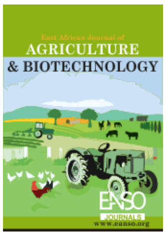

East African Journal of Agriculture and Biotechnology
eajab.eanso.org
Volume 6, Issue 1, 2023
p-ISSN: 2707-4293 | e-ISSN: 2707-4307
Title DOI: https://doi.org/10.37284/2707-4307

EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

Growth Performance and Feed Conversion Efficiency of Indigenous Chicken Fed on Diet Supplemented with Termites *(Macrotermes bellicosus)*

Milongo Olonde Susan[1*] *Dr. Matilda Atieno Ouma, PhD*[1], *Dr. Margaret Lukuyu, PhD*[2] & *Lucky Mwiinga*[1]

[1] Jaramogi Oginga Odinga University of Science and Technology, P. O. Box 210-40601, Bondo, Kenya
[2] Kenya Agricultural Research Institute, Kaptagat Rd, Loresho, 57811-00200 City Square, Nairobi, Kenya
* Author for Correspondence ORCID ID: https://orcid.org/0000-0002-2574-9523; Email: olondemilongo@gmail.com

Article DOI: https://doi.org/10.37284/eajab.6.1.1094

Date Published:

15 February 2023

Keywords:

Growth Performance, Feed conversion, Chicken, Termites,

ABSTRACT

In view of the emerging challenges of climate change and population growth, the need to ensure consumer health safety among other factors is paramount; this practice has not been standardised, and the health risks and impacts on the environment arising from the practice are not known. While the global consumption of chicken products especially chicken meat drastically increased over the years and the trend is expected to continue. Much of the increase in demand is in the developing countries coupled with demand for the four traditional feed ingredients; maise meal, soya bean meal, fish meal, and meat meal. In all three poultry production systems that are extensive, semi-intensive and intensive, a wide range of alternative feedstuffs should be available for use. Expanding populations will create greater demand for chicken products, and the importance of feed industry resources and production systems will increase. This therefore calls for a need to enhance efforts towards increased chicken productivity. This study, therefore, evaluated the growth performance, feed conversion efficiency, and cost-effectiveness of feed supplementation termite Macrotermes bellicosus for indigenous chicken diets. Three groups of twenty IC were placed on diets comprising prepared feeds with different termite inclusion levels (0%, 2.5% and 5%) for each group for six weeks. Results reveal that the termite supplementation provides high crude protein content (43.36%), which leads to enhanced weight gain but no significant differences in the FCR of ICs compared to conventional feeds. Supplementation at different levels offers varying outcomes regarding feed intake: IC on a diet T3 had a lower feed intake compared to T2 but registered higher FBW and SGR. The use of termites contributes to smallholder farms' food security by providing a cheaper alternative to commercial poultry feeds; and also increases the market value of IC, thus, increasing the profitability of IC production.

APA CITATION

Susan, M. O., Ouma, M. A., Lukuyu, M. & Mwiinga, L. (2023). Growth Performance and Feed Conversion Efficiency of Indigenous Chicken Fed on Diet Supplemented with Termites (Macrotermes bellicosus). *East African Journal of Agriculture and Biotechnology*, *6*(1), 44-57. https://doi.org/10.37284/eajab.6.1.1094

CHICAGO CITATION

Susan, Milongo Olonde, Matilda Atieno Ouma, Margaret Lukuyu and Lucky Mwiinga. 2023. “Growth Performance and Feed Conversion Efficiency of Indigenous Chicken Fed on Diet Supplemented with Termites (Macrotermes bellicosus)”. *East African Journal of Agriculture and Biotechnology* 6 (1), 44-57. https://doi.org/10.37284/eajab.6.1.1094

HARVARD CITATION

Susan, M. O., Ouma, M. A., Lukuyu, M. & Mwiinga, L. (2023) “Growth Performance and Feed Conversion Efficiency of Indigenous Chicken Fed on Diet Supplemented with Termites (Macrotermes bellicosus)”, *East African Journal of Agriculture and Biotechnology*, 6(1), pp. 44-57. doi: 10.37284/eajab.6.1.1094.

IEEE CITATION

M. O., Susan, M. A., Ouma, M., Lukuyu & L., Mwiinga, “Growth Performance and Feed Conversion Efficiency of Indigenous Chicken Fed on Diet Supplemented with Termites (Macrotermes bellicosus)”, *EAJAB*, vol. 6, no. 1, pp. 44-57, Feb. 2023.

MLA CITATION

Susan, Milongo Olonde, Matilda Atieno Ouma, Margaret Lukuyu & Lucky Mwiinga. “Growth Performance and Feed Conversion Efficiency of Indigenous Chicken Fed on Diet Supplemented with Termites (Macrotermes bellicosus)”. *East African Journal of Agriculture and Biotechnology*, Vol. 6, no. 1, Feb. 2023, pp. 44-57, doi:10.37284/eajab.6.1.1094.

INTRODUCTION

The overall growth in demand for chicken meat is accelerated by the surge in human population, rise in incomes, and urbanisation. This implies that the rural poor and landless in developing countries are bound to benefit from the expanded livestock markets and improved household incomes and this will result in improved food security, thus alleviating the prevalent micronutrient deficiencies (Godoy *et al.*, 2014). Chicken meat and eggs provide not only high-quality proteins but also essential vitamins and minerals. Chicken meat and eggs are among the best sources of quality protein and are highly needed by millions of people who live in poverty mostly in Sub-Saharan Africa and South Asia (Hoffmann, 2016). Poultry production in Kenya fluctuated substantially in the last decade. In the year 2019, the production of poultry in Kenya was 88,719 tons of meat. This dropped from 131,683 tons in the year 2018 and 106,473 in 2017 (Farrell, 2013). Poultry production and in particular indigenous chicken (IC) production has been recognised as an avenue to improve the livelihoods of rural households in Kenya (Magothe *et al.*, 2012).

Traditionally, feeding chicken on termites has been widely practised in India, Ghana, Western Uganda, and some parts of Kenya (Boafo *et al*., 2019). Most farmers relied on free-range subsistence systems of poultry production with very little supplementation. Currently, the majority of poultry farmers in the Bondo sub-county, Siaya, practice commercial production which is characterised by high initial capital. The bulk of the capital requirement is on feeding. Under semi-intensive and intensive systems of poultry production, feeding chicken accounts for approximately 75% of the total cost of production (FAO, 2004). The cost of commercial feeds has become so high and is unaffordable for most farmers in Bondo. Therefore, commercial feeds should be supplemented with a cheap source of protein such as the insect termite (*Macrotermes bellicosus)* in order to reduce the cost of production and increase productivity in the indigenous chicken in Bondo. The termites are locally available, easy to trap, and are characterised by high palatability to the indigenous chicken. This, therefore, creates a need for the study to assess whether chicken feed supplementation with insects can increase the production of meat quality.

This will stand as a solution to previous attempts trials in chicken production improvements that have had little success due to a lack of a holistic approach in solving the constraints and dissemination of inappropriate technologies given the production circumstances and market dynamics. Marketing as a constraint is often blamed for the failure of interventions to improve livelihoods, despite the lack of saturation for IC products at local and national levels and the increasing demand for the same (Okeno, 2012). The other constraint has been the challenges in the feeding aspect, where the cost of commercial

Article DOI: https://doi.org/10.37284/eajab.6.1.1094

feeds has become so high. In Kenya, poultry farming is a major livestock subsector contributing to both the income and food security of many households, particularly those residing in rural areas. Nationally, the subsector contributes about 7.8% to the national Agricultural Gross Domestic Product (GDP) and about 0.34% of the total GDP (Economic Survey, 2018). Additionally, the local farmers have not come up with proper formulae for the formulation of indigenous chicken feeds using locally available materials. This study will aim at looking into supplementing the existing diets with protein concentrates of the insect termite (*Macrotermes bellicosus*).

MATERIALS AND METHODS

Study Area

This study was carried out in Gobei village, North Sakwa ward, Bondo Sub-County in Siaya County, Kenya. Siaya is characterised by high poverty levels (47.56%) and food insecurity. Agriculture is the main source of livelihood in the County, contributing about 60% of the household income and providing almost 61% of all employment opportunities. Maise, beans, sorghum, and local poultry are the key value chain commodities in the County. Droughts and intense rainfall already constrain agricultural productivity and food security in Siaya County. Climate projections indicate increasing events of drought and intense rains. Farmers in Siaya County employ a host of on-farm strategies to cope with climate risks and shocks including the planting of drought-resistant crop varieties, diversification, conservation agriculture, value addition strategies, animal feed conservation, and farmer groups to ease access to credit, farm inputs, and market information.

Research Design

The study followed a completely randomised design, where sixty indigenous chicks at the age of eight weeks (pullets) were randomly assigned to three treatments (2.5% and 5% termite) and one control (0% termite). Each treatment comprised twenty birds which were further divided into four replicates of five birds per replicate. The cages (coops) measured eight square metres per treatment, that is, two square metres per individual cage to accommodate a density of 0.8 square metres per bird (Alchalabi, 2014).

Collection, Processing, and Storage of Termite *Macrotermes bellicosus*

The termites were obtained by trapping method where large traditional mud pots were bought from the market. The pots were used to maintain moisture and keep a cool temperature which is habitable for the termites in order to thrive even during hot weather. The pots were filled with organic material, including rotting organic matter such as fallen leaves, old cotton clothes, dry cow dung and dry maise stalks. The pots were filled with layers of materials mixed with a little soil and left loose without compaction. A small amount of water was sprinkled over each layer to keep it moist but not wet because termites do not survive underwater (Dao *et al*., 2020). The pots were inverted in shaded areas for three to four days. The areas were identified by features such as mounds and places with infestations such as on fencing posts. The pots were checked in the morning hours and their contents were emptied in small quantities. This process was done with the support of other local farmers who found delight in doing this work.

Other trapping methods of trapping termites involved farmers digging holes in the gardens and stuffing the maise husks, paddy straws, jute sacks, or dried cow dung and dried crop stubble. After harvesting, the termites were separated manually from the soil and organic wastes. The process of trapping the termites was repeated severally to obtain the required quantity. The termites were cleaned and then sun-dried to keep moisture content that would not allow any further microbial activities (Boafo *et al.*, 2019).

Article DOI: https://doi.org/10.37284/eajab.6.1.1094

Preparation of Feeds and Laboratory Analysis of Ingredients (Proximate Analysis)

Kenya Bureau of Standards (KEBS) provides the specific requirements for supplementary IC feeds as presented in *Table 1*.

Table 1: Nutrient requirements for Supplementary indigenous chicken feed

Nutrient	Diet Requirement	Test Method
Moisture %(Max)	13	ISO 6496
Metabolisable energy (Kcal/Kg) (Min)	2400	
Crude protein % (Min)	13	ISO 5983-2
Crude fibre % (Max)	8	ISO 6865
Crude Fat % (Max)	8	ISO 6492
Total Ash % (Max)	12	ISO 5984
Acid insoluble Ash % (Max)	5	ISO 5985
Calcium % (Min)	0.8	ISO 6490-1
Available Phosphorus % (Min)	0.2	ISO 6491
Sodium % (Min)	0.13	ISO 6495
Chloride % (Min)	0.2	ISO 6495-1
Total Lysine % (Min)	0.5	ISO 13903
Total Methionine%(Min)	0.25	ISO 13903

Source*:* Kenya Standards (2021)

Samples of feed ingredients to be used in this study such as maise, wheat bran, soya bean meal, and termites, were analysed for dry matter (DM), crude protein (CP), ether exact (EE), crude fibre (CF), and ash for proximate analysis. This was done at the University of Nairobi, Kabete Campus, and the Department of Animal Production in the Animal Nutrition Laboratory and the results are presented in *Table 2*.

Table 2: Results of proximate analysis of feed ingredients

Ingredients	DM	Ash	CP	Lipids	CF
Termites	94.69	17.55	43.36	2.85	13.92
Soya bean meal	91.17	6.81	53.81	3.32	9.40
Wheat bran	91.03	5.61	13.19	2.00	12.92

Abbreviations: DM, dried matter; CP, crude protein; CF, crude fibre

Feed Formulation

The Kenya Bureau of Standards (KEBS) also provides guidelines for formulating complete feeds for IC and improved IC at different development stages. *Table 3* presents recommendations for nutritional requirements in the grower’s diet.

Article DOI: https://doi.org/10.37284/eajab.6.1.1094

Table 3: Nutrient requirements for complete feed for indigenous and improved indigenous chicken

Nutrient	Growers Diet	Test method
Moisture % (Max)	13	ISO 6496
Metalizable energy (Kcal/Kg) (Min)	2400	*
Crude protein % (Min)	14	ISO 5983-2
Crude fibre % (Max)	7.5	ISO 6865
Crude Fat % (Max)	8	ISO 6492
Total Ash % (Max)	12	ISO 5984
Acid insoluble Ash % (Max)	6	ISO 5985
Calcium % (Min)	0.8	ISO 6490-1
Available Phosphorus % (Min)	0.25	ISO 6491
Sodium % (Min)	0.14	ISO 6495
Chloride % (Min)	0.2	ISO 6495-1
Total Lysine % (Min)	0.6	ISO 13903
Total Methionine%(Min)	0.3	ISO 13903

***Source**:* KEBS (2021)

Feed formulation was done by use of software (Diet Formulator), which uses inclusion instead of supplementation. This was used to formulate diets at three different levels of termite supplementation. The diets were formulated according to the recommended nutrient composition of IC and improved IC diets by KEBS commonly used in the feeding of chickens. In this respect, the diet used was a grower's diet (chicks obtained at eight weeks and fed for six weeks) which was targeted at 18% crude protein and metabolisable energy (ME) of 12MJ/KG dry matters.

Three categories of feeds were formulated using varying ratios of inclusion. Feed T1 was the control, while feed T2 and T3 contained 2.5% and 5% termite inclusion, respectively. *Table 4* presents the quantities of the ingredients in every 100 kilograms of feed. The feed samples were then sent to the laboratory for proximate analysis and the findings are presented in *Table 5*.

Table 4: Quantities of the ingredients in each 100 kg of feed

Ingredient	Feed 1 (Kg)	Feed 2 (Kg)	Feed 3 (Kg)
Maise	58	58	58
Wheat Bran	19	19	19
TERMITE	0	2.5	5
Soya Bean Meal	21	18.5	16
Lysin	0.02	0.02	0.02
Methionine	0.1	0.1	0.1
Table salt	0.2	0.2	0.2
Limestone	1.2	1.2	1.2
Grower Premix	0.25	0.25	0.25
Toxin Binder	0.1	0.1	0.1
Coccidiostat	0.1	0.1	0.1
Enzyme (Phytase)	0.1	0.1	0.1
Total	**100.07**	**100.07**	**100.07**

Table 5: Proximate analysis of feed diets

Feed	DM	ASH	CP	CF	EE	NFE
0% Termite (T1)	92.38	5.51	19.15	6.50	2.11	66.73
2.5% Termite (T2)	92.3	6.07	19.68	6.36	1.57	66.32
5% Termite (T3)	92.43	5.97	19.71	7.12	1.73	65.90

Article DOI: https://doi.org/10.37284/eajab.6.1.1094

Housing and Experimental Design

The cages were disinfected using phenolic detergents, particularly Virukill. Absorbent bedding material (Wood shavings) was locally obtained, dried, and spread on the floors of the cages to act as litter providing insulation against floor moisture (Demeke, 2012). The insulation was added to a depth of 3-5 cm to absorb spilt water from drinkers and the birds' droppings. Floor insulation also maintained temperatures in the cages at ambient room temperatures of around 24 °C, which is within the optimal temperature range for pullets (Mormino, 2021). Feeders and waterers were cleaned and placed strategically to await the incoming chicks. A foot bath was prepared by mixing 500 ml (2 cups) of chlorine bleach with 20 litres of water.

Arrival of Chicks

Chicks were not fed for twelve hours before arrival. The pullets were transported in the morning during cool temperatures to reduce levels of mortality due to heat stress. The chickens were given a stress mix (multi-vitamin) diluted in drinking water and then the individual weight of the birds were taken using a kitchen scale before being randomly assigned to cages. The feeds with different termite-inclusion ratios were given to the respective experimental groups of birds after they had settled.

Feeding and Management

The ICs were distributed randomly into the three groups, T1, T2, and T3, with each group living in separate coops. Each chicken coop was equipped with feeders and waterers, and experimental feeds in mash form were supplied after allocating birds to cages. Feed and water were administered *ad libitum* for a period of 6 weeks (42 days) with each bird getting over 300 g of feed every morning to ensure feed availability throughout the day. The feeders and drinkers have been cleaned accordingly on a daily basis and refilled with clean water and respective experimental feeds. The insulation litter was turned when soiled, and replacements were done with dry material when necessary. The birds grew with minimal stress and minimal mortality rates were recorded during the entire period of data collection.

Feed Cost

The cost of the feed was calculated based on the feed intake of the IC on each diet. The cost per kilogram of each feed was determined prior to the calculation of feed cost. The formula used for feed cost calculation was:

Total feed cost = Unit feed cost (Ksh/kg) × Total feed intake (kg)

The cost of producing an IC on each diet was then calculated in the gross margin analysis based on the cost of feed and willing-to-pay price from a study in 2018 that assessed the market value of insect-fed chicken in Kenya.

Data Collection, Management and Analysis

Data on feed intake and body weight gain for each diet formulation were recorded throughout the six-week duration of the study. The individual body weights of the three IC groups in their respective pens were taken on a weekly basis. Weights of the feed offered and feed refused were measured on a daily basis using a kitchen scale (1.8kg ±0.025). The 2007 Microsoft Excel software version was used to sort data regarding intake of dry matter (DMI) feed conversion ratio (FCR), average daily weight gain (ADG), and final body weight (FBW). DMI calculations were founded on IC feed intake:

DMI = (Feed %DM content) × feed intake (as fed basis)

Weight gain and FBW were obtained from the difference between daily weight gains and end weight on the last day of the experiment (day 42).

$$ADG = \frac{Weight\ of\ birds\ at\ day\ 42 - Average\ weight\ of\ birds\ at\ day\ 0}{42}$$

Article DOI: https://doi.org/10.37284/eajab.6.1.1094

FCR was calculated to determine the amount of feed converted to body weight through the formula:

$$FCR = \frac{Feed\ intake\ (g)}{Weight\ gain\ (g)}$$

Collected data was then analysed through one-way analysis of variance (one-way ANOVA) using the IBM® SPSS® (Statistical Package for Social Sciences) Statistics version 25 to determine the focal effects of termite supplementation of IC diet on production variables. Multiple comparisons were performed severally on the mean of experimental conditions where there were statistically significant differences or there existed a specific aspect between group means in the ANOVA as a validation when the null hypothesis is rejected

Ethical Approval

This study was permitted by the Ethical Review Committee and Board of Postgraduate Studies of JOOUST. Permission to collect data from the study site was obtained from **the** Board of Graduate Studies. Consumers who took part in the study completed consent forms and were assured of anonymity.

RESULTS

Nutritional Content of Prepared Feed

The nutrient composition of the three feeds given to the respective IC groups. The mixing ratios for the feed were based on inclusion to fit the recommended composition for the chicken grower's diet. Study results indicate that nutritional content significantly varied in levels of CP (crude protein), CF (crude fibre), EE (ether extract), and NFE (nitrogen-free extract) among the feeds formulated as indicated in the table below

Table 6: Nutrient composition of the feeds with different ratios of supplementation of termite (Macrotermes bellicosus)

Nutrient	T1	T2	T3	KEBS STD
% DM	92.35 ± 0.62^a	92.24 ± 0.49^a	91.23 ± 0.48^a	87 (Min)
% CP	18.89 ± 0.30^a	19.69 ± 0.10^b	19.81 ± 0.33^b	13 (Min)
% ASH	5.405 ± 0.28^a	5.408 ± 0.12^a	5.7 ± 0.17^a	12 (Max)
% CF	6.24 ± 0.19^a	6.58 ± 0.18^b	7.01 ± 0.07^c	8 (Max)
EE	2.10 ± 0.07^a	1.90 ± 0.11^b	1.68 ± 0.07^c	8 (Max)
NFE	66.78 ± 0.25^a	66.40 ± 0.48^b	65.18 ± 0.58^b	48.5 (Min)

Means with different superscripts in the same row are significantly different at p<0.05

Acronyms: T1, 0% termite; T2, 2.5% termite; T3, 5% termite; DM, dry matter; CP, crude protein; CF, crude fibre; EE, ether extract; NFE, nitrogen-free extract; KEBS, Kenya Bureau of Standards; STD, standard

Effect of Termite Supplementation on Feed Intake

Table 7 represents the average feed intake of the IC groups on each diet. Study results revealed a significant difference in feed intake (p = 0.018), meaning termite supplementation of IC feeds influences feed intake. Total feed intake of IC fed on diet T1 (avg. = 100.32 kg, SD = 20.32) was lower than those fed diet T2 (avg. = 111.93 kg, SD = ±28.10) and T3 (avg. = 109.15, SD = ±20.68). Further, multiple comparison test results revealed there was a significant difference in feed intake between chicken on diet T1 and T2 (p<0.05). Lower feed intake for chicken on diet T1 was not associated with termite supplementation, somewhat due to its absence since there was a significant difference between feed intake of IC on diet T1 and T2 (p = 0.13), but not between T3 and T1 or T2 (p>0.05). Diet T2 had the highest feed intake, with a termite supplementation of 5%.

Article DOI: https://doi.org/10.37284/eajab.6.1.1094

Table 7: Average Feed Intake of Indigenous Chicken

Feed	Feed intake Mean ±SD
T1	100.32±20.32 [a]
T2	111.93. ±28.10[ab]
T3	109.15±20.68 [b]
F-value	4.259
P-value	0.018

Means with different superscripts in the same column are statistically different at p<0.05
Acronyms: T1, 0% termite; T2, 2.5% termite; T3, 5% termite; ±SD, standard deviation

Weight Gain of Indigenous Chicken Fed on Termite-Supplemented Diet

Table 8 represents the weight gain results of IC groups fed on each diet at Bondo in Siaya County, Kenya. The average daily weight gain (ADWG) means for the IC on each diet was highest in T3 (16.12g±13.78) and lowest in T1 (10.86g±13.68); there was no statistical difference (p = 0.35). The final body weight (FBW) average was highest in diet T3 (avg. = 1197.12, SD = ±212.61) and the lowest in T1 (avg. = 1026.41, SD = ±175.88). Study findings revealed a statistical difference (p=0.011) in the group means of FBW of the IC. Further, multiple comparison tests revealed a significant difference in the FBW group averages between diets T1 and T3 (p = 0.008). Therefore, the null hypothesis was rejected and the alternative hypothesis was upheld: termite supplementation enhances the weight gain of IC. Enhanced weight gain may be attributed to a raised protein content in the feed.

Table 8: Weight gain for indigenous chicken fed on a diet supplemented with termite (*Macrotermes bellicosus*) for six weeks

Feed	FBW Mean ±SD	ADWG Mean ±SD
T1	1026.41±175.88[a]	10.86±13.68[a]
T2	1127.52±186.16[ab]	12.44±10.73[a]
T3	1197.12±212.61[b]	16.12±13.78[a]
F-value	4.788	1.065
P-value	0.011	0.35

Means with different superscripts in the same column are statistically different at p<0.05
Acronyms: T1, 0% termite; T2, 2.5% termite; T3, 5% termite; ±SD, standard deviation; FBW, final body weight; ADWG, average daily weight gain

Feed-to-Meat Conversion Efficiency of IC on Diet Supplemented with Termites

Table 9 represents the FCR averages for the IC groups fed on each diet. Feed conversion ratios (FCR) of each group were calculated to determine the effect of termite supplementation on weight gain. Feed conversion rate (FCR) also known as feed conversion ratio (also called growth efficiency), is a measure of the amount of feed needed to produce a unit of meat. FCRs and associated topics are typically deliberated upon in terms of efficiency. FCR is calculated by dividing the total feed weight by the net production, which is the final weight minus the starting weight (Gebhart, 2020).

Table 9: Feed conversion ratios (FCR) for IC on a diet supplemented with termites

Feed	Mean Weight±SD	Feed Intake Mean±SD	FCR Mean ±SD
T1	1026.41±175.88[a]	100.32±20.32 [a]	10.70±10.29[a]
T2	1127.52±186.16[ab]	111.93. ±28.10[ab]	10.52±6.06[a]
T3	1197.12±212.61[b]	109.15±20.68 [b]	9.28±8.09[a]
F-value	4.788	4.259	0.208
P-value	0.011	0.018	0.813

Means with different superscripts in the same column are statistically different at p<0.05

Article DOI: https://doi.org/10.37284/eajab.6.1.1094

Contribution of Termites to Smallholder-farmers' Food Security

Table 10 represents the results of the gross margin analysis over feed costs. There was a significant difference (p<0.05) in the market value of IC. The market value of IC on diet T1 (Ksh662.43±60.07) was substantially lower compared to T2 (Ksh745.13±70.49) and T3 (Ksh796.24±34.31). Additionally, gross margin analysis reveals no significant difference (p<0.05) in the production costs of the IC. The gross margin was highest in T3 (Ksh376.43±34.31) and lowest in T1 (Ksh330.19±60.07).

Table 10: Gross margin analysis for one IC fed on a termite-supplemented diet

Parameter	T1	T2	T3
Feed cost/ kg (KES)	74.16	70.67	67.17
Total feed intake(kg)	4.48	5.49	6.25
Total feed cost (KES)	332.24	387.98	419.81
Weight gain (kg)	0.46	0.53	0.68
FCR	10.70 ± 10.29^{a}	10.51 ± 6.07^{a}	9.23 ± 8.09^{a}
Sale weight (kg)	1.23± 0.19	1.38 ±0.23	1.47± 0.21
Chicken price/kg	538	538	538
Value of chicken	662.43 ± 60.07^{a}	745.13 ± 70.49^{ab}	796.24 ± 34.31^{b}
Gross margins (KES)	330.19 ± 60.07^{a}	357.15 ± 70.49^{a}	376.43 ± 34.31^{a}

This means in the same rows with the same superscripts are not significantly different p<0.05

DISCUSSION

Nutritional Value of Chicken Feed After Termite Supplementation.

The proximate composition of the feed supplemented with termites showed high levels of nutritional content, particularly proteins and dry matter. The range of proteins in the diet ranged from 19.15% to 19.71% which was slightly higher than the intended value but lies within the range for sustainable chicken production (Akulo *et al.*, 2018). DM content for formulated feed did not have a significant difference and ranged between 92.3% and 92.43% as indicated in *Table 6*.

The crude protein level in termites lies within the range of values reported by Akulo *et al.* (2018) and Sogbesan and Ugwumba (2008). Insects, including termites, have relatively higher protein content compared to lamb (19.8%), beef (22.3%), pork (22.0%), and chicken (22.25%) based on mass (Akulo *et al.*, 2018). For example, raw red muscle meat containing around 23 g of protein per 100g loses water and becomes more concentrated during cooking to have approximately 32g/100g of protein (Williams, 2007). Edible insects are good protein sources for human beings and animals which can meet the consumer's amino acid requirements and also contain rich trace elements and vitamins (Solomon *et al*., 2020). For instance, edible grasshoppers were found to contain 36-40% CP, while raw species of *Macrotermes* had approximately 43.3% (Ssepuuya *et al.*, 2017). The high levels of proteins in termites can be used to increase the dietary protein quality of chicken feed, which is particularly deficient in rural areas. Termites also contain other essential macro and micro minerals, such as potassium and iron, which are vital for sustenance. However, inefficient feed-to-food conversion can lead to environmental impacts and food insecurity (Alexander *et al*., 2017).

Effect of Termite Supplementation on Feed Intake

Diet supplemented with termites had the highest feed intake, with a termite supplementation of 5%. The difference in the feed intake could be a result of the taste of feed as termites are very palatable to chicken (Sogbesan & Ugwumba, 2008). Various reasons can lead to reduced feed intake in chickens, including feed management, dietary energy, temperature, ventilation, brooding temperature, feeding on paper, and lighting and lighting programs (Hadley & Corzo, 2016). Environmental factors or immune-related problems have the most significant effect on chicken feed intake variations. Effective management practices that alleviate environmental and health stress on the flock can enhance feed intake. Therefore, it is crucial first to identify the leading causes of disease or stress on flocks. Nonetheless, combining proteins from different sources can have a positive outcome regarding weight gain due to the synergetic effect of joining two biological compounds to produce a particular and superior outcome compared to an individual application (Sogbesan & Ugwumba, 2008). Each diet in the study contained proteins from sources other than termites, including soya bean meal and wheat bran.

Feed intake is crucial as it impacts body weight gain and feed conversion efficiency in chicken meat production. Amending poor feed intake is cumbersome and requires a comprehensive review of animal and feed management practices since several factors can influence feed intake. Mismanagement and animal health issues are more likely to be the common cause of feed intake issues compared to dietary factors (Ferket & Gernat, 2006). Diet-related factors influencing feed intake would be similar among all the chickens compounded instead of individual groups. For example, excess methionine supplementation in the maize diet reduces voluntary food intake for broiler chickens (Han & Baker, 1993).

Weight Gain of Indigenous Chicken in relation to Termite-Supplemented Diet

This study found a higher average final body weight in the supplemented diet. The results concur with a study in the Democratic Republic of Congo (DRC) which revealed that the use of 12% of termites *Kalotermes flavicollis* provided significant outcomes regarding weight gain (Mutungi *et al.*, 2017). Despite the study using different species and portions of termites, research reveals that *Macrotermes bellicosus* and *Kalotermes flavicollis* are of high quality with interspecies specificity (Ke *et al.*, 2017).

Protein products receive the most attention in chicken nutrition due to the essence of protein being a significant component of the biologically active compounds in humans and animals. Proteins also help in the synthesis and repair of tissues and the growth of the body. Results of the proximate analysis of the experimental feed reveal that termites have a significantly high amount of protein; and *Macrotermes bellicosus* is the largest termite known. Protein is among the known nutritional values of *Macrotermes bellicosus* (Magothe *et al.*, 2012). Feed T3 (5% termite) had the second highest feed intake and the highest weight gain, meaning chicken fed consumed higher amounts of proteins. The lower weight gain in chicken fed on diet T1 can be attributed to the lack of termites in the feed to supplement protein, which is vital to poultry nutrition. Lower crude protein intake inhibits the performance of IC unless attention is given to the amino acids' requirements for the production of mucin and other factors that maintain the birds' gut health (Maia *et al.*, 2021). Protein deficiency in IC diets increases energy requirements for maintenance and affects carcass protein and fat deposition (Furlan *et al.*, 2004).

Feed-to-Meat Conversion Efficiency of IC on Diet Supplemented with Termites

The study findings show no significant difference (p = 0.813) in the feed conversion ratio (FCR) of the three groups, meaning the null hypothesis is accepted: termite supplementation does not enhance FCR in IC. Results concur with a study by Ke et al. (2017), which reveals that the inclusion of termites in poultry feed does not result in a significant difference in FCR. The FCR values were lowest in chicken on diet T3 (9.28±8.09) containing termite supplementation and highest in T1 (10.70±10.29) without termite supplementation. High FCR values indicate low efficiency and vice versa. Feed ratios are commonly assigned depending on animal species. Chickens have a lower FCR compared to sheep, and thus less feed is required to produce a unit of

Article DOI: https://doi.org/10.37284/eajab.6.1.1094

chicken mean than an equal amount of beef. Most animals are inefficient converters of food since they produce fewer food products than they consume (A Well-Fed World, 2015). The appropriation of the term "inefficiency" roots from the inherent loss of crop and natural resources used in meat production. Improvements in FCR reduce emissions of greenhouse gases (GHC) including LUC (indirect land-use change) and dLUC (indirect land-use change) and minimise environmental impacts by lowering resource use and decreasing feed requirement (Wiedemann et al., 2017). Additionally, enhanced FCR positively affects downstream and upstream water resource impacts from manure production by decreasing manure production.

Contribution of Termites to Smallholder-Farmers' Food Security

This study's findings, indicating the cost-effectiveness, are confirmed by a study in DRC, which revealed that chicken feed supplemented with 12% termites was economically viable with higher profit margins compared to commercial feeds (Mutungi *et al.*, 2019). Termites also resulted in significant growth performance enhancement, as evidenced in an experiment by Kataren *et al*. (2014), where termite inclusion in the poultry diet significantly increased the percentage of gizzard, heart, and abdominal fat weight in poultry. Purchasing feed for broiler production accounts for the major expenses for farmers. Over the last decade, the cost of poultry feed ingredients has increased significantly due to the use of maise (corn) to produce ethanol and the increased demand for grain feed globally. Consequently, production costs are becoming higher and impact profitability. Feed utilisation efficiency is the main objective of breeding strategies to cut costs and maximise production and, subsequently, profits. A study in Kenya revealed that most (93%) participants were willing to pay an average of KES 537.50 for every kilogram of meat produced from insect-fed chicken (Joel, 2018). The difference in willing-to-pay prices resulted from varying market prices of chicken meat in different counties. Factors affecting the price customers are willing to pay for insect-fed chicken meat include income, preference, insect type, market outlets, age, and education level. Gender and household size did not significantly influence the prices participants were willing to pay (Joel, 2018).

Termites are palatable to chicken that can effectively replace vitamin premix, fish meal, and soybeans without inhibiting growth (Sogbesan & Ugwumba, 2008). Farmers harvest, prepare and store termites using different strategies. Nonetheless, termites are not always available, and the quantity present at a given time depends on the season, termite mound availability, and the termite species. In Kenya, the Improving Livelihoods by Increasing Livestock Production in Africa (ILIPA) project facilitates commercial insect rearing as a poultry production feed under the International Center for Insect Physiology and Ecology (ICIPE) headquartered in Nairobi (Joel, 2018). The project aims to provide a constant supply of affordable insect-based poultry feeds.

CONCLUSIONS

Indigenous chickens are a feasible avenue for improving the livelihoods of rural households in Kenya. However, market constraints are the causes of failure in achieving livelihood improvements despite Indigenous Chicken products not saturating local and national markets and the growing demand. Furthermore, the cost of poultry feed ingredients continues to rise, subsequently increasing production costs and impeding profitability in chicken farming around the world, including Kenya. Farmers need a cheaper substitute for commercial IC feeds. Termites are a viable option for protein supplementation in IC production. Efforts to promote IC production in Kenya are impeded by the lack of comprehensive frameworks that address issues and unsuitable technology dissemination, considering the current production circumstances and market trends. However, little knowledge exists on the effectiveness of cheaper alternatives including insects, and the ecological and environmental impacts of their use.

Minimising environmental degradation while feeding the rapidly-increasing population presents a global challenge that calls for the formulation of comprehensive frameworks on food production and consumption. Decreasing or abstaining from consuming animal products with low production efficiency can help conserve resources that are used to produce more food and this can be achieved through a mediated multipronged-approach in boosting the awareness and acceptability of insects as food and feeds Mwiinga et al. (2022). Despite the awareness of the effect of livestock on the environment, few feed conversion estimates of cows, pigs, and poultry products exist. These estimates are vital to mitigating diet-related environmental effects and determining the optimal production strategies. Improvement of the food conversion ratio (FCR) provides positive outcomes regarding environmental emissions and minimises the impacts of poultry production on the environment. Poultry production is currently associated with substantial emissions of ammonia, methane, and nitrates globally. Enhancing feeding efficiency through reducing the quantity of manure produced and minimising emissions can lead to reduced emissions. Thus, feed efficiency improvement can cut down production costs and increase profitability, and reduce emissions to mitigate environmental impacts.

ACKNOWLEDGEMENT

This study was conceivable with the financial help of Jaramogi Oginga Odinga University of Science and Technology through the African Centre of Excellence for sustainable use of insects as food and feed (INSEFOODS) in collaboration with the World Bank and the Kenyan government.

REFERENCES

Akullo, J., Agea, J.G., Obaa, B. B., Okwee-Acai, J. & Nakimbugwe, D. (2018). Nutrient composition of commonly consumed edible insects in the Lango sub-region of northern Uganda. *International Food Research Journal*, *25*(1), 159-165.

Alchalabi, D. (2014). Poultry Housing Design. (PhD, AE). https://doi.org/10.13140/2.1.2729.7280

Alexander, P., Brown, C., Arneth, A., Finnigan, J., Moran, D. & Rounsevell, M. D. A. (2017). Losses, inefficiencies and waste in the global food system. *Agricultural Systems*, *153*, 190-200. https://doi.org/10.1016/j.agsy.2017.01.014

Boafo, H. A., Affedzie-Obresi, S., Gbemavo, D. S. J. C., Clottey, V. A., Nkegbe, E., Adu-Aboagye, G., & Kenis, M. (2019). Use of termites by farmers as poultry feed in Ghana. *Insects*, 10(3), 1– 13. https://doi.org/10.3390/insects10030069

Dao, A. N. C., Sankara, F., Pousga, S., Coulibaly, K., Nacoulma, J. P., Ouedraogo, S., Kenis, M., & Somda, I. (2020). Traditional methods of harvesting termites used as poultry feed in Burkina Faso. *International Journal of Tropical Insect Science*, 40(1), 109–118. https://doi.org/10.1007/s42690-019-00059-w

Demeke, S. (2012). Good Practices for Family Poultry Production Hay Box Brooder: A Milestone to Increase Rural Households Poultry Production Date of publication.

Economic Survey 2022 - Kenya National Bureau of Statistics on economics.

FAO. (2004). Small-scale poultry production. Psikologi Perkembangan, 1–224. http://www.fao.org/3/a-y5169e.pdf

Farrell, D. (2013). Poultry Development. In *The role of poultry in human nutrition.*

Ferket, P. & Gernat, A. (2006). Factors That Affect Feed Intake of Meat Birds: A Review. *International Journal of Poultry Science, 5*. 10.3923/ijps.2006.905.911.

Furlan, R. L., Filho, D. E. F., Rosa, P. S. & Macari, M. (2004). Does low-protein diet improve broiler performance under heat stress conditions? *Brazilian Journal of Poultry*

Science, *6*(2), 71-79. Epub. ISSN 1806-9061. https://doi.org/10.1590/S1516-635X2004000200001.

Gebhart, G. E. (2020). *Economics of feed conversion ratios*. Langston University, https://www.langston.edu/economics-feed-conversion-ratios

Godoy, D., Dewbre, J., PIN, Amegnaglo, C. J., Soglo, Y. Y., Akpa, A. F., Bickel, M., Sanyang, S., Ly, S., Kuiseu, J., Ama, S., Gautier, B. P., Officer, E. S., Officer, E. S., Eberlin, R., Officer, P., Branch, P. A., Oduro-ofori, E., Aboagye Anokye, P., … Swanson, B. E. (2014). The future of food and agriculture: trends and challenges. In *The future of food and agriculture: trends and challenges*, 4(4). www.fao.org/publications%0Ahttp://www.fao.org/3/ai6583e.pdf%0Ahttp://siteresources.worldbank.org/INTARD/8258261111044795683/20424536/Ag_ed_Africa.pdf%0Awww.fao.org/cfs%0Ahttp://www.jstor.org/stable/4356839%0Ahttps://ediss.uni-goettingen.de/bitstream/han

Hadley, J. T. & Corzo, A. (2016, August 18). *What influences feed intake in broilers, breeders?* WATT Poultry. https://www.wattagnet.com/articles/27902-what-influences-feed-intake-in-broilers-breeders?v=preview

Han, Y., & Baker, D. H. (1993). Effects of excess methionine or lysine for broilers fed a corn-soybean meal diet. *Poultry Science*, *72*(6), 1070-1074.

Hoffmann, I. (2016). The relative contribution of indigenous chicken breeds to poultry meat and egg production and consumption in the developing countries of Africa and Asia. [Paper presentation]. Proceedings of the 12th European Poultry Conference. Verona, Italy.

Joel, H. M. (2018). *Consumer willingness to pay for chicken meat derived from chicken fed on insect-based feed in Kenya*. (Master's thesis, University of Nairobi). http://hdl.handle.net/11295/105845

Ke, Yunling & Wu, Wenjing & Zhang, Shijun & Li, Zhi-Qiang. (2017). Morphological and Genetic Evidence for the Synonymy of Reticulitermes Species: Reticulitermes dichrous and Reticulitermes guangzhouensis (Isoptera: Rhinotermitidae). Florida Entomologist. 100. 101-108. 10.1653/024.100.0115.

Ketaren, P., Sinurat, A., Purwadaria, T., Kompiang, I., & Amir, M. (2014). Use of termite

(Glyptotermes montanus) as poultry feed. Jurnal Ilmu Ternak dan Veteriner, 6(2): 100-

106. https://doi.org/10.14334/jitv.v6i2.225

Kenya Bureau Standards. (2021). *Compounded Indigenous (Kienyeji) Chicken Feed — Specification*. Nairobi: KEBS. DKS 2957: 2021. ICS 65.120

Magothe, T. M., Okeno, T. O., Muhuyi, W. B., & Kahi, A. K. (2012). Indigenous chicken production in Kenya: I. Current status. *World's Poultry Science Journal,* 68(1), 119–132. https://doi.org/10.1017/S0043933912000128

Mormino, K. S. (2021). *When to move chicks from brooder to chicken coop*. Chicken Chick. https://the-chicken-chick.com/when-to-move-chicks-from-brooder-to/

Mwiinga, L., Ogara, S., & Chaamwe, N. (2022). The Influence of Mobile App and Media, Towards Entomophagy Awareness and Acceptability. International Journal of Advanced Research, 5(1), 131-144.https://doi.org/10.37284/ijar.5.1.824

Mutungi, C., Irungu, F. G., Nduko, J., Mutua, F., Affognon, H., Nakimbugwe, D., Ekesi, S. & Fiaboe, K. K. M. (2017): Postharvest processes of edible insects in Africa: A review of processing methods, and the implications

Article DOI: https://doi.org/10.37284/eajab.6.1.1094

for nutrition, safety and new products development. *Critical Reviews in Food Science and Nutrition, 59*(7). http://dx.doi.org/10.1080/10408398.2017.1365330

Maia, R. C., Albino, L. F. T., Rostagno, H. S., Junior, M. L. X., Kreuz, B. S., Silva, R. L., Faria, B. D. & Calderano, A. A. (2021). Low crude protein diets for broiler chickens aged 8 to 21 days should have a 50% essential-to-total nitrogen ratio. *Animal Feed Science and Technology, 271*. ISSN: 0377-8401. https://doi.org/10.1016/j.anifeedsci.2020.114709.

Okeno, T. O., Kahi, A. K., & Peters, K. J. (2012). Characterisation of indigenous chicken production systems in Kenya. *Tropical animal health and production*, *44*(3), 601–608. https://doi.org/10.1007/s11250-011-9942-x

Sogbesan, O., & Ugwumba, A. (2008). Nutritional Evaluation of Termite (Macrotermes subhyalinus) Meal as Animal Protein Supplements in the Diets of Heterobranchus longifilis (Valenciennes, 1840) Fingerlings. *Turkish Journal of Fisheries and Aquatic Sciences*, *8*, 149-157.

Solomon, M. D., Solomon, L. D., Jaryum, K. H., Dabak, J. D. & Sambo, S. H. (2020). Nutrient potential and economic benefit of varies Coleoptera (grub worm): Implication for food security. *EAS Journal of Nutrition and Food Sciences*, *2*(5), 217-221.

Ssepuuya, G., Namulawa, V., Mbabazi, D., Mugerwa, S., Fuuna, P., Nampijja, Z., Ekesi, S., Fiaboe, K. K. M. & Nakimbugwe, D. (2017). Use of insects for fish and poultry compound feed in sub-Saharan Africa: A systematic review. *Journal of Insects as Food and Feed*, *3*(4), 289-302.

Wiedemann, S., McGahan, E., & Murphy, C. (2017). Resource use and environmental impacts from Australian chicken meat production. *Journal of Cleaner Production, 140*, 675- 684. https://doi.org/10.1016/j.jclepro.2016.06.086

Williams, P. (2007). Nutritional composition of red meat. *Nutrition and Dietetics, 64*(4),113-119.

