter performance and enhancing carcass characteristics in Nellore Brown sheep, thereby contributing to more efficient, high-quality meat production.

## MATERIALS AND METHODS

**Animals and experimental design:** The study was conducted between January and April 2023 using Krishi Vigyan Kendra, Yagantipalle, at the slaughterhouse of Banaganapalle in Nandyal District, Andhra Pradesh. Using a  $2 \times 4$  factorial design, with age (1-year-old, 2–3-year-old) and body condition score (BCS: 2.0, 3.0, 4.0, 5.0) as the two factors. A total of 48 Nellore Brown rams (*Ovis aries*) were selected by purposive sampling from local flocks to represent all four BCS categories within each age group, giving six rams per BCS category per age group (24 rams per age group). BCS was assessed on the 5-point scale of Russel *et al.* (1969).

**Slaughter procedure and measurements:** Pre-slaughter live body weight was recorded for each animal after 12 h of feed withdrawal. Following slaughter, the following components were separated and weighed: drained blood, skin (peeled), full gastrointestinal (GI) tract contents (for ingesta estimation), edible viscera (liver, heart, kidneys, testes), non-edible viscera (lungs, spleen), and head and legs (severed at the joints). Hot carcass weight (HCW) was recorded immediately after dressing, and dressing percentage (DP) was calculated as  $(\text{HCW} / \text{pre-slaughter live weight}) \times 100$ . Non-carcass component weights are additionally expressed as a percentage of pre-slaughter live weight to allow comparison independent of absolute body size.

**Statistical analysis:** Data were analyzed in SPSS version 25.0. The statistical model was  $Y_{ijk} = \mu + A_i + B_j + (AB)_{ij} + e_{ijk}$ , where  $Y_{ijk}$  is the response variable,  $\mu$  the overall mean,  $A_i$  the fixed effect of age ( $i = 1, 2$ ),  $B_j$  the fixed effect of BCS category ( $j = 1-4$ ),  $(AB)_{ij}$  the age  $\times$  BCS interaction, and  $e_{ijk}$  the random error. Prior to ANOVA, model residuals were checked for normality (Shapiro–Wilk test) and homogeneity of variance across groups (Levene's test); results are reported as means  $\pm$  standard error (SE). Where the ANOVA F-test was significant, means were separated using Duncan's multiple range test ( $p < 0.05$ ). Pearson's correlation coefficient was used to assess linear relationships among BCS, live weight and slaughter traits.

## RESULTS AND DISCUSSION

**Live body weight:** Live body weight increased significantly with both BCS and age ( $p < 0.05$ ), from  $24.1 \pm 0.9$  kg in 1-year-old rams at BCS 2.0 to  $35.2 \pm 1.1$  kg in 2–3-year-old rams at BCS 5.0 (Table 1). This pattern was consistent with Lambe *et al.* (2008) in Scottish Blackface rams, and reflected the combined effect of skeletal maturity and progressive fat and muscle deposition with age: as rams mature, an increasing share of nutrient intake is partitioned toward fat and muscle accretion rather than frame growth, so that at a given BCS, older animals carry more total tissue mass.

**Drained blood weight:** Drained blood weight increased with BCS in both age groups, and averaged at  $1.8 \pm 0.1$  kg in the highest-BCS, older animals (Table 2), and was

Table 1. Live body weight (kg) of Nellore brown rams by body condition score and age group

| BCS | 1-year-old (kg)  | 2–3-year-old (kg) |
|-----|------------------|-------------------|
| 2.0 | $24.1 \pm 0.9^a$ | $30.2 \pm 1.1^b$  |
| 3.0 | $26.3 \pm 0.7^a$ | $32.5 \pm 0.9^b$  |
| 4.0 | $28.5 \pm 1.0^a$ | $33.8 \pm 1.2^b$  |
| 5.0 | $30.7 \pm 1.1^a$ | $35.2 \pm 1.1^b$  |

$n = 6$  rams per BCS category per age group. Values are mean  $\pm$  SE. Means within a row bearing different superscripts (a, b) differ significantly ( $p < 0.05$ , Duncan's multiple range test following two-way ANOVA).

Table 2. Drained blood weight of Nellore brown rams by body condition score and age group

| BCS | 1-yr wt (kg)    | 1-yr (% PSW) | 2–3-yr wt (kg)  | 2–3-yr (% PSW) |
|-----|-----------------|--------------|-----------------|----------------|
| 2.0 | $1.2 \pm 0.1^a$ | 5.0          | $1.5 \pm 0.1^b$ | 5.0            |
| 3.0 | $1.3 \pm 0.1^a$ | 4.9          | $1.6 \pm 0.1^b$ | 4.9            |
| 4.0 | $1.5 \pm 0.1^a$ | 5.3          | $1.7 \pm 0.1^b$ | 5.0            |
| 5.0 | $1.6 \pm 0.1^a$ | 5.2          | $1.8 \pm 0.1^b$ | 5.1            |

$n = 6$  rams per BCS category per age group. PSW = pre-slaughter (live) weight. Values are mean  $\pm$  SE. Means within a row bearing different superscripts (a, b) differ significantly ( $p < 0.05$ , Duncan's multiple range test).

positively correlated with live weight ( $r=0.72$ ,  $p<0.01$ ), which was consistent with Ermias *et al.* (2006) in Ethiopian rams. Expressed as a proportion of pre-slaughter weight, blood yield was relatively stable across BCS and age (4.9–5.3%), indicating that blood volume scales approximately in proportion to body mass rather than tracking fat deposition specifically.

**Skin weight:** Skin weight was significantly higher ( $p<0.05$ ) in older rams at every BCS level, peaking at  $3.5 \pm 0.2$  kg at BCS 5.0 in 2–3-year-olds (Table 3), broadly consistent with hide development patterns reported by Mahgoub *et al.* (2005) in Omani sheep. As a proportion of live weight, skin contribution was slightly higher in mature rams (9.8–10.1%) than in younger animals (9.4–9.5%), suggesting continued hide thickening and subcutaneous connective tissue deposition with maturity, in addition to the increase in absolute body size.

Table 3. Skin weight of Nellore brown rams by body condition score and age group

| BCS | 1-yr wt (kg)    | 1-yr (% PSW) | 2–3-yr wt (kg)  | 2–3-yr (% PSW) |
|-----|-----------------|--------------|-----------------|----------------|
| 2.0 | $2.3 \pm 0.2^a$ | 9.5          | $3.0 \pm 0.2^b$ | 9.9            |
| 3.0 | $2.5 \pm 0.1^a$ | 9.5          | $3.2 \pm 0.2^b$ | 9.8            |
| 4.0 | $2.7 \pm 0.2^a$ | 9.5          | $3.4 \pm 0.2^b$ | 10.1           |
| 5.0 | $2.9 \pm 0.2^a$ | 9.4          | $3.5 \pm 0.2^b$ | 9.9            |

n = 6 rams per BCS category per age group. PSW = pre-slaughter (live) weight. Values are mean  $\pm$  SE. Means within a row bearing different superscripts (a, b) differ significantly ( $p<0.05$ , Duncan's multiple range test).

**Gastrointestinal tract contents:** GI tract contents (ingesta) did not differ significantly with BCS but were significantly higher in older rams ( $4.20 \pm 0.3$  kg vs.  $3.20 \pm 0.2$  kg; Table 4), which was in agreement with Nosso *et al.* (1999), and consistent with the larger rumen capacity and greater feed intake of mature animals. As a proportion of live weight, however, GI content declined with increasing BCS in both age groups (from ~12% at BCS 2.0 to ~10–12% at BCS 5.0), suggesting that better-conditioned animals carry relatively less gut fill per unit body weight, which is favorable from a dressing-percentage standpoint

Table 4. Gastrointestinal tract contents of Nellore brown rams by body condition score and age group

| BCS | 1-yr wt (kg)    | 1-yr (% PSW) | 2–3-yr wt (kg)  | 2–3-yr (% PSW) |
|-----|-----------------|--------------|-----------------|----------------|
| 2.0 | $2.9 \pm 0.2^a$ | 12.0         | $3.9 \pm 0.3^b$ | 12.9           |
| 3.0 | $3.0 \pm 0.2^a$ | 11.4         | $4.0 \pm 0.3^b$ | 12.3           |
| 4.0 | $3.1 \pm 0.2^a$ | 10.9         | $4.1 \pm 0.3^b$ | 12.1           |
| 5.0 | $3.2 \pm 0.2^a$ | 10.4         | $4.2 \pm 0.3^b$ | 11.9           |

n = 6 rams per BCS category per age group. PSW = pre-slaughter (live) weight. Values are mean  $\pm$  SE. Means within a row bearing different superscripts (a, b) differ significantly ( $p<0.05$ , Duncan's multiple range test).

since ingesta is a non-saleable component removed at dressing.

**Viscera weight:** Combined edible and non-edible viscera weight increased with BCS in both age groups (Table 5), which was consistent with Gebreselassie *et al.* (2023), who linked improved nutritional status to greater visceral organ mass. Proportionally, viscera contributed a slightly larger share of live weight in older rams (10.2–10.5%) than in younger rams (9.8–10.0%), reflecting that the higher metabolic and digestive demands were associated with greater feed throughput and body maintenance in mature animals.

Table 5. Viscera weight (edible + non-edible) of Nellore brown rams by body condition score and age group

| BCS | 1-yr wt (kg)    | 1-yr (% PSW) | 2–3-yr wt (kg)  | 2–3-yr (% PSW) |
|-----|-----------------|--------------|-----------------|----------------|
| 2.0 | $2.4 \pm 0.1^a$ | 10.0         | $3.1 \pm 0.2^b$ | 10.3           |
| 3.0 | $2.6 \pm 0.1^a$ | 9.9          | $3.3 \pm 0.2^b$ | 10.2           |
| 4.0 | $2.8 \pm 0.1^a$ | 9.8          | $3.5 \pm 0.2^b$ | 10.4           |
| 5.0 | $3.0 \pm 0.1^a$ | 9.8          | $3.7 \pm 0.2^b$ | 10.5           |

n = 6 rams per BCS category per age group. PSW = pre-slaughter (live) weight. Values are mean  $\pm$  SE. Means within a row bearing different superscripts (a, b) differ significantly ( $p<0.05$ , Duncan's multiple range test).

**Head and legs weight:** Head and legs weight was significantly higher in older rams, averaging  $3.8 \pm 0.2$  kg across BCS categories (Table 6), similar to values reported by Safari *et al.* (2005) in Dorper crosses. As a proportion of live weight, this component declined with increasing BCS in both age groups, since head and leg mass are largely determined by skeletal frame rather than by fat or muscle accretion, so its relative contribution falls as animal gains condition.

Table 6. Head and legs weight of Nellore brown rams by body condition score and age group

| BCS | 1-yr wt (kg)    | 1-yr (% PSW) | 2–3-yr wt (kg)  | 2–3-yr (% PSW) |
|-----|-----------------|--------------|-----------------|----------------|
| 2.0 | $3.0 \pm 0.2^a$ | 12.4         | $3.6 \pm 0.2^b$ | 11.9           |
| 3.0 | $3.1 \pm 0.2^a$ | 11.8         | $3.7 \pm 0.2^b$ | 11.4           |
| 4.0 | $3.2 \pm 0.2^a$ | 11.2         | $3.8 \pm 0.2^b$ | 11.2           |
| 5.0 | $3.3 \pm 0.2^a$ | 10.7         | $3.9 \pm 0.2^b$ | 11.1           |

n = 6 rams per BCS category per age group. PSW = pre-slaughter (live) weight. Values are mean  $\pm$  SE. Means within a row bearing different superscripts (a, b) differ significantly ( $p<0.05$ , Duncan's multiple range test).

**Hot carcass weight and dressing percentage:** HCW and DP both increased significantly with BCS and age ( $p<0.05$ ) and were strongly correlated with BCS ( $r=0.85$ ,  $p<0.01$ ), reaching a maximum of  $17.1 \pm 0.7$  kg and  $48.5 \pm 1.2\%$  in 2–3-year-old rams at BCS 5.0 (Table 7) comparable to the 47–50% dressing percentages reported for Washera

sheep by Mengistie *et al.* (2010). The significant BCS  $\times$  age interaction ( $p < 0.05$ ) indicated that older rams benefit disproportionately from improved condition, consistent with greater muscle maturity and a higher rate of fat deposition relative to bone growth in mature animals (Bhatta *et al.* 2019). From a nutrient-partitioning perspective, this pattern was consistent with the general growth sequence in ruminants, in which skeletal and organ growth predominate early in life while, once skeletal maturity is approached, a progressively larger share of absorbed nutrients is redirected toward muscle and then adipose tissue; because older rams have largely completed frame growth, additional condition in this group translates more directly into carcass (muscle plus fat) yield than into non-carcass tissue, whereas younger rams still allocate a meaningful share of intake to skeletal development regardless of BCS. These results carry a direct economic implication for Nellore Brown production systems: finishing rams to BCS 4.0–5.0, particularly in the 2–3-year-old group, which is likely to yield a disproportionately larger increase in saleable carcass output per unit of additional feed than finishing younger animals to the same score, which should be weighed against the added feeding costs and time to reach that BCS.

Table 7. Hot carcass weight (HCW, kg) and dressing percentage (DP, %) of Nellore Brown rams by body condition score and age group

| BCS | 1-yr HCW (kg)               | 1-yr DP (%)                 | 2–3-yr HCW (kg)             | 2–3-yr DP (%)               |
|-----|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| 2.0 | 10.3 $\pm$ 0.5 <sup>a</sup> | 42.7 $\pm$ 1.0 <sup>a</sup> | 13.7 $\pm$ 0.7 <sup>b</sup> | 45.4 $\pm$ 1.1 <sup>b</sup> |
| 3.0 | 11.2 $\pm$ 0.4 <sup>a</sup> | 42.6 $\pm$ 0.9 <sup>a</sup> | 14.9 $\pm$ 0.6 <sup>b</sup> | 45.8 $\pm$ 1.0 <sup>b</sup> |
| 4.0 | 12.4 $\pm$ 0.6 <sup>a</sup> | 43.5 $\pm$ 1.1 <sup>a</sup> | 15.8 $\pm$ 0.8 <sup>b</sup> | 46.7 $\pm$ 1.2 <sup>b</sup> |
| 5.0 | 13.6 $\pm$ 0.6 <sup>a</sup> | 44.3 $\pm$ 1.1 <sup>a</sup> | 17.1 $\pm$ 0.7 <sup>b</sup> | 48.5 $\pm$ 1.2 <sup>b</sup> |

n = 6 rams per BCS category per age group. HCW = hot carcass weight; DP = dressing percentage = (HCW / pre-slaughter live weight)  $\times$  100. Values are mean  $\pm$  SE. Means within a row bearing different superscripts (a, b) differ significantly ( $p < 0.05$ , Duncan's multiple range test).

*Correlations among BCS, live weight and slaughter traits:* Pearson correlation coefficients for the principal trait relationships referenced above are summarized in

Table 8. Pearson correlation coefficients among body condition score, live weight and slaughter traits

| Trait pair                                | Pearson r | p-value | Interpretation  |
|-------------------------------------------|-----------|---------|-----------------|
| Live weight $\times$ Drained blood weight | 0.72      | <0.01   | Strong positive |
| BCS $\times$ Hot carcass weight           | 0.85      | <0.01   | Strong positive |
| BCS $\times$ Dressing percentage          | 0.85      | <0.01   | Strong positive |

Correlations computed across all animals (n = 48) pooled across age groups.

Table 8. Both BCS–carcass and live weight–blood weight relationships were strong and highly significant, supporting the use of BCS as a practical proxy for expected carcass yield in this breed.

*Limitations:* Sample size per subgroup (n = 6) was relatively small, which limits the precision of subgroup-level estimates and the power to detect smaller interaction effects; findings should be interpreted as indicative rather than definitive until confirmed in larger cohorts. Body composition was inferred from post-slaughter dissection rather than measured in the live animal; future work could incorporate real-time ultrasound assessment of backfat and loin eye area to allow BCS-based prediction of carcass merit prior to slaughter (Lambe *et al.* 2008).

Body condition score was consistently and significantly associated with live weight, non-carcass component weights, hot carcass weight and dressing percentage in Nellore Brown rams, and this relationship was strongest, and economically most favorable, in 2–3-year-old animals. Rams scoring 4.0–5.0 on the 5-point BCS scale produced the highest carcass yields in both age groups examined. These findings support the use of BCS as a practical, on-farm criterion for selecting animals for finishing and slaughter, and for guiding feeding strategies aimed at reaching optimal condition before slaughter, particularly in mature rams. Because this study was limited to one breed, one production system and modest subgroup sizes, extrapolation of these specific values to other sheep breeds or management systems need to be made cautiously; validation in larger, multi-site cohorts is warranted before the relationships reported here are generalized.

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