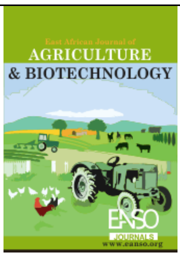

East African Journal of Agriculture and Biotechnology
eajab.eanso.org
Volume 7, Issue 1, 2024
p-ISSN: 2707-4293 | e-ISSN: 2707-4307
Title DOI: https://doi.org/10.37284/2707-4307

EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

Nutrient composition of Sorghum-Based Rations and their effect on growth of Improved Indigenous Chicken in Western Kenya

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Article DOI : https://doi.org/10.37284/eajab.7.1.1811

Date Published:

10 March 2024

Keywords:

Amino Acids, Formulated Diets, Growth Characteristics, Improved Indigenous Chicken, Low Tannin Sorghum.

ABSTRACT

Improved indigenous chicken contribute to the nutrition of farmers in rural communities. The use of maize as an energy source in chicken diets is becoming unacceptable due to competition from humans, resulting in high feed costs. Alternative energy sources like low-tannin sorghum can be grown in Western Kenya. The objective of the study was to determine the nutrient composition of sorghum-based diets and the growth of improved indigenous chicken in Busia and Siaya Counties. Dietary treatments consisted of 50% (T1), 75% (T2) sorghum inclusion, and control (commercial diet) (T3). Farmers on semi-intensive were provided dietary treatments, and free-range (T4) was not provided. Feed samples were subjected to laboratory analysis for proximate composition, amino acids, and tannin content. Growth characteristics were collected biweekly. Data were subjected to analysis of variance, and then means that differed significantly were separated using Tukey's test in Genstat 14th edition. For proximate composition, dry matter was significantly ($p<0.05$) higher in T2 (91.9%) and T3 (92.1%) compared to T1 (91.4%). Crude fat was significantly ($p<0.05$) higher in T2 (9.54%) than in T1 (6.84%) and T3 (6.57%). The crude fibre was significantly ($p<0.05$) higher in T3 (14.3%) compared to T1 (3.37%) and T2 (3.62%). Crude protein was significantly ($p<0.05$) higher in T2 (15.8%) and T1 (15.2%) compared to T3 (12.6%). Metabolizable energy was significantly ($p<0.05$) lower in T3 (2723 Kcal/Kg) compared to T1 (3569 Kcal/Kg) and T2 (3684 Kcal/Kg). Amino acids (lysine, methionine, cysteine, and tryptophan) content in diets T2 and T3 were significantly ($p<0.05$) higher than T1. The tannin content of the sorghum variety C26 was 1.24%. T1 had a significantly high ($p<0.05$) mean final weight (970 g), body weight gain (804 g), daily weight gain (14.4 g), and feed conversion ratio (5.57). Mortality was highest at T4 (17.1%). It was concluded that the inclusion of 50% low tannin sorghum meets chicken feed nutritional requirements and is best for growth performance. The study recommended that farmers rearing chicken should plant low tannin sorghum to be utilized as feed ingredient to cut the cost of production.

APA CITATION

Kiptui, B. J., Mewa, E. A., Rachuonyo, H. A., Were, B. A., Nyongesa, B. & Gudu, S. (2024). Nutrient composition of Sorghum-Based Rations and their effect on growth of Improved Indigenous Chicken in Western Kenya. *East African Journal of Agriculture and Biotechnology*, *7*(1), 128-139. https://doi.org/10.37284/eajab.7.1.1811

Article DOI : https://doi.org/10.37284/eajab.7.1.1811

CHICAGO CITATION

Kiptui, Brenda Jemutai, Eunice Akello Mewa, Harold Anindo Rachuonyo, Beatrice Ang'iyo Were, Benson Nyongesa and Samuel Gudu. 2024. "Nutrient composition of Sorghum-Based Rations and their effect on growth of Improved Indigenous Chicken in Western Kenya". *East African Journal of Agriculture and Biotechnology* 7 (1), 128-139. https://doi.org/10.37284/eajab.7.1.1811.

HARVARD CITATION

Kiptui, B. J., Mewa, E. A., Rachuonyo, H. A., Were, B. A., Nyongesa, B. & Gudu, S. (2024) "Nutrient composition of Sorghum-Based Rations and their effect on growth of Improved Indigenous Chicken in Western Kenya", *East African Journal of Agriculture and Biotechnology*, 7(1), pp. 128-139. doi: 10.37284/eajab.7.1.1811.

IEEE CITATION

B. J. Kiptui, E. A. Mewa, H. A. Rachuonyo, B. A. Were, B. Nyongesa & S. Gudu "Nutrient composition of Sorghum-Based Rations and their effect on growth of Improved Indigenous Chicken in Western Kenya", *EAJAB*, vol. 7, no. 1, pp. 128-139, Mar. 2024.

MLA CITATION

Kiptui, Brenda Jemutai, Eunice Akello Mewa, Harold Anindo Rachuonyo, Beatrice Ang'iyo Were, Benson Nyongesa & Samuel Gudu. "Nutrient composition of Sorghum-Based Rations and their effect on growth of Improved Indigenous Chicken in Western Kenya". *East African Journal of Agriculture and Biotechnology*, Vol. 7, no. 1, Mar. 2024, pp. 128-139, doi:10.37284/eajab.6.1.1811.

INTRODUCTION

Indigenous chicken is a critical component in improving food security, socio-cultural development and economic growth. The chicken is robust and can thrive in tough environments with minimal inputs (Muremera et al., 2022). Improved indigenous chicken breeds namely Kuroiler, Rainbow Rooster, Kebro, and KALRO Naivasha were developed from various indigenous chicken ecotypes to enhance the productivity of indigenous poultry (Macharia et al., 2022). The improved IC is high performing and produces 180-250 eggs compared to 80-100 by the local ones. It attains market weight at 4 to 5 months (Wambua et al., 2022). Feeding presents major financial constraints on poultry production, accounting for 70-85% of recurrent expenditure (Sanni & Ogundipe, 2005). Poultry feed is based primarily on cereal grains, mainly maize, wheat, sorghum, and vegetable protein meals, which are supplied to meet most of the energy and protein requirements in the poultry diet (Raza et al., 2019). Maize is the major cereal grain used globally in the poultry feed industry. The price volatility and changing availability of maize have stimulated interest in using other feed ingredients, less popular, but upcoming crops such as sorghum grain (Ciurescu et al., 2023).

Sorghum bicolor (L) is quantitatively ranked as the world's fifth most important cereal after wheat, maize, rice, and barley (Batista et al., 2019). The popularity of sorghum occurs due to its drought resistance (Abreha et al., 2022), higher nutritional value (Hadebe et al., 2017), resistance to pests and diseases, and adaptive to the harsh arid and semi-arid environment (Chibarabada et al., 2017) as well reducing micro-nutrient malnutrition among farming households (Govender et al., 2017; Muui et al., 2013). The common varieties within the country are Gadam, Sila, Kari Mtama 1, Kari Mtama 2, IS76, E 1291, E6518, BJ 28, Ikinyaruka DP, Serena and Seredo. Seredo variety is highly resistant to bird damage, a big challenge in sorghum production. It also matures early while still being drought-tolerant. Gadam is early maturing and has high yields. However, it is susceptible to bird damage. Serena variety has low productivity and is susceptible to bird damage (Dorcas et al., 2019). Sila varieties are suitable for fodder production (Kazungu et al., 2023). Globally, sorghum is primarily known and used as feed for livestock, even though over half of the production of sorghum grains is used for human consumption (Khoddami et al., 2023; Williams & Capps, 2020)

Sorghum is an energy-dense (3633 – 3944 Kcal kg-1 dry matter) cereal grain that can suitably replace maize in the diets of broiler chicken (Saleh et al., 2019). Nutritional composition of sorghum is 31.6 – 90.9% dry matter, 5.9 – 16.8% crude protein, 3.3 – 4.1% ether extract, 1.9 – 5.5% ash and 3.6% crude fibre (Mnisi et al., 2023). Among cereals, sorghum is considered to have better protein quality or amino acid scores (Okpala & Okoli, 2011). Only after cystine, tryptophan, whose content is higher in sorghum than in maize

Article DOI : https://doi.org/10.37284/eajab.7.1.1811

but lower than in wheat (Hulan & Proudfoot, 1982), is considered to be the first limiting amino acid in sorghum.

Sorghum, C26 variety, which is considered to be a low tannin, drought, and acid tolerant variety, was used in ration formulations. Low-tannin sorghum grain has been reported to be a suitable alternative to maize grain in some poultry diets (Manyelo et al., 2019). Sorghum contains a high level of tannins, variable amounts of phytate, kafirin and possibly betapolyphenolsin the sorghum grain may act as anti-nutritional factor (Selle et al., 2010). The presence of anti-nutrients in food limits the digestibility of proteins and carbohydrates through the inhibition of their respective proteolytic and amylolytic enzymes (Zubair et al., 2023). New hybrids of sorghum are developed to have low content of anti-nutritional substances, especially tannins (Osman et al., 2022). Improved sorghum varieties for harsh environments include RUE95, Nyadundo, and C26, which are drought-tolerant. Acid tolerant sorghum varieties include RUT53, RUE95, Nyadundo-2, N57, N68, T30B, C26, among others. Sorghum producers opted to uptake improved varieties to enhance yields (Chavula & Turyasingura, 2023).

The objective of the study was to determine the nutrient composition of sorghum-based rations and the growth of improved indigenous chicken in Busia and Siaya Counties of Western Kenya.

MATERIALS AND METHODS

Study Area

The study was carried out in Busia and Siaya counties of Western Kenya, whose climate is tropical and humid and dominated by the influence of Lake Victoria. Siaya County lies between latitudes 0026′ to 0018′ North and longitudes 33058′ East and 34033′ West. The area receives a mean annual rainfall of between 900 and 1500 mm with an average temperature of 22.3 °C. The area is dominated by ferralsols soil, which is low to moderately fertile. Major crops grown in the area include maize, beans, and sorghum, among others (MoALF, 2016b). Poultry keeping is practiced semi-intensively among all households in Siaya. Annual temperatures in Busia County range from 17 to 30 °C, with mean annual temperatures between 24 and 26 °C. Yearly average precipitation is between 900 and 1500 mm. Preferred crops include maize, beans, sorghum, groundnuts, millet, cotton, sugarcane, and cassava (MoALF, 2016a). Chicken farming is mainly small-scale, with between 15 and 20 birds in Busia County.

Sample Collection and Preparation

Feed ingredients for experimental diets were purchased from sorghum-growing farmers in Busia County. T1 and T2 diets comprised sorghum variety C26, maize, soybean, vegetable oil, omena (a high-quality protein feed ingredient rich in all the essential amino acids, Vitamin B12, and choline), limestone, and premix. Soybeans were roasted in a cooking pot for 10 minutes before being ground to improve intake and digestibility (see *Table 1*). The main feed ingredients, including maize, sorghum, omena, and soybean, were ground using Power Pak (Ludhiana, Punjab, India) before mixing with premix, vegetable oil, and limestone.

Experimental Diets, Birds and Design

Two formulated diets, T1 (50%) and T2 (75%) with sorghum-variety C26 inclusion levels, and T3, which was a purchased commercial feed to act as a control. The manufacturing company kept the T3 ingredients private and confidential. A total of 96, 4-week-old improved indigenous chicks of the Rainbow Rooster breed purchased from Kukuchic, Eldoret, were weighed and allotted to four treatments replicated three times in a randomised complete block design. Birds were housed on floors bedded with sawdust that was changed every 2 weeks. A total of 12 experimental units, 8 chicks per pen. Three treatments (T1, T2, and T3) were categorised as semi-intensive production systems where feeds (80 g/chick) were supplemented, while T4 was a free-range system where no supplementary feed was provided. Water was provided ad libitum. The feed trial duration was 56 days.

Article DOI : https://doi.org/10.37284/eajab.7.1.1811

Table 1: Sorghum-based dietary formulations used to feed improved indigenous chicken in Western Kenya

Ingredient	Dietary treatment, %	
	T1	T2
Sorghum, kg	50	75
Maize, kg	23	2.5
Soybean, kg	22	17.5
Omena, kg	2	2
Vegetable oil, lt	1	1
Limestone, kg	1.5	1.5
Premix	0.5	0.5
Total	100	100
Calculated nutrient content		
Crude protein, %	13.6	13.2
Crude fibre, %	3.2	3.1
Metabolizable energy, Kcal/kg	2861.1	2799

kg=kilograms, lt-litres, %=percent, Kcal/kg= kilocalories per kilogram

Housing and Management

Improved indigenous chickens were raised in 12 pens of deep litter houses measuring 1 x 1 x 0.5 m each. Each pen was equipped with feeding and drinking troughs. Birds in the semi-intensive system were fed two times (0700 hours and 1700 hours). They were released at 1400 hours from their houses. The amount of feed was adjusted weekly based on age. Daily feed intake was measured by collecting and weighing feed and refusals in the morning. Birds in the free-range system were released from their houses at 0700hours to scavenge for feed sources. Chickens were vaccinated against fowl pox and fowl typhoid. The weight gain of chicken was measured biweekly. The final weight gain was taken at the end of the feed trial.

Sampling and Laboratory Analysis of Formulated Sorghum-Based Feeds

Six samples, two from each treatment (T1, T2, and T3), plus sorghum, were sent to Spectralab Analytical Services Limited, Nairobi, for proximate, amino acid (cystine, tryptophan, methionine, and lysine), and tannin content analysis.

The proximate composition of dry matter, crude protein ($N\ x\ 6.25$), crude fat, crude ash, and crude fibre were determined. Amino acids were measured colorimetrically following post-column reaction with ninhydrin. (AOAC, 2005).

$$NFE = 100 - (Ash\ content + Fiber\ content + Fat\ content + CP) \quad (1)$$

Equation (1) is the Nitrogen-free extract formula. NFE is Nitrogen-free extract, and CP is crude protein.

$$ME = \{(35.5\ x\ NFE) + (81\ \ x\ Fat) + (36\ x\ Protein)\} \quad (2)$$

Equation (2) is the Metabolizable energy formula. ME is Metabolizable energy, and NFE is a Nitrogen-free extract.

Statistical Analysis

The data was analysed using Genstat 14th Edition. The data was subjected to analysis of variance, and summary statistics were generated for the proximate composition, amino acids, and growth characteristics of chickens. Means that differed significantly ($p<0.05$) were separated using Tukey's test.

RESULTS AND DISCUSSIONS

Proximate Composition of Sorghum-Based Formulations

Diet T1 (91.4%) contained lower dry matter content ($p<0.05$) compared to T2 (91.9%) and T3 (92.1%). The results obtained were slightly higher

Article DOI : https://doi.org/10.37284/eajab.7.1.1811

than those determined in a study by Ciurescu et al. (2023), where values ranged from 89.8 to 90.0%.

The highest crude ash content ($p<0.05$) was obtained in T3 (17.3%), while lower values were found in T1 (5.23%) and T2 (5.33%) as compared to those reported by Masenya et al. (2021), which ranged from 5.51 - 6.26%. Reports by Ofori et al. (2019) showed that low ash content in feed predisposes birds to diseases and poor eggshell formation. The inorganic content of the feed is described by its crude ash, which is mainly minerals. These critical nutrients are required in specific amounts in poultry diets for stronger bone, blood clotting, enzyme activation, muscle contraction, and eggshell formation (Jacquie, 2018).

Crude fibre (CF) can escape digestion and absorption in small intestines, which makes it able to affect the way other nutrients are absorbed and metabolised in the gastrointestinal tract (Tejeda & Kim, 2021). CF content in T3 (13.71%) was significantly higher ($p<0.05$) than in T1 and T2 due to increase in sorghum inclusion levels at 50% and 75% respectively. T1 (3.22%) and T2 (3.46%) values were in the range of a study reported by Masenya et al. (2021) of 3.12 – 3.83%.

Diets T1 (6.53%) and T3 (6.30%) contained lower crude fat contents. Diet T2 (9.54%) contained significantly ($p<0.05$) high crude fat content. Crude fat contents in all diets were higher compared to the 5.80% that was reported by Ciurescu et al. (2023) for birds' finisher diets of 50% sorghum level as a substitute for corn. This could be as a result of the low tannin sorghum variety used in rations. Fat in poultry diet improves the adsorption of fat-soluble vitamins and increases the palatability of feed (Carneiro Baião & Lara, 2005).

Diet T3 had significantly ($p<0.05$) low crude protein (CP) content of 12.1%, while T1 (14.5%) and T2 (15.1%) had significantly ($p<0.05$) higher CP contents due to the increasing levels of sorghum inclusion at 50% and 75% respectively. CP range in this study was lower compared to values reported by Masenya et al. (2021), ranging from 16.2% – 18.7% in experimental diets. Protein in feed provides essential amino acids and plays an important role in growth, egg production, immunity, and many other biological functions (Bedford et al., 2016).

Nitrogen free extract (NFE) in proximate analysis represents sugars and starch and is obtained by difference rather than by measurement. NFE represents soluble carbohydrates (JM et al., 2020). Diet T3 (47.9%) had the lowest ($p<0.05$) NFE content, while T1 (68.2%) and T2 (64.6%) had higher NFE contents. Percent NFE in all diets T1 and T2 were higher than 44.7 – 56.3% reported by Hayat et al. (2016) and Momoh et al. (2010) for indigenous chickens of Ethiopia and North Central Nigeria.

Sorghum-based rations, T1 (65.6%) and T2 (62.8%) had higher carbohydrate contents ($p<0.05$) than the control diet, T3 (57.8%). The high carbohydrate content in sorghum-based rations is mainly due to the inherent composition of sorghum as a carbohydrate-rich cereal grain. Carbohydrate content values obtained were in the range of values (34.7% - 69.0%) in poultry feeds (Dewa & Tikau, 2019). Carbohydrates are important sources of energy for poultry. They form part of energy-yielding nutrients (carbohydrates, fats, and protein), which are oxidised in the course of metabolism to provide the energy needed for maintenance and body tissue building (Kryger et al., 2010).

Ration T3 (2,723 Kcal kg^{-1}) had the lowest ($p<0.05$) metabolizable energy (ME). Sorghum-based rations, T1 (3,569 Kcal kg^{-1}) and T2 (3,684 Kcal kg^{-1}), had higher ME contents that exceeded SON (2018) recommended minimum requirements of 2,800 Kcal kg^{-1} for grower mash. The high metabolizable energy content in sorghum-based rations was attributed to by the natural energy density of sorghum as a carbohydrate-rich grain. All feed samples were above the minimum requirement (2,400 Kcal/kg) for chicken feeds (KEBS, 2021).

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Table 2. Nutrient and energy content of sorghum-based formulated diets

Nutrients	T1	T2	T3	SEM	Mean	KEBS 2021
Dry matter (%)	91.4[a]	91.9[b]	92.1[b]	0.21	91.8	90 (Min)
Crude ash (%)	5.23[a]	5.33[a]	17.3[b]	4.00	9.28	12 (Max)
Crude fibre (%)	3.37[a]	3.62[a]	14.3[b]	3.60	7.10	8 (Max)
Crude fat (%)	6.84[a]	9.54[b]	6.57[a]	0.95	7.65	8 (Max)
Crude protein (%)	15.2[b]	15.8[b]	12.6[a]	0.97	14.5	13 (Min)
Nitrogen-free extracts (%)	68.2[b]	64.6[b]	47.9[a]	6.25	60.2	50 - 70
Carbohydrates (%)	68.7[b]	68.3[b]	60.3[a]	2.73	65.8	30 - 60
Metabolizable energy (Kcal/Kg)	3569[b]	3684[b]	2723[a]	303	3325	2400 (Min)

(KEBS, 2021)

[a, b, c] *Means with different superscripts in the same row are significantly different ($p < 0.05$), SEM= Standard error of the mean*

Amino Acids of Sorghum-Based Formulations

Lysine content in treatment diet T2 (0.68) was higher ($p<0.05$) than T3 (0.47) and T1 (0.15). Diet T2 had high lysine content as a result of ingredients like soybean in the ration. Lysine content of diets T1 and T2 were lower than values obtained in a study by Manyelo et al. (2019), where 50% and 75% sorghum inclusion levels had 1.15% and 1.08%, respectively. Lysine was also found to improve the carcass quality and growth performance of broilers (Belloir et al., 2019).

Diet T1 (0.17) had lower methionine content ($p<0.05$) than T2 (0.75) and T3 (0.53). The lower methionine content in diet T1 was as a result of ingredients including sorghum and maize which are deficient in methionine. Diet T1 (0.17) had lower methionine content compared to a study by Manyelo et al. (2019), where a diet with a 50% sorghum inclusion level was 0.47%. Methionine plays an important role in the optimum growth performance of poultry and is involved in feather synthesis, important biochemical processes (as a methyl group donator), and muscle accretion (de Castro Goulart et al., 2011; Fagundes et al., 2020)

Ration T1 (0.15) had the lowest cysteine content ($p<0.05$), while rations T2 (0.67) and T3 (0.57) had higher cysteine contents. The lower cysteine content in ration T1 was as a result of ingredients including sorghum and maize which are deficient in methionine. Cysteine serves as a semi-essential amino acid because it can be synthesised from methionine and serine by trans-sulphuration (Stipanuk, 2004). It plays critical roles in protein structure and function and in protecting against oxidative stress.

Ration T2 (0.61) had higher tryptophan content ($p<0.05$) than T3 (0.43) due to the high soybean ingredient in the ration. Ration T1 (0.14) had the lowest ($p<0.05$) tryptophan content than a study by Corzo et al. (2005), where 0.16% resulted in satisfactory performance of broilers from 42 to 56 days of age. Tryptophan serves as a precursor to serotonin, a neurotransmitter highly involved in feed intake regulation, and is also used as a supplement through its requirement for protein synthesis (Kerr' & Kidd, 1999).

Table 3. Amino acids analysis of sorghum-based dietary formulations for improved indigenous chicken

Nutrients (%)	T1	T2	T3	SEM	Mean	KEBS 2021
Lysine	0.15[a]	0.68[c]	0.47[b]	0.15	0.43	0.50
Methionine	0.17[a]	0.75[c]	0.53[b]	0.17	0.48	0.25
Cysteine	0.15[a]	0.67[b]	0.57[b]	0.16	0.47	0.50
Tryptophan	0.14[a]	0.61[c]	0.43[b]	0.14	0.40	0.14

(KEBS, 2021)

[a, b, c] *Means with different superscripts in the same row are significantly different ($p < 0.05$), SEM= Standard error of the mean*

Article DOI : https://doi.org/10.37284/eajab.7.1.1811

Tannin Content of C26 Sorghum Variety

The tannin content in the C26 sorghum variety was 1.24%. This was lower than the findings by Shinda et al. (2022) who reported 1.76% for the Seredo sorghum cultivar. Tannin reduces starch and protein digestibility and lower weight gain in monogastric animals such as poultry and rabbits (Liu et al., 2015; Muriu et al., 2002). Tannins present in chicken diets reduce feed intake due to reduced palatability, resulting in low live weight gain, low digestibility, and poor feed conversion efficiency (Oke et al., 2015). Low concentrations of tannins can improve gut health and digestive performance in broiler chickens (Huang et al., 2018; Moritz et al., 2023).

Growth Performance of Improved Indigenous Chicken

Growth performance characteristics including mean initial weight, mean final weight, body weight gain, daily weight gain, feed conversion ratio (FCR), and mortality are shown in *Table 4*. Mean initial weight was ($p<0.05$) higher in T2 (175g) and T1 (166g), no significant difference was observed in T3 (159 g) and T4 (161 g). T1 had a significantly higher ($p<0.05$) effect on mean final weight, body weight gain, daily weight gain, and FCR whereas T2, T3, and T4 were not significantly different. This is similar to a study by Saleh et al. (2019) where broilers fed a 50% yellow corn + 50% low tannin sorghum diet had higher significant body weight gain than those fed a control diet. Daily weight gain was highest ($p<0.05$) in T1 (14.4 g) compared to T2 (9.30 g), T3 (8.54 g) and T4 (8.48 g) that did not differ significantly. These results are similar to a study by (Kwari et al., 2012). Diet T1 (5.57) had significantly lower FCR compared to diets T2 (8.60), T3 (9.37), and T4 (9.43) where no significant differences were observed. This is similar to a study by Torres et al. (2013) where FCR values at 42 days of age were better in chicken-fed low sorghum diets (50%) than those fed high sorghum diets (100%) and control diets. Mortality was significantly higher in T4 (17.1%) and lowest in T3 (5.42%). No significant differences were observed in T1 (12.5%) and T2 (12.1%). T4 findings are higher to a study by Singh et al. (2017) where free-range systems experienced up to 10% mortality.

Table 4: Comparison of growth performance of improved indigenous chicken under semi-intensive (T1, T2 and T3) and free-range (T4) systems in Western Kenya, 4 -12 weeks

Parameters	T1	T2	T3	T4	SEM	Mean
Mean initial weight (g)	166^{b}	175^{c}	159^{a}	161^{a}	3.57	165
Mean final weight (g)	970^{b}	696^{a}	637^{a}	636^{a}	79.7	735
Body weight gain (g)	804^{b}	521^{a}	478^{a}	475^{a}	78.9	570
Daily weight gain (g)	14.4^{b}	9.30^{a}	8.54^{a}	8.48^{a}	1.41	10.2
FCR (feed: gain)	5.57^{a}	8.60^{b}	9.37^{b}	9.43^{b}	0.911	8.24
Mortality (%)	12.5^{b}	12.1^{b}	5.42^{a}	17.1^{c}	2.41	11.8

$^{a, b, c}$ Means with different superscripts in the same row are significantly different ($p < 0.05$), g= grams, SEM= Standard error of the mean

CONCLUSIONS AND RECOMMENDATIONS

Diets T1 and T2 met proximate composition, while T2 and T3 met tested amino acids minimum nutrient requirements for improved indigenous chicken. The current study found that the inclusion of up to 50% of low-tannin sorghum improved variety (C26) gave the highest growth rate and the best feed conversion ratio in improved indigenous chicken. The study recommends that government extension officers should train chicken farmers in formulating diet T1 because it produces the best growth performance in improved indigenous chickens. Also, farmers should plant the C26-sorghum variety to act as a substitute for maize as an energy source in chicken diets since it is low-tannin and drought-tolerant, hence lowering the costs of chicken feeds.

ACKNOWLEDGEMENTS

Financial support for this study was provided by the McKnight Foundation through the Collaborative Crop Research Program (CCRP) grant number 20 – 085 sorghum project. I appreciate farmers under CCRP from Siaya and Busia counties accepting to be undertakers of this project. I acknowledge Spectralab Analytical Services, Nairobi, for allowing me to use their facilities to analyse the formulated diets. I appreciate the University of Eldoret and the Department of Animal Science and Management for providing me with a chance to pursue my studies.

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