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Ruminants

Effect of Processed Coffee Husk on Feed Intake, Nutrient Digestibility, Body Weight Changes and Economic Feasibility of Bonga Sheep Fed on Natural Pasture Hay as a Basal Diet

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ABSTRACT

Background: Ethiopia is one of the world's coffee producers, generating about 192,000 metric tonnes of coffee husks annually as by-products. The material can be used for ruminant diets to improve the nutrient utilisation of animals. However, coffee husk has toxic compounds, which can be minimised through different processing methods. Though the above techniques can minimise the toxicity level of coffee husk and increase the bioavailability of nutrients, there is scanty information on the comparative efficacy of these techniques, especially in ruminant nutrition.

Objective: The study was conducted to examine the effect of processed coffee husk on feed intake, nutrient digestibility, body weight changes and profitability of Bonga rams based on natural pasture hay.

Methods: In the experiment, 24 rams were used, and the rams were grouped into six blocks based on initial body weight (mean BW 21.5 ± 1.01 kg). The rams were quarantined for 21 days, and each ram was randomly assigned to one of the experimental feed treatments in a randomised complete block design (RCBD). The experimental treatment feeds include 400 g conventional concentrate mix (CM) containing Noug seed cake and wheat bran (T1); 200 g boiled coffee husk + 200 g CM (T2); 200 g roasted coffee husk + 200 g CM (T3) and 200 g raw coffee husk + 200 g CM (T4). The CM was made in the ratio of 1:1. The data collected from the 90-day experimental period were: dry matter and nutrient intakes, initial body weight, final body weight and body weight changes. After the growth experiment, a 7-day digestibility trial was followed by collecting faeces using a harness bag. The data were managed using Microsoft (MS) Excel 2010 and analysed using R software (v. 4.3.2). The chemical compositions of the CM had maximum crude protein (22%), followed by boiled coffee husk (14.74%), which was higher than natural pasture hay (6.91%) and raw coffee husk (12.4%).

Results: The total dry matter intake ($p < 0.05$), metabolisable energy, and total nutrient intakes of rams were significantly ($p < 0.001$) maximised when rams fed on boiled coffee husk (T2) than raw (T4) and roasted (T4) coffee husk, except for NDF and organic matter intakes. The apparent digestibility of nutrients and feed conversion efficiency were maximised for rams assigned to T2. There was maximum daily body weight gain ($p < 0.001$) when rams were supplemented with boiled coffee husk (T2). Also, body weight changes of rams were significantly ($p < 0.001$) higher for rams supplementation with boiled coffee husk.

Conclusion: Therefore, the boiled coffee husk as an alternative feed resource can be replaced by about half of the commercial CM without adverse effects of anti-nutritional factors and enhance the income of smallholder farmers in the coffee crop-livestock production system.

1 | Introduction

Sheep production plays a prominent role in rural Ethiopia as a livelihood with the provision of mainly meat, skin and wool products. Moreover, sheep are important sources of cash income to avoid the risk of crop failures and socioeconomic services under smallholder farming systems. In mixed crop-livestock production systems, sheep had a share of 63% of net cash income sources at the household level (Terfa et al. 2013). Nevertheless, sheep in Ethiopia are not contributing due to many interlinked problems, among which shortage of quality and adequate feed is among the major constraints that hampered sheep production (Diriba and Kebede 2020; Gobena and Tona 2017). Natural pasture and crop residues are the major feed resources that supply over 90% of feed resources for sheep and other ruminants in the country (CSA 2021). However, the availability of these feed resources is an inadequate due to the expansion of urbanisation, climate changes and poor management practices (Mengistu et al. 2017; Wassie 2020). The current expansion of urbanisation in developing countries has a negative impact on pasturelands and forage cultivation, as it causes land shortages for later activities. On the other hand, the existing scenario of climate change and climate variability has a negative impact on the adequacy and quality of feed resources. Besides this, there is a shortage of compound feeds and improved forages, as well as escalating prices to supplement feed resources, which in turn are the chronic bottleneck challenges to smallholder producers (Negash 2017; Negassa et al. 2016). These recurrent challenges in livestock producers forced smallholder farmers to search for alternative feed resources. There are potential agricultural by-products such as coffee husks (CHs) that are used as alternative feed resources (Bouafou et al. 2011; Franca and Oliveira 2010).

CH is one of the agricultural by-products produced from the coffee bean during processing. Ethiopia is one of the world's coffee producers, generating about 192,000 metric tonnes of CHs annually as by-products (Sime et al. 2017). The material can be used for different functions, such as fermentation products, poultry bedding (litter) and growth media for mushrooms (Franca and Oliveira 2009). Moreover, there is a practice of CH inclusion in the ruminant diet (Wogderess 2016) and Napier grass replacement by 10% CH without a negative effect on cattle performances (Sudarman, Listiawan, and Khodijah 2019). However, the contribution of the CH as an animal feed resource is limited due to the presence of caffeine, tannins, lignin and other polyphenols (Echeverria and Nuti 2017). These components of CH are toxic, but it is detoxified through the drying method (Hoseini et al. 2021) and other processing. Besides this, the CH cooking process is a mechanism for the loss of anti-nutrients caffeine, trigonelline and an increased glucose percentage (Cangussu et al. 2021). Roasting techniques also decreased the trypsin inhibitor activities in soya bean meals (Chufa, Tadele, and Hidosa 2022). Though the above techniques can minimise the toxicity level of CH and increase the bioavailability of nutrients, there is scanty information on the comparative efficacy of these techniques, especially in ruminant nutrition. Hence, the current experiment was conducted to assess the effects of CH boiling and roasting processing techniques on feed intake, digestibility, body weight change and profitability of Bonga rams fatting practices in Ethiopia.

2 | Material and Methods

2.1 | Study Area

The experiment was conducted at the Awurada Youth Association, Decha district, Kaffa Zone, southern Ethiopia. It is located at 486 km from Addis Ababa and about 737 km from Hawassa, and the geographical coordinates are at $07^{\circ}8'$–$07^{\circ}26'$ N of latitude, $35^{\circ}53'$–$36^{\circ}36'$ E of longitude and an altitude of 500–2300 m above sea level. The annual average minimum and maximum temperature of the area were 12.4°C and 26.8°C with precipitation of 1400 and 2000 mm during the experimental year (2021), respectively. The association was purposely selected based on active Bonga sheep fattening practices and their willingness to provide 24 rams of uniform body condition and good health status. This was done based on farmers' visual appraisal criteria in purchasing sheep for fatting (Taye et al. 2021).

2.2 | Experimental Sheep and Feed Preparation

Ethiopia is known for its high population of domestic livestock, including sheep. The sheep production system in Ethiopia is characterised as an extensive system of management based mainly on grazing with little supplementation of concentrates and agricultural by-products. Bonga sheep is one of the largest sheep breeds in the country. It is characterised by long and wide fat tailed with tapering and twisted ends. Both males and females are polled, have short and smooth hair, and mainly convex facial profiles of males and all types of colour but predominantly light red. The breed is known for its docile temperament, fattening potential, meat quality, fast growth and prolificacy (Mamo 2015). These sheep are commonly fed under grazing systems on pastures where they freely graze on open fields.

Natural pasture hay consisting of mixed pasture containing predominantly grass species was obtained from nearby farmers. It was chopped manually into 5–10 cm to increase feed intake and stored under shelter that avoids direct sunlight to maintain its nutrients. It was used as a basal diet and was offered daily as far as a 20% refusal rate. The commercial concentrate wheat bran (WB) and Noug seed cake (NSC) were purchased at the local market. The concentrate mix (CM) (WB, NSC) was a 1:1 ratio. The CH was purchased from the Awurada multipurpose cooperative. The CH was processed with an adaptation of the traditional experience of coffee preparation for an average of 20 min of boiling at 100°C and roasting at 144°C (brown spot formation in ranged 5–8 min) in the community. The total amount of supplement feeds was 400 g/day based on recommendations of CM supplementation to Washera sheep fattening (Abebe 2008). The processed CH (200 g) was mixed with CM (200 g) to maintain the nutrient requirements of the growing tropical sheep.

2.3 | Experimental Design and Treatments

A total of 24 rams uncastrated with an average age of 1.02 years were tagged using an ear tagger for identification and quarantined for 21 days. During this period, each ram was vaccinated against common diseases such as ovine pasteurellosis, sheep pox, blackleg and anthrax using 1 mL ovine pasteurellosis, 1 mL sheep pox and 1/2 mL anthrax, respectively. Albendazole and fasinex were used for deworming against the internal parasite (flat/roundworms), and diazinon was sprayed for ticks and mange. An average of three initial weights were taken after overnight fasting using a spring balance scale (50 kg × 200 g). The rams were blocked based on the initial body weight (21.5 ± 1.01 kg) into six blocks with four rams per block and assigned randomly into one of the four experimental feeds in a randomised complete block design (RCBD). The basal diet (ad libitum), common salt (1%) and water were freely accessed by experimental rams. The treatments were conventional natural pasture hay (C) and 400 g conventional CM (T1), C + 200 g CM + 200 g boiled CH (T2), C + 200 g CM + 200 g roasted CH (T3) and C + 200 g CM + 200 g raw CH (T4). The rams were placed in an individual pen with a dimension of 2 m^2 smooth earth floor, which had partitioned feed troughs. The size of the natural pasture hay trough had a width of 30 cm, a height of 40 cm and a depth of 15 cm. The water and common salt troughs were installed on the left side by the right side at the centre natural pasture hay trough. The supplement feed was offered alone with a mobile bucket for each ram. The four experimental feeds were assigned randomly with a lottery system.

2.4 | Feeding Trial

The natural pasture hays were offered once a day in the morning by measuring the required amount to ad libitum level for the rams. The supplement feeds were CM boiled CHCH, roasted CH and raw CH. The daily supplements were offered in two equal portions at 10 AM and 4 PM. Tap water and common salt (1%) were freely accessible. Data on experimental feed offered and leftovers were collected and weighed every day per individual ram, and feed intake was calculated with the difference between them. The average daily weight gain of the rams was calculated from the difference of final and initial body weight divided by the number of feeding trial days (90 days). The body weights of the rams were measured within the interval 7 days after overnight fasting of the rams. Feed conversion efficiency was computed with the ratio of average daily weight gain (g) to average daily feed intake (g) (Brown, Hindmarsh, and McGregor 2001).

2.5 | Digestibility Trial

The digestibility trial was continued for 7 days after the feeding trial, using all rams under the feeding trial. The rams were harnessed with faeces collection bags and adapted for 3 days. The representative samples were prepared using 20% of subsamples of fresh faecal collection every day. It was preserved at a temperature of −20°C for 7 days. The faecal samples were thawed at room temperature. The samples were mixed to prepare composite samples and dried at 60°C for 72 h. The apparent digestibility coefficient of current feed nutrients as a percentage was estimated from the difference of nutrient intake and nutrient in faecal (out) divided by total nutrient intake.

2.6 | Chemical Composition Analysis

The dried sample of offered feeds and collected natural pasture leftovers and faecal samples from each treatment during this trial were milled and passed through a 1 mm sieve size. The proximate analysis procedures were employed for the chemical composition analysis of representative samples for dry matter (DM), crude protein (CP) using the conventional Kjeldahl method, and ash content (AOAC 1990). The content of ash was obtained from overnight (24 h) ignited samples using a muffle furnace at 550°C. The neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) content of the samples were analysed with the procedure of the Van Soest method (Van Soest, Robertson, and Lewis 1991). The metabolisable energy (MEI) intake of experimental sheep was estimated from digestible organic matter intake using the formula ME (MJ/kg) = 0.0157 × DOMI g/kg (AFRC 1993), where DOMI = digestible organic matter intake per kg of DM.

2.7 | Data Analysis

The data collected were organised with Microsoft Excel 2010. Before the analysis of variance (ANOVA), the normality test of data was undertaken using the Shapiro–Wilk test. ANOVA was performed for these data at a significance level of $p < 0.05$. The least significant difference (LSD) test was used to separate treatment mean differences ($p < 0.05$). The general linear model (GLM) was employed to data analysis which is deployed in R software v. 4.3.2 through packages agricolae version 1.3-5 (R Core Team 2022). It was fitted to the following formula:

$$Y_{ij} = \mu + B_i + T_j + e_{ij}, \quad (1)$$

where

- Y_{ij} ram performance at ith block and jth treatment
- μ overall mean
- B_i random effect of block
- T_i fixed effect of treatment
- e_{ij} residual errors

2.8 | Partial Budget Analysis

A partial budget analysis was calculated to determine the economic feasibility of CH as an alternative supplement to natural pasture hay offered to Bonga rams. It was calculated according

TABLE 1 | The chemical composition of natural pasture hay, concentrate mix and processed and raw coffee husk.

Experimental feeds	Chemical composition (% in DM)					
	DM	OM	CP	NDF	ADF	ADL
Natural pasture hay	91.08	89.54	6.91	68.94	34.39	8.51
Concentrate mix	93.11	91.71	22.24	55.295	20.76	4.30
Boiled coffee husk	91.72	93.47	14.74	77.81	53.93	16.48
Roasted coffee husk	91.05	93.98	14.21	65.77	52.74	13.57
Raw coffee husk	91.31	93.85	12.40	79.00	62.38	17.41

Abbreviations: ADF = acid detergent fibre; ADL = acid detergent lignin; CP = crude protein; DM = dry matter; NDF = neutral detergent fibre; OM = organic matter.

to a partial budget analysis for the on-farm trial of rams with different supplementary feeds (Ehui and Rey 1992). The total variable costs (TVCs) of this experiment were the purchase of rams, feed market cost, medical cost and labour cost. The total return (TR) was the selling price of the sheep. The price of rams was estimated by experienced sheep dealers in the surrounding area. The net return (NR) was the difference between TR and TVC (NR = TR − TVC). The change in return (ΔNR) was computed as the difference between changes in the total NR of the processed and raw CH (the difference between a total NR of CH and CM [T1]) and change in variable cost (the difference between the TVC of processed and raw CH and CM [T1]) as ΔNR = ΔTR − ΔTVC. The net income change (ΔNI) concerning additional units of expenditures was measured by the marginal rate of return (MRR), which was expressed as MRR = ΔNI/ΔTVC.

3 | Results

3.1 | Chemical Composition of the Experiment Feeds

The chemical composition of the experimental feeds is summarised in Table 1. The CP and DM contents of natural pasture hay were 6.91% and 91.08%, respectively. The CM was comprised of maximum contents of DM (93.00%), organic matter (OM) (91.71%) and CP (22.24%). The processed CH had above 14.00% CP contents. However, the raw CH contained minimum CP (12.40%) and high NDF (79.00%) than the processed CH.

3.2 | Dry Matter and Nutrient Intakes

The DM and nutrient intakes of Bonga rams offered (CM, processed and raw CH) are shown in Table 2. In the current study, high total DM intake ($p < 0.05$) was recorded when rams fed on experimental feed assigned in treatment T1 and followed by T2. The maximum MEI ($p < 0.001$) was recorded in the boiled CH (6.970 MJ/kg DM) and CM (6.875 MJ/kg DM). The minimum MEI of the supplement feed was obtained in the raw CH (4.811 MJ/kg DM). Also, rams responded highly differently to the intake of CP, ADF and ADL when offered processed and unprocessed CHs. However, ram intake of organic matter was comparable between treatments ($p < 0.06$). The rams assigned in the treatment (T1) showed a maximum intake of CP (120.026 g/day) and a minimum intake of ADF (99.887 g/day) and ADL (47.850 g/day). It was followed by treatment (T2) with the intake of CP 113.403 g/day. On the other hand, the rams assigned in treatment (T4) showed a minimum intake of CP (104.525 g/day) and a maximum level of ADF (162.544 g/day). But ADL intake was maximised to 63.249 g/day when rams were supplemented with roasted CH.

3.3 | Apparent Digestibility

The apparent digestibility of nutrients in the current experimental feeds is presented in Table 3. The level of digestibility of each nutrient was strongly ($p < 0.01$) affected when rams were fed on processed and unprocessed CHs. About 57.351% apparent digestibility of DM and 59.781% organic matter were obtained from boiled CH (T2) and less than 50% from raw CH (T4). The apparent digestibility of NDF was statically similar for processed CH and higher than raw CH (28.860%). The ADF was digested more ($p < 0.05$) in the boiled CH (43.126%) and followed by the roasted CH (31.408%). But the minimum apparent digestibility of ADF was recorded from raw CH (20.343%).

3.4 | Body Weight Changes and Feed Conversation Efficiency

The body weight changes and feed conversion efficiency of Bonga rams supplemented with CM and processed and raw CH are presented in Table 4. The initial body weights of the rams were comparable ($p < 0.92$) before the rams were exposed to different feed treatments, whereas the performance of final body weight, body weight change, average daily weight gain and feed conversion efficiency of rams were highly ($p < 0.001$) affected among rams fed on control (T1), raw CH (T2), broiled CH (T3) and roasted CH (T4) under supplementation of CM. The mean final body weights of the rams were 31.280, 30.442 and 28.666 and 25.860 kg, obtained with supplementation of boiled CH, CM and roasted and raw CHs, respectively. The mean body weight gains of ram per day were improved at the rate of 108.296 g/day when half of the CM (200 g) was replaced with boiled CH (200 g). It was also comparable with the CM (T1) in which it was increased with an average body weight gain of 97.960 g/day. The minimum body weight gain (51.777 g/day) was recorded from treatment (T4). The feed conversation efficiency was maximum (0.047 g) for treatment T2 and followed by T1 (0.043 g), whereas it was 0.023 g for raw CH (T4).

3.5 | Partial Budget Analysis

The partial budget analysis results of rams fed on natural pasture hay as a basal diet with supplementation of CM and processed and raw CH are tabulated in Table 5. The maximum TR (61.65 USD) was obtained from rams supplemented with boiled CH in comparison to raw and roasted CH. Raw CH supplementation resulted in a minimum TR (45.02 USD). The MRRs of boiled, roasted and raw CHs were 10.31, 9.77 and 9.33 for T2, T3 and T4, respectively.

TABLE 2 | Dry matter and nutrient intakes of Bonga rams.

Feed intake g/day)	Treatments					
	T1	T2	T3	T4	SEM	*p*-value
Dry matter intake						
NPH DMI	383.878[a]	361.327[ab]	351.516[b]	345.396[b]	19.376	<0.05
Supplement DMI	372.440[a]	369.660[b]	368.320[d]	368.840[c]	0.000	<0.001
Total DMI	756.318[a]	730.987[ab]	719.836[b]	714.236[b]	19.376	<0.05
MEI(MJ/kg DM)	6.875[a]	6.970[a]	6.530[b]	4.811[c]	0.313	<0.001
Nutrient intakes						
Total OMI	759.109	741.008	736.302	725.035	18.526	<0.06
Total CPI	120.026[a]	113.403[b]	107.782[c]	104.525[d]	1.321	<0.001
Total NDFI	512.640	512.037	498.61	521.161	14.892	<0.16
Total ADFI	99.887[c]	140.919[b]	140.169[b]	162.544[a]	12.581	<0.001
Total ADLI	47.850[c]	61.249[b]	66.223[a]	63.249[b]	2.092	<0.001

Note: Means with different superscripts in a row were significantly different at $p < 0.05$, $p < 0.001$ and not significantly different at $p > 0.05$. T1 = conventional natural pasture hay (C) and 400 g conventional concentrate mix (CM); T2 = C + 200 g CM + 200 g boiled coffee husk; T3 = C + 200 g CM + 200 g roasted coffee husk; T4 = C + 200 g CM + 200 g raw coffee husk.

Abbreviations: ADFI = acid detergent fibre intake; ADLI = acid detergent lignin intake; CPI = crude protein intake; DM = dry matter; DMI = dry matter intake; MEI = metabolisable energy intake; NDFI = neutral detergent fibre intake; NPH = natural pasture hay; OMI = organic matter intake; SEM = standard error of means.

TABLE 3 | Apparent digestibility of Bonga rams fed natural pasture hay and supplemented with concentrate mix and processed and raw coffee husk.

Apparent digestibility (%)	Treatments					
	T1	T2	T3	T4	SEM	*p*-value
DM	65.527[a]	57.351[b]	53.669[c]	38.155[d]	2.781	<0.001
OM	67.557[a]	59.781[b]	56.460[c]	42.371[d]	2.825	<0.001
NDF	58.422[a]	48.684[b]	44.840[b]	28.860[c]	4.023	<0.001
ADF	68.146[a]	43.126[b]	31.408[c]	20.343[d]	5.448	<0.001

Note: Means with different superscripts in a row were significantly different at $p < 0.001$. T1 = conventional natural pasture hay (C) and 400 g conventional concentrate mix (CM)400 g concentrate mix (CM); T2 = C + 200 g CM + 200 g boiled coffee husk 200 g boiled coffee husk (CH) + 200 g CM; T3 = C + 200 g CM + 200 g roasted coffee husk 200 g roasted CH + 200 g CM; T4 = C + 200 g CM + 200 g raw coffee husk 200 g raw CH + 200 g CM.

Abbreviations: ADF = acid detergent fibre; DM = dry matter; NDF = neutral detergent fibre; OM = organic matter; SEM = standard error of means.

TABLE 4 | Body weight performance and feed conversion efficiency of rams fed on natural pasture hay as basal diet and supplemented with CM, processed and raw coffee husk.

Parameters	Experimental treatments					
	T1	T2	T3	T4	SEM	*p*-value
IBW (kg)	21.625	21.533	21.625	21.200	1.066	<0.92
FBW (kg)	30.442[a]	31.280[a]	28.666[b]	25.860[c]	1.175	<0.001
BWC (kg)	8.816[a]	9.746[a]	7.042[b]	4.660[c]	1.105	<0.001
ADG (g/day)	97.960[a]	108.296[a]	78.241[b]	51.777[c]	14.470	<0.001
FCE	0.043[a]	0.047[a]	0.034[b]	0.023[c]	0.006	<0.001

Note: Means with different superscripts in a row were significantly different at $p < 0.001$ and not significantly different at $p > 0.05$. T1 = conventional natural pasture hay (C) and 400 g conventional concentrate mix (CM) 400 g concentrate mix (CM); T2 = C + 200 g CM + 200 g boiled coffee husk 200 g boiled coffee husk (CH) + 200 g CM; T3 = C + 200 g CM + 200 g roasted coffee husk 200 g roasted CH + 200 g CM; T4 = C + 200 g CM + 200 g raw coffee husk 200 g raw CH + 200 g CM.

Abbreviations: ADG = average daily weight gain; BWC = body weight change; FBW = final body weight; FCE = feed conversion efficiency; IBW = initial body weight; SEM = standard error of means.

TABLE 5 | Partial budget analysis of rams fed on natural pasture hay as basal diet and supplemented with CM, processed and raw coffee husk.

Parameters	Treatments			
	T1	T2	T3	T4
Number of sheep	6.00	6.00	6.00	6.00
Purchase price of rams (USD/head)	43.03	43.64	43.03	43.06
Total NPH consumed (kg/head)	38.38	36.21	35.36	34.35
Purchase price of NPH (USD/head)	3.45	3.26	3.18	3.09
Total con. mix consumed (kg/head)	36.00	18.00	18.00	18.00
Purchase price of CM (USD/head)	6.84	3.42	3.42	3.42
Total CH consumed (kg/head)	0.00	18.00	18.00	18.00
Purchase price of CH (USD/kg)	0.00	1.00	1.00	1.00
Processing cost (USD/head)	0.00	1.20	1.20	0.08
Medical cost (USD/head)	1.24	1.24	1.24	1.24
Total input cost	10.29	8.88	8.80	7.59
Total return/TR (USD/head)	123.28	114.17	107.22	95.67
Total variable cost/TVC (USD/head)	53.32	52.52	51.83	50.65
Net return/NR (USD/head)	69.96	61.65	55.39	45.02
ΔTVC	-	−0.81	−1.49	−2.67
ΔTNR	-	−8.30	−14.57	−24.94
MRR = ΔTNR/ΔTVC	-	10.31	9.77	9.33

Abbreviations: CH = coffee husk; CM = concentrate mix; MRR = marginal rate of return; NPH = natural pasture hay; USD = United States Dollar; ΔNI = change in net income; ΔTVC = change in total variable cost.

4 | Discussion

4.1 | Chemical Composition of the Experiment Feeds

Natural pasture hay is a major animal feed resource for livestock production at smallholder farmer practices in the area. The CP content of natural pasture hay composed mainly of grass species was minimum (6.91%) to supply optimal rumen fermentation for rams (Table 1). In the current study, the result is comparable to 6.8% of CP, which was reported by Tilaye et al. (2022). Nevertheless, it was lower than the major natural pasture grass species (from 8.46%–12.90% of CP) reported in different parts of Ethiopia (Bayissa, Dugumaa, and Desalegn 2022; Hailecherkos, Asmare, and Mekuriaw 2021). The inconsistency of results might be associated with species composition, handling and production methods of natural pasture hay. Nevertheless, the value of CP is inadequate for the proper biological and physiological processes within the animal, which required greater than 7% CP in the diet (Haddad, Nasr, and Muwalla 2001; Sileshi et al. 2021; Van Soest 1982). Hence, the basal diet used in the present study must have been supplemented with CM as a protein source.

The protein content of the CM (22%) was greater than the maintenance requirements of sheep (Haddad, Nasr, and Muwalla 2001; Sileshi et al. 2021; Van Soest 1982). Similarly, the protein content of boiled CH was about 14.74%, which met the protein requirement of the rams. Hence, it might be a potential candidate to replace animal feed with optimum nutrient content, particularly protein content. It was in line with CH blanching and had more appropriate properties for potential applications in food (Cangussu et al. 2021). The protein content of roasted CH had nearly similar values. The raw CH had minimum protein contents but was not advisable as direct animal feed due to the effect of anti-nutritional factors (Echeverria and Nuti 2017). Thus, the utilisation of locally available agricultural by-products of processed CH in coffee cultivation agroecology is one of the alternative strategies to substitute 50% of the CM to boost rams performances. It is also explained by the previous report on coca pod husk processed with *Aspergillus oryzae* that it can be used as a replacement for 20%–40% commercial concentrates without hurting sheep health (Rakhmani and Puastuti 2022).

4.2 | Dry Matter and Nutrient Intakes

The DM intake was improved by more than 16.751 g/day in comparison to raw CH when the boiled CH was offered to rams (Table 2). This might be due to the effectiveness of the boiling method for loosening the digestible fraction of the plant material and lignin fraction and reducing anti-nutritional factors of the CH. Furthermore, metabolised energy intake of CH was significantly influenced by the types of processing. It was high when rams were supplemented with concentrate and followed by a boiled CH. These results might be due to the loss of anti-nutrients caffeine, an alkaloid (trigonelline) and hydrolysis of polysaccharides such as hemicellulose, pectin and cellulose at high temperatures during boiling (Cangussu et al. 2021). This result showed a similar metabolised energy intake of

Doyogena sheep fed steam-processed sweet lupin (Tilaye et al. 2022).

In the current feeding trial, organic matter and NDF intakes were not affected when rams were fed either processed or unprocessed CH. On the other hand, when the treatment feeds were changed from raw to boiled and roasted CHs, the intake of ADF, ADL and CP by the rams was significantly affected. This indicates that processed CH enhanced the intake of protein more than raw CH, but ADFI and ADLI were inconsistent for roasted (T3) and raw (T4). It might be due to the effect of processing on ADF and ADL. These results confirmed that the intake of nutrients was significantly affected when ram fed processed CH than raw, which is comparable to the nutrient intake of processed sweet lupine (Tilaye et al. 2022). It is similarly reported as an opposite trend between low protein and high NDF, ADF and ADL intake levels for different supplement reports (Mekonnen et al. 2019; Sileshi et al. 2021; Tilaye et al. 2022). Moreover, the rams fed raw and roasted CH characterised a high level of ADF, ADL intake, and the low level of protein might be due to the filling of reticulorumen space and then minimised the intake of protein. This is in line with the nutrient intake of cows, which can be limited due to reticulorumen capacity receiving high-fibre diets (Dado and Allen 1995).

4.3 | Apparent Digestibility

In the present study, rams fed with boiled CH (T2) had maximum apparent digestibility of DMD and OMD in comparison with raw and roasted CH (Table 3). This might be due to the boiling process of CH minimising the content of caffeine, tannins and phenolic acid contents, which enhanced the digestibility of the husk in rams. Boiling as a treatment on mangrove leaves reduces these compounds and increases nutrient digestibility (Basyuni et al. 2023). Moreover, CH blanching also caused hydrolysis of polysaccharides, proteins and alkaloids (Cangussu et al. 2021), which might be a cause for the increment of the apparent digestibility of it in this study, whereas rams fed with roasted CH had minimum apparent digestibility. This could be due to excessive heat treatment during roasting, which caused a change in the texture and retrogradation of crude fibre and decreased the size of the washable fraction (at 136°C), which reduces degradability within the rumen microbes (Ahn et al. 2019; Goelema et al. 1999; Iommelli et al. 2022; Sajilata, Singhal, and Kulkarni 2006). Moreover, the apparent digestibility of ADF significantly deferred between raw and processed CH and CMs. The minimum apparent digestibility of raw CH might be attributed to the high content of NDF and ADF yet not treated as the processed CH.

The apparent digestibility of Bonga ram in this experiment was in line with the apparent digestibility of Washera (Alemu, Animut, and Tolera 2014) and Simada sheep (Dessie et al. 2010) fed a basal diet of natural pasture hay supplemented with *Millettia ferruginea* leaf hay (dried Bribra) and graded levels of CM, respectively. However, it was lower than the report on Doyogena sheep fed a basal diet of natural pasture hay supplemented with steamed sweet lupine (Tilaye et al. 2022). Thus, the apparent digestibility of nutrient differences in the diet of rams might be due to the difference in the breeds of sheep, source of basal diet and supplement feed resources.

4.4 | Body Weight Changes of Rams

The maximum body weight change was comparable with the body weight change of Doyogena sheep fed on processed sweet lupine (soaked) in the same region in south Ethiopia (Tilaye et al. 2022). However, the mean daily weight gain of ram was 108.296 g/day (Table 4), which is lower than the mean weight gain of Doyogena sheep per day fed on a basal diet supplemented with processed sweet lupine (145 g/day) (Tilaye et al. 2022) The daily average body weight gain performance in the current study is higher than the value (56.0–87.7 g/day/h) reported by Mengistu, Assefa, and Tilahun (2020) who performed supplementary feeding of different protein sources for the same breed of sheep in Ethiopia. The discrepancy of reports might be related to the ages of lambs and feeding management practices during the experiments. Moreover, the present finding is higher than Sidama sheep (51.1 g/day), Washera sheep (71 g/day) fed on a basal diet supplemented with 350 g CM (Dessie et al. 2010) and 25% tree lucerne dried leaves and 75% CM (Hailecherkos, Asmare, and Mekuriaw 2021), respectively, in the different parts of Ethiopia. The Bonga sheep breeds with high rate of growth and weight gain with better secondary metabolites (tannins) reduction strategy responses might have improved the performances of this particular breed (Tarekegn, Shitaye, and Gafaro 2022; Yisehak et al. 2016). The feed conversion efficiency was maximised for rams under the treatment of boiled CH. However, it had lower feed conversion efficiency than Washera and Doyogena sheep (Hailecherkos, Asmare, and Mekuriaw 2021; Tilaye et al. 2022). This might be due to genetic differences between sheep breeds and the type of supplement feeds. Hence, based on the maximum body weight changes of rams, boiled CH had the potential to replace 50% of the commercial CM and be used as an alternative supplement feed containing essential nutrients alike. Essential nutrients are significant for rumen microbe and provide nutrients at the tissue level for the host ruminant (McDonald et al. 2002).

4.5 | Partial Budget Analysis

Southwestern Ethiopia is the home of Bonga sheep and a potential coffee production area. Therefore, the CH is a potential feed resource that can be used for fattening sheep. The utilisation of boiled CH as a supplement and the natural pasture hay diet offered to rams increased the income of smallholder farmers. It might be due to the significant mean daily weight gain of the rams, reduction of anti-nutrition factors (caffeine, alkaloids), enhancement of nutrient intakes and apparent digestibility of boiled CH (T2), but raw CH feeding practices reduced the income (T4) (Table 5). Boiled CH can be an economical alternative supplement feed resource used as a substitution for CM (NSC and WB ratio [1:1]).

5 | Conclusion

In the current feeding experiment, Bonga rams fed natural pasture hay as basal diet supplemented with conventional CM and processed and raw CH, which resulted in a highly significant difference in the nutrient intake, apparent digestibility and average daily body weight gain. These variables were maximised when the rams fed on alone the conventional CM and the boiled CH rather than a roasted and raw CH. Boiling CH improved nutrient availability, enhanced feed intake and reduced the adverse effect of anti-nutritional factors. These considerations make direct feeding approaches of raw CHs inappropriate, which may explain the low performance of the rams. Thus, the nutritional value of boiled CH improved the biological performance of the rams and proved to be more cost-effective than other types of raw and roasted CHs and conventional CMs. It can replace about 50% of the CM of NSC and WB ratio (1:1) for better growth performance of rams with maximum total NR in the area of coffee production.

Author Contributions

Lidya Marew: conceptualisation, data curation, formal analysis, investigation, methodology, software, validation, visualisation, writing–original draft. **Fentahun Meheret:** conceptualisation, data curation, formal analysis, funding acquisition, investigation, methodology, software, supervision, validation, visualisation, writing–original draft, writing–review and editing. **Bimrew Asmare:** conceptualisation, data curation, formal analysis, methodology, software, supervision, validation, visualisation, writing–original draft, writing–review and editing.

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The authors have nothing to report.

Ethics Statement

The current research was conducted based on research ethic of Bahir Dar University Research Ethics.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The datasets generated during and/or analysed during the current study are available from the corresponding author upon reasonable request.

Peer Review

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References

Abebe, H. 2008. "Supplementation of Graded Levels of Concentrate Mix on Feed Intake, Digestibility, Live Weight Change and Carcass Characteristics of Washera Sheep Fed Urea Treated Rice Straw." Master's thesis, Haramaya University.

Agricultural Food and Research Council (AFRC). 1993. *Energy and Protein Requirements of Ruminants*. Wallingford, UK: CAB International.

Ahn, J. S., J. S. Shin, M. J. Kim, et al. 2019. "A Study on Comparative Feeding Value of Corn Flakes According to Temperature and Retention Time in the Pressurized Steam Chamber." *Journal of Animal Science and Technology* 61, no. 3: 170.

Alemu, B., G. Animut, and A. Tolera. 2014. "Effect of *Millettia ferruginea* (Birbra) Foliage Supplementation on Feed Intake, Digestibility, Body Weight Change and Carcass Characteristics of Washera Sheep Fed Natural Pasture Grass Hay Basal Diet." *SpringerPlus* 3, no. 1: 50.

AOAC. 1990. *Official Methods of Analysis Association of Official Analytical Chemists*. Washington, DC: AOAC.

Basyuni, M., M. R. Rizaldi, R. Amelia, et al. 2023. "Nutritional Values of *Avicennia marina* Leaves and Its Application as Fodder for Kacang Goat (*Capra aegagrus*)." *Biodiversitas Journal of Biological Diversity* 24, no. 2: 1039–1048.

Bayissa, T., B. Dugumaa, and K. Desalegn. 2022. "Chemical Composition of Major Livestock Feed Resources in the Medium and Low Agroecological Zones in the Mixed Farming System of Haru District, Ethiopia." *Heliyon* 8, no. 2: e09012.

Bouafou, K., B. Konan, V. Zannou-Tchoko, and S. Kati-Coulibally. 2011. "Potential Food Waste and By-Products of Coffee in Animal Feed." *Electronic Journal of Biology* 7, no. 4: 74–80.

Brown, L., R. Hindmarsh, and R. McGregor. 2001. *Dynamic Agriculture. Book 3*. McGraw Hill Education/Australia: McGraw-Hill.

Cangussu, L. B., J. C. Melo, A. S. Franca, and L. S. Oliveira. 2021. "Chemical Characterization of Coffee Husks, a By-Product of Coffea Arabica Production." *Foods* 10, no. 12: 3125.

Chufa, A., Y. Tadele, and D. Hidosa. 2022. "Assessment on Livestock Feed Resources and Utilization Practices in Derashe Special District, Southern-Western Ethiopia: Status, Challenges and Opportunities." *Journal of Animal Science* 5, no. 1: 1–14.

CSA. 2021. "Agricultural Sample Survey Livestock and Livestock Characteristics (Private Peasant Holding)." *Ethiopia Stat Bull* 2: 585.

Dado, R., and M. Allen. 1995. "Intake Limitations, Feeding Behavior, and Rumen Function of Cows Challenged With Rumen Fill From Dietary Fiber or Inert Bulk." *Journal of Dairy Science* 78, no. 1: 118–133.

Dessie, J., S. Melaku, F. Tegegne, and K. J. Peters. 2010. "Effect of Supplementation of Simada Sheep With Graded Levels of Concentrate Meal on Feed Intake, Digestibility and Body-Weight Parameters." *Tropical Animal Health and Production* 42, no. 5: 841–848.

Diriba, L., and T. Kebede. 2020. "Assessments of Breeding Practices, Major Constraints and Opportunities of Sheep and Goat Production in Sinana District, Bale Zone, Ethiopia." *Journal of Dairy, Veterinary & Animal Research* 9: 78–83.

Echeverria, M., and M. Nuti. 2017. "Valorisation of the Residues of Coffee Agro-Industry: Perspectives and Limitations." *Open Waste Management Journal* 10, no. 1: 13.

Ehui, S. K., and B. Rey. 1992. "Partial Budget Analysis for On-Station and On-Farm Small Ruminant Production Systems Research: Method and Data Requirements." In *Small Ruminant Research and Development in Africa: Proceedings of the First Biennial Conference of the African Small Ruminant Research Network*, edited by B. Rey, S. H. B. Lebbie, and L. Reynolds. Nairobi, Kenya: ILRAD.

Franca, A. S., and L. S. Oliveira. 2009. "Coffee Processing Solid Wastes: Current Uses and Future Perspectives." *Agricultural Wastes* 9: 155–189.

Franca, A. S., and L. S. Oliveira. 2010. "Alternative Uses for Coffee Husks—A Solid Waste From Green Coffee Production." In *Chemical, Biological and Environmental Engineering*, edited by G. S. Ashworh and P. Azevedo, 21–24. Nova Publishers.

Gobena, M. M., and M. Tona. 2017. "Sheep Production System, Marketing and Constraints in Ethiopia." *Journal of Biology, Agriculture and Healthcare* 7, no. 19: 34–42.

Goelema, J., A. Smits, L. Vaessen, and A. Wemmers. 1999. "Effects of Pressure Toasting, Expander Treatment and Pelleting on In Vitro and In Situ Parameters of Protein and Starch in a Mixture of Broken Peas, Lupins and Faba Beans." *Animal Feed Science and Technology* 78, no. 1–2: 109–126.

Haddad, S., R. Nasr, and M. Muwalla. 2001. "Optimum Dietary Crude Protein Level for Finishing Awassi Lambs." *Small Ruminant Research* 39, no. 1: 41–46.

Hailecherkos, S., B. Asmare, and Y. Mekuriaw. 2021. "Evaluation of Tree Lucerne (*Chamaecytisus palmensis*) Dried Leaves as a Substitution for Concentrate Mixture on Biological Performance and Socioeconomic of

Washera Sheep Fed on Desho Grass Hay." *Veterinary Medicine and Science* 7, no. 2: 402–416.

Hoseini, M., S. Cocco, C. Casucci, V. Cardelli, and G. Corti. 2021. "Coffee By-Products Derived Resources. A Review." *Biomass and Bioenergy* 148: 106009.

Iommelli, P., F. Zicarelli, N. Musco, et al. 2022. "Effect of Cereals and Legumes Processing on In Situ Rumen Protein Degradability: A Review." *Fermentation* 8, no. 8: 363.

Mamo, M. M. 2015. "On-Farm Performance Evaluation and Community Based Traditional Selection Methods of Bonga Sheep in Adiyo Kaka Woreda, Southern Ethiopia".

McDonald, P., R. Edwards, J. Greenhalgh, and C. Morgan. 2002. *Animal Nutrition*. London: UK: Prentice Hall, Publishers Ltd.

Mekonnen, E., Y. Mekuriaw, F. Tegegne, and B. Asmare. 2019. "Evaluation of Fodder Biomass Yield of Hydroponically-Grown Barley and Oats and the Effects on Intake, Digestibility and Weight Gain of Washera Sheep When Fed as a Supplement to a Basal Diet of Natural Pasture Hay in Ethiopia." *Tropical Grasslands-Forrajes Tropicales* 7, no. 5: 519–526.

Mengistu, A., G. Kebede, F. Feyissa, and G. Assefa. 2017. "Review on Major Feed Resources in Ethiopia: Conditions, Challenges and Opportunities." *Academic Research Journal of Agricultural Science and Research* 5, no. 3: 176–185.

Mengistu, G., G. Assefa, and S. Tilahun. 2020. "Noug Seed (*Guizotia abyssinica*) Cake Substituted With Dried Mulberry (*Morus indica*) and *Vernonia amygdalina* Mixed Leaves' Meal on Growth Performances of Bonga Sheep at Teppi, Ethiopia." *Journal of Nutrition and Metabolism* 2020: 1–10.

Negash, D. 2017. "Review on Compound Animal Feed Processing in Ethiopia: Condition, Challenges and Opportunities." *Journal of Nutrition and Health* 3, no. 2: 60–64.

Negassa, A., B. I. Shapiro, T. Kidane, A. Abdena, and J. Hanson. 2016. *Ex-Ante Assessment of Demand for Improved Forage Seed and Planting Materials Among Smallholder Farmers in Ethiopia: A Contingent Valuation Analysis*. Nairobi, Kenya: International Livestock Research Institute.

R Core Team. 2022. *A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing.

Rakhmani, S. I., and W. Puastuti. 2022. "Utilization of Fermented Cocoa Pod Husk (CPH) as Feed Ingredient for Sheep." In 9th International Seminar on Tropical Animal Production (ISTAP 2021), 26–30. Dordrecht, The Nethelands: Atlantis Press.

Sajilata, M. G., R. S. Singhal, and P. R. Kulkarni. 2006. "Resistant Starch—A Review." *Comprehensive Reviews in Food Science and Food Safety* 5, no. 1: 1–17.

Sileshi, G., E. Mitiku, U. Mengistu, T. Adugna, and F. Fekede. 2021. "Effects of Dietary Energy and Protein Levels on Nutrient Intake, Digestibility, and Body Weight Change in Hararghe Highland and Afar Sheep Breeds of Ethiopia." *Journal of Advanced Veterinary and Animal Research* 8, no. 2: 185.

Sime, W., R. Kasirajan, S. Latebo, et al. 2017. "Coffee Husk Highly Available in Ethiopia as an Alternative Waste Source for Biofuel Production." *International Journal of Scientific and Engineering Research* 8, no. 7: 1874–1880.

Sudarman, A., G. Listiawan, and L. Khodijah. 2019. "The Use of Coffee Husk as Napier Grass Substitution and Its Effect on Madura Cattle Performance." *Jurnal Ilmu Ternak Dan Veteriner* 24, no. 4: 166–172.

Tarekegn, K., Y. Shitaye, and T. Gafaro. 2022. "Does Bonga Sheep Producers' Cooperative Membership Improve Households' Income in Southern Ethiopia?" *African Journal of Science, Technology, Innovation and Development* 14, no. 5: 1253–1264.

Taye, D., Z. Worku, S. Demeke, and M. Etefa. 2021. "Assessment of Sheep Fattening Practices Under Smallholder Farmers in Genji District of West Wollega, Western Oromia, Ethiopia." *International Journal of Veterinary Sciences and Animal Husbandry* 6: 18–25.

Terfa, Z. G., A. Haile, D. Baker, and G. T. Kassie. 2013. "Valuation of Traits of Indigenous Sheep Using Hedonic Pricing in Central Ethiopia." *Agricultural and Food Economics* 1, no. 1: 1–13.

Tilaye, H., B. Asmare, F. Meheret, M. Bezabih, and W. Jane. 2022. "Effect of Processed Sweet Lupin (*Lupinus angustifolius*) Grain Supplementation on Growth Performance and Socioeconomic Feasibility of Doyogena Sheep in Ethiopia." *Veterinary Medicine and Science* 8, no. 5: 2206–2214.

Van Soest, P. J. 1982. *Nutritional Ecology of the Ruminant*. Corvallis, OR: O & B Books Inc.

Van Soest, P. V., J. B. Robertson, and B. A. Lewis. 1991. "Methods for Dietary Fiber, Neutral Detergent Fiber, and Non-Starch Polysaccharides in Relation to Animal Nutrition." *Journal of Dairy Science* 74, no. 10: 3583–3597.

Wassie, S. B. 2020. "Natural Resource Degradation Tendencies in Ethiopia: A Review." *Environmental Systems Research* 9: 1–29.

Wogderess, A. S. 2016. "Available Information on the Feeding Value of Coffee Waste and Ways to Improve Coffee Waste for Animal Feed." *African Journal of Biological Sciences* 3: 243–257.

Yisehak, K., Y. Kibreab, T. Taye, M. Ribeiro Alves Lourenço, and G. P. J. Janssens. 2016. "Response to Dietary Tannin Challenges in View of the Browser/Grazer Dichotomy in an Ethiopian Setting: Bonga Sheep Versus Kaffa Goats." *Tropical Animal Health and Production* 48: 125–131.