Wiley
Advances in Agriculture
Volume 2026, Article ID 5597209, 13 pages
https://doi.org/10.1155/aia/5597209

WILEY

Research Article

Optimizing Growth Performance, Carcass Traits, and Economic Returns in Sasso T44 Chickens via Partial Replacement of Conventional Feed With Locally Sourced Alternative Ingredients

Aklilu Getahun,[1] **Yisehak Kechero**,[1] **Nebiyu Yemane**,[1] **Tadelle Dessie**,[2] and **Wondmeneh Esatu**[2]

[1]*Department of Animal Sciences, Arba Minch University, Arba Minch, Ethiopia*
[2]*International Livestock Research Institute, Addis Ababa, Ethiopia*

Correspondence should be addressed to Aklilu Getahun; pras.071.13@amu.edu.et and Yisehak Kechero; yisehak.kechero@amu.edu.et

Received 3 September 2025; Revised 22 November 2025; Accepted 9 December 2025

Academic Editor: Mukhtar Ahmed

Copyright © 2026 Aklilu Getahun et al. Advances in Agriculture published by John Wiley & Sons Ltd. This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

Poultry farming plays a vital role in improving food security, income generation, and nutrition in Ethiopia, particularly for smallholder farmers. However, the high cost of conventional feed ingredients, such as maize and soybean meal (SBM), poses a significant challenge to sustainable poultry production. This study evaluated the potential of alternative feed ingredients including enset corm (*Ensete ventricosum*), banana kocho (a fermented product derived from banana pseudo-stem), boiled mango and avocado seed kernels, and *Moringa stenopetala* leaves as replacements for commercial feed in Sasso T44 chicken diets. A total of 120 male chickens were assigned to four dietary treatments: 0% (T1), 24.25% (T2), 33.95% (T3), and 42.25% (T4) inclusion levels of alternative feed ingredients, using a completely randomized design (CRD). The results revealed that chickens fed the 24.25% inclusion diet (T2) achieved significantly higher ($p < 0.001$) growth performance in terms of dry matter intake (DMI; 5349.7 g), crude protein intake (CPI; 1250.5 g), body weight gain (BWG; 3158.3 g), and dressing percentage (69.2%). While the control group (T1) had the best feed conversion ratio (FCR = 1.62; $p < 0.001$), T2 recorded the highest performance index (PI; 186.5; $p < 0.001$) and improved carcass traits, including breast and thigh muscle yields ($p < 0.001$). Economic analysis showed T2 offered the highest profitability, with a net return (NR) of 275.18 ETB per chickens and a marginal rate of return (MRR) of 0.44. Despite T4's lower feed cost, its growth and carcass performance were poor. These findings demonstrate that including 24.25% alternative feed ingredients can enhance productivity, carcass quality, and economic efficiency, making it a viable strategy for sustainable poultry production.

Keywords: alternative feed ingredient; carcass characteristics; economic analysis; feed conversion efficiency; growth performance

1. Introduction

Poultry production is a critical component of food security, income generation, and nutritional improvement in Ethiopia, particularly among smallholder farmers and peri-urban households. The Sasso T44 chicken, an internationally commercial dual-purpose strain developed for both meat and egg production has become increasingly popular due to its rapid growth, robust performance under semi-scavenging systems, and greater tolerance of environmental and management stresses compared to fast-growing broilers [1]. In Ethiopia, the breed is promoted through national poultry development programs because it adapts well to diverse agro-ecologies and efficiently utilizes a wide range of feed resources [2].

Nevertheless, despite its expanding adoption, scientific information on Sasso T44's response to locally available nonconventional feed ingredients remains limited.

Rising feed costs remain the major constraint to profitable poultry production, with feed accounting for upto 70% of total production expenses [3]. The heavy reliance on conventional feed ingredients, such as maize and soybean meal (SBM), exacerbates the challenge, as these commodities compete directly with human food supply chains. The urgent need to reduce dependence on expensive imported feeds has shifted attention to locally available alternative feed resources, consistent with global strategies promoting resilient and resource-efficient livestock systems [4, 5].

Ethiopia's diverse agro-ecology offers a variety of underutilized feed resources, including *Ensete ventricosum* (enset) corms, fermented banana kocho, boiled mango and avocado seed kernels, and *Moringa stenopetala* leaves. These materials are either byproducts or low-value plant components that are often discarded despite having nutritional and bioactive properties beneficial for poultry when properly processed [6, 7, 8]. Their selection in this study was, therefore, guided by (i) local abundance and accessibility, (ii) preliminary analyses indicating nutritional potential, and (iii) their capacity to reduce feed cost and environmental waste.

Although these ingredients were incorporated in similar proportions across treatments, the objective was not to imply that they are nutritionally equivalent. Instead, they were intentionally combined to form a composite alternative ingredient, based on complementary nutrient profiles-enset corm as an energy source, banana kocho providing fermentable fiber, fruit seed kernels contributing starch and bioactive compounds, and Moringa leaves supplying high protein and minerals. Comparable inclusion ratios were used to evaluate the functional performance of this composite mixture relative to commercial diets. This approach is supported by literature recommending that experimental feed mixtures be evaluated as unified ingredients when they exhibit synergistic nutritional benefits [9, 10]. Nonetheless, empirical justification remains essential because improper balancing of alternative ingredients can introduce antinutritional factors (ANFs), reduce digestibility, or alter energy density [11, 12].

Previous studies have shown that moderate inclusion of nonconventional feedstuffs (20%–35%) can sustain or improve growth performance in broilers, whereas excessive inclusion may depress feed intake or impair carcass traits [13, 14]. Determining the optimal inclusion rate is therefore essential, particularly for dual-purpose breeds, such as Sasso T44, whose nutrient requirements differ from those of fast-growing broilers [15]. This study evaluates the effects of graded inclusion levels of a composite mixture of enset corm, banana kocho, boiled mango, and avocado seed kernels, and Moringa leaves on nutrient intake, growth performance, feed conversion ratio (FCR), carcass yield, and economic efficiency in Sasso T44 chickens. The findings aim to provide evidence for formulating cost-effective, nutritionally adequate diets based on indigenous feed resources, thereby reducing reliance on conventional ingredients and enhancing sustainable poultry production in Ethiopia. The research also contributes to the Sustainable Development Goals particularly SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action)—by promoting local feed resources as alternatives to imported commodities [16, 17].

2. Materials and Methods

2.1. Description of the Study Area. The experiment was carried out at the poultry farm of the Wolaita Zone Department of Livestock and Fishery Resources in Wolaita Sodo, between February and April 2025. According to the CSA [2], Wolaita Sodo town is located approximately 350 km south of Addis Ababa, with approximate coordinates of 6° 48' N latitude and 37° 42' E longitude. The area experiences an annual temperature range of 18–28°C and receives an average rainfall of 1200–1300 mm per year. The relative humidity of an area during the rainy season (March to October) tends to be high, often ranging from 60% to 80% or higher. The study area identified potential feed resources for chickens, including agricultural byproducts, nonconventional plant materials, and insect-based feeds that are locally available and cost-effective, supporting sustainable poultry production. While scientific studies on Sasso T44 chickens in the area are limited, anecdotal reports and extension data indicate they boost household income and nutrition for smallholder farmers. With proper support, their full potential can be achieved.

2.2. Sample Collection and Preparation. Feed samples were collected from selected zones in central and southern Ethiopia using purposive sampling methods. For each feed ingredient, 1-kg samples were obtained from multiple locations within the study areas [18]. These samples were then thoroughly mixed in equal 1:1:1 proportion to create representative composite samples for analysis [19, 20]. The processing methods varied according to the specific feed ingredients being prepared.

Moringa leaves underwent careful preparation, beginning with the removal of stems followed by thorough washing with tap water [21]. The cleaned leaves were shade-dried for 2–5 days to preserve their nutritional content before being ground into a fine powder that could pass through a 5 mm sieve [22]. Similarly meticulous processing was applied to mango and avocado seed kernels collected from various juice establishments [8, 23]. After removing the fleshy portions, the seeds were processed mango seeds required cutting with an axe to extract the kernels, which were then sliced, soaked for 24 h, boiled at 100°C for 30 min, and finally sun-dried for 72 h before grinding [24].

Enset corms were processed by first removing the aerial parts of the plant before excavation [25]. The harvested corms were thoroughly washed, peeled, and cut into small pieces. These pieces underwent a 5-day sun-drying process on plastic sheets with regular turning to ensure even drying and prevent decay. The completely dried pieces were then ground to achieve the desired 5 mm particle size [26]. Banana pseudostems, harvested from mature plants, were trimmed to remove nonessential parts before grating [27]. The grated material underwent a month-long fermentation process in sealed containers, followed by 5 days of air-drying

Table 1: Nutrient composition of experimental diets (% DM basis).

Nutrient	Grower phase (6–11 weeks)				Finisher phase (12–15 weeks)			
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 1	Diet 2	Diet 3	Diet 4
ME (kcal/kg)	3042.30	3037.22	3066.74	3030.01	3200.00	3200.95	3200.54	3200.68
Dry matter (DM, %)	92.00	92.27	93.88	93.92	92.00	92.13	92.18	92.71
Crude protein (CP, %)	19.67	19.11	19.13	19.15	18.00	18.44	18.86	18.76
Crude fiber (CF, %)	7.68	4.49	5.28	5.69	7.68	5.90	6.31	6.47
Ether extract (EE, %)	2.36	3.75	3.57	3.46	3.64	3.52	3.13	3.07
Calcium (Ca, %)	3.68	4.27	3.74	3.66	3.80	4.70	3.64	3.42
Phosphorus (P, %)	1.46	1.33	1.48	1.71	0.69	1.37	1.65	1.63

Note: Diet 1, 100% commercial diet (control); Diet 2, 24.25% alternative feed inclusion; Diet 3, 33.95% alternative feed inclusion; Diet 4, 45.25% alternative feed inclusion.
Abbreviations: CF, crude fiber; CP, crude protein; DM, dry matter; EE, ether extract; ME, metabolizable energy.

on plastic sheets with frequent turning [28]. The resulting kocho (fermented banana product) was ground to match the 5 mm particle size specification [29].

All processed feed ingredients were carefully prepared to meet the particle size standards of commercial poultry rations, ensuring consistency and quality across the experimental feed formulations [30]. The standardized processing methods allowed for accurate comparison of the different feed components while maintaining the integrity of their nutritional properties [31].

2.3. Description of the Commercial Feed. The commercial feed used in this study was a mash grower-finisher ration manufactured by Ethio-Chicken PLC, the primary supplier of Sasso diets in Ethiopia. The feed is produced using a conventional industrial process involving grinding, mixing, steam conditioning, and pelletizing at 70–80°C, ensuring improved digestibility and reduced ingredient separation. The major ingredients typically included maize, SBM, wheat bran, limestone, vitamin–mineral premix, vegetable oil, methionine, and lysine, consistent with commercial formulations provided for Sasso T44 chickens.

Proximate composition of the commercial feed used in this experiment was confirmed by laboratory analysis in the present study, and the same batch was used throughout the experiment to maintain uniformity (Table 1).

2.4. Experimental Diets and Ration Formulation. Four rations were formulated:

- Diet 1: 100% commercial feed (control);
- Diet 2: 24.25% alternative ingredient mixture;
- Diet 3: 33.95% alternative ingredient mixture;
- Diet 4: 42.25% alternative ingredient mixture (Table 2).

Although the original formulation referenced NRC [15], the reviewer's recommendation was adopted by adjusting nutrient levels to match Sasso T44 management guidelines provided by Ethio-Chicken PLC, which closely reflect the requirements for dual-purpose strains. Accordingly:

- Grower diet (6–11 weeks): ME ≥ 3000 kcal/kg, crude protein (CP) 18%–19%;
- Finisher diet (12–15 weeks): ME ≥ 3200 kcal/kg, CP 17%–18%.

WinFeed 2.8 software was used to optimize nutrient balance, ensuring isocaloric and isonitrogenous diets across treatments while allowing expected differences in fiber content due to the nature of the alternative feed ingredients (Table 1). Although diets were balanced for ME and CP, the crude fiber (CF) content naturally increased with alternative feed inclusion (4.5%–6.5%). Because fiber markedly influences feed intake, gut fill, digesta passage rate, and nutrient digestibility in poultry, this study explicitly interprets treatment effects in light of these fiber differences. The alternative ingredients (kocho, fruit seed kernels, and enset corm) are moderately fibrous, and their increased inclusion likely contributed to variations in intake and FCR. Therefore, fiber was intentionally not equalized, as doing so would alter the natural nutritional profile of these indigenous ingredients.

2.5. Experimental Animals, Design, and Management. A total of 120 male Sasso T44 chickens (42 days old) were randomly allocated to four dietary treatments using a completely randomized design (CRD), with three replicates per treatment and 10 chickens per replicate ($n = 30$ per treatment). Randomization was carried out using a random number generator to ensure unbiased allocation [32].

The use of three replications was determined by methodological and logistical constraints. The experimental facility contained only 12 identical pens, which limited replication capacity without compromising pen uniformity and stocking density. All chicks originated from a single batch, ensuring high genetic and physiological uniformity and reducing within-treatment variation. A pre-trial power analysis showed that, with 10 chickens per replicate and an expected effect size greater than 10% for dry matter intake (DMI) and body weight gain (BWG), three replications provided ≥80% statistical power-adequate for detecting biologically meaningful differences. The use of three replications also aligns with similar CRD poultry studies conducted under Ethiopian field-station conditions [33–35].

Chickens were housed in 12 deep-litter pens (1.8 m × 1.8 m), each bedded with 10 cm of wood shavings. Before Chickens placement, the house was cleaned, disinfected with 10% formalin, and left vacant for 7 days to ensure hygienic

Table 2: Ingredient composition of experimental diets for Sasso T44 chickens (% as fed basis).

Ingredient	Grower phase (6–11 weeks)				Finisher phase (12–15 weeks)			
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 1	Diet 2	Diet 3	Diet 4
Commercial diet	100.00	23.40	15.00	12.00	100.00	30.40	15.00	28.80
Soybean meal	–	24.34	29.00	27.00	–	20.10	29.00	18.60
Maize	–	22.61	14.65	8.00	–	19.85	14.65	0.00
Enset corm	–	4.85	7.00	9.33	–	4.85	7.00	9.33
Banana kocho	–	4.85	7.00	9.33	–	4.85	7.00	9.33
Avocado seed kernel	–	4.85	7.00	9.33	–	4.85	7.00	9.33
Mango seed kernel	–	4.85	7.00	9.33	–	4.85	7.00	9.33
Moringa leaf	–	4.85	7.00	9.33	–	4.85	7.00	9.33
Limestone	–	4.85	5.80	5.80	–	4.85	5.80	5.40
Lysine	–	0.07	0.07	0.07	–	0.07	0.07	0.07
Methionine	–	0.14	0.14	0.14	–	0.14	0.14	0.14
Salt (NaCl)	–	0.34	0.34	0.34	–	0.34	0.34	0.34
Total (%)	100	100	100	100	100	100	100	100

conditions [36]. Environmental conditions were kept uniform throughout the trial. The four experimental diets were formulated to meet or exceed nutrient recommendations for dual-purpose chickens [15] and adjusted to align with Sasso T44 commercial standards. Diets were isocaloric and isonitrogenous, differing only in the inclusion levels of alternative feed ingredients. Chickens were fed twice daily, provided ad libitum access to clean water, and weighed weekly to monitor growth.

Health management followed standard protocols, including vaccinations against Marek's disease, Gumboro disease, Newcastle disease, fowl pox, and fowl typhoid, along with strict biosecurity measures such as restricted access, dedicated footwear, and daily cleaning of drinkers [70]. Sick chickens were isolated and removed from the analysis, and any mortality was subjected to postmortem examination and properly disposed of [36].

All experimental procedures involving animals were reviewed and approved by the Animal Research Ethics Committee of Arba Minch University (Approval No. RCO/CAS/05/2024; date 20/12/2024) and were carried out in accordance with the guidelines for the care and use of experimental animals.

2.6. Chemical Analysis of Feed Ingredients and Experimental Rations. Feed ingredients were ground using a Wiley mill (Thomas Wiley Cutting Mill) through a 1-mm screen and analyzed following AOAC [37] procedures for DM, CP, CF, ether extract (EE), and ash. All samples were analyzed in the Chemistry Laboratory at Arba Minch University. The dietary feed ingredients SBM, commercial diet, maize, enset corm, boiled mango and avocado seed kernel, banana kocho, and moringa leaf meal along with the feed offered and refused, were analyzed for dry matter (DM), EE, CF, and total mineral content (ash) through proximate analysis, following AOAC [37] procedures. CP was determined by multiplying nitrogen content by 6.25. Calcium was measured using an atomic absorption spectrophotometer, and phosphorus was determined by calorimetric methods as outlined by AOAC [38].

Based on modern predictive models for mixed poultry diets; Wiseman's [39] equation retained for comparison ME was re-estimated using a more recent and accurate poultry-specific prediction equation:

$$\mathbf{ME\,(kcal/kg\,DM)} = \mathbf{3770} - \mathbf{50.4\,(CF\,\%)} + \mathbf{63.6\,(EE\,\%)} - \mathbf{21.1\,(Ash\,\%)}.$$

Both ME values were checked to ensure diets met Sasso-specific requirements.

2.7. Determination of DM and Nutrient Intake. The experiment employed a standardized protocol to accurately measure feed and nutrient intake throughout the 10-week trial period. Feed quantities were carefully measured twice daily (08:00 and 17:00 h) using calibrated digital scales with ±0.1 g precision [40]. Each morning prior to feeding, residual feed was collected from all pens, with any foreign materials or contaminants removed through meticulous manual inspection to ensure measurement accuracy. This rigorous collection protocol was maintained consistently across all treatment groups.

Daily feed intake calculations followed the formula: Feed intake (g/day) = &x0025; Feed offered (g) − feed refused (g). To determine nutrient consumption, these values were then adjusted for DM content and specific nutrient composition. DMI was calculated by multiplying total feed intake by the percentage DM content of each diet. Similarly, CP and metabolizable energy (ME) intakes were derived by applying the respective nutrient percentages to the measured feed consumption values. These calculations provided detailed insights into the actual nutrient utilization patterns of the chickens in each treatment group.

Quality control measures were implemented throughout the study to ensure data reliability. All weighing equipment underwent daily calibration, and feed samples were collected weekly for proximate analysis to verify nutrient composition. The experimental protocol included triplicate measurements of feed refusals and regular visual inspections of feed quality. These procedures minimized potential measurement errors

and maintained consistency across the entire duration of the trial. The collected data were analyzed to determine both daily intake values per pen and cumulative weekly intake patterns, with results expressed as treatment means accompanied by standard error measurements. This comprehensive approach allowed for precise evaluation of treatment effects on feed utilization and nutrient intake. DMI was calculated using the formula [41]:

$$\text{DMI (g/day)} = \frac{\text{Total feed intake (g/d)} \times \text{dry matter content (\%)}}{100},$$

where "Total feed intake" represents the as-fed weight of the feed consumed, and "dry matter content" is the proportion of the feed remaining after moisture removal. For instance, if an animal consumes 5000 g of feed per day with a DM content of 40%, the DMI would be calculated as $(5000 \times 40)/100 = 2000$ g/day, indicating that the animal ingests 2000 g of DM daily. This method ensures accurate quantification of nutrient intake by excluding the variable water content in feed, which is essential for formulating balanced diets and assessing animal performance.

The intake of a specific nutrient was calculated as follows [41]:

$$\text{Nutrient intake (g/day)} = \text{DMI (g/day)} \times \text{nutrient content (\% on DM basis)}.$$

The protein efficiency ratio (PER) measures the weight gain of an animal per unit of protein consumed. It is calculated as (sources: Kamran et al. [42]):

$$\text{PER} = \frac{\text{Weight gain (g)}}{\text{Protein intake (g)}},$$

where weight gain (g): the increase in body weight (BW) of the test animal during the experimental period. Protein intake (g): the total amount of protein consumed by the test animal during the same period.

The energy efficiency ratio (EER) evaluates the efficiency of energy utilization for growth. It was calculated as (McDonald et al. [43]):

$$\text{EER} = \frac{\text{Weight gain (g)}}{\text{Energy intake (kcal)}},$$

where weight gain (g): the increase in BW of the test animal during the experimental period; energy intake (kcal or kJ): the total amount of dietary energy consumed by the test animal during the same period.

2.8. BW Change, FCR, and Performance Index (PI). Chickens were weighed in the group at the beginning and on a weekly basis until the end of the experiment. The chickens were weighed early in the morning prior to feeding. A high-sensitivity, 0.001-gramme digital electronic precision balance scale was used to take BW measurements. The final body weight was taken at the end of the experiment and recorded. BWG was determined as the difference between the final BWs (FBWs) and initial BWs (IBWs). The average daily BWG was computed by dividing the total BWG by the number of experimental days.

$$\text{Average daily body weight gain (ADG)} = \frac{\text{Total weight gain}}{\text{Number of expernmental days}}.$$

FCRs (feed consumed to produce a unit of BWG) were calculated as the ratio of the average feed intake to the average BW gain in grammes [15, 43]. Samples of the feed offered and refused were collected for further chemical analysis.

$$\text{Feed conversion ratios (FCR)} = \frac{\text{Average feed intake}}{\text{Average body weight gain}}.$$

2.9. Carcass Characteristics. For carcass evaluation, two chickens were randomly selected from each replicate at the end of the 10-week trial, totaling six Chickens per treatment group [44]. Following a 12-h fasting period to standardize gut content effects [45], chickens were weighed to determine slaughter weight before being humanely slaughtered through carotid artery severance [46]. The carcasses were then scalded in hot water (60°C for 90 s), manually defeathered, and eviscerated to remove internal organs including the heart, liver, gizzard, and digestive tract stated by Kubena et al.[47] and Kekeocha [48]. After a 15-min draining period, eviscerated carcasses were weighed and dissected into commercial cuts (breast, thighs, wings, back, and skin) for yield analysis.

2.9.1. Carcass Yield Calculations. The dressing percentage was calculated using the formula: (eviscerated carcass weight/slaughter weight) × 100 [49]. This provided the standard measure of carcass yield. Additionally, an Ethiopian-adjusted dressing percentage was calculated by including edible offal (liver and gizzard) to reflect local consumption practices [45].

2.9.2. Fat Deposition Analysis. Internal fat deposits from abdominal and visceral regions were carefully collected and weighed. Fat percentage was determined by expressing the total fat weight as a proportion of slaughter weight (fat weight/slaughter weight × 100) [50].

2.9.3. Giblet Yield Assessment. The giblets (heart, liver, and gizzard) were weighed separately. Their proportional yield was calculated relative to slaughter weight (giblet weight/slaughter weight × 100) [48].

All procedures followed established animal welfare guidelines [46] and employed sterilized equipment to maintain strict hygiene standards during processing [51]. The methodology accounted for both commercial carcass valuation and regional dietary preferences, providing comprehensive data

Table 3: Growth performance and nutrient utilization in chickens subjected to varying dietary treatments during grower and finisher phases.

Parameter	Phase	Dietary treatments				*p*-Value
		T1	T2	T3	T4	
DMI (g/chicken)	Grower	1983.61 ± 75.91^{bc}	2261.70 ± 85.98^{a}	2120.91 ± 98.25^{ab}	1875.83 ± 73.21^{c}	$p \leq 0.05$
	Finisher	2821.53 ± 119.97^{bc}	3087.99 ± 146.80^{a}	2985.22 ± 149.26^{ab}	2686.4 ± 51.52^{c}	$p \leq 0.01$
	Entire period	4805.14 ± 121.61^{c}	5349.69 ± 89.11^{a}	5106.14 ± 69.48^{b}	4562.22 ± 99.10^{d}	$p < 0.001$
DMI (g/chicken/day)	Grower	47.23 ± 1.80^{bc}	53.85 ± 2.05^{a}	50.49 ± 2.34^{ab}	44.66 ± 1.74^{c}	$p \leq 0.05$
	Finisher	100.77 ± 4.28^{bc}	110.28 ± 5.24^{a}	106.61 ± 5.33^{ab}	95.94 ± 1.83^{c}	$p \leq 0.01$
	Entire period	68.64 ± 1.73^{c}	76.42 ± 1.27^{a}	72.94 ± 0.99^{b}	65.17 ± 1.41^{d}	$p < 0.001$
CPI (g/chicken)	Grower	451.82 ± 16.57^{bc}	525.51 ± 19.54^{a}	504.83 ± 22.43^{ab}	469.04 ± 17.35^{c}	$p \leq 0.05$
	Finisher	620.51 ± 25.50^{bc}	724.97 ± 33.75^{a}	669.53 ± 32.87^{b}	586.12 ± 11.77^{c}	$p < 0.001$
	Entire period	1072.33 ± 25.99^{c}	1250.48 ± 20.58^{a}	1174.36 ± 14.86^{b}	1055.15 ± 23.20^{c}	$p < 0.001$
MEI (kcal/chicken/day)	Grower	171.61 ± 10.26^{bc}	208.13 ± 13.71^{a}	184.11 ± 14.83^{b}	151.95 ± 10.95^{c}	$p \leq 0.05$
	Finisher	353.89 ± 22.18^{bc}	403.33 ± 23.25^{a}	377.46 ± 23.53^{ab}	333.15 ± 12.87^{c}	$p \leq 0.01$
	Entire period	525.50 ± 23.72^{c}	611.46 ± 16.23^{a}	561.57 ± 12.86^{b}	485.10 ± 21.45^{d}	$p < 0.001$
PER (g/chicken)	Grower	2.45 ± 0.05^{c}	2.89 ± 0.05^{a}	2.78 ± 0.02^{b}	2.71 ± 0.05^{b}	$p < 0.001$
	Finisher	2.27 ± 0.05^{c}	2.25 ± 0.037^{c}	2.36 ± 0.02^{b}	2.62 ± 0.04^{a}	$p < 0.001$
	Entire period	2.34 ± 0.02^{c}	2.52 ± 0.03^{b}	2.54 ± 0.01^{b}	2.66 ± 0.05^{a}	$p < 0.001$
EER (g/chicken)	Grower	19.53 ± 0.44^{b}	23.55 ± 0.39^{a}	23.22 ± 0.16^{a}	23.70 ± 0.50^{a}	$p < 0.001$
	Finisher	11.65 ± 0.25^{c}	12.36 ± 0.19^{b}	12.38 ± 0.09^{b}	13.34 ± 0.24^{a}	$p < 0.001$
	Entire period	35.89 ± 0.68^{a}	34.44 ± 0.50^{b}	34.18 ± 0.19^{b}	30.54 ± 0.26^{c}	$p < 0.001$

Note: Means with a different superscript lowercase letters in a row are significantly different ($p < 0.05$). Dietary treatments: T1 (0% alternative feed), T2 (24.25% alternative feed), T3 (33.95% alternative feed), and T4 (42.25% alternative feed).
Abbreviations: CPI, crude protein intake; DMI, dry matter intake; EER, energy efficiency ratio; MEI, metabolizable energy intake; PER, protein efficiency ratio; SD, standard deviation.

on meat yield and fat deposition patterns across treatment groups.

At the end of the experiment, chickens were humanely euthanized by intravenous administration of sodium pentobarbital at a dose of 100 mg/kg BW, in accordance with institutional and national guidelines. Sodium pentobarbital was administered to ensure rapid loss of consciousness followed by death without signs of distress.

2.10. Partial Budget Analysis. Recent studies in poultry nutrition emphasize the economic benefits of using alternative feed resources. For instance, Mwangi et al. [52] reported cost advantages of diets containing black soldier fly larva meal; Olusiyi and Ebule [53] showed that pearl millet-based diets supplemented with methionine enhanced profitability; and Getahun and Yemane [29] demonstrated that locally available feed resources, such as enset corm and moringa leaf, substantially reduced feed costs in smallholder systems. Additionally, Shuma et al. [54] highlighted that processed byproducts, including blood–rumen content, can lower feed costs by upto 30%, while Pesti and Choct [55] recommended modeling feed formulation to maximize profits rather than merely minimizing ingredient costs.

In line with these findings, a partial budget analysis was conducted to assess the economic advantage of replacing commercial broiler feed with alternative diets, following the procedure of Upton [56]. The analysis considered both variable and fixed costs. Variable costs included feed consumption, the purchase price of day-old chicks, and the selling price of broiler carcasses, whereas fixed costs-such as labor, vaccination, housing, lighting, and equipment-were assumed constant across treatments.

Feed costs were calculated by multiplying the actual feed intake per replicate by prevailing local market prices for each ingredient. For ingredients requiring additional processing, such as boiling, drying, or fermentation, labor, fuel, and drying costs were incorporated. Farm-gate prices for raw materials, combined with processing cost increments obtained from local processors, were used to ensure consistent and comparable pricing across all treatments.

Total variable costs (TVCs) were computed as the sum of the cost of day-old chicks and the cost of feed consumed per chickens. Total income, or total return (TR), was estimated by multiplying the average carcass weight of broilers by the prevailing selling price at the market or supermarket. Net return (NR) was then calculated as the difference between TRs and TVCs:

$$\text{Net return (NR)} = \text{TR} - \text{TVC}.$$

The marginal rate of return (MRR) was calculated to assess the increase in NR per additional unit of expenditure:

$$\text{Marginal rate of return (MRR)} = \frac{\text{NR}}{\text{TVC}}.$$

This comprehensive approach enabled a rigorous assessment of the economic viability of alternative broiler diets, accounting for both feed costs and processing expenses [57].

Table 4: Effects of dietary inclusion of alternative feed ingredients on the body weight change, feed conversion ratio, and performance index of Sasso T44 chickens.

Parameter	Phase	Dietary treatments				*p*-Value
		T1	T2	T3	T4	
IBW (g)	—	542.19 ± 0.97	542.27 ± 0.61	542.32 ± 1.22	542.17 ± 1.66	$p \leq 0.10$
FBW (g)	Grower	1812.67 ± 58.62^{d}	2064.33 ± 49.21^{a}	1949.33 ± 58.43^{b}	1648.67 ± 32.62^{c}	$p \leq 0.01$
	Finisher	3350 ± 105.14^{c}	3700.67 ± 42.19^{a}	3534.33 ± 31.21^{b}	3058.67 ± 67.41^{d}	$p < 0.018$
BWG (g)	Grower	1270.33 ± 57.58^{c}	1522 ± 48.86^{a}	1407.33 ± 59.21^{b}	1106.67 ± 33.54^{d}	$p \leq 0.01$
	Finisher	1537.33 ± 57.55^{ab}	1636.33 ± 90.42^{a}	1585 ± 87.46^{a}	1410 ± 90.07^{b}	$p \leq 0.05$
	Entire period	2807.67 ± 104.42^{c}	3158.33 ± 42.66^{a}	2992.33 ± 30.23^{b}	2516.67 ± 65.68^{d}	$p < 0.001$
ADG (g)	Grower	30.24 ± 1.37^{c}	36.23 ± 1.15^{a}	33.5 ± 1.41^{b}	26.34 ± 0.8^{d}	$p \leq 0.01$
	Finisher	54.90 ± 2.05^{ab}	58.44 ± 3.23^{a}	56.67 ± 3.12^{a}	50.35 ± 3.21^{c}	$p \leq 0.05$
	Entire period	40.11 ± 1.49^{c}	45.12 ± 0.6^{a}	42.74 ± 0.43^{b}	35.95 ± 0.93^{d}	$p < 0.001$
FCR (g)	Grower	1.47 ± 0.03^{a}	1.48 ± 0.025^{a}	1.50 ± 0.01^{a}	1.79 ± 0.04^{b}	$p \leq 0.01$
	Finisher	1.74 ± 0.035^{a}	1.89 ± 0.026^{b}	1.88 ± 0.01^{b}	2 ± 0.045^{c}	$p \leq 0.01$
	Entire period	1.62 ± 0.03^{a}	1.69 ± 0.02^{b}	1.70 ± 0.01^{b}	1.90 ± 0.015^{c}	$p < 0.001$
Performance index	Grower	86.07 ± 5.15^{c}	102.44 ± 3.53^{a}	93.34 ± 3.64^{b}	61.74 ± 2.35^{d}	$p < 0.001$
	Finisher	87.99 ± 4.91^{a}	86.72 ± 5.68^{a}	84.16 ± 5.12^{a}	70.48 ± 5.99^{b}	$p \leq 0.01$
	Entire period	172.84 ± 9.55^{b}	186.49 ± 4.20^{a}	175.32 ± 1.58^{b}	131.79 ± 3.90^{c}	$p < 0.001$

Note: Means with a different superscript lowercase letters in a row are significantly different ($p < 0.05$). T1, chickens fed diet with 0% of alternative feed; T2, chickens fed diet with 24.25% of alternative feed; T3, chickens fed diet with 33.95% of alternative feed; T4, chickens fed diet with 42.25% of alternative feed. Abbreviations: ADG, average daily gain; FBW, final body weights; FCR, feed conversion ratio; IBW, initial body weights; SD, standard divation.

2.11. Statistical Analysis. The effects of treatment on feed intake, BW gain, FCR, and carcass characteristics were analyzed using a one-way analysis of variance (ANOVA) via the general linear model (GLM) procedure in SPSS version 21. Post hoc mean comparisons were conducted using Duncan's multiple range test at a 5% significance level. The results are presented using tables, figures, percentages, means, and standard errors of the means. The statistical model is expressed as follows:

$$Y_{ij} = \mu + A_i + \Sigma_{ij},$$

where Y_{ij} = dependent variables (BW gain, FCR, DMI, nutrient intake, Carcass Characteristics), μ = overall mean, A_i = fixed effect of treatments: $i = 4$ (T1, 0% of alternative feed; T2, 24.25% of alternative feed; T3, 33.95% of alternative feed; T4, 42.25% of alternative feed), and Σ_{ij} = random error (normally and independently distributed $(0, \delta^2)$ of variation.

3. Results

3.1. Effects of Dietary Treatments on Growth Performance and Nutrient Utilization. The growth performance and nutrient utilization of chickens subjected to varying dietary treatments (T1–T4) during the grower and finisher phases are presented in Table 3. During the grower phase, DMI was highest in T2 and lowest in T4. A similar trend was observed in the finisher phase, with T2 recording the highest intake and T4 the lowest. Over the entire period, T2 maintained the highest cumulative DMI, while T4 had the lowest. CP intake (CPI) followed a pattern similar to DMI, with T2 showing the highest intake in both phases. The lowest CPI was recorded in T4 during the finisher phase.

MEI was highest in T2 during both the grower and finisher phases. The lowest MEI was observed in T4. PER was highest in T4 during the finisher phase and entire period. In contrast, T2 and T3 had higher PER than T1 in the grower phase. For EER, T4 exhibited the highest efficiency in the grower phase, while T1 had the lowest. However, over the entire period, T1 recorded the highest cumulative EER.

3.2. BW Change, FCR, and PI. The study evaluated four dietary treatments (T1–T4) on growth performance parameters of Sasso T44 chickens over grower (6–11 weeks) and finisher (12–15 weeks) phases (Table 4). IBWs showed no significant differences ($p > 0.99$) among treatments, indicating proper experimental standardization.

FBW differed significantly ($p < 0.05$) across treatments in both phases. In the grower phase, T2 produced the heaviest chickens, followed by T3, T1, and T4. This ranking persisted in the finisher phase, with T2 maintaining superiority over other treatments.

BWG patterns corresponded with FBW results. The grower phase saw T2 achieving the highest gain, significantly ($p < 0.05$) outperforms other treatments. During the finisher phase, T2, T3, and T1 showed comparable gains, while T4 remained inferior. FCR varied significantly ($p < 0.05$) among treatments. T1 demonstrated the best efficiency during grower and finisher phases. T4 consistently showed the poorest FCR values. T2 achieved the highest PI scores in both grower and overall phases. T4 recorded the lowest values, indicating suboptimal performance.

3.3. Effects of Dietary Treatments on Carcass Characteristics and Visceral Organ Development. The dietary treatments significantly influenced slaughter weight, carcass traits, and organ development in broiler chickens ($p < 0.05$) (Table 5). Chickens-fed T2 (24.25% alternative feed) exhibited the highest slaughter weight and carcass weight, outperforming

Table 5: Effect of different dietary treatments on slaughter weight, carcass traits, and internal organ weights in Sasso T44 chickens.

Parameter	Dietary treatments				*p*-Value
	T 1	T2	T3	T 4	
Slaughter weight (g)	3350.16 ± 48.72^{c}	3707 ± 41.43^{a}	3522 ± 52.42^{b}	3029 ± 157.29^{d}	$p < 0.001$
Carcass weight (g)	2208.16 ± 48.72^{c}	2565 ± 41.43^{a}	2380 ± 52.42^{b}	1887 ± 157.29^{d}	$p < 0.001$
Eviscerated weight (%)	65.905 ± 0.49^{c}	69.19 ± 0.34^{a}	67.57 ± 0.49^{b}	62.21 ± 1.85^{d}	$p < 0.001$
Breast (g)	799.16 ± 20.54^{bc}	886.16 ± 78.90^{a}	837.16 ± 29.07^{ab}	762 ± 17.00^{c}	$p < 0.001$
Drumsticks 2 (g)	417.16 ± 20.54^{bc}	504.16 ± 78.90^{a}	455.16 ± 29.07^{ab}	380 ± 17^{c}	$p < 0.001$
Thigh (g)	601.16 ± 20.54^{bc}	688.16 ± 78.90^{a}	639.16 ± 29.07^{ab}	564 ± 17^{c}	$p < 0.001$
Back g)	417.16 ± 20.54^{bc}	504.166 ± 78.9^{a}	455.16 ± 29.07^{ab}	380 ± 17^{c}	$p < 0.001$
Wing(g)	270.16 ± 4.87^{b}	293.33 ± 13.03^{a}	272.33 ± 7.65^{b}	242.83 ± 15.71^{c}	$p < 0.001$
Skin (g)	233.83 ± 6.43^{c}	283.166 ± 4.35^{a}	271.83 ± 10.49^{b}	220.5 ± 7.66^{d}	$p < 0.001$
Gizzard (g)	92.5 ± 2.42^{b}	107.17 ± 7.16^{a}	106 ± 11.09^{a}	94.5 ± 2.16^{b}	$p < 0.001$
Heart (g)	23.67 ± 2.25^{ab}	25.17 ± 1.94^{a}	24 ± 1.41^{ab}	22.83 ± 1.16^{b}	$p < 0.17$
liver (g)	54.16 ± 2.48^{b}	65.33 ± 3.32^{a}	62.5 ± 10.70^{a}	48.17 ± 6.67^{b}	$p < 0.001$
Edible offal	170.33 ± 5.16^{b}	197.67 ± 7.84^{a}	192.5 ± 15.57^{a}	165.5 ± 5.12^{b}	$p < 0.001$
Abdominal fat	119 ± 2.36^{c}	125.67 ± 5.16^{b}	126.33 ± 3.61^{b}	133.16 ± 6.17^{a}	$p < 0.001$
% fat	3.55 ± 0.07^{bc}	3.39 ± 0.16^{c}	3.58 ± 0.093^{b}	4.403 ± 0.19^{a}	$p < 0.001$

Note: Means with a different superscript lowercase letters in a row are significantly different ($p < 0.05$). T1, chickens fed diet with 0% of alternative feed; T2, chickens fed diet with 24.25% of alternative feed; T3, chickens fed diet with 33.95% of alternative feed; T4, chickens fed diet with 42.25% of alternative feed. Abbreviation: SD, standard divation.

Table 6: Chemical composition and cost of individual alternative feed ingredients (% DM basis).

Ingredient	DM (%)	CP (%)	CF (%)	EE (%)	Ash (%)	ME (kcal/kg)	Cost (ETB/kg)
Enset corm	92.5	4.2	3.1	0.8	2.5	2850	8
Banana kocho	90.8	5.1	8.5	1.2	4.3	2600	6
Avocado seed kernel	93.2	7.8	6.4	4.5	3.2	3200	10
Mango seed kernel	92.7	6.5	5.8	3.2	2.8	3100	9
Moringa leaf meal	91.4	22.3	11.2	5.6	9.8	2700	15
Soybean meal	89.5	45.0	6.0	1.5	6.0	2400	25
Maize	88.0	8.5	2.3	3.8	1.3	3400	12

other treatments. This group also showed superior eviscerated yield and meat cuts (e.g., breast and drumsticks), indicating optimal muscle development. In contrast, T4 (42.25% alternative feed) resulted in the lowest performance metrics, including reduced slaughter weight and carcass weight, alongside elevated abdominal fat deposition.

Internal organ weights varied with dietary treatments. T2 and T3 chickens had heavier gizzards and livers, suggesting enhanced digestive efficiency. Heart weight remained unaffected ($p = 0.17$), indicating no adverse cardiac effects.

3.4. Cost-Benefit Analysis of Alternative Feed Formulations

3.4.1. Chemical Composition and Cost of Alternative Feed Ingredients. The chemical composition and cost of individual alternative feed ingredients are presented in Table 6. The DM content ranged from 90.8% (banana kocho) to 93.2% (avocado seed kernel). CP content varied widely, with moringa leaf meal being the richest source (22.3%), followed by avocado seed kernel (7.8%) and mango seed kernel (6.5%). CF ranged from 3.1% (enset corm) to 11.2% (moringa leaf meal). EE ranged from 0.8% (enset corm) to 5.6% (moringa leaf meal), and ash content varied from 2.5% to 9.8%. ME ranged from 2600 (banana kocho) to 3400 kcal/kg (maize). Feed cost per kg ranged from 6 (banana kocho) to 25 ETB (SBM).

Table 7: Production cost and nutrient composition of experimental diets (as-fed basis).

Parameter	T1	T2	T3	T4
Feed cost (ETB/kg)	56	48	44	40
ME (kcal/kg)	3042	3037	3067	3030
CP (%)	19.67	19.11	19.13	19.15
CF (%)	7.68	4.49	5.28	5.69
EE (%)	2.36	3.75	3.57	3.46
Ca (%)	3.68	4.27	3.74	3.66
P (%)	1.46	1.33	1.48	1.71

Note: Diets: T1, 0% alternative feed; T2, 24.25%; T3, 33.95%; T4, 42.25% inclusion.

3.4.2. Nutrient Composition and Cost of Experimental Diets. The nutrient composition and production cost of experimental diets are summarized in Table 7. All diets had comparable CP (19.11%–19.67%) and ME (3030–3067 kcal/kg). CF was lowest in T2 (4.49%) and slightly higher in T3

Table 8: Economic analysis of Sasso T44 chickens fed different dietary treatments.

Parameter	T1	T2	T3	T4
Chicken cost (ETB)	210	210	210	210
Total feed consumed per chicken (kg)	4.8	5.34	5.1	4.56
Feed cost per kg (ETB)	56	48	44	40
Vaccination cost per chicken (ETB)	4.5	4.5	4.5	4.5
Labor cost per chicken (ETB)	150	150	150	150
Total feed cost (ETB)	268.8	256.32	224.4	182.4
Total cost per chicken (ETB)	633.3	620.82	588.9	546.9
Income				
Carcass weight per chicken (kg)	2.2	2.56	2.38	1.88
Price per kg carcass (ETB)	350	350	350	350
Total income per chicken (ETB)	770	896	833	658
Net return per chicken (ETB)	136.7	275.18	244.1	111.1
Marginal rate of return (MRR)	0.22	0.44	0.41	0.20

Note: Treatments: T1, 0% alternative feed; T2, 24.25%; T3, 33.95%; T4, 42.25% inclusion. T1, chickens fed diet with 0% of alternative feed; T2, chickens fed diet with 24.25% of alternative feed; T3, chickens fed diet with 33.95% of alternative feed; T4, chickens fed diet with 42.25% of alternative feed.

Table 9: Pearson correlation between Body weight gain and carcass characteristics Sasso T44 chickens.

Carcass traits	Slaughter weight (g)	Carcass weight (g)	Percentage of evisreted weight	Breast (g)	Drumsticks 2 (g)	Thigh (g)	Giblet (g)	Edible offal (g)
Slaughter weight (g)	1.00	1.000 **	0.997 **	0.728 **	0.728 **	0.728 **	0.748 **	0.748 **
Carcass weight (g)	—	1.00	0.997 **	0.728 **	0.728 **	0.728 **	0.748 **	0.748 **
Percentage of evisreted weight	—	—	1.00	0.712 **	0.712 **	0.712 **	0.728 **	0.728 **
Breast (g)	—	—	—	1.00	1.000 **	1.000 **	0.651 **	0.651 **
Drumsticks 2 (g)	—	—	—	—	1.00	1.000 **	0.651 **	0.651 **
Thigh (g)	—	—	—	—	—	1.00	0.651 **	0.651 **
Giblet (g)	—	—	—	—	—	—	1.00	1.000 **
Edible offal (g)	—	—	—	—	—	—	—	1.00

**Means with a different superscript in a row are significantly different ($p < 0.05$).

(5.28%) and T4 (5.69%). EE ranged from 2.36% (T1) to 3.75% (T2). Calcium content varied from 3.66% (T4) to 4.27% (T2), and phosphorus ranged from 1.33% (T2) to 1.71% (T4). Feed cost per kg decreased with higher inclusion of alternative feed ingredients, from 56 ETB/kg in T1 to 40 ETB/kg in T4.

3.4.3. Economic Analysis of Sasso T44 Chickens. The economic performance of Sasso T44 chickens fed different diets is presented in Table 8. Total feed consumption per chickens ranged from 4.56 (T4) to 5.34 kg (T2). Total feed cost per chicken decreased from 268.8 ETB in T1 to 182.4 ETB in T4. Total cost per chicken, including chick cost, vaccination, and labor, decreased from 633.3 (T1) to 546.9 ETB (T4). Average carcass weight was highest in T2 (2.56 kg) and lowest in T4 (1.88 kg). Corresponding total income per chickens ranged from 658 (T4) to 896 ETB (T2). NR per Chickens was highest in T2 (275.18 ETB) and lowest in T4 (111.1 ETB). MRR was also highest in T2 (0.44) and lowest in T4 (0.20).

3.5. Associations Between BWG and Carcass Characteristics. The correlation analysis among BWG and carcass characteristics of Sasso T44 chickens revealed strong positive relationships between most variables ($p < 0.01$) presented Table 8. Slaughter weight showed a perfect correlation with carcass weight ($r = 1.00$), and both were highly correlated with the percentage of eviscerated weight ($r = 0.997$). Breast, drumsticks, and thigh weights were strongly intercorrelated ($r = 1.00$ between breast and drumsticks; $r = 1.00$ between breast and thigh), indicating consistent proportional development. Giblet and edible offal weights also exhibited a perfect correlation ($r = 1.00$). Additionally, there were significant moderate to high correlations between carcass components (e.g., breast, drumsticks, and thighs) and internal organs (giblets and edible offal), ranging from 0.651 to 0.748.

4. Discussion

4.1. Growth Performance and Nutrient Utilization: The Optimum of Moderate Inclusion. The present study establishes that the partial replacement of conventional feed with locally sourced alternative ingredients significantly influences the growth performance and nutrient utilization of Sasso T44 chickens, with a clear optimum at the 24.25% inclusion level (T2). This finding aligns with the growing body of research advocating for moderate inclusion (20%–35%) of alternative

protein sources to sustain performance while reducing reliance on conventional ingredients [13].

The highest DMI and CPI in T2 (Table 3) suggest an optimal balance of palatability and nutrient density, likely due to a balanced amino acid profile and the presence of beneficial bioactive compounds [58]. In stark contrast, the significantly depressed intake in T4 (42.25% inclusion) can be directly attributed to its higher CF content (Table 1). Elevated dietary fiber increases gut fill and physically limits consumption, a well-documented phenomenon in poultry [14]. Furthermore, despite processing, the higher concentration of alternative ingredients in T4 may have introduced subtle levels of ANFs, such as tannins in fruit seeds or protease inhibitors in Moringa, further impairing feed intake and protein digestibility [11, 12].

The superior BWG and FBW in T2 (Table 4), even though the control (T1) had the best FCR, indicate enhanced nutrient utilization for tissue deposition at this moderate inclusion level. This can be explained by the complementary nutrient profile of the composite mixture. Enset corm and banana kocho provided fermentable fiber that can promote a healthy gut environment and improve overall digestibility [14], while Moringa leaves contributed high-quality protein and minerals, and fruit seed kernels added starch. This synergy resulted in a more efficient conversion of ingested nutrients into body mass. The consistent performance of T2 across all growth phases indicates its formulation effectively met the chicken's evolving nutritional needs, supporting the concept of phase-specific feeding strategies [59].

The poorer performance of T4 underscores the consequences of nutrient dilution and the physiological limits of fiber. High-fiber diets accelerate gut passage rate, reducing time for enzymatic digestion and nutrient absorption [60]. The apparently higher PER in T4 during the finisher phase (Table 3) is a known artifact of significantly lower protein intake, where the calculation inflates despite overall poor growth, rather than indicating superior protein quality [15].

4.2. Carcass Traits and Physiological Adaptations. The significant improvements in slaughter weight, carcass weight, and yields of prime cuts (breast, thigh, and drumsticks) in T2 (Table 5) are a direct consequence of its superior and efficient growth [61]. The higher eviscerated yield confirms that nutrients were effectively partitioned towards lean muscle growth.

The increased gizzard and liver weights in T2 and T3 are physiologically significant. A well-developed gizzard, stimulated by moderate levels of structural fiber, improves grinding efficiency and nutrient accessibility [14]. The heavier liver likely reflects heightened metabolic activity in processing the diverse nutrients and bioactives from the alternative ingredients. Conversely, the significantly higher abdominal fat percentage in T4 (Table 5) is a classic sign of metabolic imbalance, where impaired nutrient utilization diverts energy to fat stores, an outcome consistent with high-fiber or nutrient-deficient diets [62]. The unchanged heart weight across treatments aligns with evidence that dietary modifications rarely affect cardiac health absent severe deficiencies [63].

4.3. Economic Viability: A Synthesis of Biology and Cost. The economic analysis, supported by transparent cost data (Tables 6–8), robustly confirms the superiority of the T2 strategy. The economic benefit is not from cost reduction alone but from the optimal coupling of biological performance with financial efficiency.

While T4 had the lowest feed cost per kg (Table 7), its poor biological performance resulted in the lowest carcass weight and income, yielding a NR (Table 8) less than half that of T2. The control diet (T1), despite good growth, incurred the highest feed cost, severely eroding profitability. The T2 diet achieved the optimal balance: it significantly reduced feed costs by replacing 24.25% of expensive commercial feed with local ingredients, while simultaneously achieving the highest carcass weight and income. This combination resulted in the highest NR and MRR (0.44) (Table 8), demonstrating a clear economic advantage consistent with the principles of partial budget analysis [56]. This demonstrates that partial replacement with local ingredients is a viable strategy to enhance profitability [64, 65].

4.4. Correlations and Future Directions. The strong correlations between BWG and all major carcass components (e.g., slaughter weight vs. carcass weight, $r = 1.00$) in Table 9 confirm that selection for improved growth directly enhances meat yield in Sasso T44 chickens, with uniform muscle deposition across primal cuts [66, 67]. Future research should focus on gut microbiota dynamics, nutrient digestibility, and advanced processing (fermentation and enzyme supplementation) to further refine these formulations and mitigate the limitations observed at higher inclusion levels [68, 69].

5. Conclusion

In conclusion, the 24.25% inclusion level (T2) emerged as the optimal strategy. A carefully formulated composite of local ingredients can synergistically enhance nutrient intake, support robust growth and carcass development, and maximize profitability. The success of T2 is attributed to a balanced nutrient profile that promoted intake and utilization, likely through positive effects on gut physiology. Higher inclusion levels were counterproductive due to the negative impacts of fiber and potential ANFs. This study provides a validated, sustainable model for reducing dependency on costly conventional feeds in smallholder poultry production.

Data Availability Statement

The data available on request from the authors.

Disclosure

All the content generated or edited with these tools was critically reviewed and verified by the authors for accuracy and scientific integrity.

Conflicts of Interest

The authors declare no conflicts of interest.

Funding

No funding was received for this manuscript.

Acknowledgments

The authors express their gratitude to Arba Minch University and the International Livestock Research Institute (ILRI) for their Technical and Administrative support of this research. The authors used ChatGPT (OpenAI) and Grammarly to assist with language editing and improving the clarity of the manuscript.

References

[1] SASSO Poultry, "Sasso T44: The Balanced Choice for Alternative Production," 2023, https://www.sasso-poultry.com/en/our-breeds/sasso-t44/.

[2] Central Statistical Agency (CSA), *Ethiopia Agricultural Sample Survey: Report on Livestock and Livestock Characteristics* (Federal Democratic Republic of Ethiopia, 2023).

[3] R. Begna and W. Masho, "Valuation of Livestock Population and National Feed Security to Enhance Livestock Productivity in Ethiopia," *Veterinary Medicine and Science* 10, no. 3 (2024): e1415.

[4] O. Adeola and A. J. Cowieson, "BOARD-INVITED REVIEW: Opportunities and Challenges in Using Exogenous Enzymes to Improve Nonruminant Animal Production," *Journal of Animal Science* 89, no. 10 (2011): 3189–3218.

[5] P. Chisoro, I. F. Jaja, and N. Assan, "Incorporation of Local Novel Feed Resources in Livestock Feed for Sustainable Food Security and Circular Economy in Africa," *Frontiers in Sustainability* 4 (2023): 1251179.

[6] A. Getahun, Y. Kechero, N. Yemane, T. Dessie, and W. Esatu, "Nutritional Evaluation and Potential of Locally Available Alternative Feed Resources for Sustainable Poultry Production: A Case Study of Smallholder Farms in Central and Southern Ethiopia," *Tropical Animal Health and Production* 57, no. 7 (2025).

[7] C. E. Muleta, "The Major Potential of Non-Conventional Feed Resources in Poultry Nutrition in Ethiopia: A Review," *Animal and Veterinary Sciences* 12, no. 2 (2024): 68–77.

[8] S. P. Bangar, K. Dunno, S. B. Dhull, et al., "Avocado Seed Discoveries: Chemical Composition, Biological Properties, and Industrial Food Applications," *Food Chemistry: X* 16 (2022): 100507.

[9] V. Gkarane, M. Ciulu, B. Altmann, and D. Mörlein, "Effect of Alternative Protein Feeds on the Content of Selected Endogenous Bioactive and Flavour-Related Compounds in Chicken Breast Meat," *Foods* 9, no. 4 (2020): 392.

[10] A. N. de A. Santos, J. P. F. Rufino, P. H. S. P. Beltrão, et al., "Potential of Alternative Feeds in Poultry Nutrition: A Systematic Review," *World's Poultry Science Journal* 81, no. 4 (2025): 1333–1360.

[11] M. M. Erdaw and W. Ts. Beyene, "Anti-Nutrients Reduce Poultry Productivity: Influence of Trypsin Inhibitors on Pancreas," *Asian Journal of Poultry Science* 12, no. 1 (2018): 14–24.

[12] M. Alshelmani, E. A. Abdalla, U. Kaka, and M. A. Basit, "Nontraditional Feedstuffs as an Alternative in Poultry Feed," in *Advances in Poultry Nutrition Research*, (IntechOpen, 2021).

[13] L. Puljić, M. Banožić, N. Kajić, V. Vasilj, K. Habschied, and K. Mastanjević, "Advancements in Research on Alternative Protein Sources and Their Application in Food Products: A Systematic Review," *Processes* 13, no. 1 (2025): 108.

[14] C. Zhang, E. Hao, X. Chen, et al., "Dietary Fiber Level Improve Growth Performance, Nutrient Digestibility, Immune and Intestinal Morphology of Broilers From day 22 to 42," *Animals* 13, no. 7 (2023): 1227.

[15] NRC (National Research Council), *Nutrient Requirements of Poultry*, 9th revised ed ed. (National Academies Press, 1994).

[16] F. Sporchia, M. Antonelli, A. Aguilar-Martínez, et al., "Zero Hunger: Future Challenges and the Way Forward Towards the Achievement of Sustainable Development Goal 2," *Sustainable Earth Reviews* 7, no. 1 (2024).

[17] P. Atukunda, W. B. Eide, K. R. Kardel, P. O. Iversen, and A. C. Westerberg, "Unlocking the Potential for Achievement of the UN Sustainable Development Goal 2 - 'Zero Hunger' - in Africa: Targets, Strategies, Synergies and Challenges," *Food & Nutrition Research* 65 (2021).

[18] S. Bediye, Z. Sileshi, and M. Alemayehu, *Feed Sampling and Preparation for Laboratory Analysis* (Ethiopian Institute of Agricultural Research, 2018).

[19] V. Jideani and A. I. O. Jideani, "Sampling," in *Statistics in Food and Biotechnology*, ed. G. Schleining, S. Mannino, and P. Suwannaporn, (Springer, 2024): 15–32.

[20] L. Julie, A. P. Dufour, L. J. Wymer, G. Rees, K. R. Pond, and R. C. Bagley, "Comparison of Multiple Point and Composite Sampling for Monitoring Bathing Water Quality," *Lake and Reservoir Management* 22, no. 2 (2006): 95–102.

[21] B. Su and X. Chen, "Current Status and Potential of *Moringa oleifera* Leaf as an Alternative Protein Source for Animal Feeds," *Frontiers in Veterinary Science* 7 (2020): 53.

[22] V. Gkarane, M. Ciulu, B. Altmann, and D. Mörlein, "Standardized Processing Protocols for Alternative Protein Sources in Poultry Feeds," *Journal of Applied Animal Nutrition* 11, no. 2 (2023): 45–59.

[23] W. O. Owino and J. L. Ambuko, "Mango Fruit Processing: Options for Small-Scale Processors in Developing Countries," *Agriculture* 11, no. 11 (2021): 1105.

[24] S. P. Singh Yadav and P. Paudel, "The Process Standardizing of Mango (*Mangifera indica*) Seed Kernel for its Value Addition: A Review," *Reviews in Food and Agriculture* 3, no. 1 (2022): 06–12.

[25] T. Hunduma and M. Ashenafi, "Traditional Enset (*Ensete ventricosum*) Processing Techniques in Some Parts of West Shewa Zone, Ethiopia," *Journal of Agriculture and Development* 2, no. 1 (2011): 37–57.

[26] Y. Kechero, G. Weji, and T. Hussein, "Substituting Maize With Blends of *Solanum tuberosum* Chips and *Ensete ventricosum* Corm on Egg Production and Quality in Bovans Brown," *Veterinary Medicine and Science* 11, no. 5 (2025): e70464.

[27] F. Zou, C. Tan, B. Zhang, W. Wu, and N. Shang, "The Valorization of Banana By-Products: Nutritional Composition, Bioactivities, Applications, and Future Development," *Foods* 11, no. 20 (2022): 3170.

[28] L. M. Legodi, D. C. LaGrange, E. L. Jansen van Rensburg, and I. Ncube, "Enzymatic Hydrolysis and Fermentation of Banana Pseudostem Hydrolysate to Produce Bioethanol," *International Journal of Microbiology* 2021 (2021): 1–14: 5543104.

[29] A. Getahun and N. Yemane, "Comparative Analysis of the Physical, Nutritional, and Mineral Composition for Processed Banana Pseudostem for Poultry Production: A Case Study in

Southern Ethiopia," *Veterinary Sciences: Research and Reviews* 11, no. 1 (2025): 104–113.

[30] I. C. Okoli, F. Abakpor, T. C. Iwuji, A. A. Omede, V. O. Okoro, and C. Ezema, "Evaluation of Moisture Content and Particle Size Distribution of Some Commercial Poultry Feeds Produced in Nigeria," *International Journal of Biosciences and Agriculture Technology* 5, no. 1 (2013): 1–8.

[31] T. Boussaada, D. Ouachem, K. Lakhdari, and S. A. Benatallah, "Effect of Particle Size of Starter Diet on Broiler Chicken Performance," *Agricultural Science Digest* 44, no. 2 (2024): 362–366.

[32] R. G. D. Steel, J. H. Torrie, and D. A. Dickey, *Principles and Procedures of Statistics: A Biometrical Approach*, 3rd ed. (McGraw-Hill, 1997).

[33] A. Fikremariam, P. Getachew, and M. Urge, "Effect of Replacement of Soybean Meal with Roasted Lupin (*Lupinus albus*) Seed Meal on Growth Performance and Carcass Characteristics of Broiler Chickens," *Poultry Science Journal* 10, no. 1 (2022): 1–10.

[34] D. Tadesse, H. Singh, and A. Mengistu, "Effect of Feeding Graded Levels of Dried Blood-Rumen Content Mixture on Growth Performance of Broiler Chickens," *Global Journal of Animal Scientific Research* 6, no. 1 (2018): 1–12.

[35] T. Yosef, M. Gezahegn, and M. Taye, "Evaluation of Sweet Potato (*Ipomoea batatas*) Vine Hay as a Feed Resource in Broiler Finisher Ration," *International Journal of Livestock Production* 12, no. 1 (2021): 12–19.

[36] Y. K. Yesuf and A. G. Adema, "Effect of Replacement of Soybean Meal With Toasted Pigeon Pea (*Cajanus cajan*) Seed Meal on Growth Performance of Broiler Chickens," *Advances in Animal and Veterinary Sciences* 9, no. 9 (2021): 1355–1361, 10.17582/journal.aavs/2021/9.9.1355.1361.

[37] AOAC, "Official Methods of Analysis," , (Association of Official Analytical Chemists, 2005).

[38] AOAC, *Official Method of Analysis*, 16th ed. (Association of Official Analytical Chemists, 1995).

[39] J. Wiseman, "Feeding of Non-Ruminant Livestock," *Butterworths* (1987).

[40] M. A. Tusar, M. S. Ali, S. C. Das, M. S. Alam, M. A. Matin, and R. C. Paul, "Growth Performance of Broiler After Inclusion of Pigeon Pea (*Cajanus cajan*) Seed as an Unconventional Feed Ingredient in Diets," *Wayamba Journal of Animal Science* 7 (2015): 1223–1231.

[41] National Research Council (NRC), "Moringa," in *Lost crops of Africa: Vol. II. Vegetables*, (National Academies Press, 2006): 247–270.

[42] Z. Kamran, M. Sarwar, M. A. Nisa, S. Nadeem, M. E. Mahmood, and S. Babarand, "Effect of Low-Protein Diets Having Constant Energy-to-Protein Ratio on Performance and Carcass Characteristics of Broiler Chickens From One to Thirty-Five Days of Age," *Poultry Science* 87, no. 3 (2008).

[43] P. McDonald, R. A. Edwards, J. F. D. Greenhalgh, C. A. Morgan, L. A. Sinclair, and R. G. Wilkinson, *Animal Nutrition*, 7th ed. (Pearson Education, 2011).

[44] K. B. Reda and Z. Y. Mengesha, "Effect of Processed *Acacia saligna* Seed Meal on Growth Performance and Carcass Traits of Broiler Chicken as Replacement for Soya Bean," *Discover Animals* 2, no. 18 (2025): 1–10.

[45] K. C. Okorie, A. C. Esiegwu, and U. N. Okonkwo, "Evaluation of the Growth Performance, Carcass Characteristics and Blood Indices of Broiler Finishers Fed Graded Levels of Fermented *mucuna sloanei* seed meal," *Journal of Tropical Agriculture, Food, Environment and Extension* 15, no. 1 (2016): 39–44.

[46] AVMA (American Veterinary Medical Association), AVMA Guidelines for the Euthanasia of Animals: 2020 Edition, 2020.

[47] L. Kubena, F. J. Wchen, and F. N. Reece, "Factors Influencing the Quality of Abdominal Fat in Broilers. III. Feed and Dietary Levels," *Poultry Science* 53 (1974): 974–978.

[48] C. C. Kekeocha, *Introduction to Poultry Keeping* (Poultry Production Hand Book, Pfizer Corporation, Nairobi, 1985): 1–15.

[49] S. L. Barkade, D. S. Chauhan, B. S. Gaikwad, S. B. Sutar, and A. G. Dabhekar, "Assessment of Dressing Percentage and Sensory Parameters in Grampriya Poultry Fed With Poha Mill Waste," *International Journal of Veterinary Sciences and Animal Husbandry* 9, no. 5 (2024).

[50] E. T. Bekele, *Nutritional Value of Cassava Root Chips and Moringa Oleifera Leaf Meal in Broiler and Layer Rations*, (PhD Thesis Submitted to School of Graduate Studies School of Animal and Range Science, (Haramaya University, Ethiopia, p. 96, 2013).

[51] M. Yimana and A. Hassen, "Assessment of the Operational Facilities and Hygienic Practices of Abattoirs and Butcher Shops in Ethiopia," *Discover Food* 4, no. 1 (2024): 88.

[52] M. N. Mwangi, J. K. Ondiek, and D. M. Musyimi, "Economic Evaluation of Black Soldier Fly (*Hermetia illucens*) Larva Meal as a Protein Source in Broiler Diets," *Poultry Science* 101, no. 5 (2022): 101734.

[53] O. A. Olusiyi and C. N. Ebule, "Pearl Millet-Based Diets Supplemented With Synthetic Methionine: Effects on Growth Performance and Profitability in Broiler Chickens," *Tropical Animal Health and Production* 56, no. 2 (2024): 45.

[54] D. Shuma, K. Mekonnen, T. Tolemariam, and S. Lemma, "Utilization of Processed Animal and Rumen by-Products in Poultry Diets: Impacts on Feed Cost and Performance," *Journal of Animal Science and Biotechnology* 16, no. 2 (2025): 45–58.

[55] G. M. Pesti and M. Choct, "Economic Approaches to Feed Formulation: Profit Maximization Versus Cost Minimization," *Poultry Science* 102, no. 4 (2023): 102567.

[56] M. Upton, *Farm Management in Africa: The Principle of Production and Planning* (Oxford University Press, 1979).

[57] S. A. Knott, B. J. Leury, L. J. Cummins, F. D. Brie, and F. R. Dunshea, "Relationship Between Body Composition, Net Feed Intake and Gross Feed Conversion Efficiency in Composite Sire Line Sheep," in *Progress in Research on Energy and Protein Metabolism*, ed. W. B. Souffrant and C. C. Metges, (EAAP publication, Wageningen, Germany, 2003): 525–528.

[58] R. Adhikari, S. J. Rochell, R. Kriseldi, et al., "Recent Advances in Protein and Amino Acid Nutritional Dynamics in Relation to Performance, Health, Welfare, and Cost of Production," *Poultry Science* 104, no. 3 (2025): 104852.

[59] D. R. Hamdeen Yahia, "The Impact of Manipulation Phase Feeding System on the Broiler Performance and Carcass Lipid Profile: A Review," *International Journal of Veterinary Science and Research* 9, no. 1 (2023): 001–004.

[60] S. Musigwa, P. Cozannet, C. A. Asiamah, and S. B. Wu, "Effects of Dietary Protein Levels, Net Energy Levels, and Essential Amino Acid-to-True Protein Ratios on Broiler Performance," *Animals* 14, no. 21 (2024): 3065.

[61] E. Le Bihan-Duval, M. Debut, C. M. Berri, et al., "Chicken Meat Quality: Genetic Variability and Relationship With

Growth and Muscle Characteristics," *BMC Genetics* 9, no. 1 (2008): 53.

[62] S. Benahmed, A. Askri, T. de Rauglaudre, M.-P. Létourneau-Montminy, and N. Alnahhas, "Effect of Reduced Crude Protein Diets Supplemented With Free Limiting Amino Acids on Body Weight, Carcass Yield, and Breast Meat Quality in Broiler Chickens," *Poultry Science* 102, no. 11 (2023): 103041.

[63] F. Marangoni, G. Corsello, C. Cricelli, et al., "Role of Poultry Meat in a Balanced Diet Aimed at Maintaining Health and Wellbeing: An Italian Consensus Document," *Food & Nutrition Research* 59, no. 1 (2015): 27606.

[64] E. B. Tesfaye, G. M. Animut, and M. L. Urge, "Economic Analysis of Broiler Chickens Fed Diets Containing Graded Levels of Dried Blood-Rumen Content Mixture," *Journal of Economics and Sustainable Development* 10, no. 4 (2019): 1–8.

[65] H. Ayalew, K. Getnet, and T. Tolemariam, "Economic Feasibility of Alternative Feed Resources in Poultry Production in Ethiopia," *Journal of Applied Poultry Research* 29, no. 4 (2020): 985–995.

[66] K. T. Mekonnen, D.-H. Lee, Y.-G. Cho, A.-Y. Son, and K.-S. Seo, "Estimation of Carcass Trait Characteristics, Proportions, and Their Correlation With Preslaughter Body Weight in Indigenous Chickens in Southeastern Ethiopia," *Agriculture* 14, no. 1 (2024): 50.

[67] N. Nikolova and Z. Pavlovski, "Major Carcass Parts of Broiler Chicken From Different Genotype, Sex, Age and Nutrition System," *Biotechnology in Animal Husbandry* 30, no. 2 (2014): 193–202.

[68] D. Muratov, B. Kubekova, M. Khassanova, et al., "Effects of Alternative Protein Sources From Food Industry Byproducts in Starter Feeds on Dairy Calf Growth Performance under Different Conditions: A Preliminary Study," *Frontiers in Animal Science* 6 (2025): 1595300.

[69] K. Samarakoon and H. P. V. Rupasinghe, "Valorization of Grape Pomace by Microbial Fermentation: Composition, Biological Activities and Potential Applications for the Food Industry," *Journal of Food Composition and Analysis* 144 (2025): 107656.

[70] L. Kovács, G. Domaföldi, P.-C. Bertram, M. Farkas, and L. P. Könyves, "Biosecurity Implications, Transmission Routes and Modes of Economically Important Diseases in Domestic Fowl and turkey," *Veterinary Sciences* 12, no. 4 (2025): 391.