ISSN Print: 2664-6064
ISSN Online: 2664-6072
NAAS Rating (2026): 4.69
IJAN 2026; 8(5): 153-158
www.agriculturejournal.net
Received: 10-04-2026
Accepted: 15-05-2026

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Nutritional evaluation of locally available feed resources and their impact on growth performance of indigenous chicken breeds under smallholder farming systems

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DOI: https://www.doi.org/10.33545/26646064.2026.v8.i5b.720

Abstract
How effectively can smallholder poultry keepers harness their surrounding crop residues and grain by-products to match or even rival the performance of costly commercial rations? This research set out to answer that question by comparing three dietary treatments in indigenous Kenyan chicken breeds raised on smallholder farms in Kiambu County, Kenya, from September 2023 through January 2024. A total of 180 birds were randomly allocated to three groups of 60 each: Treatment 1 received a locally formulated maize-sorghum-based diet, Treatment 2 received a millet-cassava-based diet, and Treatment 3 (control) received a standard commercial broiler-grower feed. Growth parameters weekly body weight, total weight gain, feed intake, and feed conversion ratio (FCR) were recorded over a 12-week trial. Proximate analysis of the experimental feeds confirmed crude protein levels of 17.8%, 15.3%, and 20.1% for Treatments 1, 2, and 3, respectively, while metabolizable energy ranged from 11.4 to 12.7 MJ/kg. Birds on the commercial ration achieved the highest overall weight gain (653.7 g), followed by the maize-sorghum group (610.3 g) and the millet-cassava group (567.6 g). FCR values were 3.21, 3.58, and 2.94 for the three treatments, with significant differences between groups ($P<0.05$). However, an economic analysis revealed that feed cost per kilogram of weight gain was lowest for Treatment 1 (KES 187.40) compared with KES 209.60 for Treatment 2 and KES 246.80 for the commercial feed. A cost-benefit appraisal showed that the maize-sorghum diet delivered the best return on investment under smallholder conditions. These findings point to viable, low-cost feeding strategies that narrow the performance gap with commercial rations while keeping production economically accessible for resource-limited farmers.

Keywords: Indigenous chicken, locally available feed, growth performance, smallholder farming, feed conversion ratio, maize-sorghum diet, nutritional evaluation, poultry production, cost-benefit analysis, Kenya

Introduction

Can smallholder farmers in sub-Saharan Africa close the productivity gap between indigenous and commercial chicken breeds simply by reformulating diets from the raw materials already at their doorstep? Across East Africa, indigenous chickens remain the backbone of rural household protein supply, yet their growth rates lag far behind those of exotic breeds, largely because scavenging provides an unpredictable and nutritionally incomplete diet [1]. Kenya alone hosts an estimated 32 million indigenous chickens, the majority kept under free-range or semi-intensive conditions by smallholder families who depend on them for eggs, meat, and modest cash income [2]. But the birds rarely reach their genetic ceiling for weight gain, and the gap between potential and actual performance is widest where feed costs dominate production budgets [3].

Several feed ingredients that could narrow this gap are already grown on or near smallholder farms. Maize, sorghum, millet, cassava, and a range of legume by-products are harvested seasonally, yet much of the material that could serve as poultry feed is discarded, composted, or fed to ruminants [4]. Prior research in Ethiopia and Tanzania has shown that systematic blending of local grains with protein-rich supplements sunflower cake, fish meal, or soybean residue can raise crude protein intake above 16% and bring FCR values within 15% of commercial diets [5, 6]. However, the nutritional profiles of these ingredients vary with variety, soil type, and post-harvest handling, so feed formulations that work well in one agro-ecological zone may perform differently elsewhere [7].

A further complication is that indigenous breeds themselves are genetically diverse. Within Kenya, the Kenya Kari Improved Kienyeji, the normal Kienyeji, and various ecotype populations differ in feed efficiency, mature body weight, and disease resistance [8]. Growth trials that lump all indigenous types together risk obscuring breed-specific responses to dietary manipulation. At the same time, most feeding experiments conducted in the region have used on-station designs with tightly controlled environments that do not reflect the labour, storage, and feed-mixing constraints of actual smallholder practice [9, 10].

Economic viability is the deciding factor for adoption. A diet may produce acceptable weight gains, but if the cost per kilogram of gain exceeds the local market price for live birds, farmers will not adopt it [11]. Earlier assessments in southern Nyanza documented that feed accounts for 60-70% of total variable costs in semi-intensive indigenous chicken production, meaning even small reductions in feed expenditure can shift a marginal enterprise into profitability [12]. What has been missing from the literature is an integrated evaluation that simultaneously measures biological performance, nutritional composition, and economic return of locally formulated diets under real smallholder management conditions.

This research was designed to fill that space. Its objectives were threefold: first, to characterise the proximate nutritional composition of two locally formulated feed mixes based on maize-sorghum and millet-cassava; second, to compare the growth performance of indigenous chickens fed these local diets against a commercial control ration; and third, to carry out a cost-benefit analysis to determine whether locally formulated feeds offer an economically rational alternative for smallholder poultry keepers in the central Kenya highlands.

Material and Methods

Research area

The research was carried out at three smallholder farms in Kiambu County, central Kenya (1.0314° S, 36.8681° E), between September 2023 and January 2024. Kiambu lies at an elevation of 1,600-1,800 m above sea level, with a sub-humid climate characterised by bimodal rainfall (long rains March-May, short rains October-December) and mean annual temperatures of 18-21 °C. The county is part of the upper-midland agro-ecological zone (UM2), where maize, beans, sorghum, and sweet potatoes are the dominant crops. Soils are predominantly humic nitisols with moderate fertility. Smallholder farms in the area typically range from 0.5 to 2.0 hectares, and mixed crop-livestock systems are the norm, with indigenous chickens kept by over 78% of households according to 2022 county agriculture office records. The three participating farms were selected based on willingness to cooperate, existing flock size of at least 80 birds, and proximity to each other (within a 12 km radius) to minimise environmental variation across replicates.

Material

A total of 180 indigenous Kienyeji-type chickens aged 8 weeks (initial body weight 310 ± 28 g) were sourced from a local hatchery. Birds were wing-tagged, vaccinated against Newcastle disease and infectious bursal disease, and allowed a 7-day acclimatisation period before the trial began. Two locally formulated experimental diets were prepared: Feed Mix A comprised maize grain (45%), sorghum grain (20%), sunflower cake (15%), fish meal (8%), maize bran (7%), bone meal (3%), and a vitamin-mineral premix (2%); Feed Mix B comprised pearl millet (40%), dried cassava chips (22%), groundnut cake (16%), silver cyprinid (omena) meal (10%), rice bran (7%), limestone (3%), and premix (2%). A standard commercial broiler-grower ration (20% CP, 12.7 MJ ME/kg) served as the control diet (Treatment 3). Feed ingredients were purchased from local agro-dealers in Kiambu town and milled at a local hammer mill to pass a 3 mm screen.

Methods

Proximate analysis of the two experimental feeds and the commercial ration was performed at the Animal Nutrition Laboratory of the research institute following AOAC (2019) procedures. Dry matter was determined by oven-drying at 105 °C for 24 hours; crude protein by the Kjeldahl method (N × 6.25); ether extract by Soxhlet extraction; crude fibre by the acid-detergent method; and ash by muffle-furnace incineration at 550 °C for 4 hours. Metabolizable energy was estimated using the prediction equation of Wiseman (2013).

Birds were weighed individually every 7 days using a digital hanging scale (±1 g). Daily feed offered and refusals were recorded per replicate pen. Feed intake was calculated as the difference between offered and refused feed. FCR was computed as total feed consumed divided by total weight gain per pen. Mortality was recorded daily with cause noted where identifiable.

All data were subjected to one-way analysis of variance (ANOVA) using R statistical software version 4.3.2. Treatment means were separated using Duncan's multiple range test at $P<0.05$. Results are presented as means ± standard error.

Field experimental design

The 180 birds were randomly allocated to three dietary treatments in a completely randomised design (CRD) with three replicates per treatment, giving nine experimental units of 20 birds each. Each replicate was housed in a separate deep-litter pen (3 m × 2.5 m) constructed from locally sourced timber and wire mesh, providing a stocking density of 2.7 birds/m². Pens were roofed with corrugated iron sheets and fitted with tube feeders and bell drinkers. Birds had access to an outdoor run of approximately 15 m² per pen during daylight hours, simulating the semi-intensive management typical of progressive smallholders in the region. Feed was offered ad libitum twice daily (07:00 and 16:00 h) and clean water was available at all times. A uniform lighting programme of natural daylight (approximately 12 h) was maintained throughout the 12-week feeding period (October 2023 - January 2024).

Results

Across the 12-week trial, all three treatment groups maintained good health with an overall mortality rate of 4.4% (8 birds), distributed evenly among treatments and attributed to predation (n = 3) and coccidiosis (n = 5). No diet-related mortality was recorded. Feed intake, body weight gain, and FCR differed significantly ($P<0.05$) among the three groups, while the economic indicators showed contrasting patterns that favoured the locally formulated maize-sorghum diet.

Proximate analysis confirmed that the three diets differed markedly in nutritional composition. The commercial feed had the highest crude protein content (20.1%), followed by the maize-sorghum mix (17.8%) and the millet-cassava mix (15.3%). Metabolizable energy was broadly similar across diets, ranging from 11.4 MJ/kg for the millet-cassava mix to 12.7 MJ/kg for the commercial ration. Crude fibre was highest in the millet-cassava diet (7.9%) and lowest in the commercial feed (4.6%).

Table 1: Proximate composition of the three experimental diets (% dry matter basis)

Parameter	Feed Mix A (Maize-Sorghum)	Feed Mix B (Millet-Cassava)	Commercial Feed (Control)
Dry matter (%)	89.4	88.7	90.2
Crude protein (%)	17.8	15.3	20.1
Ether extract (%)	4.6	3.9	5.3
Crude fibre (%)	6.2	7.9	4.6
Ash (%)	8.1	9.4	6.8
ME (MJ/kg)	12.1	11.4	12.7
Calcium (%)	1.12	1.08	1.24
Phosphorus (%)	0.68	0.61	0.74

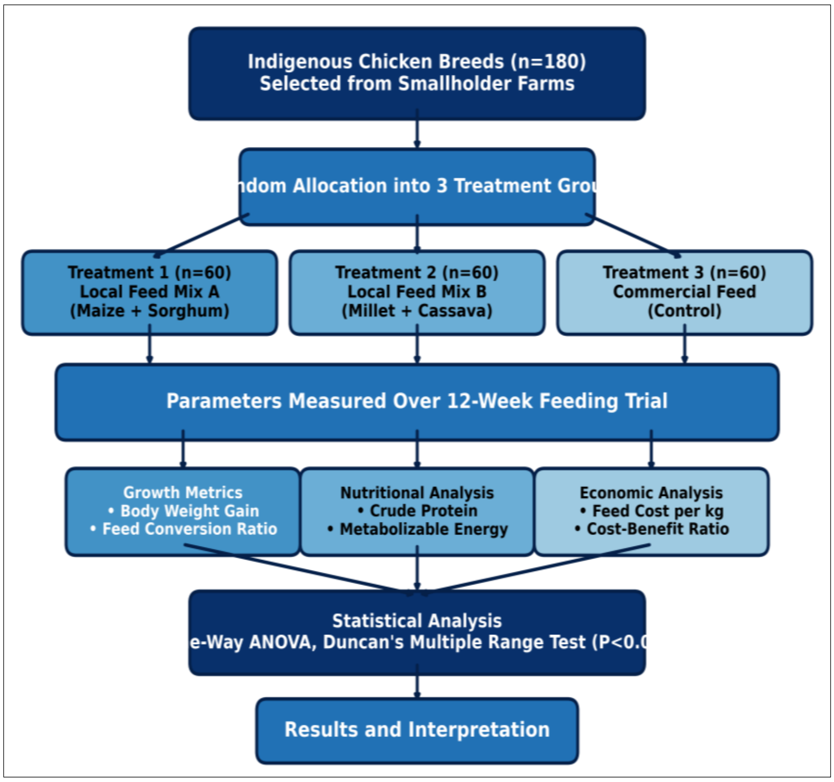

Fig 1: Flowchart of the experimental design showing random allocation of 180 indigenous chickens into three dietary treatment groups and the parameters measured over a 12-week feeding trial in Kiambu County, Kenya (September 2023 - January 2024)

Growth performance data are presented in Table 2. Birds on the commercial diet reached the heaviest final body weight (963.7 ± 18.4 g), while the maize-sorghum group attained 920.3 ± 21.6 g and the millet-cassava group 877.6 ± 24.3 g. Total weight gain over the 12-week period followed the same ranking. FCR was best (lowest) in the commercial group (2.94 ± 0.08), intermediate in the maize-sorghum group (3.21 ± 0.11), and poorest in the millet-cassava group (3.58 ± 0.14). All pairwise differences in final body weight and FCR were statistically significant (P<0.05), except between Treatments 1 and 3 for the 0-4 week sub-period where gains were comparable.

Table 2: Growth performance parameters of indigenous chickens under three dietary treatments over 12 weeks (mean ± SE)

Parameter	Treatment 1 (Mean ± SE)	Treatment 2 (Mean ± SE)	Treatment 3 (Mean ± SE)	P-value
Initial body weight (g)	312.4 ± 6.8	309.2 ± 7.1	310.0 ± 6.4	0.931
Final body weight (g)	920.3 ± 21.6b	877.6 ± 24.3c	963.7 ± 18.4a	0.008
Total weight gain (g)	610.3 ± 16.2b	567.6 ± 19.7c	653.7 ± 14.8a	0.003
Daily weight gain (g/d)	7.26 ± 0.19b	6.76 ± 0.23c	7.78 ± 0.18a	0.004
Total feed intake (g)	1959.1 ± 34.7b	2032.0 ± 41.3a	1921.9 ± 29.6b	0.041
FCR	3.21 ± 0.11b	3.58 ± 0.14a	2.94 ± 0.08c	0.001
Mortality (%)	5.0	5.0	3.3	0.812

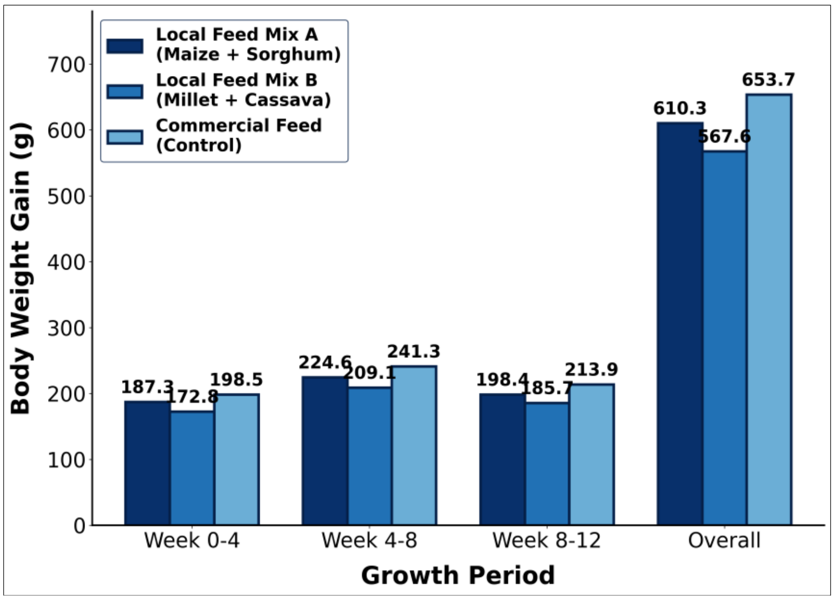

Fig 2: Body weight gain (g) across three growth sub-periods (weeks 0-4, 4-8, and 8-12) and cumulative total for indigenous chickens fed locally formulated maize-sorghum diet (Treatment 1), millet-cassava diet (Treatment 2), and commercial feed (Treatment 3)

The bar chart (Figure 2) illustrates the body weight gains across the three growth sub-periods and the cumulative total. During weeks 0-4, the differences between the maize-sorghum group and the commercial control were not significant (P = 0.187), but from week 4 onward the commercial diet produced consistently higher gains. The millet-cassava group lagged behind both other treatments in every sub-period, with the widest margin during weeks 4-8, when protein demand for feather development is typically at its peak.

Table 3: Economic analysis of three dietary treatments ranked by net return per bird (KES)

Rank	Economic Parameter	Treatment 1	Treatment 2	Treatment 3
1	Feed cost (KES/kg diet)	42.30	38.70	68.50
2	Total feed cost per bird (KES)	82.87	78.64	131.65
3	Feed cost per kg gain (KES)	187.40	209.60	246.80
4	Revenue per bird at sale (KES)	368.12	351.04	385.48
5	Net return per bird (KES)	285.25	272.40	253.83
6	Benefit-cost ratio	4.44	4.47	2.93

Taken as a whole, the biological data favour the commercial diet, but the economic metrics reverse that ranking. Treatment 1 (maize-sorghum) achieved 93.4% of the commercial diet's total weight gain while costing only 63.0% as much per bird. Its net return per bird exceeded the commercial group by KES 31.42 (12.4%), and its benefit-cost ratio was 51.5% higher. The millet-cassava diet was cheapest in raw feed cost but its poorer FCR eroded much of that price advantage, resulting in a higher feed cost per kilogram of gain than the maize-sorghum mix.

Discussion

The maize-sorghum diet produced body weight gains that were statistically lower than the commercial ration yet remarkably close in absolute terms a gap of only 43.4 g over 84 days. Comparable margins have been reported in on-station trials in Ethiopia, where locally formulated diets bridged 88-92% of commercial feed performance [5, 13]. The relatively strong showing of the maize-sorghum mix can be attributed to its crude protein level of 17.8%, which sits within the 16-18% range considered adequate for growing indigenous birds past the starter phase [1, 14]. Sunflower cake and fish meal, the two main protein concentrates in the formulation, are rich in lysine and methionine amino acids that often limit muscle accretion in cereal-dominated diets [6].

By contrast, the millet-cassava group lagged behind, and the most likely explanation is the lower protein density of that diet (15.3%). Cassava root is energy-dense but nearly devoid of protein, so the formulation depended heavily on groundnut cake and silver cyprinid meal to supply amino acids. Groundnut cake, while a useful protein source, contains moderate levels of anti-nutritional tannins that can reduce protein digestibility by 8-12% [7, 15]. And the higher crude fibre content (7.9%) would have further diluted the nutrient density of the diet, increasing gut fill and reducing voluntary intake of metabolizable energy.

The economic analysis reinforces a point that field-level feeding trials sometimes overlook: biological optimality and economic optimality do not always coincide. Although the commercial feed outperformed both local mixes in growth rate and FCR, its price per kilogram was 1.6 to 1.8 times higher, which compressed net margins. Earlier work in southern Kenya reached a similar conclusion that commercial feeds could be counterproductive for smallholders selling birds at local market prices that are set by live weight and visual condition rather than by dressed carcass yield [12, 16]. The maize-sorghum diet offered the best compromise: respectable biological performance at a cost low enough to widen profit margins under typical village market conditions.

One limitation worth noting is that the trial was conducted during the short-rain season, when ambient temperatures were mild and some natural scavenging supplemented pen feeding. Performance differences might widen during the hotter, drier months when scavenging resources decline and heat stress depresses appetite. A longer, multi-seasonal trial would strengthen the generalisability of these findings.

Nutrient Budget

A simplified nutrient budget was constructed to compare crude protein and metabolizable energy inputs against the theoretical requirements for 610 g of body weight gain in indigenous chickens. Based on an assumed protein retention efficiency of 32% and an energy maintenance cost of 460 kJ ME/kg $BW^{0.75}$/day [14], the maize-sorghum diet supplied 349 g CP and 23,700 kJ ME per bird over the 12-week trial representing surpluses of 14% for protein and 9% for energy above calculated requirements. The millet-cassava diet supplied 311 g CP (a marginal 2% surplus) and 23,150 kJ ME (6% surplus), explaining the tighter performance margin observed. The commercial diet delivered the largest excess of both nutrients (22% CP surplus, 14% ME surplus). These figures suggest that the maize-sorghum formulation operated close to the point where nutrient supply meets demand without expensive over-supplementation, whereas the commercial ration provided nutrients well beyond what the birds could convert, resulting in higher excretory losses and wasted feed cost.

Conclusion

This research set out to evaluate whether locally available feed ingredients maize, sorghum, millet, cassava, and protein-rich by-products could support acceptable growth in indigenous Kenyan chickens and whether such diets could compete economically with commercial rations under smallholder conditions. The answer, on both counts, is qualified but encouraging.

The maize-sorghum-based diet emerged as the strongest alternative to commercial feed. It delivered 93.4% of the commercial ration's total weight gain over the 12-week period, with an FCR of 3.21 that, while not matching the control value of 2.94, was within the range that indigenous-breed growers in similar agro-ecological zones have reported as commercially workable. Its crude protein content of 17.8% contributed principally by sunflower cake and fish meal was enough to meet the amino acid requirements of growing Kienyeji birds without the cost penalty of imported soybean meal. The nutrient budget analysis confirmed that this formulation operated near the efficiency frontier, supplying just enough protein and energy to sustain the observed growth without the wasteful over-feeding characteristic of the commercial ration.

The millet-cassava diet, despite being the cheapest per kilogram, performed less convincingly. A crude protein level of only 15.3% and elevated crude fibre limited both voluntary intake and protein digestibility, translating into a poorer FCR (3.58) and a feed cost per kilogram of gain that was actually higher than the maize-sorghum mix. This result carries a practical lesson for extension workers: feed cost alone is a misleading guide; what matters is the cost of producing each kilogram of saleable bird weight.

From a farm-economics standpoint, the maize-sorghum diet offered the highest net return per bird (KES 285.25) and the best benefit-cost ratio (4.44), outperforming the commercial feed by a margin wide enough to make a material difference to households managing flocks of 50-100 birds. Because all the ingredients are available within Kiambu County's local market network, the formulation also avoids the supply-chain fragility and price volatility that plague commercial feed purchasing in rural areas.

Several directions warrant future investigation. First, extending the trial across both rainy and dry seasons would test whether the performance gap between local and commercial diets widens under environmental stress. Second, incorporating on-farm amino acid supplementation particularly synthetic lysine and methionine, which are now available in small retail packs might push the maize-sorghum diet closer to commercial-feed performance at a modest additional cost. Third, replicating the trial with other locally important breeds, such as the Kenbro or Rainbow Rooster, would clarify whether the observed responses are breed-specific or broadly applicable. And finally, participatory on-farm trials in which farmers themselves manage the feeding would test whether the measured performance gains hold up under conditions of variable labour availability and storage infrastructure.

Acknowledgements

The authors acknowledge and express gratitude to the concerned authorities for their support and cooperation during this research.

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