Carcass Characteristic of Indigenous Chicken Fed on Diets Containing German Cockroach (Blattela germanica) Meal in Kenya

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Abstract

Edible insects are available for use in insect-based-feed, however there is limited information on carcass characteristics and sensory tests of chicken fed on German cockroaches (Blattela germanica). This study assessed the effects of replacing fishmeal (FM) with varying levels of processed B. germanica meal (BGM). Seventy-two grower chicken of eight weeks old, comprising an equal number of males and females, were used as sampling units in a completely randomized design (CRD). Four treatments were replicated three times and fed ad lib on different diets for period of fifty-six days. The treatments were isocaloric and isonitrogenous and comprised of - diet TA (3.5 %FM, 0.5% PBGM), TB (2.5 %FM, 1.5% PBGM), TC (2 % FM, 2% PBGM), and TD (4 %FM, 0% FM). Four birds per treatment were sacrificed on day 112. The birds were slaughtered, dressed, and dissected into prime cuts (thighs, drumstick, breast, wings) that were weighed and expressed as a percentage of live birds. Samples of breast were cooked and served to a panellist for an organoleptic test. Data were subjected to a one-way analysis of variance for a CRD where samples were treatments while panellists were replicates in SPSS. Weights of plucked bird, dressed bird, thighs, drumstick, and wings of chicken fed on TA, TB, and TC was not significantly different from those feds on the control diet (TD). Similarly, the average percentage of the dressed carcass (65%) and other prime cuts was not different from the control. The flavour, smell, taste, colour, and overall acceptability of breast samples were not significantly different, with a mean score of 4.0 rated as good. The study revealed that replacing up to 50% of fishmeal with BGM does not affect meat quality, meat sensory attributes, and consumers' acceptability thus actors in the chicken value chain should embrace use of German cockroaches as a protein feedstuff.

Keywords: Cockroach, feed, chicken, carcass, quality

INTRODUCTION

Meat is a reliable source of protein in human diets. A matrix of inter-correlated factors determines the consumption of meat. Demographics, urbanization, incomes, prices, tradition, religious beliefs, cultural norms, environmental, ethical/animal welfare, and health concerns are vital factors that affect the level and the type of meat consumption (OECD/FAO, 2021). Global consumption of chicken meat has been increasing gradually in the last decade. This has been attributed to limited social taboos, lower prices, product consistency, and desired carcass characteristics such as higher protein, lower fat, and norms associated consumption of chicken meat across most societies in the world (Mlaga *et al*., 2022); the projected consumption by 2030 is 150 metric tonnes (OECD/FAO, 2021) representing 52% increase.

Carcass characteristics such as slaughter, dressing, and prime cuts are weights associated with the economics of chicken production. The characteristics mentioned earlier greatly depend on the nutritional value, and chemical composition of the diet chicken consumes (Elahi *et al*., 2020). Chicken meat is rich in macro and micronutrients. The quantities vary with the muscle type but are sufficient to support human health. Nutritional value of chicken meat is influenced by other factors such as age, sex, and farming system (Northcutt and Buhr, 2010). Smallholder chicken farming dominates the proportion of chicken meat consumed in Kenya; however, they are constrained by the supply of quality protein feedstuffs for their flock. As a result, the quality of chicken meat is affected (Atela, 2016). Insect-based feeds (IBF) are being fronted as an alternative to leverage the cost of chicken production. However, some producers are risk averse as limited information is available on the impact of insect meals, such as cockroaches, on the quality of chicken meat produced regarding consumer preference. The inclusion of BSFL in chicken feeds at an increasing rate led to a proportional increase in the deposition of abdominal fat mass. However, there was no difference in the protein content of breast muscle (Mlaga *et al*., 2022). A study revealed that chickens fed on grasshoppers had tastier and thus had a higher market price at a lower cost than those fed with conventional feed (Khusro *et al*., 2012). More studies have been done to exploit grasshoppers for feeds than cockroaches, yet they belong to the same order; this is probably due poor attitude many societies have toward the later.

Colour is the main factor used in the quick assessment of meat quality. Other factors are muscle fibres (number and size), chemical composition (crude protein, fats, minerals), fragrance, ultimate PH, water holding capacity, abdominal fat pad, intramuscular fat, ionic acid, cooking loss, drip loss and organoleptic test (smell, flavour, juiciness, mouth-filling) (Yang *et al*., 2011). Diet and nutrition of a bird during growth influence the final composition of the carcass. For instance, a low-fat and high-carbohydrate diet decreases carcass fat, carcass yield, and breast meat yield but does not influence sensory characteristics (Smith *et al*., 2002). Feeding diets containing omega-6 series (sunflower oils) or omega-3 series (fish oils) lower abdominal fat pad mass in broilers compared to fats rich in saturated fatty acids (Nguyen and Bunchasak, 2005; Massuquetto *et al.,* 2020). Increase of protein or single amino acid in feed with a subsequent decrease in fat or energy results in an increase in protein or amino acid in the carcass (Ahmed and Arabi, 2015). A limited number of insect meals that have been tested do not affect meat quality; including housefly larvaes in broilers' diet (8%) did not significantly affects carcass traits and meat quality (Elahi *et al*., 2020), meals from some species, such as mealworm have been reported affect meat colour by darkening it (Veldkamp and Bosch, 2015).

Studies have yet to be done relating to characteristics of dual-purpose birds such as KALRO-improved indigenous (KC) birds fed on novel feeds such as insects. This study aimed to evaluate carcass and meat quality traits and especially the sensory properties of KC fed on diets containing German cockroach meals from 56 to 112. This present research will also provide a backdrop for further research in understanding the sensory profiles of chicken fed on other edible insects.

MATERIALS AND METHODS

Study Site and Design

The study was conducted in Kakamega county, Westren Kenya in a completely randomized design with four treatments and three replicates. Four birds from each treatment were in in the carcass evaluation of carcass. Thirty-six panelists formed the replicates in the sensory evaluation. Each of the panelists was provided with a standard questionnaire to score for various attributes during the evaluation of the samples.

Chicken Management and Feeding Procedure

National Commission on Science and Technology (NACOSTI) authorized the research under license No. NACOST/II/P/22/20771. The research was conducted with approval from Jaramogi Oginga Odinga University of Science and Technology ethical committee approval No. 7/19/ERC/10/01/22-07 and following principles and guidelines of KALRO Animal Handling and Care.

Table 1: Ingredient and Nutritional Composition of Grower diets

	Treatment Diets			
Ingredients (%)	Diet TA	Diet TB	Diet TC	Diet TD
Maize grain	59	59	59	59
Wheat bran	17	17	17	17
Fishmeal	3.5	2.5	2	4
Cockroach meal	0.5	1.5	2	0
Soya beans	18	18	18	18
Limestone	1.3	1.3	1.3	1.3
DCP	0.3	0.3	0.3	0.3
Vitamin Premix	0.2	0.2	0.2	0.2
NaCl	0.2	0.2	0.2	0.2
MycoBinder	0.1	0.1	0.1	0.1
Calculated Analysis				
Dry Matter (%)	90.53	90.55	90.54	90.53
ME(Kcal/Kg)	2907	2912	2909	2909
Crude Protein %	16.0	15.9	15.91	16.0
Crude Fibre (%)	4.69	4.7	4.71	4.7
Crude Fat (%)	7.3	7.3	7.3	7.31
Methionine	0.77	0.77	0.78	0.78
Lysine	0.80	0.8	0.81	0.81
Determined Analysis				
Dry Matter (%)	89.64	89.89	90.04	90.04
ME(Kcal/Kg)	3255	3329	3356	3298
Crude Protein %	17.71	17.31	17.7	17.7
Crude Fibre (%)	4.99	5.37	5.38	5.38
Crude Fat (%)	6.49	7.24	7.58	7.24
Ash	10.81	10.47	9.81	11.61
Carbohydrates	49.64	49.15	49.91	48.47

Vitamin premix to provide the following per kg of diet: Vitamin A, 10,000 IU; Vitamin D_3*, 2000 IU, Vitamin E, 5 mg; Vitamin K, 2 mg; Riboflavin, 4.2 mg; Nicotinic acid, 20 mg; Vitamin* B_{12}*, 0.01mg; Pantothenic acid, 5 mg; Folic acid, 0.5 mg; Choline, 3 mg; Mg, 56 mg; Fe, 20 mg; Cu, 10 mg; Zn, 50 mg; Co, 125 mg; Iodine, 0.08 mg.*

Chickens were allocated to 12 cages within a standard deep–litter system house, naturally well ventilated, with a daily photoperiod of 12 hours of light. The house, feeders, and drinkers were washed in clean water and disinfectant; it was fumigated before the arrival of the chicks. Each of the 12 pens was an experimental unit and measured one metre by two metres on a floor covered with dry wood shavings.

Each experimental unit had a drinker, and a round feeder was assigned from weeks 8 to 12; after that, a feeder was replaced with Naivasha long feeder from week 13 to week 16. Birds were also provided with clean water and fresh feeds at *adlibitum*. Fresh feed was weighed before being added into the feeding trough, and remnants were removed and weighed the next day before the fresh feed was added. The Composition of diets with 0 % (TD), 12.5 % (TA), 37 % (TB) and 50 % (TC) substitution of fishmeal with *B. germanica* in growers' diet as shown in Table 1.

Before the feeding trial, birds were subjected to standard routine management to vaccinate against common poultry diseases like Mareks, New castle disease, Infectious Bronchitis, Gumboro, and coccidiostats. On occasions when there was morbidity, the sick birds were isolated and treated with conventional medications and then returned to the flock. The bedding material (wood shaving) was changed weekly, and the experiment lasted eight weeks. Any mortality was removed from cages, and a post mortem conducted to rule out feed-related death.

Carcass Evaluation Procedure

At the end of the feeding trial on day-112, twenty-four birds (six from each treatment) were weighed using an electron compact scale at a precision of two decimal points. Six birds (three males and three females) were selected from those with the highest weight from each treatment, tagged, starved overnight (12 hours) with *ad libitum* access to water, and weighed in the morning and before being sacrificed. Each bird was weighed, stunned by cervical dislocation, and bled after cutting off the jugular vein. The birds were scalded with hot water (70^0 C) for about two minutes.

Carcass Characteristics

Sixteen birds were de-feathered after scalding and eviscerated to remove the internal organs (liver, kidney, gastrointestinal tract, and proventriculus-gizzard). The hot carcass was chilled to 40^0 C before being dissected into prime cut parts (head, neck, wings, breast, back, drumstick, shank) and then weighed (Figure 1) and recorded. The weights of prime cuts and the internal organs were expressed as a percentage of live weight. The dressing percentage was calculated according to the method described in (Kairalla *et al*., 2022) using the formulae:

i. Dressing weight % = [dressing weight / per-slaughter live body weight] × 100
ii. Where: Dressing weight = weight of empty carcass (Offal free) without head and legs.
iii. Prime cut weight % = [prime cut / dressing weight] × 100

Where prime cut = thigh, drumstick, wings, breast, liver

Sensory Evaluation of Carcass Quality

The sensory evaluation for the carcass was conducted in accordance with recommended standards as outline in Lawless and Heymann, (1984) in a controlled environment at KALRO-Kakamega guest house.

Meat Sample Preparation

Breast meat samples from twenty-four dressed carcass was used in sensory evaluation. Samples from each treatment (TA, TB, TC, and TD) were grouped separately, chilled, and cut into pieces of approximately 4 cm cubes. The samples were cooked by boiling them separately in a covered bowl for 30 minutes, to an end- point temperature of 82°C, which was verified by a temperature probe. No spice was added to the meat. All samples were handled and stored in a hygienic manner until testing.

Organoleptic Test

Cooked meat samples were served to a panelist of 36 semi-trained, male and female aged between 20-60 years from KALRO Kakamega staff. A one-hour pre-testing training was conducted for the assessors to familiarize them with appropriate matrix and score of the descriptors using samples from control treatment (TD). Olfactory, gustative, and textural aspects were assessed.

The mode of evaluation was a descriptive sensory analysis. Each panelist was given four samples wrapped in aluminum foil and served to the panel in a random sequence. A glass of water was provided to each panelist to rinse the mouth before testing subsequent sample.

The meat attribute assessed were colour, juiciness, flavour, tenderness, and overall acceptability. Each assessor was given a questionnaire to guide them score for each attribute on 5-point hedonic point scale. The score was arranged in descending order thus 1-very bad, 2-bad, 3-fair, 4-good, 5-very good. The questionnaire also collected some information on age, education level).

Physiochemical Properties Analysis

Chilled breast samples were analysed for proximate composition as per the AOAC (1990) procedures for dry matter (method 967.03), protein (Kjeldahl method), ether extract (method 920.29).

Cooking loss (%) = [Weight before cooking / weight after cooking] × 100
Drip loss (%) = [Weight before storage / weight after storage (24 hrs)] × 100

Statistical Data Analyses

Individual bird was used as an experimental unit to analyze the carcass characteristics and meat quality parameters. The data were analyzed by one-way variance analysis using R version 4.1.2 software. Individual bird weight expressed as a percentage of live weight was tested for normality and homogeneity before analysis of variance. Least square means were obtained using the Bonferroni test, and the significance was calculated at a 5% confidence level. The results were expressed as the mean and standard error of the mean (SEM). A mixed model (PROC MIXED) in SPSS was used to detect any dietary influence on sensory analysis scores, therefore considering the experimental diet and the panelists as fixed and random effects, respectively. The following statistical model:

$\mathbf{Y_{ij} = \mu + \alpha_i + \varepsilon_{ij}}$ was used,
Where; $\mathbf{Y_{ij}}$ = single observation, $\boldsymbol{\mu}$= is the overall mean; $\boldsymbol{\alpha_i}$ = is effect of the treatment diet (i = A, D); $\boldsymbol{\varepsilon_{ij}}$ = is the error term associated with the observation.

RESULTS

Results of Diet with B. germanica Meal on Carcass Characteristics of Indigenous Chicken

The loading matrix for the principal component analysis for the carcass characteristic is shown in Table 1. Liveweight, plucked weight, eviscerated weight and dressed weight accounted for the large variation.

Table 2: Principal component analysis of carcass weights of indigenous chicken fed on diets with German cockroach

Summary	PC1	PC2	PC3
Liveweight	0.609	-0.408	0.409
Plucked weight	0.497	-0.027	0.013
Eviscerated weight	0.450	0.074	-0.831
Dressed weight	0.403	0.279	0.279
Thigh weight	0.068	0.043	0.043
Drumstick weight	0.082	-0.101	-0.101
Wings weight	0.047	-0.021	-0.021
Abdominal Fat	-0.0001	-0.009	0.009
Full-gizzard	0.023	-0.020	0.086
Breast weight	0.051	0.041	0.209
Liver weight	0.008	-0.019	-0.019

The result in Table 3 shows the weights of the prime cuts investigated, which included breast, wings, drumsticks, thighs, plucked weight, dressed weight, liver, and gizzard-proventriculus. There was no significant (p>0.05) difference in the weight of the primary cuts and other parts across the treatment diets result presented in Table 3 shows the weights of the prime cuts investigated which included breast, wings, drumsticks, thighs, plucked weight, dressed weight, liver, and gizzard-proventriculus. There was no significant (p>0.05) difference in weight of the parts of the primary cuts and other parts across the treatment diets.

Table 3: Effects of dietary variation on the carcass traits of indigenous chicken fed with 0 %(TD), 12.5 %(TA), 37 %(TB) and 50 %(TC) substitution of fishmeal with B. germanica in their grower diet (n=16)

Parameter	Diet TA	Diet TB	Diet TC	Diet TD	SEM	P-value
Live-weight(g)	1360a	1420^{a}	1523^{a}	1605^{a}	88.23	20.95
Plucked-Weight(g)	1059^{a}	1165.65^{a}	1271^{a}	1288.67^{a}	66.09	0.6919
Dressed-Weight(g)	759^{a}	915.67^{a}	995.33^{a}	1035.67^{b}	52.8	0.6225
Gizzard-P(g)	67.67^{a}	89.67^{b}	82.33^{a}	71.33^{a}	4.30	0.695
Thigh(g)	124^{a}	160^{a}	171.69^{a}	176.67^{b}	9.39	0.599
Drumstick(g)	135.33^{a}	144.33^{a}	159.33^{a}	170.67^{b}	11.1	0.61
Wings(g)	112.33^{a}	129^{a}	141^{a}	136^{a}	6.27	0.710
Breast(g)	170^{a}	178.66^{a}	168.33^{a}	178.33^{a}	8.91	0.075
Liver(g)	21.67^{a}	26^{a}	29.33^{ab}	29.33^{ab}	1.48	0.447

SEM= standard error of mean, abcd=figures within the same row with different superscripts differ significantly p<0.05.

Weight of birds and prime cut weights expressed as percentage of liveweight are as shown in Table 4.

The dressing percentage was similar (p> 0.05), ranging from 63- 66% of live weight. The percentage of the liver, wings, breast, and wings for birds fed on diet TA, TB, and TC were not different from that fed on control (TD). There was a significant difference (p<0.05) in the percentage of full gizzard-proventriculus, probably due to differences individual bird's rates to digest feeds.

Table 4: Effects of dietary variation on the carcass traits(%) of indigenous chicken fed with 0 %(TD), 12.5%(TA) , 37%(TB) and 50%(TC) substitution of fishmeal with BGM in their grower diet(n=16)

Parameter	Diet TA	Diet TB	Diet TC	Diet TD	SEM	P-value
Live-weight,LW(g)	1365	1420	1523	1605	88.23	20.95
Plucked-Weight(%LW)	82.65^{a}	81.76^{a}	83.18^{a}	80.71^{a}	0.37	0.0789
Carcass Weight (g)	759	915.69	995.33	1035.67	52.8	0.6225
Carcass-Weight(%LW)	63.94^{a}	64.36^{a}	65.59^{a}	64.38^{a}	1.05	0.962
FullGizzard(%LW)	5.43^{a}	5.47^{a}	5.35^{a}	4.80^{ab}	0.17	0.81
Thigh (%LW)	10.78^{a}	11.34^{a}	11.44^{a}	10.88^{a}	0.27	0.849
Drumstick (%LW)	10.89^{a}	10.31^{a}	8.01^{b}	10.65^{a}	0.56	0.615
Wings (%LW)	9.15^{a}	9.01^{a}	9.08^{a}	8.65^{a}	0.15	0.685
Breast (%LW)	9.63^{a}	11.53^{a}	11.35^{a}	11.25^{a}	0.38	0.259
Liver (%LW)	1.78^{a}	1.84^{a}	1.81^{a}	1.84^{a}	0.08	0.994

BGM = Blattela germanica meal, LW= Live weight, SEM= standard error of mean, abcd=figures within the same row with different superscripts differ significantly p<0.05.

Physicochemical Properties of Breast from Chicken Fed on Diets with B. germanica Meal

Cooking loss and drip loss was not significantly different between the treatments and the control (P>0.05). Samples from birds fed on diet TD had the highest cooking loss (4.34 %) whereas samples from diet TB had the highest drip loss (2.95%) (Table 5). In this study, the cooking loss was similar for all meat samples; an indication that replacing fishmeal with cockroach meal did not affect the physicochemical properties of the chicken under experiment.

Table 5: Physic-chemical Properties of breast meat of chicken fed with 0 % (TD), 12.5 % (TA), 37 % (TB) and 50 %(TC) substitution of fishmeal with B. germanica in their grower diet

Treatment	Cooking Loss (%)	Drip Loss (%)	Crude Protein (%DM)	Ether Extract (%)
TA	3.96^{a}	3.01^{a}	61.2	6.3
TB	3.80^{a}	2.95^{a}	62.8	6.1
TC	3.57^{a}	3.18^{a}	63.6	6.4
TD	4.34^{a}	2.99^{a}	61.5	6.2
SEM	0.181	0.181		
P-Value	0.55	0.99		

abcd=figures within the same row with different superscripts differ significantly p<0.05.

Sensory Analysis of Breast Meat from Indigenous Chicken Fed on Diets with B. germanica Meal

The score of meat attributes by the panelist were summarized as shown in Table 6. There was no significant difference p >0.05 in scores for meat colour, flavour, taste and juiciness. Significance difference was recorded in tenderness and overall acceptability (p<0.05). According to the panelist, the samples TD tasted good with an average hedonic mean score of 4 (good) than other samples (3) fair as indicated in Table 6.

Table 6: ANOVA mean squares of sensory attributes of breast meat of chicken fed with 0 %(TD), 12.5 %(TA), 37 %(TB) and 50 %(TC) substitution of fishmeal with B. germanica in their grower diet

S.O.V	DF	Colour	Aroma	Taste	Juiciness	Tenderness	Overall
Treatment	3	0.396^{ns}	0.526^{ns}	0.711^{ns}	0.488^{ns}	2.000^{***}	0.815^{ns}
Error	140	0.671	0.783	0.793	0.642	0.483	0.597
P-value	-	0.623	0.571	0.445	0.518	0.008	0.256
CV	-	21.56	23.29	23.44	21.56	17.13	19.13
R^2	-	0.012	0.014	0.019	0.016	0.082	0.028

*Key: SOV= Source of variations; DF= Degree of freedom; CV= Coefficient of variation; R^2 = Coefficient of determination; ns= Not significant at $p \leq 0.05$; ***= is significant at the 0.01 level*

Diets had no significant effect on colour, aroma, taste, juiciness and overall acceptability but affected tenderness ($p<0.05$) as depicted in Table 6. The coefficient of variation was low (21%) for all parameters except for tenderness (17). The R^2 was low (<0.019) for all parameters such as colour, aroma, taste, juiciness, tenderness and over all acceptability.

Table 7: Overall mean score of sensory attributes of different samples of breast meat of chicken fed with 0 %(TD), 12.5 %(TA), 37 %(TB) and 50 %(TC) substitution of fishmeal with B. germanica in their grower diet

Sample	Colour	Aroma	Taste	Juiciness	Tenderness	Overall Acceptability
TD	3.69 ± 0.16^{a}	3.75 ± 0.18^{a}	3.64 ± 0.17^{a}	3.75 ± 0.14^{a}	3.78 ± 0.12^{b}	3.94 ± 0.15^{a}
TB	3.78 ± 0.11^{a}	3.78 ± 0.13^{a}	3.75 ± 0.13^{a}	3.56 ± 0.12^{a}	3.94 ± 0.11^{ab}	3.94 ± 0.12^{a}
TC	3.94 ± 0.13^{a}	3.69 ± 0.17^{a}	3.83 ± 0.15^{a}	3.72 ± 0.14^{a}	4.22 ± 0.11^{a}	3.89 ± 0.14^{a}
TA	3.78 ± 0.13^{a}	3.97 ± 0.11^{a}	3.97 ± 0.14^{a}	3.83 ± 0.14^{a}	4.28 ± 0.12^{a}	4.22 ± 0.10^{a}

Key: *abcd=figures within the same row with different superscripts differ significantly $p<0.05$.*

Colour, aroma, taste, juiciness and overall acceptability of samples from chicken fed on diet with fishmeal (TD) was not significantly different ($p>0.05$) from that fed on diets with BGM except for tenderness as shown Table 7.

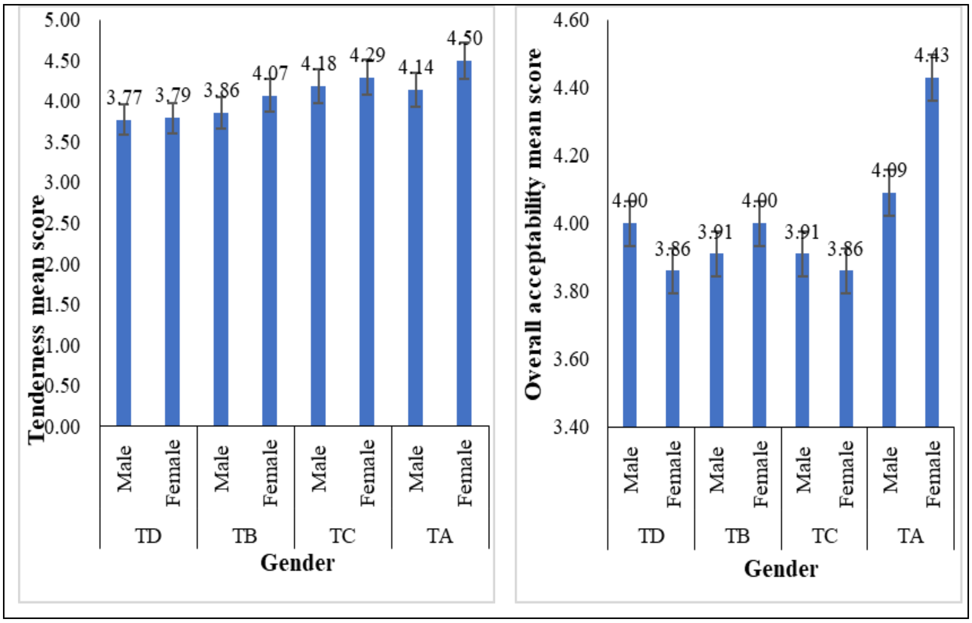

Figure 1: Influence of gender on mean scores of tenderness and overall acceptability for different samples

Gender and level of education had no effects on parameters such as tenderness indicated in Figure 1 and Table 8.

Table 8: Influence of socio-demographic characteristic on tenderness and overall score of breast meat of chicken fed with 0 % (TD), 12.5 % (TA), 37 % (TB) and 50 %(TC) substitution of fishmeal with B. germanica in their grower diet

Socio-demographic characteristic		Tenderness	Overall acceptability
Age	20- 29 years	3.91±0.12^{a}	4.00±0.99^{a}
	30- 39 years	4.08±0.09^{a}	4.15±0.09^{a}
	40- 49 years	4.30±0.15^{a}	3.80±0.21^{a}
	>50 years	4.05±0.17^{a}	3.75±0.19^{a}
Education	Primary	4.25±0.17^{a}	4.13±0.18^{a}
	Secondary	3.83±0.12^{ab}	3.86±0.12^{a}
	College	4.10±0.10^{ab}	4.04±0.13^{a}
	University	4.10±0.12^{ab}	3.98±0.11^{a}
	No formal	3.75±0.25^{b}	4.25±0.48^{a}

Key: Means with the same letter within each socio-demographic characteristic are not significantly different

Table 9: Correlation coefficients of sensory attributes of breast meat of chicken fed with 0 %(TD), 12.5 %(TA), 37 %(TB) and 50 %(TC) substitution of fishmeal with B. germanica in their grower diet

	Colour	Aroma	Taste	Juiciness	Tenderness	Overall
Colour	1.000	0.400**	0.426**	0.212*	0.354**	0.365**
Aroma		1.000	0.590**	0.444**	0.228**	0.583**
Taste			1.000	0.332**	0.193*	0.578**
Juiciness				1.000	0.186*	0.451**
Tenderness					1.000	0.327**
Overall						1.000

Key: **= Correlation is significant at the 0.01 level; *= Correlation is significant at the 0.05 level

DISCUSSION

Effect of Substituting Fishmeal with B. germanica Meal on Prime Cuts of Indigenous Chicken

Limited information exists on studies where cockroach has been used to replace fishmeal in chicken diets. The results of the current study were compared with studies where other edible insects were used. For the present study, feeding chickens on diets containing an insect meal (German cockroach) did not affect the sizes and weight of prime cuts. Results of the present study indicate that replacing fishmeal with German cockroach had little effect on the nutrition composition of diets and ultimately on birds that feed on them. It affirms that German cockroaches are as good as fishmeal in chicken nutrition. Similar results were reported for other edible insects by (Téguia *et al*., 2002). Findings in this study contradict reports for studies where other edible insects' meal was studied. For instance, a report by Teguia and Beynen (2005) reported an increase in the sizes of gizzard and liver for chicken fed on maggot meal that was attributed to the presence of toxins the liver was trying to eliminate. For the current study, the liver and gizzard were similar in weight even after exposure to varying levels of the German cockroach meal in diets. The probable implication is that the German cockroach meal had no toxins or the toxin level was so low to cause any significant change in the sizes of internal organs.

The current study reported no significant difference ($p>0.05$) in the level of abdominal fat deposition between the birds fed on the control and diets with German cockroach meal. The current study's findings contradict those of Mlaga *et al*. (2022), who reported a progressive increase in abdominal fat with the increased inclusion of blacksoldier fly meal in chicken diets. Dietary fats influence the fatty acid composition of chicken meat and adipose tissue; medium-chain fatty acid like lauric acid has been associated with a modulating effect on lipid metabolism resulting in increased deposition of abdominal fat mass in chicken. In the current study, isolipidic, isonitrogenous, and isocaloric diets were used. This is the probable reason the level deposition of abdominal fat was similar for all the birds.

Dressing percentage is a critical parameter meat processors and sellers use to predict the possible benefit they will accrue from a live bird. Higher dressing percentages (>60 %) are preferred as they indicate a higher consumable portion. Findings of the current research of a carcass dressing (64.6 %) and breast (10.9 %) for an indigenous chicken are promising but comparatively lower to that of the Lohmann dual-purpose chicken breed of (67%) and (12.7%) that was reported by Siekmann *et al.* (2018).

Meat loose moisture through evaporation when left *insitu*. Processors would prefer minimal losses as higher losses would dent into saleable weights, thus denting their profit margin. For the current study, the drip loss and cooking loss were lower than that documented for similar chicken parameters in Siekmann *et al*. (2018).

Effects of Substituting Fishmeal with B. germanica Meal on Physico-chemical Properties of Meat from Indigenous Chicken

Samples from breast muscles (Musculi pectorales superficiales) were used to analyze the meat quality traits. The physicochemical property of indigenous chicken was not affected by incorporating B. germanica meal into chicken feed. These findings constitute a significant positive factor in consumers' evaluation of this new alternative ingredient in poultry nutrition and feeding. Mlaga et al. (2022) and Bovera et al. (2016) reported similar results who fed chicken on diets with black soldier fly meal. Animal feed is an essential factor influencing fat composition in meat, and consumers are health conscious of the level in a carcass. In this study, the fat composition in breast muscles was about (6%) for the control, similar to other treatments.

High cooking loss is associated with high-fat composition in the carcass, which liquidity during cooking. In this study, the cooking loss was similar for all meat samples. An indication that replacing fishmeal with cockroach meal did not affect the physicochemical properties of the chicken during an experiment. Meat processors are always averse to high cooking loss because significant loss may lead to a high loss of saleable weight. Drip loss indicates a carcass's capacity to retain interstitial water within a given period. Carcasses with higher drip loss shrink faster, thus dropping the initial weight; long storage could lead to tremendous weight loss. The lower the drip loss, the better the quality of the carcass. Similarity in the drip loss for all treatment samples indicates that replacing up to fishmeal with B. germanica does not affect the water-holding capacity of meat. In meat marketing, meat processors will prefer meat samples with lower drip loss because they will not incur significant losses in the weight of meat during the storage period.

Effects of Substituting Fishmeal with B. germanica Meal on Sensory Characteristics of Meat Indigenous Chicken

There is scanty information on cockroach meals' effects on chicken organoleptic traits. Similar studies showed no significant difference in the flavour, taste, and juiciness of broilers fed on diets supplemented with insect meals (Khan *et al*., 2018; Hwangbo *et al.*, 2009; Awonyi *et al*., 2004). The results in this study are similar to those obtained when black soldier fly (BSF) was used to replace fishmeal in broiler diets (Onsongo *et al*., 2018).

Organoleptic tests of meat samples play an important role in determining consumer acceptability. Some of the factors influencing organoleptic meat tastes originate from the animal's feeds and the panellists factors such as the participant's age, the panellist's training, and professional background. In this study, replacing up to 50 % of fishmeal with cockroach meals did not affect the meat quality. Cockroach meals can thus be used to replace fishmeal in poultry diets without affecting consumer preference. In Eastern Africa, the utilization of cockroach meals in compounded chicken diets has yet to be adopted. However, scavenging chickens have been confirmed to feed on cockroaches while scouting for food.

CONCLUSION AND RECOMMENDATION

Using cockroaches as alternative chicken feed should be promoted because replacing 50% fishmeal (omena) with German cockroach meal in chicken feed does not alter the sizes and weight of prime cuts. Similarly, the physicochemical properties of chicken meat, such as crude protein, crude fat, cooking loss, and drip loss, were not significantly different from the control. Sensory qualities of meat, such as colour, flavour, taste, smell, and overall acceptability of chicken fed on diets with cockroach is similar to those fed on control (fishmeal). The current study affirms that cockroach meal is as good as fishmeal in when used in chicken, and therefore farmers should embrace feeding chicken on cockroach meals for sustainable production and foster food security.

Ethical Approval; The research was conducted with ethical approval from Jaramogi Oginga Odinga University of Science and Technology (JOOUST) and NACOSTI

Conflict of interests; The researchers declared no conflict of interest.

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