Nutritional Evaluation and Utilization of Locally Available Alternative Feed Resources for Poultry Production: Case Study of Smallholder Farms in Southern Ethiopia

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Abstract

Poultry farming plays a vital role in the livelihoods of smallholder farmers in Southern Ethiopia by providing protein and income. However, the high cost of conventional feeds has created a need for alternative feed ingredients. This study identifies and assesses the nutritional value of locally available alternative feed resources for poultry in the region. Data were collected from 360 households across the Hadiya, Wolaita, and Gamo zones to examine household demographic and socio-economic characteristics, feeding practices, and the use of alternative feeds such as enset (Ensete ventricosum) corm, avocado (Persea americana) seed kernel, mango (Mangifera indica) seed kernel, and moringa (Moringa stenopetala) leaf meal. A multistage sampling technique and field measurements were employed for data collection. The common alternative feeds were sampled and analysed for their nutritional characteristics. The majority of households (80%, N = 288) engaged in supplementary feeding, primarily using cereal grains. Nutritional evaluations revealed significant differences in nutrient content: moringa leaf meal had the highest crude protein (CP, 30.8 ± 0.35%), while mango seed kernel had the highest carbohydrate content (79.62%). On average, alternative feeds had higher crude protein content ($p < 0.05$) than conventional feeds such as maize (8.5% CP) but lower than soybean meal (40.1% CP). Among the alternative feed resources, avocado seed kernel contained 4185.97 ± 43.37 Kcal ME/kg DM, mango seed kernel 3755.48 ± 32.3 Kcal ME/kg DM, and enset corm 3611.16 ± 5.04 Kcal ME/kg DM, showing comparability with conventional feeds. Alternative feeds generally exhibited higher carbohydrate levels ($p < 0.05$) and comparable essential nutrient contents, demonstrating their potential as poultry diet supplements. Some alternative feed ingredients contained anti-nutritional factors like tannins (mean = 2.3%) and oxalates (mean = 1.1%), but their harmful effects could be eliminated through proper processing. This underscores the importance of processing to minimize adverse effects. The findings highlight the potential of local feed resources to reduce reliance on expensive conventional feeds and support sustainable poultry production. Recommendations include raising awareness, providing training on the use of alternative feeds, and implementing government support measures to reduce dependence on imported feeds in Southern Ethiopia.

Introduction

Poultry production is one of the fastest-growing sectors within the global animal protein industry. The demand for poultry products, particularly chicken meat, is projected to grow significantly in the coming years, driven by increasing global preferences for healthier meat options (Mottet & Tempio, 2020; Abdollahi & Ravindran, 2021; Nkukwana *et al.*, 2021). Additionally, the poultry sector holds the potential to combat malnutrition, generate employment, and strengthen rural economies (Sonale et al., 2020). This expected growth will substantially impact the demand for traditional poultry feeds. Several factors, including population growth, a shift towards high-protein diets, limited agricultural land for crop cultivation, climate change, rising fossil fuel costs, and the diversion of key feed ingredients, particularly cereals, towards biofuel production, present ongoing challenges to the feed supply (Mottet and Tempio, 2020; Abdollahi and Ravindran, 2021).

In rural or backyard poultry production systems, small numbers of chickens are typically kept and dedicated poultry housing is rare. The birds primarily rely on scavenging, with occasional supplementation from homegrown grains and kitchen scraps. These systems often lack regular health management programs, biosecurity measures, and established marketing channels. Native, dual-purpose breeds that are well-suited to scavenging are predominantly kept, while hybrid and exotic breeds are more common in larger-scale operations outside of village settings (Emebet and Kidane, 2016; Wondmeneh et al., 2017; FAO, 2020). Approximately 80% of households that own poultry maintain between one and nine chickens, with the sector largely characterized by indigenous breeds, extensive scavenging practices, and small-scale family poultry production methods (CSA, 2017; FAO, 2020).

Feed costs are the most significant expense in poultry production, comprising 55–75% of total production costs (Al-Khalaifah et al., 2020; Yared *et al.*, 2021). In Ethiopia, feed ingredient prices fluctuate depending on regional availability and source. Even when the costs of primary feed components drop by over 50%, the overall price of mixed feed remains prohibitively high (Yared *et al.*, 2021). There is also competition for essential grains such as maize and soybeans, which are vital for poultry feed but are in limited supply, affecting both human and livestock nutrition (Mammo, 2012). As a result, the dual challenges of feed shortages and high prices for these conventional protein and energy sources have negatively impacted poultry productivity (EIAR, 2016; Melkamu, 2017).

The adoption of non-conventional feed resources may help alleviate feed supply deficits, reduce competition for food between humans and livestock, lower feed costs, and enhance nutrient self-sufficiency through locally sourced feed materials (Belay & Janssens, 2021). Utilizing inexpensive and readily available local feed resources could substantially boost poultry productivity (Lukuyu et al., 2011).

Developing low-cost poultry feeds using locally sourced alternative energy and protein ingredients has the potential to enhance chicken productivity and positively impact the poultry sector (El-Deek *et al.*, 2020). However, a clear understanding of the sources and applications of alternative feed ingredients is lacking in the study area. This study investigates the feeding practices of smallholder poultry farmers in Southern Ethiopia, focusing on alternative feed ingredients, evaluating their nutritional composition, comparing them with conventional feeds, and examining anti-nutritional factors. It also explores the potential of these alternatives to reduce feed costs, support sustainable production, and enhance farmer livelihoods while developing recommendations for raising awareness, providing training, and assessing their economic feasibility.

Materials and Methods

2.1. About the study area

The research was conducted in three administrative zones: Wolaita, Gamo, and Hadiya. The first two zones are located in the Southern Nations, Nationalities, and Peoples' Region (SNNPR) of Ethiopia, while the Hadiya Zone is situated in the central Ethiopian region. According to the Central Statistical Agency (2023), the Wolaita Zone, approximately 350 kilometers south of Addis Ababa, has a population of about 2 million and depends heavily on agriculture, particularly crop and livestock production. The Gamo Zone, located 400 kilometers from Addis Ababa between latitudes 6.0°–7.5° N and longitudes 37.0°–38.0° E, is home to an estimated 1.6 million people, with barley and enset cultivation as key agricultural activities. The Hadiya Zone, situated 360 kilometers south of Addis Ababa between latitudes 7.0°–8.0° N and longitudes 37.5°–38.5° E, has a population of approximately 1.9 million and focuses primarily on cereal agriculture (CSA, 2023).

2.2. Sampling methods and sample size

A multi-stage sampling approach was utilized to delineate the study area, encompassing zones, districts, kebeles, and households within the research framework. Initially, three zones were identified through purposive sampling, focusing on their potential for poultry production. This was followed by the random selection of two districts from each of the chosen zones. In the next phase, three kebeles from each district were selected using randomized stratified random sampling methods. Ultimately, households with prior experience in chicken rearing were identified through purposive sampling to determine the sample size for each kebele. The total sample size for the study was computed using the formula established by Yemane (1967).

$$n = \frac{N}{1 + N(e)^2}$$

Where: n, required sample size, n, total household size, e, desired level of precision.

2.3. Methods of data collection

Both primary and secondary data were utilized in this study. Primary data were collected using household surveys, focus group discussions, laboratory analyses and interviews with key informants. Secondary data were obtained from multiple sources, including books, theses, reports, journals, official records, and statistical yearbooks.

2.4. Sample collection and preparation

All feed samples obtained from a defined region comprising three selected zones. After necessary processing, the samples mixed in equal proportions of 1:1:1. Moringa leaves (Moringa stenopetala) gathered, detached from stems, sorted, washed with tap water, and dried in shade for 2 to 5 days. Once dried, Moringa leaves ground to powder passing through sieve mesh size 5 mm. Fresh mango and avocado seed kernels sourced from various juice establishments in each zonal town. Fleshy portions of mango and avocado seeds removed to isolate seeds. For mango seeds, additional cutting with axe required to extract kernels. Kernels sliced, soaked in water for 24 hours, boiled in tap water at 100°C for 30 minutes, sun-dried for 72 hours, ground in hammer mill to pass through 5 mm sieve. Fresh Enset corms excavated after aerial parts of Enset plant removed. Entire corms washed, cleaned, peeled, cut into small pieces, spread on plastic sheet, placed under direct sunlight to dry for five days, turned regularly for even drying, prevent decay. Dried Enset corms ground to size passing through 5 mm sieve, matching dimensions of commercial rations.

Upon ripening, banana fruit harvested, pseudostems selected for processing. Banana pseudostems laid on plastic sheet, trimmed to remove non-essential parts. Banana stem grated similar to traditional enset processing, mixture allowed to ferment in sealed environment for one month. After fermentation, mixture spread on plastic sheet, air-dried for five days, turned regularly for uniform drying, prevent spoilage. Dried banana kocho ground to particle size passing through sieve openings of 5 mm, aligning with specifications of commercial feed.

2.5. Analysis of nutritional components

The alternative feed ingredient samples were subjected to analysis for dry matter; ether extracts (EE), crude fiber (CF), total ash, and crude proteins, following the AOAC (2020) methodology. Calcium (Ca) content was measured using an atomic absorption spectrophotometer, while phosphorus (P) was assessed through calorimetric methods as outlined by AOAC (2020). All analyses were conducted in the analytical chemistry laboratory at Arba Minch University. The estimation of metabolizable energy (ME) was performed using the formula:

ME (Kcal/kg DM) = 3951 + 54.4EE − 88.7CF − 40.8Ash (Wiseman, 1987).

Where M.E represents Metabolizable Energy, kcal stands for kilocalories, kg denotes kilograms, DM refers to Dry Matter, EE is Ether Extract, and CF signifies Crude Fiber.

The assessment of anti-nutritional factors in each alternative feed sample was carried out using the following methods: phytic acid was analyzed according to the procedure by Lucas and Markakes (2020), tannin was determined using the method of Maga (2021), and oxalate and saponin were evaluated following the standard procedures established by AOAC (2020).

Results and Discusion

3.1. Socioeconomic characteristics of respondent households

The findings of the study provide insights into the household characteristics of respondents from Wolaita, Gamo, and Hadiya zones. The results are summarized in Table 1 and discussed below. The majority of respondents were female (64.2% overall), with a statistically significant variation across the zones ($P = 0.001$; $\chi2 = 37.04$). Female-headed households were most common in Gamo Zone (85.8%) and least common in Hadiya Zone (51.7%). Conversely, male-headed households were more prevalent in Hadiya Zone (48.3%) and Wolaita Zone (45%). These differences may reflect variations in cultural norms, economic activities, or migration patterns. Previous research has shown that female-headed households often face unique challenges in accessing resources and decision-making roles (Al-Fara, 2024).

Educational attainment showed significant variation ($P = 0.05$; $\chi2 = 15.27$). A substantial proportion of respondents across all zones had completed at least primary education, with secondary education (9–12 years) being most common in Gamo Zone (30%) and Wolaita Zone (19.2%). Notably, the proportion of respondents with a diploma or higher education was highest in Wolaita Zone (17.5%) and lowest in Hadiya Zone (5.8%). The relatively higher illiteracy rate in Hadiya Zone (22.5%) could limit access to modern agricultural technologies and income-generating opportunities (Martinez and Fernandez, 2010).

The mean age of respondents ranged from 38.53 ± 1.1 years in Gamo Zone to 41.48 ± 1.3 years in Hadiya Zone, with no statistically significant differences ($P = 0.15$). This uniform distribution suggests that middle-aged individuals, who are generally more experienced and actively involved in farming and household management, dominate the respondent demographic. The average household size differed significantly across zones ($P = 0.001$). Hadiya Zone had the largest average family size (8.13 ± 0.24), followed by Wolaita Zone (6.79 ± 0.17) and Gamo Zone (6.04 ± 0.18). Larger families in Hadiya Zone may offer greater labor resources but could also strain household resources, particularly in areas with limited land availability. Smaller family sizes in Wolaita and Gamo zones may ease resource demands but potentially reduce the labor pool for agricultural activities (FAO, 2022).

The total land owned by households varied significantly ($P = 0.02$). Respondents in Hadiya Zone reported the largest average land holding (1.28 ± 0.09 ha), while those in Wolaita Zone had the smallest (0.79 ± 0.06 ha). Larger land holdings in Hadiya Zone may allow for diverse farming practices and higher productivity, whereas smaller land sizes in Wolaita Zone require intensive land-use strategies. Land size has a direct impact on household income and food security, as highlighted by Kassie et al. (2023). The variations in household characteristics across the zones underscore the importance of context-specific interventions. For instance, addressing the high prevalence of female-headed households in Gamo Zone with targeted support programs could enhance resource management and household resilience. Similarly, improving educational access in Hadiya Zone and promoting land-use efficiency in Wolaita Zone are critical for sustainable agricultural development. These findings align with broader research emphasizing the interplay between household characteristics and agricultural productivity in rural Ethiopia (IFPRI, 2023). Tailored policies and programs that consider these regional disparities can significantly enhance household welfare and economic opportunities.

Table 1
The socioeconomic characteristics of respondent households in Southern Ethiopia

Parameters	Wolaita Zone (N = 120)	Gamo Zone (N = 120)	Hadiya Zone (N = 120)	Overall	P value	χ2
Sex of respondent households (%)						
Male	54(45)	1714.2)	58(48.3)	129(35.8)	0.001	37.04
Female	66(55)	103(85.8)	62(51.7)	231(64.2)		
Educational level of respondant (%)						
Illiterate	16(13.3)	16(13.3)	27(22.5)	59(16.4)	0.05	15.27
Primary school primary cycle(1–4)	24(20)	18(15)	19(15.8)	61(16.9)		
Primary school secondary cycle(5–8)	36(30)	37(30.8)	38(31.7)	111(30.8)		
Secondary school(9–12)	23(19.2)	36(30)	29(24.2)	88(24.4)		
Diploma and above	21(17.5)	13(10.8)	7(5.8)	41(11.41)		
Mean age of respondents (Mean ± SD)	38.96 ± 1.21	38.53 ± 1.1	41.48 ± 1.3	39.66 ± 0.7	0.153	
Average family size/HH (Mean ± SD)	6.79 ± 0.17^{b}	6.04 ± 0.18^{bc}	8.13 ± 0.24^{a}	6.99 ± 0.125	0.001	
Total owned land (Mean ± SD)	0.79 ± 0.06^{b}	1.06 ± 0.13^{ab}	1.28 ± 0.09^{a}	1.04 ± 0.05	0.022	

N, number households interviewed; χ2, chi-square; ^{abc}Means in the same row with distinct superscripts are significantly different ($P < 0.05$) as separated by Duncan multiple range test. SD, Standard deviation

3.2. Flock structure and size of chicken

The study assessed flock sizes and composition across Wolaita, Gamo, and Hadiya zones in Southern Ethiopia (Table 2). The results are summarized in the table and discussed below. The average total chicken per household varied across the zones, with Hadiya Zone reporting the highest (11.75 ± 0.85) and Wolaita Zone the lowest (9.3 ± 0.57). However, these differences were not statistically significant (P > 0.05). The overall mean flock size was 10.6 ± 0.89. This suggests that while flock size differs slightly, households across zones generally maintain similar numbers of chickens, potentially.

The average number of cocks was consistent across the zones, with no significant differences (P > 0.05). Similarly, the number of hens ranged from 4.09 ± 0.32 in Wolaita Zone to 5.17 ± 0.39 in Hadiya Zone, but these differences were not statistically significant. The presence of hens is critical for egg production and breeding, indicating that hens form a substantial proportion of flocks in all zones. Significant differences were observed in the number of cockerels (P = 0.001) and pullets (P = 0.001) among zones. Hadiya Zone reported the highest numbers of pullets (2.73 ± 0.71), suggesting a stronger emphasis on rearing young hens for replacement or growth. Gamo Zone had the fewest cockerels (0.34 ± 0.09), which may reflect differences in management practices or market preferences.

The number of chicks varied across zones, with Gamo Zone reporting the highest average (3.03 ± 2.44) and Hadiya Zone the lowest (0.9 ± 0.28). Although the differences approached significance ($P = 0.09$), this variability may be influenced by factors such as hatching success rates, mortality, or management practices. The number of local chickens differed significantly across zones ($P = 0.001$). Hadiya and Wolaita zones had higher numbers of local chickens compared to Gamo Zone. The average number of local hens was highest in Hadiya Zone (2.19 ± 0.23), and cocks were more prevalent in Wolaita Zone (0.72 ± 0.09). Local chickens are often valued for their adaptability to local conditions and resilience to diseases (Kassie et al., 2023).

Exotic chicken numbers were highest in Gamo Zone (9.51 ± 2.47), followed by Hadiya Zone (6.84 ± 0.92). Significant differences were observed in the number of exotic hens ($P = 0.001$), with Gamo Zone reporting the highest. This suggests a greater adoption of exotic breeds in Gamo Zone, likely due to their higher productivity under improved management conditions (FAO, 2022).

The variations in flock size and composition reflect regional differences in household priorities, management practices, and resource availability. The dominance of exotic chickens in Gamo Zone may indicate better access to inputs such as feed and veterinary care, while the prevalence of local chickens in Hadiya and Wolaita zones underscores the importance of resilience and adaptability to local conditions. These findings highlight the need for targeted interventions to optimize poultry production, such as improving access to inputs in zones with higher exotic chicken populations and enhancing disease management for local breeds in other areas.

Table 2
Chicken Flock Structure and Average Flock Size per Household in Southern Ethiopia

Flock size	Study Location of the Southern Ethiopia			Overall	P value
	Wolaita Zone	Gamo Zone	Hadiya Zone		
Total chicken	9.3 ± 0.57	10.74 ± 2.47	11.75 ± 0.85	10.6 ± 0.89	NS
Cock	1.81 ± 0.21	1.83 ± 0.18	1.97 ± 0.12	1.87 ± 0.12	NS
Hen	4.09 ± 0.32[b]	4.73 ± 0.23[ab]	5.17 ± 0.39[a]	4.66 ± 0.18	NS
Cockerels	1.09 ± 0.26[a]	0.34 ± 0.09[b]	1.11 ± 0.24[a]	0.85 ± 0.12	0.001
Pullets	1.28 ± 0.27[b]	0.79 ± 0.22[b]	2.73 ± 0.71[a]	1.60 ± 0.27	0.001
Chick	1.02 ± 0.22	3.03 ± 2.44	0.9 ± 0.28	1.65 ± 0.82	0.09
Local chicken	4.38 ± 0.37[a]	1.09 ± 0.23[b]	4.45 ± 0.48[a]	3.31 ± 0.23	0.001
Cock	0.72 ± 0.09[a]	0.16 ± 0.06[b]	0.92 ± 0.12[a]	0.6 ± 0.05	0.001
Hen	2.08 ± 0.17[a]	0.59 ± 0.11[b]	2.19 ± 0.23[a]	1.62 ± 0.11	0.001
Cockerels	0.16 ± 0.05a[b]	0.02 ± 0.01[b]	0.25 ± 0.07[a]	0.14 ± 0.03	0.001
Pullets	0.48 ± 0.13[a]	0.00 ± 0.00	0.45 ± 0.11[a]	0.28 ± 0.06	0.001
Chick	1.02 ± 0.22[a]	0.33 ± 0.13[b]	0.66 ± 0.25a[b]	0.67 ± 0.12	0.029
Exotic chicken	4.78 ± 0.63[a]	9.51 ± 2.47[ab]	6.84 ± 0.92[b]	7.04 ± 0.91	NS
Cock	1.05 ± 0.2a[b]	1.64 ± 0.18[a]	0.89 ± 0.19[b]	1.19 ± 0.11	NS
Hen	1.91 ± 0.31[b]	4.08 ± 0.24[a]	2.73 ± 0.38[b]	2.91 ± 0.18	0.001
Cockerels	0.93 ± 0.26	0.33 ± 0.09	0.83 ± 0.24	0.69 ± 0.12	0.001
Pullets	0.88 ± 0.25[b]	0.79 ± 0.22[b]	2.18 ± 0.71[a]	1.28 ± 0.26	0.001
Chick	0.00 ± 0.00	2.66 ± 2.44	0.21 ± 0.14	0.96 ± 0.81	0.01

[a,b]Mean ± SE; Values in the same row with different superscripts are significantly different ($P < 0.05$) as determined by the Duncan multiple range test; SD, Standard deviation.

2.3. Practice and feeds used for supplementation

The study evaluated the supplementation practices and feed types used by households across Wolaita, Gamo, and Hadiya zones in Southern Ethiopia. The findings are summarized in Table 3 and discussed below. A significant proportion of households (80%) across all zones practiced supplementation, although the prevalence varied significantly ($P = 0.005$; $\chi 2 = 10.73$). The highest rate of supplementation was observed in Wolaita Zone (89.2%), followed by Gamo Zone (78.3%) and Hadiya Zone (72.5%). This variation may be attributed to differences in resource availability, awareness of supplementation benefits, or management practices. Previous studies (FAO, 2022) have shown that supplementation is critical for improving poultry productivity, particularly in resource-constrained systems.

The lower supplementation rates in Hadiya Zone could indicate limited access to supplementary feeds or prioritization of other livestock. Conversely, the higher rates in Wolaita Zone may reflect better integration of supplementation into poultry management practices. Grains were the most commonly used supplementary feed, with 64.2% of households across all zones using them. However, the usage rates varied significantly ($P = 0.001$; $\chi 2 = 31.41$). Wolaita Zone had the highest usage (76.6%), followed by Gamo Zone (63.8%) and Hadiya Zone (49.4%). Grains are a readily available and cost-effective feed option, especially for smallholder farmers, but their use may be influenced by local availability and economic factors (Kassie et al., 2023).

Commercial feed usage varied across zones, with Hadiya Zone reporting the highest prevalence (50.6%), compared to Wolaita Zone (33.3%) and Gamo Zone (26.6%). This trend suggests that households in Hadiya Zone are more inclined to invest in commercial feed, potentially to boost productivity in exotic chicken breeds, which are more common in this zone. The relatively lower usage in Gamo and Wolaita zones may reflect economic constraints or limited access to commercial feed suppliers. Only 3.8% of households overall used kitchen waste for supplementation, with the highest prevalence in Gamo Zone (8.5%). Kitchen waste is an inexpensive feed source but may be less commonly used due to cultural preferences or concerns about feed hygiene and quality. Root crops were rarely used for supplementation, with only one household in Gamo Zone (1.1%) reporting their use. This minimal utilization may be due to the preference for human consumption of root crops or their limited availability as a feed resource. The results highlight the critical role of supplementation in poultry management, with most households adopting the practice to improve productivity. However, the type of feed used varies significantly across zones, reflecting differences in resource availability and economic priorities.

The widespread use of grains suggests a reliance on locally available resources, but the increasing adoption of commercial feed in Hadiya Zone indicates a shift toward market-oriented poultry production. Interventions to improve feed availability and affordability, particularly in zones with lower supplementation rates, could enhance poultry productivity and household incomes. Additionally, promoting the safe use of alternative feed sources, such as kitchen waste, may provide cost-effective supplementation options for resource-constrained households. These findings align with broader research emphasizing the importance of tailored feeding strategies to improve poultry production in smallholder systems (IFPRI, 2023).

Table 3
Supplementation practices and types of feeds used for chickens in Southern Ethiopia

Variables	Study Location of the Southern Ethiopia				P value	χ2
	Wolaita Zone (N = 120)	**Gamo Zone (N = 120)**	**Hadiya Zone (N = 120)**	**over all**		
Practice of supplementation (%)						
Yes	107(89.2)	94(78.3)	87(72.5)	288(80)	0.005	10.73
No	13(10.8)	26(21.7)	33(27.5)	72(20)		
Feeds used for supplementation (%)						
Grains	82(76.6)	60(63.8)	43(49.4)	185(64.2)	0.001	31.41
Commercial feed	18(33.3)	25(26.6)	44(50.6)	91(31.6)		
Kitchen waste	3(2.8)	8(8.5)	0(0.0)	11(3.8)		
Root crops	0(0.0)	1(1.1)	0(0.0)	1(0.3)		

N, number households interviewed, χ2, chi square; p, probability value ($P < 0.05$)

2.4. Identified alternative feed ingredients

The study identified alternative feed ingredients for chickens across Wolaita, Gamo, and Hadiya zones, with the percentages of respondents in each zone who identified each feed item as viable options shown in Table 4. Enset corm (Ensete ventricosum) was the most commonly mentioned alternative feed, with 24.4% of respondents across all zones indicating its use. The majority of these respondents were from Hadiya Zone (66.7%), followed by Wolaita Zone (18.7%) and Gamo Zone (6.4%). The high ranking of enset corm reflects its local availability and significance as a multipurpose crop in southern Ethiopia, with its use in chicken feed likely linked to its energy-rich composition and ease of processing (Abera, 2022).

Mango seed kernel (Mangifera indica L.) ranked second, with 23.2% of respondents identifying it as an alternative feed. Gamo Zone had the highest percentage of respondents (30.6%), followed by Wolaita Zone (21.1%) and Hadiya Zone (14.2%). Mango seed kernel, a byproduct of mango consumption, represents a cost-effective feed ingredient and highlights the resourcefulness in utilizing agricultural byproducts for animal feed (Choudhary et al., 2023).

Moringa leaf (Moringa stenopetala) ranked third, with 22.2% of respondents overall. It was most frequently cited in Gamo Zone (44.6%), while its usage was minimal in Hadiya Zone (0.4%). Moringa leaves are rich in protein, vitamins, and minerals, making them a valuable supplement for poultry nutrition (Peñalver *et al.*, 2020; FAO, 2023). The high prevalence of moringa in Gamo Zone suggests its suitability as an alternative feed in that region.

Avocado seed kernel (*Persea americana*) ranked fourth, with 16.7% of respondents mentioning it as an alternative feed. It was most commonly cited in Wolaita Zone (30.8%), with fewer respondents in Gamo Zone (5.6%) and Hadiya Zone (9.8%). The avocado seed kernel, often discarded as waste, presents an innovative alternative feed source and highlights the potential to reduce waste while enhancing poultry nutrition (Kassie et al., 2023; Sandoval et al., 2023).

Banana kocho (Musa paradisiaca) was ranked fifth, with 13.5% of respondents identifying it as an alternative feed. Its use was most prevalent in Wolaita Zone (16.6%), followed by Gamo Zone (12.8%) and Hadiya Zone (8.9%). Banana kocho, a byproduct of banana processing, is a readily available and cost-effective feed ingredient in regions where banana farming is prevalent.These findings underscore the adaptability of smallholder farmers in leveraging locally available resources for poultry production. The preference for enset corm and mango seed kernel highlights the importance of crop byproducts in poultry feeding systems, particularly in regions where conventional feeds are expensive or unavailable. Regional differences in feed preferences reflect the influence of local crop production patterns and resource availability on feed choices. For instance, the popularity of moringa leaves in Gamo Zone suggests its potential for wider adoption in other zones, given its nutritional benefits. Similarly, the use of avocado and mango seed kernels demonstrates the potential for sustainable poultry feeding through waste recycling.

Promoting the processing and safe utilization of these alternative feed ingredients could enhance poultry productivity while reducing feed costs. Integrating these feeds into extension programs could further support resource-constrained farmers in improving poultry production, aligning with global trends that emphasize the use of agricultural byproducts and unconventional feeds in smallholder systems.

Table 4
Local and scientific names of alternative feed ingredients locally included for chickens as identified by respondent farmers

Name of selected feed item	Percentage of respondats indicted as alternative feed for chicken				Rank
	Wolaita Zone	Gamo Zone	Hadiya Zone	Over all	
Enset corm (*Ensete ventricosum*)	18.7	6.4	66.7	24.4	1
Mango seed kernel (*Mangifera indica* L.)	21.1	30.6	14.2	23.2	2
Moringa leaf (*Moringa stenopetala*)	12.8	44.6	0.4	22.2	3
Avocado seed kernel(*Persea americana*)	30.8	5.6	9.8	16.7	4
Banana kocho(*Musa paradisiaca*)	16.6	12.8	8.9	13.5	5

2.5. Chemical composition of identified alternative feed ingredients

The proximate composition of selected alternative feed ingredients and conventional feed items for chickens in Southern Ethiopia is presented in Table 5. This analysis highlights significant differences among the feed items, emphasizing their potential as alternatives to conventional poultry feed. Banana kocho had the highest ash content (20.34%), significantly higher than conventional feeds like maize (1.50%) and soybeans (9.01%) ($P = 0.001$). The high ash content of banana kocho indicates its mineral richness, making it a potential supplement to address mineral deficiencies in poultry diets, particularly in resource-limited settings. This is consistent with findings by Abbas, (2023), who emphasized the importance of ash-rich feed in poultry nutrition

Enset corm (10.47%) and boiled avocado seed kernel (10.27%) had the highest moisture content, making them more prone to spoilage if not properly dried ($P = 0.001$ $P = 0.001$ $P = 0.001$). Conversely, banana kocho (6.41%) had the lowest moisture content, enhancing its shelf life and storage potential. Effective drying methods are crucial to maintaining feed quality, especially for high-moisture feeds, as noted by Jimoh et al. (2023); Katarzyna et al. (2021).

Soybeans had the highest crude protein content (37.51%), followed by moringa leaf meal (30.8%) (P = 0.001 P = 0.001 P = 0.001). Among the alternative feeds, boiled avocado seed kernel (15.86%) was a notable protein source, while enset corm (3.35%) and boiled mango seed kernel (5.39%) were significantly lower. These findings suggest that protein-rich feeds like moringa leaf meal and boiled avocado seed kernel could supplement conventional protein sources, as also highlighted by Amad and Zentek. (2024); Pexas et al. (2019).

Boiled avocado seed kernel (11.74%) and soybeans (23.92%) had the highest ether extract content, indicating their suitability as energy-dense feed options (P = 0.001 P = 0.001 P = 0.001). Banana kocho (0.88%) and enset corm (0.57%) were low in fat, making them less effective as primary energy sources but suitable as carbohydrate sources. Similar findings were reported by Musigwa et al. (2023), emphasizing the value of fat-rich feeds in energy-intensive poultry production.

Boiled mango seed kernel (79.62%) and enset corm (77.69%) were the most carbohydrate-rich feeds, comparable to maize (71.21%) (P = 0.001 P = 0.001 P = 0.001). These feeds are excellent energy sources and could partially replace maize in poultry diets. In contrast, soybeans (19.02%) and moringa leaf meal (38.85%) had lower carbohydrate content, aligning with their roles as protein-focused feeds (Das et al. 2015).

Boiled avocado seed kernel (4,185.97 Kcal/kg DM) and soybeans (4200 Kcal/kg DM) had the highest metabolizable energy (ME) values (P = 0.001 P = 0.001 P = 0.001). These results highlight their suitability for high-energy dietary formulations. Banana kocho had the lowest ME (1719.48 Kcal/kg DM), limiting its role to supplementary energy feeds. According to Massuquetto et al. (2020), energy-dense feeds are essential for improving feed efficiency and growth performance.

Moringa leaf meal (3.023 mg/100g) had the highest calcium content, significantly surpassing conventional feeds like maize (2 mg/100g) (P = 0.001). Calcium is crucial for bone development and egg shell formation, making moringa leaf meal a valuable feed ingredient, as supported by Antyev et al. (2020).
Boiled mango seed kernel (9.37 mg/100g) had the highest oxalate content, which can interfere with calcium absorption and reduce feed utility (P = 0.001). Conversely, banana kocho (1.97 mg/100g) and boiled avocado seed kernel (1.37 mg/100g) had lower oxalate levels, making them safer options. Nguyen et al. (2022) highlighted that processing, such as boiling, effectively reduces oxalates in feed ingredients.

This study demonstrates the potential of alternative feed ingredients, including moringa leaf meal, boiled avocado seed kernel, and banana kocho, as viable options to replace or complement conventional feeds like maize and soybeans. These alternative feeds can enhance nutrient diversity and reduce dependency on costly conventional feeds, promoting sustainable poultry production in Southern Ethiopia. However, anti-nutritional factors like tannins and oxalates must be addressed through proper processing to optimize their use.

Table 5
Nutritional composition (mean ± SD) comparison of alternative and conventional feed ingredients for chickens in southern Ethiopia

Parameter	Banana kocho	Mango seed kernal	Avacado seed kernal	Enset corm	Moringa leaf meal	Maize	Soybeans	Pvalue
Ash (%)	20.34 ± 0.66^{a}	2.37 ± .08d^{e}	3.33 ± 0.089^{c}	4.8 ± 0.082^{c}	9.55 ± 0.09^{b}	1.50 ± 0.10^{e}	9.01 ± 0.01^{b}	0.001
Moisture (%)	6.41 ± 0.05^{d}	7.79 ± 0.2^{c}	10.27 ± 0.03^{a}	10.47 ± 0.32^{a}	8.67 ± 0.16^{b}	9.05 ± 1.20^{b}	8.30 ± 0.29^{bc}	0.001
Crude Protein (%)	10.04 ± 0.24^{c}	5.39 ± $.05^{e}$	15.86 ± 0.1d^{e}	3.35 ± 0.1^{f}	30.8 ± 0.35^{b}	7.05 ± 0.01^{d}	37.51 ± 0.15^{a}	0.001
Ether Extract (%)	0.88 ± 0.23^{e}	2.29 ± 0.6^{d}	11.74 ± 0.44^{b}	0.57 ± 0.02^{e}	2.36 ± 0.31^{d}	5.68 ± 0.59^{c}	23.92 ± 0.51^{a}	0.001
Carbohydrate (%)	45.97 ± 0.72^{e}	79.62 ± 0.78^{a}	65.77 ± 0.35^{d}	77.69 ± 0.39^{b}	38.85 ± 0.16^{f}	71.21 ± 0.05^{c}	19.02 ± 0.30^{g}	0.001
ME (Kcal/kg DM)	1719.48 ± 39^{f}	3755.48 ± 32^{c}	4185.97 ± 43^{a}	3611.16 ± 5^{d}	2822.88 ± 47^{e}	3,923 ± 31^{b}	4,200 ± 41^{a}	0.001
Calcium(mg/100g)	0.83 ± 0.03^{c}	0.51 ± 0.04^{d}	0.71 ± 0.04^{cd}	0.63 ± 0.08^{cd}	3.023 ± 0.06^{a}	2 ± 0.04^{b}	2.8 ± 0.1^{a}	0.001
Tannin(mg/100g)	2.62 ± 0.02^{a}	0.23 ± 0.01^{e}	0.68 ± 0.03^{b}	0.17 ± 0.003^{e}	0.44 ± 0.00^{c}	0.18 ± 0.02^{e}	0.32 ± 0.03^{d}	0.001
Oxalete(mg/100g)	1.97 ± 0.087^{b}	9.37 ± 0.17^{a}	1.37 ± 0.087^{c}	2.07 ± 0.05^{b}	1.97 ± 0.08^{b}	0.6 ± 0.02^{d}	0.71 ± 0.04 ^{d}	0.001

Values in the same row with different superscripts (a, b, c, d, e, f, g) are significantly different (P < 0.05) according to the Duncan multiple range test. SD refers to the standard deviation.

Conclusions

The study provides valuable insights into the household characteristics, feeding practices, and the potential of alternative feed ingredients for poultry production in Southern Ethiopia. The results show that the majority of households in the Wolaita, Gamo, and Hadiya Zones engage in supplementary feeding practices, with grains being the most commonly used supplement. Moreover, alternative feed ingredients such as enset corm, mango seed kernel, and moringa leaf meal were identified as important sources of nutrients, offering a potential solution to the rising costs of conventional feeds. The proximate composition analysis of selected alternative feed ingredients revealed substantial differences in key nutrients, such as crude protein, fat, and carbohydrate content, with some alternative ingredients like moringa leaf meal and boiled avocado seed kernel showing favorable nutritional profiles. However, the presence of anti-nutritional factors such as tannins and oxalates in some of these feeds calls for further processing to improve their nutritional value and safety for poultry.

Recommendations and Future Research Directions

To improve poultry production in Southern Ethiopia, it is important to promote the use of locally available alternative feeds such as moringa leaf meal, mango seed kernel, and enset corm. Educating farmers on the nutritional benefits and proper use of these feeds through extension services is essential. Additionally, training on processing methods to mitigate anti-nutritional factors, such as tannins and oxalates, should be prioritized. Encouraging sustainable production practices and conducting research on the long-term effects of alternative feeds will enhance poultry performance. Government support, including training programs and subsidies, is crucial for facilitating the adoption of these feeds, while policies should focus on encouraging local feed production to reduce dependence on imports.

Declarations

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Authors contribution

A.G.A, Y.K.K, N.Y.A& W.E.G have contributed equally to this full-length research article.

Conflict of interests

The authors have declared no conflicts of interest.

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Data Availability Statement

The data supporting the results of this study are included in the manuscript

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