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Economic and Growth Performance of Locally Formulated Broiler Feeds

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Abstract

The cost and availability of commercial poultry feeds remain critical constraints for broiler production in Ghana, creating interest in locally formulated alternatives. This study evaluated the growth performance, feed consumption and feed-related economic indicators of three locally formulated Akwaaba broiler diets relative to a commercial Koudijs diet under farm conditions. Four dietary treatments (T1-T4) were assessed, with 50 birds assigned to each treatment and monitored from Day 1 to Day 48. At Day 48, mean body weights were 2.675, 2.926, 2.962 and 3.080 kg/bird for T1, T2, T3 and T4, respectively. Cumulative feed consumption was 223.842, 243.175, 257.810 and 276.229 kg, respectively. Apparent feed conversion ratios (FCRs) were 1.74 for T1, 1.72 for T2, 1.81 for T3 and 1.82 for T4. Feed cost per kilogram of live-weight gain was GH₵10.41 for T1, GH₵10.12 for T2, GH₵10.64 for T3 and GH₵19.19 for T4. The results highlight a trade-off between biological performance and economic efficiency: while T4 produced the numerically heaviest birds, T3 achieved a mean body weight approximately 96.2% of T4's value at a substantially lower feed cost per kilogram of gain. These findings underscore the potential of locally formulated diets, particularly when supported by enzyme supplementation, to reduce dependence on expensive commercial feeds. Because each treatment was represented by a single pen, the findings are descriptive observations rather than statistically validated treatment effects. Replicated trials with verified feed records, standardized sampling procedures and complete mortality-adjusted calculations are required to establish reproducibility and commercial

relevance. Nevertheless, the study provides preliminary farm-level evidence that locally formulated Akwaaba diets can approach the growth performance of a commercial benchmark while offering cost advantages, thereby contributing to strategies for improving economic efficiency in Ghanaian broiler production.

Keywords

Broiler Chickens, Feed Efficiency, Feed Conversion Ratio, Wheat Bran, Feed Economics, Local Feed Formulation, Ghana, Poultry Production

1. Introduction

The poultry sector represents an important component of Ghana's livestock economy and contributes to food security, employment, household income and the supply of relatively affordable animal protein [1] [2]. Despite this importance, the competitiveness of commercial broiler production in Ghana remains constrained by high and variable production costs, with feed representing one of the most important components of production expenditure [3] [4]. Weak enforcement and socio-economic pressures, which increase the risk of zoonotic spillovers in Ghana [5]-[7], reinforce the importance of strict biosecurity protocols in poultry production. Effective biosecurity not only protects public health but also ensures that the poultry sector remains highly profitable irrespective of prevailing sectoral challenges. Recent evidence from Ghana shows that poultry producers face important economic decisions regarding whether to purchase commercially manufactured feeds or prepare their own feeds, reflecting the trade-off between feed quality, production cost, technical capacity and profitability [8] [9]. This challenge extends beyond Ghana, as feed expenditure is widely recognized as a major determinant of poultry production efficiency and profitability.

The economic importance of feed, however, cannot be assessed solely from its purchase price [10]. A lower-cost feed is economically advantageous only when the reduction in feed expenditure is not offset by poorer growth, greater feed consumption or deterioration in feed conversion efficiency. Feed conversion ratio (FCR), conventionally expressed as feed consumed relative to body-weight gain, therefore provides an important measure linking nutritional performance with economic efficiency [11]. Genetic and nutritional research has established FCR as one of the principal indicators of feed efficiency in broiler production, although its interpretation is influenced by growth rate, maintenance requirements and production objectives [12] [13]. More recent evidence from systematic review and meta-regression further demonstrates a close relationship between body-weight gain and FCR, indicating that improvements in growth performance and feed efficiency are biologically interconnected rather than independent production outcomes [14] [15].

This distinction is important because maximizing final body weight does not necessarily maximize economic return. A heavier bird may require disproportionately more feed to achieve the additional gain, whereas a slightly lighter bird may generate a more favourable economic outcome if it achieves its market weight with substantially lower feed expenditure. Consequently, feed cost per kilogram of live-weight gain provides an economically meaningful complement to body weight, weight gain and FCR because it incorporates both the biological response of the bird and the monetary cost of achieving that response. Studies of broiler production have consequently emphasized the importance of considering feed efficiency and production economics together rather than evaluating diets solely according to final live weight [4].

This biological-economic relationship becomes particularly important in feed systems that depend heavily on purchased raw materials. Maize and soybean meal are major components of conventional broiler diets because they provide important sources of dietary energy and protein. However, the prices and availability of these ingredients can fluctuate, increasing the incentive to identify alternative ingredients and formulation strategies [16]. Local feed formulation can potentially reduce exposure to commercial feed prices and allow manufacturers to exploit locally available raw materials and agro-industrial by-products. Nevertheless, replacing conventional ingredients with cheaper alternatives is not automatically beneficial. The nutritional value, fibre concentration, amino-acid balance, energy density, digestibility and interactions among ingredients must be considered simultaneously.

Wheat bran illustrates this formulation dilemma particularly well. Wheat bran can reduce the ingredient cost of poultry diets, but its relatively high fibre content can limit nutrient utilization when incorporated at excessive levels [17]. Experimental evidence from Ghana demonstrated that increasing wheat-bran inclusion in broiler finisher diets increased feed intake while reducing body-weight gain and efficiency of feed utilization at high inclusion levels [18]. At the same time, increasing wheat bran reduced the cost of feed per kilogram and the feed cost per kilogram of live-weight gain [18]. This finding is particularly important because it demonstrates that a dietary ingredient can simultaneously generate a biological penalty and an economic advantage, making simple comparisons based only on growth or feed price inadequate.

The interaction between ingredient composition and feed additives adds another dimension to this problem. Osei and Oduro (2000), working with broilers in Ghana, reported that enzyme supplementation in wheat-bran-containing diets reduced feed consumption while improving growth rate and feed conversion efficiency [19]. The highest enzyme treatment also reduced total feed cost per bird and feed cost per kilogram of gain. These findings suggest that the economic value of an alternative ingredient cannot always be evaluated independently of the nutritional technologies used to formulate the complete diet. Enzymes and other feed additives may modify nutrient availability and thereby influence the biological

and economic consequences of using ingredients that would otherwise constrain performance.

This leads to a broader conceptual issue in evaluating locally formulated poultry feeds. The relevant question is not simply whether a local ingredient is cheaper than a commercial ingredient, but whether the complete feed formulation converts relatively inexpensive inputs into an economically efficient unit of live-weight production. In this sense, feed formulation can be viewed as a biological-economic system in which ingredient selection affects nutrient supply and utilization, nutrient utilization affects growth and feed intake, and these biological responses determine the quantity and cost of feed required to produce marketable live weight. The economic outcome therefore emerges from the interaction of formulation cost and biological efficiency rather than from either component in isolation.

Evidence from Ghana supports the importance of this integrated perspective. Wongnaa, Apike [20], using data from 163 poultry farmers, found that farmers' choice between commercially prepared and self-prepared feeds was associated with profitability, production characteristics, education, technical knowledge and access to financial support. Although their analysis provides important evidence on the economic and behavioural dimensions of feed choice, it focused on poultry farmers and layer production rather than experimentally comparing specific broiler-feed formulations under controlled conditions. Thus, the study establishes the importance of feed choice at the farm level but does not resolve whether a particular locally formulated broiler feed can achieve an economically favourable balance between biological performance and feed expenditure.

Evidence from neighbouring West African production systems similarly indicates that locally formulated feeds can generate substantially lower feed costs while producing lower biological performance than commercial feeds. Afolayan, Dafwang [21] and Thirumalaisamy, Muralidharan [22], for example, compared locally formulated and commercial broiler feeds and found that commercial feeds produced greater weight gain, whereas the locally formulated feed had a substantially lower feed cost per kilogram of gain. This finding is important because it demonstrates that lower feed cost and higher biological performance may occur in different treatments. Consequently, the appropriate commercial decision cannot be made from either body weight or feed price alone.

Economic evidence from the Ghanaian poultry value chain reinforces the importance of this distinction. Research examining local hatchery performance in Ghana found meaningful differences in feed cost per unit of weight gain and profitability among production groups, demonstrating that biological production outcomes translate into economic consequences through feed utilization [23]. The implication is that production efficiency should be assessed using indicators that connect biological output with resource requirements.

The literature therefore reveals an important gap. A considerable body of research has examined individual feed ingredients, alternative feed resources, en-

zyme supplementation, feed conversion and profitability. Other studies have examined farmers' choices between commercial and self-formulated feeds. However, relatively little experimental evidence from Ghana simultaneously evaluates multiple locally formulated broiler feeds against a commercial benchmark using an integrated set of biological and economic indicators. In particular, there is limited evidence showing whether a locally manufactured feed can approach the growth performance of a commercial feed while simultaneously reducing feed expenditure per kilogram of live-weight gain under the same production conditions.

The present study addresses this gap by evaluating three Akwaaba broiler-feed formulations against a commercially available Koudijs diet used as a benchmark. Rather than defining competitiveness as the treatment producing the highest numerical final body weight, the study adopts a broader biological-economic perspective. The central proposition is that a feed can be commercially competitive when it achieves acceptable or biological performance for which no statistically significant difference is detected while requiring less feed expenditure to produce a unit of live weight. This distinction separates maximum biological performance from economically efficient biological performance.

Accordingly, the conceptual logic underlying the study can be represented as:

Feed formulation → nutrient supply and utilization → feed intake and growth → feed conversion → feed required per unit of live-weight gain → feed cost per unit of live-weight gain → economic competitiveness.

This framework provides a basis for interpreting the performance of alternative formulations without assuming that lower-cost feed ingredients will automatically generate better economic outcomes. It also provides a more meaningful basis for comparing locally formulated feeds with commercial products because it recognizes the trade-off between biological performance and production cost.

The study therefore aimed to evaluate three Akwaaba broiler-feed formulations against a commercial Koudijs diet in terms of: i) growth performance; ii) feed intake; iii) average daily gain; iv) feed conversion efficiency; v) feed cost per kilogram of live-weight gain; and vi) potential economic competitiveness under prevailing Ghanaian live-broiler prices.

The study descriptively compared final body weight, feed consumption, average daily gain, apparent FCR and estimated feed cost per kilogram of live-weight gain across the four feeding programmes. Because there was only one pen per treatment, the study was not designed to support inferential testing of treatment effects.

The study interprets numerical differences descriptively and does not treat the absence of inferential testing as evidence of equivalence or non-inferiority. Formal equivalence or non-inferiority would require a prespecified margin and an appropriately powered, independently replicated experimental design.

The principal contribution of the study is therefore not merely the comparison of four broiler diets. It is the integration of biological performance and economic efficiency into a single framework for evaluating locally formulated poultry feeds. Such an approach provides a stronger basis for assessing whether local feed man-

ufacturing can offer a commercially viable alternative to established commercial feeds in Ghana. The study also contributes empirical evidence to the broader question of whether feed competitiveness should be defined by maximum growth alone or by the efficiency and cost with which marketable live weight is produced.

2. Materials and Methods

2.1. Study Site and Experimental Design

The feeding experiment was conducted at the BNARI Research Farm under the Socio-Economic and Commercialisation Center (SECC), Biotechnology and Nuclear Agriculture Research Institute (BNARI), Ghana Atomic Energy Commission (GAEC), Ghana. The study was designed as a controlled farm-based feeding trial to evaluate the biological and economic performance of locally formulated Akwaaba broiler feeds relative to a commercially available broiler feed.

Four dietary treatments were evaluated: three locally formulated Akwaaba broiler diets (T1, T2 and T3) and a commercially available Koudijs broiler diet (T4), which served as the control. Each treatment was assigned to one pen containing 50 broiler chickens, giving an initial total of 200 birds. Dietary treatment was therefore applied at the pen level, and the pen constituted the experimental unit. Because only one pen was used per treatment, there was no independent pen-level replication within treatments. Accordingly, comparisons of growth performance, feed intake, feed conversion and feed-cost indicators are presented descriptively rather than as inferential treatment comparisons.

In accordance with recommendations for reporting animal experiments, the study design distinguishes between the animal-level observational unit and the experimental unit to which the dietary treatment was applied [24] [25]. The experimental unit was defined as the independently managed treatment group/pen receiving a common diet. Accordingly, feed intake and feed-conversion measures were interpreted at the group level, whereas individual bird body weights were used to characterize within-treatment variation. The exact number of independent pens or replicates should be reported where available.

2.2. Experimental Objectives and Outcomes

The objective was to describe the growth performance and feed-related economic indicators of the locally formulated Akwaaba broiler diets relative to the commercial Koudijs feed. Given the single-pen-per-treatment design, comparisons were descriptive rather than hypothesis tests.

The primary biological outcome was mean Day-48 body weight. Secondary outcomes included body-weight gain, average daily gain (ADG), cumulative feed intake, apparent feed conversion ratio (FCR), estimated feed cost per kilogram of live-weight gain and estimated revenue per bird.

2.3. Experimental Diets and Feeding Management

Four dietary treatments were evaluated in the experiment. Treatments T1, T2 and

T3 consisted of locally formulated Akwaaba broiler feeds, while T4 consisted of commercially available broiler feed (Koudijs), which served as the benchmark control. The locally formulated diets were provided in three feeding phases: starter, grower and finisher. The ingredient composition of the T1 to T4 diets for each phase is presented in correspondence Tables.

The T1 treatment was designated *Akwaaba No*. 60% *with wheat bran*, while T2 was designated *Akwaaba No*. 60% *without wheat bran*. The principal distinction between these two treatments was the inclusion of wheat bran in the T1 starter formulation and its absence from the T2 formulations. And the No. 60% means without meat and bone meal. The ingredient quantities for each phase were standardized to a nominal batch size of 1000 kg. The ingredient composition of T3 differed from that of T1 and T2 and included maize, soybean meal, concentrate, wheat bran, meat-and-bone meal and calcium carbonate. The ingredient quantities reported for the experimented diets are presented in the corresponding formulation table.

The feeding programme followed three successive phases. The starter diet was fed from Day 1 through Week 3, the grower diet from Week 3 through Week 5, and the finisher diet from Week 5 through Week 7. Thus, the starter, grower and finisher diets were intended to support the birds during the early, intermediate and finishing stages of growth, respectively. The appropriate phase-specific diet was supplied to each treatment group according to the feeding programme. The experiment commenced on Day 1 and continued through Day 48; therefore, the finisher phase was observed only up to the final day of the experiment.

Treatment T4 consisted of commercial broiler feed used as the benchmark against which the locally formulated diets were evaluated. The commercial products were supplied in phase-specific forms, including starter, grower and finisher feeds. Their declared nutrient specifications, as provided on the product labels, are summarized in Tables below. These specifications included the nutrient values reported by the manufacturers, such as crude protein, crude fat, lysine, methionine, calcium, phosphorus and metabolizable energy where available. Because the commercial product labels did not provide the inclusion percentages of individual ingredients, the commercial diets are described using their declared label specifications rather than as complete ingredient formulations.

All feed ingredients used in the experimental diets were procured from the Ashiaman Timber Market, Greater Accra Region, Ghana, which is a major hub for both localized and imported feed ingredients. Prices of maize, soybean meal, wheat bran, meat-and-bone meal, calcium carbonate, and other inputs were obtained directly from traders at the market at the time of purchase.

Commercial broiler feeds (Koudijs starter, grower, and finisher diets) were likewise purchased from licensed distributors at the Ashiaman Timber Market. The prevailing retail prices recorded at the point of purchase were used in calculating feed expenditures. The ingredient-based costs of the locally formulated diets were estimated using the recorded market prices of the feed ingredients. The cost of

each formulation was calculated by multiplying the quantity of each ingredient included in the 1000 kg batch by its corresponding unit price and summing the resulting costs. These estimates represent ingredient costs and do not, by themselves, include other potential manufacturing, transport, storage or handling expenses. The commercial feeds were evaluated using their recorded purchase prices.

The designation "No. 60%" was retained as the formulation name used for T1 and T2 during the feeding trial as shown in Table 1.

Table 1. Experimental dietary treatments.

Treatment	Feed description
T1	Akwaaba formulation No. 60% (meat and bone meal) with wheat bran
T2	Akwaaba formulation No. 60% (meat and bone meal) without wheat bran
T3	Akwaaba formulation with 60% (meat and bone meal) and with wheat bran
T4	Commercial Koudijs broiler feed (control)

The diets were supplied according to the relevant feeding phase. The Akwaaba formulations comprised starter, grower and finisher diets, while the Koudijs control consisted of the corresponding commercial starter, grower and finisher feeds.

The inclusion of wheat bran was of particular methodological interest because wheat bran is a relatively fibrous feed ingredient whose effects on broiler performance can depend on inclusion level and the use of exogenous enzymes. Previous work in Ghana demonstrated that enzyme supplementation of wheat-bran-containing broiler diets could improve growth and feed-conversion efficiency [19] [26] [27].

2.4. Composition of Experimental Diets (T1-T4)

The four dietary treatments differed in ingredient composition and commercial formulation. Treatments T1, T2 and T3 comprised locally formulated Akwaaba broiler feeds, while T4 comprised commercially manufactured broiler feed used as the control. The locally formulated diets were prepared for the starter, grower and finisher phases, with the ingredient quantities specified for each phase. The commercial feed was supplied according to its manufacturer's phase-specific product specifications.

Treatment T1: Akwaaba No. 60% with wheat bran. The T1 formulation consisted of maize, soybean meal, broiler concentrate, wheat bran and calcium carbonate (Table 2). Wheat bran was included in the starter formulation but was not included in the grower and finisher formulations. The proportions of the ingredients differed across the three feeding phases to reflect the respective formulations used during the experiment.

Table 2. Ingredient composition of T1 Akwaaba broiler diets (kg/1000kg).

Ingredient	Starter	Grower	Finisher
Maize	560	623	680
Soybean meal	300	260	203
Broiler concentrate	100	100	100
Wheat bran	24	0	0
Calcium carbonate	16	17	17
Total	1000	1000	1000

Treatment T2: Akwaaba No. 60% without wheat bran. The T2 formulation consisted of maize, soybean meal, broiler concentrate and calcium carbonate (Table 3). Wheat bran was excluded from the starter, grower and finisher formulations. The ingredient quantities varied across the feeding phases, while each formulation was standardized to a total batch weight of 1000 kg.

Table 3. Ingredient composition of T2 Akwaaba broiler diets (kg/1000kg).

Ingredient	Starter	Grower	Finisher
Maize	608	664	715
Soybean meal	280	225	175
Broiler concentrate	100	100	100
Wheat bran	0	0	0
Calcium carbonate	12	11	10
Total	1000	1000	1000

Treatment T3: Akwaaba formulation containing wheat bran and meat-and-bone meal. The T3 diet consisted of maize, soybean meal, broiler concentrate, wheat bran, meat-and-bone meal and calcium carbonate (Table 4). The quantities of these ingredients varied among the starter, grower and finisher formulations. The formulation therefore differed from T1 and T2 in both ingredient selection and ingredient proportions. The quantities reported in the corresponding formulation table represent the intended composition of each 1000 kg batch.

Treatment T4: Commercial broiler feed. T4 consisted of commercially manufactured broiler feed used as the benchmark control. The commercial products included phase-specific starter, grower and finisher feeds (Table 5). Their declared nutrient composition was obtained from the available product labels. These label specifications were used to describe the commercial feeds because the available information did not provide the percentage inclusion of each individual ingredient in the complete commercial formulations.

Table 4. Ingredient composition of the T3 Akwaaba broiler diet.

Ingredient	Starter (kg)	Grower (kg)	Finisher (kg)
Maize	625	624	666
Soybean meal	219	212	180
Broiler concentrate	100	100	100
Wheat bran	23	30	20
Meat-and-bone meal	20	20	20
$CaCO_3$	13	14	14
Total	1000	1000	1000

Table 5. Declared nutrient composition of the commercial feeds used as T4.

Nutrient	De Heus starter	De Heus grower	Koudijs Galdus/Finisher
Crude protein (%)	22.50	18.13	22.50
Crude fat (%)	3.25	3.93	5.00
Crude fibre (%)	Not stated	Not stated	4.00
Crude ash (%)	Not stated	Not stated	8.00
Lysine (%)	1.38	0.91	Not stated
Methionine (%)	0.68	0.75	Not stated
Calcium (%)	0.98	0.90	1.00
Phosphorus (%)	0.72	0.69	0.55
Sodium (%)	Not stated	Not stated	0.25
Metabolizable energy (kcal/kg)	2888	2788	Not stated

Note: "Not stated" means that the supplied label information did not provide that value. The commercial feeds' ingredient inclusion percentages were not available, so Table 3 reports declared nutrient composition rather than a complete ingredient formulation.

The ingredient compositions of the locally formulated starter, grower and finisher diets for T1, T2 and T3 are presented in Tables 2-4, respectively. The manufacturer-declared nutrient specifications of the commercial feeds used for T4 are presented separately in Table 5. The distinction between ingredient formulations and commercial label specifications is maintained because the two sources of information describe different aspects of feed composition.

The Akwaaba formulation retained a constant broiler-concentrate inclusion of 100 kg across feeding phases, while the proportions of maize, soybean meal and wheat bran varied with the nutritional requirements of the starter, grower and finisher stages.

2.5. Calculated Nutrient Composition

The calculated nutrient composition of the Akwaaba diets was phase-specific (Table 6).

Table 6. Calculated nutrient composition of the Akwaaba broiler diets.

Nutrient	Starter	Grower	Finisher
Crude protein (%)	22.01	19.93	18.04
Metabolizable energy (kcal/kg)	3004.18	3054.23	3100.03
Calcium (%)	1.02	0.96	0.90
Available phosphorus (%)	0.47	0.46	0.46
Crude fat (%)	3.06	3.20	3.33
Crude fibre (%)	3.07	2.96	2.85
Lysine (%)	1.36	1.22	1.09
Methionine (%)	0.70	0.67	0.65
Methionine + cystine (%)	1.08	1.02	0.97
Arginine (%)	1.40	1.24	1.09
Threonine (%)	0.84	0.76	0.68

The formulations also contained declared vitamin, mineral and enzyme components, including phytase, xylanase, glucanase and protease. The presence of exogenous enzymes is relevant when interpreting diets containing wheat bran because enzyme supplementation can influence nutrient utilization and feed efficiency [19].

2.6. Feed Management and Measurement of Feed Intake

Feed was supplied to each treatment group according to the designated feeding phase. The quantity of feed offered was recorded, and feed remaining at the end of the feeding period was collected and weighed.

Daily feed intake was calculated as:

$$\mathrm{FI}_d = F_{\mathrm{offered},d} - F_{\mathrm{refused},d}$$

where FI_d is feed consumed on day d, $F_{\mathrm{offered},d}$ is feed offered, and $F_{\mathrm{refused},d}$ is feed remaining.

Cumulative feed intake was calculated by summing daily feed consumption over the experimental period:

$$\mathrm{CFI} = \sum_{d=1}^{D} \mathrm{FI}_d$$

where CFI represents cumulative feed intake and D is the number of experimental days.

Because feed was supplied to treatment groups rather than independently to each bird, cumulative feed intake was considered a **group-level measure**. Consequently, feed intake and feed-efficiency comparisons were interpreted in relation to the number of independent treatment replicates available rather than treating individual birds within the same feed group as independent observations.

2.7. Measurement of Growth Performance

Individual live body weight was measured at successive observation points from Day 1 through Day 48. Body weight was recorded in grams using the same weighing procedure throughout the experiment. Day 48 was designated as the primary endpoint for the final body-weight comparison.

Body-weight gain (BWG) was calculated as:

$$\mathrm{BWG} = \mathrm{BW}_f - \mathrm{BW}_i$$

where BW_f is final body weight and BW_i is initial body weight.

Average daily gain (ADG) was calculated as:

$$\mathrm{ADG} = \frac{\mathrm{BW}_f - \mathrm{BW}_i}{D}$$

where D is the number of days elapsed between the initial and final measurements. For the Day 1-Day 48 comparison, $D = 47$ days because Day 48 is 47 days after Day 1.

Repeated body-weight observations provide additional information on growth trajectories. Multiple measurements can increase statistical information when appropriately incorporated into the analysis rather than treating repeated observations as independent observations.

2.8. Mortality and Meat-Quality Sampling

Each treatment initially comprised 50 birds. One mortality was recorded in each of T1, T2 and T3, while no mortality occurred in T4. The T3 bird died on Day 2 and weighed 33 g; the T1 bird died on Day 7 and weighed 120 g; and the T2 bird died on Day 10 and weighed 136 g. Cumulative mortality was 2% in T1, T2 and T3 and 0% in T4.

Following weighing on Day 47, birds were randomly selected from each treatment for meat-quality analysis. The subsequent final-weight records contained 45 observations per treatment. These records were used to describe the observed distribution of body weights. The number of birds weighed, the number selected for meat-quality analysis and the number of surviving birds were treated as distinct quantities in interpreting the results.

2.9. Feed Conversion Ratio

Feed conversion ratio was used as an indicator of feed-use efficiency and calculated as:

$$\text{FCR} = \frac{\text{FI}}{\text{BWG}}$$

where FI is feed consumed and BWG is live-weight gain over the corresponding period.

Lower FCR values indicate greater feed-use efficiency. The calculated values were described as **apparent FCR** because complete mortality-adjusted feed-intake and weight-gain information was not available for all treatment groups.

FCR was interpreted together with body-weight gain and feed cost rather than as an isolated measure of feed quality. This approach is consistent with comparative broiler feeding studies in which growth performance, feed intake, FCR and feed cost are considered jointly when assessing locally formulated and commercial diets.

2.10. Feed-Cost Estimation

Feed costs were estimated using the ingredient prices supplied for the preparation of the Akwaaba diets. The prices used are presented in Table 7.

Table 7. Ingredient prices used to estimate Akwaaba feed costs.

Ingredient	Market unit	Price (GH₵)
Broiler concentrate	50 kg	650
Meat-and-bone meal	50 kg	410
Maize	50 kg	210
Wheat bran	25 kg	85
Soybean meal	50 kg	400
Calcium carbonate	50 kg	175

The corresponding Koudijs commercial feed prices supplied for the analysis were GH₵447 per 25 kg for starter, GH₵425 per 50 kg for grower and GH₵423 per 50 kg for finisher feed.

The cost of each Akwaaba formulation was calculated by converting each ingredient price to a cost per kilogram and multiplying it by the quantity of that ingredient incorporated into the formulation. Total feed cost was then estimated from the quantity of each feed phase consumed.

Feed-cost analysis is particularly important when evaluating locally formulated diets because lower biological performance does not necessarily imply lower economic value if the reduction in feed cost is sufficiently large. Comparative broiler feeding research has similarly demonstrated that locally formulated feeds may have substantially lower feed cost per kilogram of gain even when commercial feeds produce greater weight gain.

2.11. Feed Cost per Kilogram of Live-Weight Gain

Feed cost per kilogram of live-weight gain was calculated as:

$$\mathrm{FCG} = \frac{\mathrm{TFC}}{\mathrm{TLWG}}$$

where FCG is feed cost per kilogram of live-weight gain, TFC is total feed cost and TLWG is total live-weight gain.

This measure was selected as the principal economic efficiency indicator because it integrates feed price, feed consumption and biological weight gain. Lower values indicate that less expenditure on feed was required to produce each kilogram of live-weight gain.

2.12. Revenue Estimation

For the feed-related economic assessment, the live broiler market price was set at GH₵72/kg. Estimated revenue per bird was calculated as:

$$R_i = \mathrm{BW}_{f,i} \times P$$

where R_i is estimated revenue for bird i, $\mathrm{BW}_{f,i}$ is its final live weight in kilograms and P is the assumed market price of GH₵72/kg.

The resulting revenue estimates were used only to illustrate the potential contribution of final live weight to gross sales value. They were not interpreted as net profit.

The economic analysis was deliberately restricted to feed-related costs and returns. Costs associated with day-old chicks, labour, medication, vaccines, utilities, housing, equipment, mortality, transportation and other overheads were excluded. Consequently, the analysis represents a partial feed-cost assessment rather than a complete enterprise profitability analysis.

2.13. Statistical Analysis and Descriptive Evaluation

The experiment comprised four pens, with one pen assigned to each dietary treatment (T1, T2, T3 and T4). Each pen initially contained 50 birds, giving a total of 200 birds. The pen was treated as the experimental unit, while individual birds within pens were observational units for body-weight measurements.

Day-48 body weight was evaluated as the primary growth-performance endpoint. For each treatment, individual bird weights were summarized using the number of observations (n), mean, standard deviation, minimum and maximum. Numerical differences between treatment means were used to describe variation in final body weight. These summaries compared the performance patterns of the locally formulated Akwaaba diets (T1, T2 and T3) with the commercial Koudijs feed (T4).

Growth measurements collected at earlier time points were summarized to characterize growth patterns over the experimental period. Feed consumption and feed-conversion measures were evaluated at the pen level using recorded feed quantities and bird-performance data.

The economic evaluation was based on ingredient costs, feed consumption and observed live-weight performance for each treatment. Feed cost indicators were calculated from production records and interpreted alongside biological performance measures. The results provide a farm-level comparison of the four feeding programmes under the conditions of this experiment.

3. Results and Discussion

3.1. Mortality and Bird Survival

Three deaths were recorded among the 200 broiler chickens initially allocated to the experiment, giving an overall mortality rate of 1.5%. One bird died in each of T1, T2 and T3, corresponding to a mortality rate of 2.0% per treatment, while no mortality was recorded in T4. The T3 bird died on Day 2 (33 g), the T1 bird on Day 7 (120 g), and the T2 bird on Day 10 (136 g). The numbers of surviving birds were therefore 49 in each of T1, T2 and T3 and 50 in T4.

3.2. Growth Performance of Broilers Fed the Experimental Diets

The growth performance of the broilers differed numerically among dietary treatments throughout the production period. Although the birds started with relatively similar initial body weights, differences in observed live weight became increasingly apparent as the feeding trial progressed. At Day 48, the observed mean final body weights were 2674.58 g/bird for T1 (No. 60% with wheat bran), 2925.69 g/bird for T2 (No. 60% without wheat bran), 2961.71 g/bird for T3 (No. 60% with wheat bran and meat-and-bone meal), and 3079.69 g/bird for T4 (commercial Koudijs diet). The commercial diet had the highest observed mean final body weight, followed by T3, T2 and T1.

The observed mean final body weight of T3 was 117.98 g/bird lower than that of T4, representing approximately 3.8% lower observed final body weight. These differences are interpreted descriptively because each dietary treatment was represented by only one pen. Although individual bird weights were recorded, the birds within each pen did not constitute independent experimental replicates; therefore, no inferential statistical tests were used to establish treatment differences.

These observations can be considered alongside previous research comparing locally formulated and commercial broiler feeds. Afolayan, Dafwang and Omage (2009) reported that one commercial feed outperformed other diets in weight gain and feed efficiency, while overall growth performance on on-farm feeds was broadly comparable with that of commercial feeds. Importantly, their study also highlighted lower feed cost per kilogram of weight gain for on-farm diets. This distinction underscores the importance of evaluating both biological performance and economic efficiency when comparing alternative broiler diets, since the diet producing the highest final body weight does not necessarily provide the lowest cost of production.

The present trial showed that T3 had an observed mean final body weight rela-

tively close to that of T4. Whether this difference is economically acceptable depends on verified feed costs, cumulative feed consumption and feed cost per kilogram of weight gain. The numerical pattern is consistent with published comparisons showing that locally prepared feeds can approach the growth performance of some commercial diets, although the magnitude and reproducibility of this response depend on feed formulation and experimental conditions. In this study, T3 warrants further evaluation because its reported mean final body weight was numerically close to that of T4, while offering potential cost advantages under Ghanaian farm conditions.

3.3. Growth Rate and Average Daily Gain

From day 1 to day 48, total weight gain was 2637.56, 2889.85, 2925.85 and 3043.50 g for T1, T2, T3 and T4, respectively. Corresponding average daily gains were 56.12, 61.49, 62.25 and 64.76 g/day.

The numerical ranking therefore remained T4 > T3 > T2 > T1. These are descriptive values from the observed pens, not inferential estimates of treatment effects.

The magnitude of the ADG observed in T3 is also broadly comparable with results reported in controlled broiler feeding experiments. For example, a study investigating fermented wheat bran reported overall ADG values of approximately 62 - 64 g/day over 37 days, with no significant deterioration in growth performance from inclusion of fermented wheat bran. Although direct comparison must be made cautiously because the birds, diets, experimental durations and management systems differed, the similarity suggests that incorporation of wheat-bran-containing diets can support commercially relevant growth when the overall nutrient formulation is adequate.

The Day-48 weight records contain 45 observations for each treatment. The recorded means and standard deviations are shown in Table 8:

Table 8. Day-48 descriptive statistics of broiler body weight under four dietary treatments (T1-T4).

Treatment	Recorded birds weighed	Mean final weight (g)	SD (g)
T1	45	2674.58	384.44
T2	45	2925.69	313.02
T3	45	2961.71	397.95
T4	45	3079.69	321.11

These are bird-level descriptive statistics; they do not overcome the lack of independent pen replication.

3.4. Role of Wheat Bran and Enzyme Supplementation

One important feature of the T3 diet was the inclusion of wheat bran together with meat-and-bone meal and a commercial concentrate containing several feed

additives, including phytase, xylanase, glucanase and protease. The nutrient specification also provided relatively high dietary protein and metabolizable energy during the starter, grower and finisher phases. The role of wheat bran in poultry nutrition requires careful consideration. Wheat bran is widely used in developing-country poultry diets because it is locally available and can reduce dependence on expensive cereal and protein ingredients. However, wheat bran contains non-starch polysaccharides (NSPs), which can limit nutrient utilization. Research has therefore emphasized the use of exogenous enzymes to improve the nutritional value of wheat-bran-containing diets.

A recent controlled study published in *Livestock Science* evaluated wheat-bran inclusion at 0, 4, 8 and 12%, with and without a multi-enzyme preparation. The authors found an interaction between wheat bran and enzyme supplementation for body weight and average daily gain (ADG) and reported that multi-enzyme supplementation improved overall feed conversion ratio (FCR). They identified approximately 4% wheat bran as the optimum inclusion level under their experimental conditions.

Earlier Ghanaian research provides further context. Donkoh, Atuahene and Dzineku (1999) examined wheat bran in broiler diets and highlighted both its cost advantages and nutritional limitations. Osei and Oduro (2000), working at the then University of Science and Technology in Kumasi, reported that enzyme supplementation of broiler diets containing wheat bran improved growth rate and feed conversion efficiency. Their highest enzyme treatment produced birds that were 5.8% heavier at seven weeks and improved feed efficiency by approximately 21% relative to the unsupplemented diet. Importantly, they also found reductions in feed cost per bird and cost per kilogram of gain.

The present study provides a descriptive observation on a formulation containing wheat bran, meat-and-bone meal and a commercial concentrate that included enzyme additives. Because several ingredients and formulation characteristics differed among treatments, the observed performance cannot be attributed specifically to wheat bran or enzyme supplementation. Nevertheless, the findings are compatible with the rationale for evaluating enzyme-supported local formulations.

Other studies have shown that the response to wheat bran depends on inclusion level, enzyme combination, particle size, diet composition and bird age. For example, research on fermented wheat bran found that 25 or 50 g/kg inclusion did not adversely affect growth, feed intake or nutrient digestibility, whereas the *Livestock Science* study demonstrated that increasing wheat-bran levels could increase FCR unless appropriately supported by enzyme supplementation.

Taken together, Ghanaian and international evidence indicates that wheat bran can contribute to lower feed costs, but its biological value depends on inclusion level, the nutritional balance of the complete diet and the use of appropriate feed additives. The observed performance of T3 supports optimized wheat-bran utilization, rather than unrestricted inclusion, and highlights the potential of enzyme-supported local formulations in Ghanaian poultry production.

3.5. Feed Consumption, Feed Conversion and Economic Evaluation

Feed cost was an important differentiating factor between the locally formulated diets and the commercial control. Based on ingredient prices, the cost of T3 feed was GH₵5.96/kg for starter, GH₵5.93/kg for grower and GH₵5.82/kg for finisher, compared with GH₵17.88/kg, GH₵8.50/kg and GH₵8.46/kg for the corresponding commercial feeds. These values represent feed prices per kilogram, not feed cost per kilogram of live-weight gain.

Total feed expenditure was GH₵1341.90 for T1, GH₵1431.67 for T2, GH₵1518.43 for T3 and GH₵2912.28 for T4. Dividing these amounts by live-weight gain gave feed costs of GH₵10.41, GH₵10.12, GH₵10.64 and GH₵19.19 per kilogram of gain, respectively (Table 9).

Table 9. Feed expenditure, live-weight gain and feed cost per kilogram of gain for broilers under four dietary treatments (T1-T4).

Treatment	Feed expenditure (GH₵)	Live-weight gain (kg)	Feed cost/kg gain (GH₵)
T1	1341.90	128.883	10.41
T2	1431.67	141.531	10.12
T3	1518.43	142.718	10.64
T4	2912.28	151.763	19.19

These results demonstrate clear cost advantages of the locally formulated Akwaaba diets compared with the commercial Koudijs feed, highlighting the economic efficiency of locally sourced formulations under Ghanaian farm conditions.

Comparative research provides useful context. Osei and Oduro (2000) reported that enzyme supplementation reduced feed intake while improving feed-conversion efficiency in replicated broiler trials. Similarly, Idan *et al.* (2023) found that multi-enzyme supplementation in wheat-bran diets improved overall FCR, while also showing that wheat-bran inclusion level affected the response. These findings reinforce the importance of considering both feed consumption and feed conversion when evaluating diet efficiency.

Evidence from Ghana further supports the economic implications of feed choice. A 2023 study of 163 poultry farmers in the Ashanti Region found that 77% mainly used farmer-prepared feed while 23% used commercial feed, emphasizing that feed preparation skills and appropriate equipment improve efficiency and reduce overhead costs. Research on the Ghanaian poultry value chain has likewise highlighted feed cost per kilogram of weight gain as a critical determinant of profitability.

The present study contributes a commercial comparison by considering feed costs alongside growth and feed-use indicators. T3's mean Day-48 weight was ap-

proximately 96.2% of the T4 mean. At a live-broiler selling price of GH₵72/kg, the mean final live-bird values were GH₵192.57, GH₵210.65, GH₵213.24 and GH₵221.74 for T1, T2, T3 and T4, respectively. T4 generated the highest numerical live-bird value due to greater final weight, but profitability was reduced by substantially higher feed expenditure.

3.6. Comparison of T3 with the Commercial Benchmark

The most commercially relevant comparison in this study is between T3 and T4. T4 produced approximately 117.98 g more live weight per bird than T3 at Day 48, with mean body weights of 3079.69 g and 2961.71 g, respectively. The T3 mean was approximately 96.2% of the T4 mean. Based on the corrected daily feed records, T3 consumed approximately 18.419 kg less feed than T4 at the treatment level. The apparent FCR was 1.81 for T3 and 1.82 for T4; this small numerical difference is descriptive and should not be treated as evidence of superior feed efficiency.

This creates an important trade-off between maximum observed biological output and estimated feed cost. T4 produced the numerically heaviest birds, while T3 had a lower feed cost per kilogram of live-weight gain (GH₵10.64 versus GH₵19.19). This pattern is consistent with the broader principle that the diet producing the highest absolute body weight does not necessarily provide the lowest feed cost per unit of gain.

Comparative studies reinforce this interpretation. Afolayan, Dafwang and Omage (2009) found that one commercial diet produced the greatest weight gain and feed efficiency, while on-farm diets offered lower feed cost per kilogram of gain. Thirumalaisamy *et al.* (2016) likewise reported that locally formulated diets could reduce feed costs even when growth performance was slightly lower than commercial controls. These findings illustrate the possibility of a trade-off between maximum biological output and feed-related economic efficiency.

In the present experiment, the observed numerical differences should not be interpreted as evidence of equivalence, non-inferiority or superiority, since each treatment was represented by only one pen. The available design supports descriptive comparisons only. Nevertheless, T3 is a promising candidate for further evaluation because its reported mean Day-48 body weight was numerically close to that of the commercial benchmark, while its estimated formulation cost per kilogram of feed was lower. This combination is commercially relevant, but replicated trials with reconciled feed-cost calculations are required to establish whether the apparent advantage persists under comparable production conditions.

3.7. New Findings and Contribution of the Present Study

Three findings from this experiment are particularly noteworthy.

First, the observed mean Day-48 body weight for T3 was 2961.71 g, compared with 3079.69 g for T4, a numerical difference of 117.98 g/bird. This shows that the locally formulated T3 diet produced a final mean body weight numerically close

to that of the commercial benchmark.

Second, the feed-cost calculation showed GH₵10.64/kg of live-weight gain for T3 and GH₵19.19/kg for T4, indicating a substantial economic advantage for the locally formulated diet. This finding highlights the potential for locally sourced formulations to reduce feed-related costs under Ghanaian farm conditions.

Third, the results demonstrate that locally available feed ingredients, when combined with enzyme-supported feed technology, can produce a diet capable of approaching the performance of a commercial benchmark. This is particularly relevant to Ghana, where feed prices remain a major constraint to poultry production and where locally formulated diets can reduce dependence on expensive commercial products.

The study connects growth performance, feed efficiency and feed-related economic indicators within a direct comparison between locally formulated Akwaaba diets and a commercial benchmark, highlighting the potential of local feed innovations to improve economic efficiency in Ghanaian poultry production.

These observations are consistent with the general findings of Afolayan *et al*. (2009), who reported that commercial diets produced the greatest weight gain and feed efficiency while on-farm diets offered lower feed cost per kilogram of gain. They also align with Donkoh *et al*. (1999), who examined the trade-offs associated with wheat-bran inclusion, and Osei and Oduro (2000), who demonstrated the contribution of enzyme supplementation in wheat-bran-containing diets. Together, these studies reinforce the importance of integrating biological and economic indicators when evaluating feed alternatives.

The principal contribution of this study is the integration of growth measurements and feed-related cost estimates in a Ghanaian farm setting to identify locally formulated diets for further evaluation. The results provide a practical basis for refining the Akwaaba formulations and designing more rigorous confirmatory experiments. Their value lies in identifying promising performance and cost patterns, rather than in establishing treatment superiority from an unreplicated trial.

3.8. Implications for Further Development of Akwaaba Feed

The results provide preliminary grounds for further evaluating the T3 formulation, but they do not establish superiority over Koudijs. Any commercial development decision should be informed by replicated trials and verified feed-cost calculations. A useful development objective is to reduce the numerical body-weight gap of approximately 118 g/bird while retaining any verified feed-cost advantage.

Optimization should focus on digestible amino-acid balance, energy-to-protein ratio, wheat-bran inclusion level, mineral availability, enzyme efficacy and feed physical quality. Because previous studies demonstrate that the response to wheat bran depends strongly on inclusion level and enzyme supplementation, subsequent trials should systematically evaluate several wheat-bran inclusion levels with replicated pens and standardized enzyme treatments.

Future trials should also incorporate complete mortality records, replicated

pen-level feed intake, mortality-adjusted FCR, carcass yield, nutrient digestibility and a complete partial-budget analysis. Such evidence would allow Akwaaba Feeds to establish not only whether its feed can produce competitive broilers, but also whether the formulation consistently delivers a superior cost per kilogram of live weight produced under commercial Ghanaian conditions.

In addition, further development should begin with verification of the actual ingredient quantities used in each diet and the nutrient specifications of the finished feeds. The formulation labels, including the meaning of the existing "No. 60%" terminology, should be clarified from the original formulation records and applied consistently throughout the manuscript. The commercial-feed product names, phase-specific labels and purchase prices should likewise be confirmed.

The next experimental stage should use multiple independently managed pens per treatment, with consistent numbers of birds and standardized procedures for weighing, feeding and recording mortality. Feed offered, feed refusals and any feed wastage should be recorded daily. The removal of birds for meat-quality assessment should be documented by treatment and date, and the calculations of weight gain and FCR should use consistent bird counts and measurement periods. This would support a more reliable assessment of treatment-level performance.

Overall, T3 is a candidate for further evaluation among the Akwaaba formulations tested. Its observed combination of growth and estimated feed-cost indicators warrants a replicated trial, but the current study does not establish treatment superiority or a definitive commercial advantage. The immediate priority is to verify the formulation and production records, establish reliable feed-efficiency and cost-per-gain estimates, and test the candidate diets using independently replicated pens. This approach would convert the promising descriptive observations from the present study into a stronger evidence base for feed formulation, quality assurance and commercial decision-making in Ghana.

4. Conclusions

This study evaluated the growth performance, feed consumption and feed-related economic indicators of three locally formulated Akwaaba broiler diets relative to a commercial Koudijs diet under farm conditions in Ghana. T4 recorded the highest observed Day-48 mean body weight (3.080 kg/bird), followed by T3 (2.962 kg), T2 (2.926 kg) and T1 (2.675 kg). The mean body weight for T3 was 117.98 g/bird lower than that of T4, equivalent to approximately 96.2% of the commercial treatment's mean.

Cumulative feed consumption was 223.842 kg for T1, 243.175 kg for T2, 257.810 kg for T3 and 276.229 kg for T4. Apparent feed conversion ratios (FCRs) were 1.74 for T1, 1.72 for T2, 1.81 for T3 and 1.82 for T4. Feed cost per kilogram of live-weight gain was GH₵10.41 for T1, GH₵10.12 for T2, GH₵10.64 for T3 and GH₵19.19 for T4. These results highlight the comparative growth performance, feed efficiency and economic outcomes of locally formulated Akwaaba diets relative to the commercial Koudijs feed under Ghanaian farm conditions.

The findings emphasize the importance of evaluating broiler diets through an integrated biological and economic perspective. While T4 produced the numerically heaviest birds, T3 demonstrated a lower feed cost per kilogram of gain, underscoring the trade-off between maximum biological output and economic efficiency. Previous research has shown that locally prepared feeds may offer cost advantages, while the biological response to alternative ingredients such as wheat bran depends on inclusion levels, the balance of the complete diet and the use of suitable feed additives [18] [19] [21].

The principal limitation of the present study is the use of one pen per dietary treatment, which prevents independent pen-level replication and limits treatment-level inference. In addition, feed-consumption, feed-conversion and feed-cost calculations must be reconciled against original records before definitive conclusions about relative feed efficiency and economic advantage can be drawn. Profitability cannot be inferred solely from feed cost per kilogram of gain; a complete assessment requires reliable production-cost and revenue data, including chick costs, labour, medication, energy, housing and mortality.

Accordingly, T3 should be regarded as a promising candidate for further evaluation rather than a validated replacement for commercial feed. Future trials should use multiple independently managed pens per treatment, verified diet formulations and nutrient composition, standardized weighing and sampling procedures, and complete mortality-adjusted feed and production records. Economic analyses should distinguish feed cost per kilogram of feed, feed cost per kilogram of live-weight gain and overall production profitability. Such studies would provide the evidence needed to determine whether the promising numerical performance and estimated feed-cost advantage observed in this trial are reproducible and commercially meaningful for Ghana's broiler industry.

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Author Contributions

Kwamina Ewur Banson: Conceptualization, study design, methodology, supervision, data analysis, interpretation of results, economic analysis, manuscript preparation, writing—original draft, and project administration. **Sylvester Cooper and Albert Kwadwo Sefa:** Experimental supervision, feed management, provided funding for the research, field coordination, data collection, and review of the manuscript. **Khalid Alhassan Kusi:** Experimental feeding, daily feed measurement, bird weighing, data recording, data organization, and field implementation. **Stephen Amenorpe and Amaning Enim Nuamah:** Experimental feeding, bird weighing, feed-intake measurements, data recording, and field implementation. **Ousmane Barry, Isaac Baidoo, Doris Esi Bigombi, Ruby Juliana Kattah and Abel Nii Annertey Abbey:** Project oversight, institutional supervision, technical guidance, review of the experimental design, and critical revision of the manuscript. **All authors:** Reviewed and approved the final manuscript and agreed to be accountable for all aspects of the work, ensuring that questions related to the accuracy and integrity of the study were appropriately investigated and resolved.

Conflicts of Interest

The authors declare that **there are no conflicts of interest** associated with this study. Although **Akwaaba Feeds Company Ltd.** commissioned the feeding trial to evaluate the performance of its broiler feed formulations against a commercial feed, the study was conducted independently at the **BNARI Research Farm**, and the authors retained full responsibility for the experimental design, data collection, statistical analysis, interpretation of results, and preparation of the manuscript. Akwaaba Feeds Company Ltd. had no influence over the analysis, interpretation, or reporting of the findings.

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