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Research Article

Effects of Noug Seed Cake Substitution with Cowpea Hay on Growth Performance in Arsi Bale Sheep

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ABSTRACT

Introduction: The high cost and limited availability of traditional protein dietary supplements constrain sustainable small ruminant production in Ethiopia. Identifying domestically available, less expensive feed sources is crucial for improving sheep productivity and profitability. The present study aimed to evaluate the effects of replacing noug seed cake (NSC; *Guizotia abyssinica*) with graded levels of cowpea (*Vigna unguiculata*).
Methods and materials: The current study was conducted at Adami Tullu Agricultural Research Center, Ethiopia, using 30 yearling intact male Arsi-Bale sheep with an initial body weight of 18.51 ± 0.38 kilograms. Animals were stratified by initial body weight and randomly assigned to one of five nutritional treatment groups (six animals per group) using a randomized complete block design with six blocks. Treatment groups included 100% NSC, 0% CH (T1), 75% NSC, 25% CH (T2), 50% NSC, 50% CH (T3), 25% NSC, 75% CH (T4), and T5 0% NSC, 100% CH (T5), with wheat bran held constant across all groups and Rhodes grass hay provided *ad libitum* as the basal roughage. Feed intake, body weight changes, carcass characteristics, and economic parameters were evaluated.
Results: Replacement of NSC with CH did not significantly affect final body weight, total weight gain, average daily gain, hot carcass weight, dressing percentage, or most non-carcass components. Net returns increased gradually as NSC substitution with CH increased, rising from 1325.20 ETB in Group T1 to 1754.55 ETB in Group T5. Groups T2 and T3 yielded higher net returns than the control treatment.
Conclusion: Replacing NSC with CH did not significantly alter growth performance or carcass characteristics of Arsi-Bale lambs, while net returns increased progressively with increasing replacement levels. Cowpea hay may therefore serve as a locally available alternative protein feed for sheep, particularly where conventional protein supplements are costly or limited.

1. Introduction

There is a large and diverse livestock population in Ethiopia, comprising approximately 61.5 million cattle, 33.0 million sheep, 39.0 million goats, and 59.4 million poultry, among other livestock species[1]. The livestock sector plays an important role in household food security, income generation, employment, agricultural production, and the national economy[2]. However, livestock productivity remains below its potential due to several constraints, including inadequate feed supply and quality, animal health problems, and limited access to improved management practices[3].

Sheep are one of the most important livestock species in Ethiopia and contribute substantially to household income, food supply, and livelihood security. Ethiopian sheep exhibit significant genetic and phenotypic diversity, reflecting adaptation to a wide range of agroecological conditions. Genetic and morphological studies have identified 14 traditional sheep populations and proposed classifying them into six breed groups and nine breeds[4,5]. Despite this diversity and adaptability, sheep production is generally marked by low productivity, particularly in smallholder production systems.

One of the major constraints to sheep production in Ethiopia is the limited availability of good-quality feed, especially during the dry season[6]. Natural pastures and crop

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residues are major feed resources, however, they are often of poor, nutritional quality, with relatively low CP and high fibre contents, which can limit nutrient supply and animal performance[7,8]. Supplementation with protein-rich feeds is therefore an important strategy for improving the use of low-quality basal diets and enhancing sheep performance[9,10].

Within the context of Ethiopian sheep production systems, noug seed cake (NSC; *Guizotia abyssinica*) represents a significant protein supplement from locally available feed materials. This agricultural product serves as a conventional protein supplementation option in sheep nutritional systems. According to Shitaneh et al.[10], a CP concentration of 36.5% was observed in NSC during a feeding trial with Gumuz lambs. The application of this material as a protein supplement can enhance nutrient availability and livestock performance in the basal diet and supplementation level. However, the limited availability and high cost of conventional protein supplements may restrict their adoption among smallholder farming operations, creating a need to identify regionally accessible and economically viable substitutes.

Cowpea (*Vigna unguiculata*) is a valuable forage legume option because of its relatively high protein concentration, adaptability to diverse environments, and potential to provide both grain and forage. Studies undertaken in Ethiopia have revealed considerable genetic diversity among cowpea cultivars regarding herbage and nutritional composition. Agza et al.[1] reported considerable forage production and CP concentrations across cowpea cultivars assessed in the northwestern lowland regions of Ethiopia, whereas Lemore et al.[7] indicated that cowpea herbage dry-matter accumulation and certain nutritional characteristics were influenced by both genotypic and environmental factors. The mentioned characteristics make cowpea hay (CH) as a potentially valuable protein supplement for livestock, particularly in circumstances where conventional protein feeds are costly or challenging to obtain.

Recent studies also indicates that CH possesses the capacity to serve as a substitute for NSC in sheep diets. Shitaneh et al.[10] conducted an assessment of CH as a replacement for NSC in Gumuz lambs and determined that CH could effectively substitute NSC while preserving adequate nutrient intake, growth performance, carcass characteristics, and economic viability. Nevertheless, information on the response of Arsi-Bale sheep to graded replacement of NSC with CH, particularly when Rhodes grass hay is used as the basal diet, remains insufficient. Consequently, the present study aimed to assess the impacts of replacing NSC with CH on feed intake, productive performance, meat quality attributes, and economic returns of Arsi-Bale sheep maintained on Rhodes grass hay as a basal diet.

2. Materials and Methods

2.1. Ethical approval

The study was conducted at the Oromia Agricultural Research Institute (OARI), Adami Tulu Agricultural Research Center (ATARC), Batu, Ethiopia. All experimental procedures involving animals were conducted in accordance with the institution's established guidelines pertaining to animal care and welfare. Throughout the study period, all sheep were treated humanely, with comprehensive protocols implemented to reduce stress and ensure health and wellbeing standards.

2.2. Study location

The study was conducted at the Adami Tulu Agricultural Research Center (ATARC), located in the central Rift Valley of Ethiopia, approximately 167 km south of Addis Ababa. The center lies at an approximate elevation of 1,650 meters above the sea level. The area exhibits semi-arid to sub-humid agroecological conditions and is predominantly dominated by Acacia woodland ecosystems. The region receives an approximate mean annual precipitation pattern of 760 mm, with a bimodal and variable distribution typical of the Rift Valley. The mean minimum temperature is approximately 12.6°C, while the mean maximum temperature reaches 27°C. The dominant soil consists of sandy loam, comprising approximately 34% sand, 38% silt, and 18% clay, providing relatively good drainage.

2.3. Diet

The dietary protocol incorporated Rhodes grass (*Chloris gayana*) hay as the foundational coarse forage component, with supplementary concentrate formulations in which cowpea (*Vigna unguiculata*) hay replaced NSC at progressively increasing proportions. Cowpea cultivation followed established forage production methods and was harvested at approximately 50% flowering. The harvested forage was dried in the shade and stored in well-ventilated conditions to minimize nutrient loss and spoilage. Similar procedures for producing CH for sheep feeding have been reported in Ethiopia, where cowpea was harvested at 50% flowering and conserved in the shade[6]. A local feed industry formulated and manufactured the concentrates to incorporate dried cowpea forage at the respective treatment levels. Feeding occurred twice daily at 08:00 and 16:00 hours. Rhodes grass hay was available without restriction and offered *ad libitum*, and feed offered and refused were recorded daily. Feed allocation was adjusted based on previous intake to ensure adequate feed availability throughout the experimental period. Potable water of appropriate quality was provided twice daily.

2.4. Animals

Thirty intact yearling male Arsi-Bale sheep with an average initial body weight (IBW) of 18.51 ± 0.38 kg (range: 18.5-24.6 kg) and approximately 12 months of age were purchased from local markets for the study. Upon their arrival, the animals underwent a 15-day quarantine and adaptation period to facillitate acclimatization and comprehensive health screening prior to the feeding experiment. During the adaptation period, the animals were vaccinated against endemic pathogens, including pasteurellosis, anthrax, and sheep pox, using commercially procured vaccines manufactured by the National Veterinary Institute in Bishoftu, Ethiopia, in accordance with veterinary guidelines. Following completion of the quarantine and

adaptation period, each sheep was individually identified and randomly allocated to the treatment groups. All animals were maintained in an isolated, well-ventilated pen equipped with a dedicated feeding trough to permit accurate measurement of feed intake and prevent competition. During the experimental period, conventional management was maintained consistent with established sheep feeding trials.

2.5. Experimental design and treatments

The current study was conducted using a randomized complete block design comprising five dietary treatments and six blocks, encompassing 30 intact male Arsi-Bale sheep. The animals were grouped into six blocks by IBW, ensuring each block included one animal from each treatment group. Experimental treatments were randomly assigned among animals within each block to minimize variation associated with differences in IBW. Blocking animals according to IBW is a standard approach in agricultural experiments where initial variation among experimental units may influence subsequent responses. The experimental dietary treatments involved systematically substituting NSC with CH at progressive levels of 0%, 25%, 50%, 75%, and 100% of the NSC component, designated as treatments T1, T2, T3, T4, and T5, respectively. The quantities of NSC and CH were adjusted proportionally to each replacement level, while wheat bran was maintained at a consistent concentration across treatment groups. Rhodes grass hay was provided without restriction as the basal roughage component. Consequently, the substitution treatments varied the nutritional composition of the concentrate formulations, with notable differences, particularly in CP content.

2.6. Feeding trial and data collection

The feeding trial was conducted over a 90-day period, following an initial 15-day quarantine and adaptation phase. During the experimental period, each sheep was provided with feed individually, and feed intake was recorded daily. Rhodes grass hay was offered *ad libitum*, while the designated concentrate formulations were distributed according to the treatment allocation. Daily measurements were taken of both the quantity of feed provided and the quantity refused by each animal, with periodic adjustments to the offered amount based on previous intake to maintain adequate feed availability.

Representative samples of the feed ingredients, concentrate mixtures, and refusals were collected during the experimental period to facilitate the determination of their chemical composition. Feed samples were obtained at regular intervals, pooled by feed category or treatment, and maintained under suitable storage conditions prior to laboratory analysis. The daily dry matter intake (DMI) of each animal was determined by the difference between the quantity of feed offered and the quantity of feed rejected, after adjustment for their respective dry matter (DM) contents. Throughout the experimental period, all animals were provided potable water of appropriate quality. Animals were monitored regularly to assess the health status, and any abnormal clinical signs or health-related events were recorded

2.7. Live weight change

Body weight of each experimental sheep was recorded at the beginning of the feeding trial and subsequently at 14-day intervals throughout the 90-day experimental period. Weighing was conducted in the morning before feeding utilizing a weighing scale. The total weight gain (TWG) was determined using Formula 1 by calculating IBW and final body weight (FBW). Average daily gain (ADG) was calculated using Formula 2.

$$TWG\ (kg) = FBW - IBW \quad \text{(Formula 1)}$$

$$ADG\ (g/day) = (FBW - IBW) \times 1000 / \text{Number of feeding days} \quad \text{(Formula 2)}$$

Feed conversion ratio (FCR) was calculated as the amount of DMI required to produce one unit of body-weight gain according to Formula 3.

$$FCR = DMI\ (kg/day) / ADG\ (kg/day) \quad \text{(Formula 3)}$$

Body weight was measured at the beginning of the experiment and at regular intervals throughout the feeding period to monitor changes in live weight and compare growth responses among dietary treatments. Body-weight gain and feed-utilization metrics represent critical assessment tools for evaluating the response of sheep to alternative protein supplements, including CH used to replace NSC[6].

2.8. Carcass characteristics

Upon completion of the 90-day feeding trial, all sheep were fasted overnight with unrestricted water access prior to being weighed and slaughtered. The slaughtering procedure was carried out by means of severing the jugular vein and carotid arteries. After bleeding, the animals underwent dermal removal, were eviscerated, and the gastrointestinal tract was removed. The gastrointestinal tract was assessed gravimetrically before and after evacuation to determine the empty body weight (EBW). Mesenteric fat and other edible and non-edible offal components were also recorded.

The hot carcass weight (HCW) was recorded immediately after dressing, while the carcasses were subsequently chilled for 24 hours and weighed to obtain the cold carcass weight (CCW). The dressing percentage (DP) was determined by calculating as the ratio of HCW to slaughter weight (SW) multiplied by 100. The rib-eye area (REA) was measured on the exposed surface between the 11th and 12th ribs after the chilling process. The exposed REA was traced on paper and subsequently measured using graph paper measurement techniques. The carcass components were systematically separated into three distinct components, including muscle tissue, fat tissue, and bone fractions. Each fraction was individually weighed and quantified as a percentage of the total dissected carcass weight. Muscle-to-bone and muscle-to-fat ratios were calculated by dividing muscle weight by bone and fat weight, respectively[10].

2.9. Chemical analysis

During the feeding trial, representative samples of Rhodes grass hay, comprising concentrate ingredients, concentrate mixtures, and feed refusals were collected. The samples were oven-dried at 65°C for 72 hours, ground to pass through a 1-mm sieve, and subsequently preserved in airtight containers pending analysis. Dry matter, ash, organic matter, and nitrogen (N) contents were determined in accordance with the procedures of AOAC[11]. The CP was calculated as N × 6.25[11]. Neutral detergent fibre (NDF), acid detergent fibre (ADF), and acid detergent lignin were determined using detergent-fibre procedures for feed analysis. These analytical procedures were subsequently applied to the feed ingredients, concentrate mixtures, Rhodes grass hay, and refusal samples.

2.10. Partial budget analysis

A partial budget analysis was performed to evaluate the economic feasibility of the feeding interventions, recording all variable expenditures incurred during the experiment, including feed expenses, livestock purchase costs, veterinary services, labor compensation, and operational costs[12]. The production cost of cowpea forage was determined by summing expenses for land preparation, associated with planting, weeding, harvesting, and seed procurement using Formula 4.

$$PCcf = LP + PL + WD + HV + SC \quad \text{(Formula 4)}$$

The PCcf represents the total production cost of cowpea forage (ETB ha^{-1}), and LP, PL, WD, HV, and SC denote land preparation, planting, weeding, harvesting, and seed procurement costs, respectively.

Net income (NI) was calculated as the difference between total return (TR) and total variable cost (TVC) using Formula 5.

$$NI = TR - TVC \quad \text{(Formula 5)}$$

The NI represents net income (ETB $animal^{-1}$), TR is total return from sale of sheep (ETB $animal^{-1}$), and TVC is total variable cost incurred during the feeding period. The TVC is further calculated using Formula 6.

$$TVC = FC + OC \quad \text{(Formula 6)}$$

The FC represents feed cost (ETB $animal^{-1}$), and OC represents other variable costs.

The partial budget formulas employed are consistent with standard economic assessment methods used for livestock feeding trials, as demonstrated in comparable studies evaluating feed supplementation strategies in sheep. In this approach, net return is determined by deducting total variable costs from total returns, and the marginal rate of return is calculated to assess the economic feasibility of dietary interventions.

2.11. Statistical analysis

Data on feed intake, growth performance, and carcass trait measurements were analyzed using the General Linear Model (GLM) procedure in SAS software version 9.0 (SAS Institute Inc., Cary, NC, USA). Within the framework of randomized block design, the observed response for the ith treatment administered in the jth block is modeled as $Yij=\mu+Ti+Bj+Eij$. In this formula, Yij represents the observed response variable for the combination of treatment i and block j, μ is the overall mean common to all observations, Ti signifies the effect of the ith treatment (reflecting the systematic variation attributable to that particular treatment), Bj denotes the effect of the jth block (reflecting the systematic variation attributable to that block), and Eij represents the random experimental error associated with the observation, capturing unexplained variation not accounted for by the overall mean, treatment effects, or block effects. A p-value of 0.5 or less was considered significant. Data of the present study were reported as means ± standard deviation (SD).

3. Results and Discussion

3.1. Chemical composition of the experimental diet

The chemical composition of the experimental diets administered to Arsi-Bale sheep, which were fed Rhodes grass hay as a basal diet and supplemented with varying proportions of CH and NSC, is presented in Table 1.

Table 1. Chemical composition of the experimental diets fed to Arsi-Bale sheep during the 90-day feeding period (% of dry matter)

Experimental diets	DM	Ash	CP	NDF	ADF	ADL
T1	92.97	9.55	31.03	32.83	15.92	7.38
T2	91.77	7.95	28.64	33.68	17.04	7.83
T3	90.40	7.76	28.30	33.18	19.70	7.71
T4	90.76	8.67	27.72	33.24	17.45	7.99
T5	90.20	9.47	23.86	32.96	17.96	8.19
Rhodes grass hay	91.46	11.22	8.14	72.59	47.36	5.92

DM: Dry matter, CP: Crude protein, NDF: Neutral detergent fibre, ADF: Acid detergent fibre, ADL: Acid detergent lignin, NSC: Noug seed cake, CH: Cowpea hay. T1: 100% noug seed cake and 0% cowpea hay, T2: 75% noug seed cake and 25% cowpea hay, T3: 50% noug seed cake and 50% cowpea hay, T4: 25% noug seed cake and 75% cowpea hay, and T5: 0% noug seed cake and 100% cowpea hay

The DM content of Rhodes grass hay in the present study was 91.46%. Crude protein decreased progressively from 31.03% in T1 to 23.86% in T5, while NDF remained relatively similar among the concentrate mixtures. The reduction in CP reflects the lower protein concentration of CH compared with NSC in the present experiment[1]. Consequently, these dietary formulations cannot be considered as isonitrogenous, and the physiological

responses observed in the animals should be interpreted within the context of their nutrient composition disparities.

The CP content of NSC in the present study (31.03%) was notably lower than the 36.5% reported by Shitaneh et al.[10] in NSC used in a sheep-feeding experiment in Ethiopia. This difference may be attributable to variation in seed quality, oil extraction efficiency, processing methods, and storage conditions. The cowpea hay used in the current study contained 23.86% CP, higher than the 18.31% reported by Shitaneh et al.[10]. This discrepancy may be associated with variation in cowpea genotype, growing environment conditions, soil fertility, agronomic management, and harvesting stage. Nevertheless, the CP concentration observed in the present study indicates that CH can provide a substantial source of dietary protein for sheep. Rhodes grass hay contained relatively low CP (8.14%) and high NDF (72.59%) and ADF (47.36%)[4]. This nutritional profile indicates that the basal roughage was relatively fibrous and protein deficient. Consequently, supplementation with protein-rich feeds, including NSC and CH, was essential to enhance the overall nutrient supply of the experimental diets. The ash content demonstrated variability across the experimental diets; however, no consistent pattern was observed in relation to the levels of CH replacement.

3.2. Body weight

The IBW, FBW, TWG, ADG, FCR, and feed intake of Arsi-Bale sheep fed diets containing different proportions of NSC and CH are presented in Table 2.

Table 2. Final body weight and weight gain of Arsi-Bale sheep fed noug seed cake and cowpea hay over a 90-day period

Parameters \ Groups	T1	T2	T3	T4	T5	Overall mean
IBW (kg)	18.59 ± 0.610	18.43 ± 0.698	19.01 ± 0.704	18.21 ± 1.110	18.26 ± 1.312	18.51 ± 0.381
FBW (kg)	25.22 ± 0.431	25.28 ± 0.613	25.52 ± 0.691	24.89 ± 1.070	24.60 ± 1.197	25.11 ± 0.351
TWG (kg)	6.63 ± 0.314	6.85 ± 0.695	6.51 ± 0.576	6.68 ± 0.479	6.34 ± 0.619	6.60 ± 0.224
ADG (g/day)	73.61 ± 3.486	76.11 ± 7.720	72.32 ± 6.398	74.26 ± 5.326	70.45 ± 6.879	73.35 ± 2.486
Feed intake (kg/day)	0.482 ± 0.011	0.480 ± 0.020	0.402 ± 0.081	0.492 ± 0.022	0.497 ± 0.027	0.469 ± 0.019
FCR	15.27	15.86	17.99	15.09	14.18	15.67

IBW: Initial body weight, FBW: Final body weight, TWG: Total weight gain, ADG: Average daily gain, FCR: Feed conversion ratio. T1: 100% noug seed cake and 0% cowpea hay, T2: 75% noug seed cake and 25% cowpea hay, T3: 50% noug seed cake and 50% cowpea hay, T4: 25% noug seed cake and 75% cowpea hay, and T5: 0% noug seed cake and 100% cowpea hay. Data are presented as mean ± SD.

No significant differences were observed among treatments in IBW, FBW, TWG, or ADG ($p > 0.05$). Final body weight ranged from 24.60 kg in T5 to 25.52 kg in T3, while ADG ranged from 70.45 to 76.11 g/day. The highest numerical ADG was indicated in T2, whereas T5 had the lowest. Feed intake ranged from 0.402 to 0.497 kg/day, with the lowest value recorded in T3. Overall, the numerical variations in feed intake and growth performance did not indicate a consistent response to increasing replacement of NSC with CH. The overall FBW of 25.11 kg was comparable with values reported for Arsi-Bale sheep under other feeding conditions. Wegi et al.[13] evaluated yearling Arsi-Bale sheep fed varieties of faba bean straw supplemented with concentrate during a 90-day feeding period. Variations observed across the studies may be attributable to differences in IBW, basal diet, supplement composition, nutritional supply, and feeding management. Similarly, Shitaneh et al.[10] reported significant effects of replacing NSC with CH on ADG and feed conversion efficiency in Gumuz lambs, whereas no significant treatment effects on growth performance were observed in the present study. Differences may be associated with breed, dietary formulation, nutrient composition, and experimental conditions. Based on the stated FCR calculation, feed conversion ranged from 17.99 in T3 to 14.18 in T5. Although T3 had the highest numerical FCR, this difference should not be interpreted as a treatment effect because statistical significance was not established. Overall, replacing NSC with CH did not significantly affect the growth performance of Arsi-Bale sheep under the conditions of the present study.

3.3. Carcass characteristics

The SW, EBW, HCW, CCW, DP, and REA of the experimental sheep are presented in Table 3. None of the measured carcass characteristics differed significantly among treatments ($p > 0.05$). Slaughter weight ranged from 23.47 kg in T5 to 25.28 kg in T4, while HCW ranged from 9.07 to 9.87 kg. The CCW varied from 8.56 kg in T5 to 9.39 kg in T4. Dressing percentage was relatively similar among treatments, ranging from 38.67 to 39.33%. Rib-eye area ranged from 6.07 cm^2 in T1 to 7.83 cm^2 in T4. Although numerical differences were observed, they were not statistically significant and therefore did not indicate a treatment effect. Carcass responses were comparable across dietary treatments, suggesting that replacing NSC with CH did not substantially alter carcass development in Arsi-Bale sheep. This lack of variation may be attributed to the relatively similar growth performance and FBW across treatment groups. Discrepancies between the current findings and those reported in previous studies may reflect variation in breed, IBW, SW, dietary composition, nutrient supply, and management conditions. Overall, substituting NSC with CH at the tested levels did not significantly affect the measured carcass characteristics of Arsi-Bale sheep under the conditions of the present study. The obtained results can also be compared with those of Shitaneh et al.[10], who evaluated CH as a replacement for NSC in Gumuz lambs. Shitaneh et al.[10] reported significant differences in HCW and REA among treatment groups, whereas in the present study these traits did not differ significantly among treatment groups. Accordingly, the differences between these two

studies may be associated with variation in breed, basal roughage, dietary formulation, supplement level, and other experimental conditions. Table 4 represents the proportions of muscle, fat, and bone and their ratios.

Table 3. Carcass characteristics of Arsi-Bale sheep fed noug seed cake and cowpea hay over a 90-day period

Parameters \ Groups	T1	T2	T3	T4	T5	Overall mean	p-value
EBW (kg)	23.97 ± 1.51	24.37 ± 1.07	24.32 ± 1.51	25.58 ± 1.33	22.95 ± 1.39	24.44 ± 0.50	> 0.05
SW (kg)	24.67 ± 0.92	24.67 ± 1.01	24.68 ± 1.21	26.28 ± 1.69	23.47 ± 1.34	24.55 ± 0.50	> 0.05
HCW (kg)	9.73 ± 0.35	9.69 ± 1.01	9.55 ± 1.21	9.87 ± 1.69	9.07 ± 1.34	9.58 ± 0.50	> 0.05
CCW (kg)	9.17 ± 0.40	9.16 ± 0.49	9.00 ± 0.71	9.39 ± 0.79	8.56 ± 0.70	9.06 ± 0.25	> 0.05
Dressing percentage (%)	39.44	39.28	38.7	39.04	38.64	39.00	> 0.05
Rib-eye area (cm^2)	6.07 ± 0.52	7.50 ± 0.87	7.33 ± 0.88	7.83 ± 0.44	6.83 ± 0.17	7.11 ± 0.58	> 0.05

EBW: Empty body weight, SW: Slaughter weight, HCW: Hot carcass weight, CCW: Cold carcass weight. T1: 100% noug seed cake and 0% cowpea hay, T2: 75% noug seed cake and 25% cowpea hay, T3: 50% noug seed cake and 50% cowpea hay, T4: 25% noug seed cake and 75% cowpea hay, and T5: 0% noug seed cake and 100% cowpea hay. p > 0.05 indicates that treatment differences were not statistically significant. Data presented as mean ± SD.

Table 4. Proportions of muscle, fat, and bone components of Arsi-Bale sheep fed noug seed cake and cowpea hay over a 90-day period

Parameters \ Groups	T1	T2	T3	T4	T5	Overall mean
Muscle (%)	59.02	62.13	61.25	64.95	64.37	62.36
Fat (%)	28.29	26.60	27.17	25.36	28.74	27.13
Bone (%)	12.69	11.28	11.58	9.69	6.90	10.50
Muscle: Bone ratio	4.65	5.51	5.29	6.70	9.33	5.94
Muscle: Fat ratio	2.09	2.34	2.25	2.56	2.24	2.30

T1: 100% Noug seed cake and 0% cowpea hay, T2: 75% Noug seed cake and 25% cowpea hay, T3: 50% Noug seed cake and 50% cowpea hay, T4: 25% Noug seed cake and 75% cowpea hay, and T5: 0% Noug seed cake and 100% cowpea hay

While statistical significance was not indicated in the analysis, the muscle proportion and the muscle-to-bone ratio were numerically higher in T4 and T5. The obtained results and the numerical differences needed a careful interpretation, as they failed to achieve statistical significance and therefore did not provide sufficient evidence of a treatment effect on carcass composition or lean tissue deposition. The muscle, fat, and bone proportions in the present study were consistent with the carcass tissue findings reported by Wegi et al.[13], who found no significant differences in the proportions of muscle, bone, and fat among Arsi-Bale sheep fed different varieties of faba bean straw with concentrate supplementation.

3.4. Partial budget analysis

Table 5 presents a partial budget analysis evaluating the economic performance of yearling Arsi-Bale sheep receiving different levels of CH as a substitute for NSC. The identical gross return of ETB 5614.40 per sheep across treatments reflects the use of a fixed market value per head. Consequently, differences in net return were mainly associated with differences in feed costs. Substantial differences were observed in the economic returns among treatment groups. Sheep receiving complete substitution (100%) of NSC with CH (T5) demonstrated the highest net return, followed by T4. The higher net return among treatment groups was mainly associated with the lower cost of CH compared with NSC, while growth performance remained statistically comparable among treatment groups. Likewise, Shitaneh et al.[10] evaluated the economic feasibility of substituting NSC with CH and reported the highest profit at the highest level of CH inclusion. The increasing net return observed with higher levels of CH substitution in the present study suggests that CH may provide a cost-effective alternative to NSC within the experimental parameters examined.

Table 5. Partial budget analysis of experimental diets fed to Arsi-Bale sheep over a 90-day period

Parameters \ Groups	T1	T2	T3	T4	T5
Number of sheep	6	6	6	6	6
Initial purchase price/sheep (ETB)	2800	2800	2800	2800	2800
Feed cost/sheep (ETB)	993.84	872.32	672.72	642.73	564.49
Labor cost/sheep (ETB)	440.36	440.36	440.36	440.36	440.36
Veterinary cost/sheep (ETB)	55	55	55	55	55
Total cost/sheep (ETB)	4289.20	4167.68	4038.09	3897.08	3859.85
Gross return/sheep (ETB)	5614.40	5614.40	5614.40	5614.40	5614.40
Net return/sheep (ETB)	1325.20	1446.72	1576.31	1717.32	1754.55

T1: 100% noug seed cake and 0% cowpea hay, T2: 75% noug seed cake and 25% cowpea hay, T3: 50% noug seed cake and 50% cowpea hay, T4: 25% noug seed cake and 75% cowpea hay, and T5: 0% noug seed cake and 100% cowpea hay. ETB: Ethiopian currency

4. Conclusion

The present study indicated that replacing NSC with CH at 25%, 50%, 75%, and 100% did not significantly affect growth performance or carcass characteristics of yearling Arsi-Bale sheep. Therefore, CH can effectively replace NSC

as a protein supplement while maintaining productivity levels, with complete replacement (100%) generating the highest net return. The current results indicated that CH is a nutritionally effective and economically advantageous alternative for sheep fed diets based on Rhodes grass hay.

Declarations

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Authors' contributions

Genet Hailu Dadi solely conducted the conceptualization, methodology, study design, field investigation, data collection, field management, laboratory analysis, data curation, data analysis, interpretation of results, and writing of the original draft. The author reviewed and approved the final edition manuscript for publication.

Availability of data and materials

The datasets generated and/or analyzed during the current study are included in this manuscript. All relevant data supporting the findings of this study are presented within the manuscript. Additional data are available upon reasonable request from the corresponding author.

Competing interests

The author declares no conflicts of interest.

Ethical considerations

This study is being submitted for the first time, and the authors have checked the manuscript for plagiarism, duplication, misconduct, and fabrication. The authors declare that no AI tools were used to prepare this study. The authors accept responsibility for the originality of this study prior to submission and after acceptance.

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