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Response Of Kenyan Improved Indigenous Chicken (IIC) To Diets Composed Of Serena And Kari Mtama 1 Sorghum Grain Varieties And Phytase Enzyme

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Abstract:
Background*: Globally, scientists have shifted their attention to alternative sources of energy in feed formulation including poultry feed due to increased cost of corn attributed to reduced production and climate change. Sorghum being the fifth most important cereal in terms of production is being studied by scientists due to its ability to grow in semi-arid areas and its high productivity. Therefore, this study aimed to evaluate the effects of Serena and Kari Mtama 1 sorghum varieties on feed intake, growth performance, feed conversion efficiency and carcass characteristics of IIC.*
Materials and Methods*: The study was carried out at the poultry unit, YMCA college of Agriculture and technology, Limuru Kenya. The study employed a completely randomized design where 10 chicks were randomly subjected to any of the diets. The diets were formulated by substituting maize with Serena and Kari Mtama 1 sorghum varieties at 0, 25, 50, and 100%. Two hundred and ten IIC chicks were studied in this project whereby each treatment was replicated 3 times. Data analysis was done using Stata version 12. Data was subjected to ANOVA to determine significant differences in performance indicators and tibia analysis among the 7 treatments.* ***Results****: The feed intake of feeds formulated using 25% white sorghum was similar to the control. Weight gain among the IIC was constant between weeks 1 to 7 while at week 8 there was a significant increase in weight gain. Chicken fed using feed formulated using white sorghum showed significantly better feed conversion efficiency (3.99- 4.66) as compared to the control (5.18). Feeds formulated using 100% white sorghum resulted to significantly high levels of zinc (19.06mg/100g) and manganese (1.13mg/100g) in the chicken bones as compared to birds fed using the control. The iron and magnesium levels in bones of chicken fed using feeds formulated using 100% white sorghum were comparable to the control. There was no differences in Calcium and phosphorus levels among birds fed using the different diet regimes.*
Conclusion: *In conclusion white sorghum is a suitable to alternative corn in poultry feed formulation which requires to be utilized by the feed industry.*

Key Word*:Sorghum varieties; Poultry feed; Feed intake; Growth performance.*

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I. Introduction

There is an increase in demand for feed ingredients that provide energy and protein due to the consistent development of poultry production [1]. Globally corn is the major cereal used in poultry feed formulation [2]. The price of maize has been on an increasing trend due to its utilization in food consumption, ethanol production among other uses, as a result scientists are focusing on using other cereals such as sorghum as alternatives to corn in poultry feed formulation. Furthermore maize production has been significantly hampered by climate change resulting to decline in production. Interestingly climate change which is characterized by drought and high temperatures favors the production of sorghum [1].

Globally sorghum is the fifth most important cereal in regards to production after wheat, rice, corn and barley. Sorghum is a popular cereal since it is drought resistance [3–5], has high yield [6,7] and diverse industrial applications. Sorghum has the ability to withstand a long period of time without precipitation often with almost no damage to the plant as compared to corn. Furthermore scientists are continuously improving sorghum varieties by developing low tannin varieties [8]. Evidence further indicates that low tannin sorghum has been utilized in substituting corn in swine and poultry feed with only subtle impact on the growth performance [9,10].

Conversely high tannin sorghum has been shown to significantly affect growth performance in broilers [1]. Low tannin sorghum varieties have been reported to contains phytochemicals such as phytosterols, anthocyanins, tannins and phenolic acids which may confers poultry health when used in feed formulation [11]. Therefore Sorghum has the potential of replacing corn as an alternative cereal base in poultry feed formulation [12].

In Kenyan small-holder farmers prefer to rear indigenous chickens because of their capacity to withstand harsh weather conditions and feed fluctuations, among other attributes [13]. Furthermore, indigenous chicken products are preferred over exotic breeds due to their attributes such as leanness, better taste and the belief that they are organic products [13]. However, IC production systems are characterized by low productivity despite their potential to contribute to the Kenya's economy and nutrition. Scientists and other poultry stakeholders disseminated the Improved Indigenous Chicken (IIC) to Kenyan farmers as a productivity-boosting strategy. IIC is a better crossbreed of various indigenous chicken ecotypes from various Kenyan communities. IIC chickens have a dual function (eggs and meat) and have been shown to mature faster, produce more eggs, and reach market weight more quickly [13].

There is however reluctance among farmers to utilize sorghum based feeds in poultry production due to perceptions on low productivity. Furthermore this is scarce data on the use of sorghum based feeds in production of IIC in Kenya. Therefore this study aim was to investigate the effects of substituting maize with Serena and Kari Mtama 1 sorghum varieties on the growth performance of IIC.

II. Material And Methods

Study area: The study was carried out at the poultry unit,Kenya YMCA college of Agriculture and technology, Limuru, due to the availability of animal nutrition Research facilities.

Study design: Experimental study design was used for the study where CRD (complete randomized design with three replicas for each treatment.

Study animals: A total of 210 improved indigenous chicks weighing an average of 41gm, was obtained from KALRO Naivasha and was used to determine feed intake of the IIC fed on two different sorghum grain varieties and Phytase enzyme. The two sorghum varieties were Kari mtama1 low phytic variety and Serena high phytic variety, which were purchased from Machakos County where they are grown. The enzymes were purchased from Home co- suppliers ltd.

The experimental cages, watering and feeding troughs were thoroughly cleaned and disinfected with appropriate disinfectants two weeks before the commencement of the experiment. The experimental chicks were housed in an open experimental wire mesh pen built on the concrete floor ($1.5m^2$) of the poultry house. Partitioning of the pens was done by using the wire mesh. Each pen was equipped with a nipples line for drinking water and two (5kg) feeders that were cleaned and disinfected prior to the start of feeding. The heights of the feeders and water lines were adjusted to accommodate the chicks' progressive growth.

On arrival the chicks were assigned into different cages (10chicks per cage) (42 × 75 × 25 cm) and antistress tablets were then be administered in the drinking water and left for a week to adapt for the experiment. Chicks were also be administered with multi-vitamins (AD3E+coliston) 0.2ml/1L in the drinking water during the first three days to boost immunity and reduce stress. Bio sol (Anti-bactericide and coccidiostat) and liquid paraffin (oil to soften the droppings) were administered to the chick on the day of arrival. Water and the feed were *ad libitum*. Chicks were also be vaccinated as presented in Table 3.1.

Table 1: Vaccination

Age	Vaccine	Mode of administration
Day 10	Gumboro/ Infectious Bursal Disease	Drinking water
Day 18	Gumboro/ Infectious Bursal Disease	Drinking water
3 weeks	Newcastle	Eye drop or drinking water
6 weeks	Fowl pox	Wing web jab
8 weeks	Newcastle	Eye drop or drinking water
8 weeks	Fowl typhoid	Intramuscular injection

Experimental layout and Treatments: Two sorghum varieties that were used for the study were selected on their outstanding yield performance, agronomic characteristics, and preference by farmers and tannin contents. The chemical and nutritional properties of the selected varieties were considered according to Mabelebele et al.,[14]. The sorghum varieties grown in Kenya and their characteristics are described in Table 3.2.

Table 2: Sorghum varieties grown in Kenya and their characteristics

Attributes	Sorghu m varieties	
	Serena	Kari Mtama 1
Plant height	150-160 cm	50-170 cm

Flowering	69-78 days	58-65 days
Maturity	110-120 days	95-100 days
Grain colour	Brown	White
Potential yield (kg/ha)	1800-2300	1800-4000
Tolerance	Striga, drought	Drought
Pests	-	Quelea birds

Source: KARI (2006)

For experiment each treatment was randomly assigned 3 pens (each pen was assigned 10 chicks) in a factorial arrangement in a completely randomized block design using initial body weight as the blocking criterion to ensure that the treatments had the same average body weight at day 0. The chicks were distributed to their corresponding treatment diets. For treatment 3, 4, 5 and 6 each treatment had two groups because of the two sorghum varieties table 3.3. Sorghum, and diet samples were analyzed for their proximate composition according to [15].

Table 3: Description of the treatments used in the study

Treatment	Description
T1	Control (diet with Phytase enzyme) Fed on chick mash, growers mash and layer mash as in T1 with inclusion of Phytase enzyme. (0% sorghum inclusion levels)
T2 , T5	Fed on chick mash, growers mash and layer mash as in T1 with inclusion of sorghum in all diets to substitute maize (25% inclusion levels) and also inclusion of Phytase enzyme to the diet
T3 ,T6	Fed on chick mash, growers mash and layer mash as in T1 with inclusion of sorghum in all diets to substitute maize (50% inclusion levels) and also inclusion of Phytase enzyme to the diet
T4 ,T7	Fed on chick mash, growers mash and layer mash as in T1 with inclusion of sorghum in all diets to substitute maize (75% inclusion levels) and also inclusion of Phytase enzyme to the diet

Formulation of experimental diets (100kg)

Chick mash was formulated for the study. Sorghum was used to substitute maize at five inclusion levels designated as T1 (0 %), T2 (25 %), T3 (50 %) and (T4 100%). As shown in tables 3.5 and 3.6, two sorghum grain varieties were used as another source of energy in place of maize in the feed ration. Phytase enzyme was added to all diets in (T1, T5, T6 and T7) except for treatment 1 Table 3.4.

Table 4: Feed formulation for Treatment 1 (T1)

Type of feed	Chick Mash
Maize (kg)	70
Soya beans meal (kg)	18
Fish meal (kg)	9
Limestone (kg)	2
Premix (kg)	1
Total (Kg)	100

Table 5: Mixing ratios for the different ingredients in each 100 kg of treatment ration for sorghum variety one (Kari Mtama 1)

Type of feed		Chick Mash					
Treatments	T1	T2	T3	T4			
Maize (kg)	70	52.5	35	0			
Sorghum (kg)		17.5	35	70			
Soya beans meal (kg)	18	18	18	18			
Fish meal (kg)	9	9	9	9			
Limestone (kg)	2	2	2	2			
Premix (kg)	1	1	1	1			
Total (Kg)	100	100	100	100			

Phytase enzyme was added to all diets in (T2,T3 and T4) except for treatment 1 Table 3.4.

Table 6: Mixing ratios for the different ingredients in each 100 kg of treatment ration for sorghum variety two (Serena)

Type of feed	Chick mash			
Treatments	T1	T5	T6	T7
Maize (kg)	70	52.5	35	0
Sorghum (kg)	0	17.5	35	70
Soya beans meal (kg)	18	18	18	18
Fish meal (kg)	9	9	9	9
Limestone (kg)	2	2	2	2
Premix (kg)	1	1	1	1
Total (Kg)	100	100	100	100

Phytase enzyme was added to all diets in (T5, T6, and T7) except for treatment 1 Table 3.4.

Feeding and data collection

Feeding: The birds were fed according to their daily ration requirements, which range from 20 to 30 grams per chick per day for day 0 to the 8th week as shown in table 3.3 (T1). Equitable distribution of feeds in each pen was ensured by weighing the feeds using a weighing balance so as to avoid bias in feeding the chicken. Water was provided ad-libitum.

Performance Indicators: Weekly measurements of intake of feeds and body weight were taken and used to measure growth performance. This was achieved by subtracting the number of birds that died during the experimental period from the total number of birds stocked, divided by the total number of birds stocked multiplied by 100 (percent). The difference between the final body weight (g) and the initial body weight in grams over a period of time was also calculated on each pen to determine average daily weight gain. Daily feed intake / Average daily weight gain/bird was used to calculate the feed conversion ratio. The formulae that was used to calculate each measurement is as follows:

- Weekly feed intake (g) = 1000 x [(feed given-feed refused)/ ∑ (number of day-old chicks placed on day 0 – number of mortalities on day 7)
- Weekly weight gain (g/bird/day) = (body weight (g) on day 1 – body weight (g) on day 7)

Tibia analysis: At the end of the study three chicken were slaughtered from each treatment for tibia analysis. Analysis of tibia was carried out using both left and right tibias that were preserved in a deep freezer. Before the analysis, it was taken out of the freezer and allowed to thaw at room temperature.

The tibias were ashed and mineral content determined using atomic absorption spectrophotometry (AAS). The tibias were divided such that 234 bones (13 bones per treatment) undergo tibia ash analysis and 234 bones (13 bones per treatment) undergo mineral analysis. The cartilage caps were then removed from all tibias before commencing the analysis.

Data analysis and presentation: Data was analyzed using Stata version 12. Two-way ANOVA was done to determine the statistical differences in intake of feed, conversion efficiency of feed, increase of body weight and carcass characteristics among IIC feed on different sorghum varieties with varying concentration. All the analysis was done at 95% confidence interval. Data was presented using tables.

Ethical Review and logistical considerations: The study proposal was reviewed by Kenyatta University and approval granted by the Graduate School. The indigenous chicken were raised in conditions that promote good health and animal welfare.

III. Result

Proximate composition of chicken feeds and Kenya IIC

Sorghum variety and substitution level of maize with sorghum had a significant effect on the dry matter content of the chicken feeds ($p<0.05$). The dry matter content decreased with increase in levels of substitution with the control having the highest dry matter content while chicken feed formulated using 50% white sorghum and 100% brown sorghum had the least dry matter content. Protein content of the chicken feeds was significantly affected by sorghum variety used in formulation as well as levels of substitution of maize with sorghum ($p<0.05$). Protein content increased with increase in levels of substitution with chicken feed formulated using 50% white sorghum, 100% white sorghum and 100% brown sorghum having the highest content as compared to the control. In terms of the fat content, the chicken feed was significantly affected by the sorghum variety used in formulation and levels of substitution of maize with sorghum. In chicken feed formulated using white and brown sorghum fat content significantly decreased with increase in substitution levels of maize with sorghum. Sorghum variety and substitution levels of maize with sorghum significantly influenced the ash content of the chicken feeds (p<0.05). The ash content of the chicken feeds significantly increased with increase in levels of substitution of maize with sorghum with the 100% substitution level recording the highest value while the control had the least. The fiber content of the poultry feeds differed significantly with feeds formulated by substituting maize with 25% and 50% white sorghum having the highest fiber content while feeds formulated using 100% white sorghum, 25% and 50% brown sorghum having the least fiber content. The carbohydrate content of the chicken feed was significantly influenced by the sorghum variety used in formulation and the levels of substitution of maize with sorghum (p<0.05). In chicken feed formulated using white sorghum there was significant decline in carbohydrate content at 25% substitution level followed by a decrease with further increase in levels of substitution.

Table 7: Proximate composition of chicken feed formulated with varying levels of white and brown sorghum

Sorghum varieties	Substitution levels	Dry matter (%)	Protein (%)	Fat (%)	Ash (%)	Fiber (%)	Carbohydrates (%)
White sorghum	Control	90.27 ± 1.22^{d}	10.08 ± 0.74^{a}	24.89 ± 0.91^{d}	2.74 ± 1.66^{a}	2.11 ± 0.10^{b}	55.24 ± 3.06^{bc}
	25%	80.15 ± 1.50^{a}	11.41 ± 0.51^{b}	11.12 ± 1.22^{ab}	5.35 ± 1.30^{b}	2.80 ± 0.10^{c}	52.2 ± 3.17^{ab}
	50%	81.33 ± 1.44^{ab}	12.39 ± 0.09^{bc}	16.13 ± 1.38^{c}	5.76 ± 1.78^{b}	2.83 ± 0.14^{c}	56.37 ± 4.30^{bc}
	100%	85.08 ± 2.82^{bc}	12.03 ± 0.28^{bc}	7.67 ± 1.84^{a}	7.69 ± 1.62^{bc}	1.21 ± 0.10^{a}	69.39 ± 5.91^{d}
Brown sorghum	Control	90.27 ± 1.22^{d}	10.08 ± 0.74^{a}	24.89 ± 0.91^{d}	2.74 ± 1.66^{a}	2.11 ± 0.10^{b}	55.24 ± 3.06^{bc}
	25%	87.38 ± 1.35^{e}	9.78 ± 0.41^{a}	13.76 ± 1.31^{bc}	4.72 ± 1.44^{b}	1.41 ± 0.10^{a}	65.57 ± 3.00^{cd}
	50%	86.40 ± 1.43^{cd}	9.38 ± 0.30^{a}	15.79 ± 1.63^{c}	5.57 ± 1.12^{b}	1.23 ± 0.11^{a}	60.91 ± 3.86^{cd}
	100%	81.15 ± 0.25^{ab}	13.22 ± 0.22^{c}	11.48 ± 0.96^{ab}	9.06 ± 1.36^{c}	1.93 ± 0.11^{b}	57.8 ± 2.63^{c}

Values are means ± SD. Means with different superscript letters along the columns are significantly different at p<0.05.

Feed intake of the Kenya IIC

Sorghum variety and number of weeks had a significant effect on the weekly feed intake of Kenyan IIC (p =0.0001). In the first week, there was a significantly high consumption of feeds formulated using 25% brown sorghum, 100% brown sorghum and control diets as compared to the other feeds. In week 2 there was a significant increase in feed intake of all the different feed compositions. The feed intake of feeds formulated using 25% and 100% brown sorghum stagnated in week 3 followed by a significant decline in week 4 while for all the other feed formulations, feed intake increased upto week 4. In weeks 5 and 6 there was a stagnation in feed intake of all the feed formulations followed by a significant increase in feed intake upto week 9.

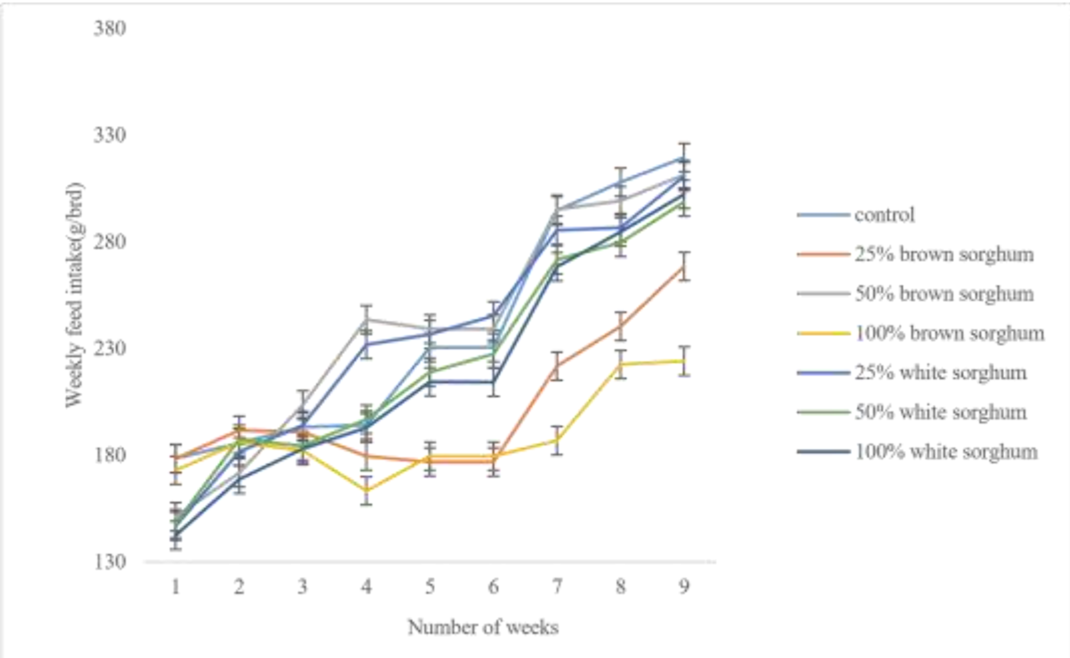

Figure 1: Weekly feed intake (g/bird) of Kenyan IIC fed on chicken feed comprising white and brown sorghum varieties over a period of 9 weeks

Growth performance of Kenya IIC

Weekly weight gain of the Kenyan IIC was significantly influenced by sorghum variety used in chicken feed formulation and the number of weeks (p = 0.0001). Between week 1 and week 7 there was similarity in weight gain among the Kenya IIC fed on the control and the white and brown sorghum feed formulations. Furthermore in week 8 there was a significant increase in weight gain among the Kenya IIC fed on all the feed formulations. It is worth noting that in week 8 chicken fed on feeds formulated using 25% and 100% white sorghum recorded the highest weight gain while chicken fed with the control diet and feed formulated using 100% brown sorghum recorded the least weight gain. In week 9, there was a stagnation in weight gain among chicken fed on the control diet, feeds formulated using 50% brown sorghum, 25%, 50% and 100% white sorghum while there was a significant decline in weight gain in chicken fed using feeds formulated using 25% and 100% brown sorghum.

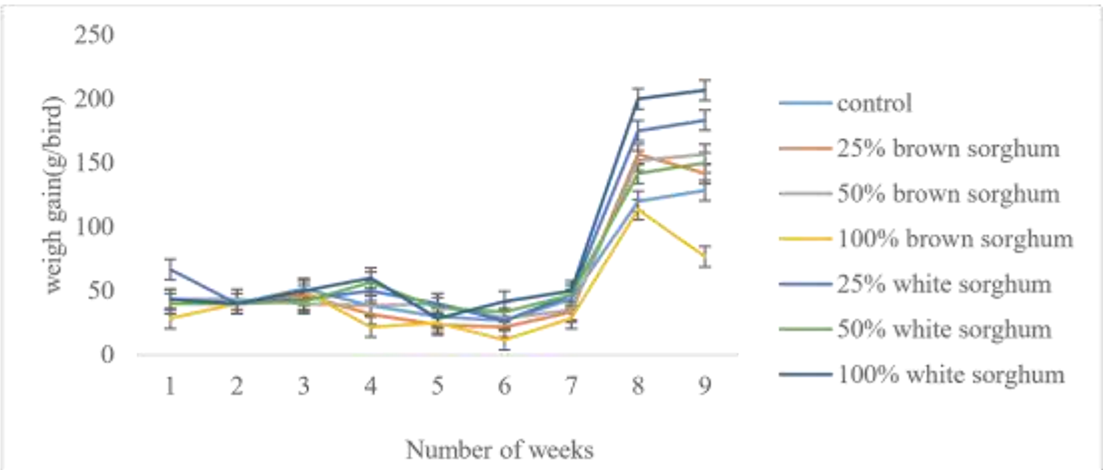

Figure 2: Weight gain (g/bird) of Kenyan IIC fed on chicken feed comprising white and brown sorghum varieties over a period of 9 weeks

Correlation between feed intake and weight gain

There was a significant strong positive correlation between feed intake and weight gain among Kenyan IIC fed using chicken feed formulated using varying levels of substitution of maize with white sorghum and brown sorghum (p<0.05).

Table 8: Correlation between feed intake and weight gain of Kenyan IIC fed on chicken feed comprising white and brown sorghum varieties at varying levels

	Weight gain						
Feed intake	1	2	3	4	5	6	7
1.Control	0.6667*						
2. 25% white sorghum		0.7620*					
3. 50% white sorghum			0.5290*				
4.100% white sorghum				0.5815*			
5. 25% brown sorghum					0.5063*		
6. 50% brown sorghum						0.6677*	
7.100% brown sorghum							0.7486*
*Correlation is significant at the 0.05 level (2-tailed).							

Feed conversion efficiency of the Kenya IIC

The feed conversion efficiency of the Kenyan IIC was significantly affected by sorghum variety used in chicken feed formulation and substitution level of maize with sorghum (p<0.05). Chicken fed using feed formulated using white sorghum showed significantly better feed conversion efficiency as compared to the control. Feed conversion efficiency in chicken fed using feed formulated using white sorghum improved with increase in level of substitution with 50% and 100% substitution levels having the best feed conversion efficiency. To the contrary chicken fed using feed formulated using brown sorghum showed significantly poor feed conversion efficiency as compared to the control. In addition, the feed conversion efficiency inthe chicken declined with increase in substitution levels of maize with sorghum with 50% and 100% levels recording the least feed conversion efficiency.

Mineral composition

The zinc content of the chicken bones was significantly affected by the sorghum variety used in feed formulation, level of substitution of maize with sorghum and part of the chicken bone ($p<0.05$). The zinc content in the chicken bones increased significantly with increase in levels of substitution for chicken fed on feeds formulated using white sorghum while the levels decreased with increase in substitution levels for chicken fed with feeds formulated using brown sorghum. In addition, the femur bone at 25% and 100% white sorghum substitution level had significantly higher zinc content as compared to the tibia. The iron content of the chicken bones was significantly affected by the part of chicken bone whereby the femur of chicken fed with the control and chicken feed formulated by 25% substituting maize with white and brown sorghum had significantly higher iron content as compared to the tibia. Sorghum variety used in chicken feed formulation, level of substitution of maize with sorghum and the part of chicken bone significantly affected the manganese content of the chicken bones ($p<0.05$). Chicken fed using feeds formulated by substitution 25% of maize with brown sorghum had the highest Manganese content while the control and those fed with chicken feed formulated using 25% and 50% white sorghum had the least. In addition the femur of chicken fed on the control and chicken feed formulated by substituting maize with 25% and 50% white sorghum had significantly higher manganese content as compared to the tibia. The magnesium content of the chicken bones was significantly affected by the substitution level of maize with sorghum ($p<0.05$) with the chicken fed on feeds formulated using 100% white and brown sorghum having significantly higher values as compared to the control.

Table 10: Mineral composition of femur and tibia of Kenyan IIC fed on chicken feed with varying levels of white and brown sorghum varieties

Sorghum varieties	Treatments	Bone parts	Zinc (mg/100g)	Iron (mg/100g)	Manganese (mg/100g)	Magnesium (mg/100g)	Calcium (g/kg)	Phosphorus (g/kg)
White sorghum	Control	Femur	$137.15±11.63^{bc}$	$18.75±2.58^{b}$	$0.94±0.12^{b}$	$11.31±3.39^{ab}$	$23.75±1.34^{a}$	$14.44±0.18^{a}$
		Tibia	$135.74±11.63^{bc}$	$13.13±2.58^{a}$	$0.65±0.12^{a}$	$8.64±3.39^{a}$	$25.21±1.34^{a}$	$14.01±0.18^{a}$
	25%	Femur	140.35±11.63c	$21.93±2.58^{bc}$	$0.92±0.12^{b}$	$12.26±3.39^{b}$	$24.21±1.34^{a}$	$13.97±0.18^{a}$
		Tibia	$102.58±11.63^{a}$	$12.64±2.58^{a}$	$0.65±0.12^{a}$	$9.62±3.39^{a}$	$25.87±1.34^{a}$	$14.24±0.18^{a}$
	50%	Femur	$145.58±11.63^{c}$	$16.96±2.58^{b}$	$0.96±0.12^{b}$	$8.64±3.39^{a}$	$24.59±1.34^{a}$	$13.92±0.18^{a}$
		Tibia	$143.86±11.63^{c}$	$17.64±2.58^{b}$	$0.69±0.12^{a}$	$7.52±3.39^{a}$	$25.22±1.34^{a}$	$14.19±0.18^{a}$
	100%	Femur	$195.06±11.63^{d}$	$20.93±2.58^{b}$	$1.13±0.12^{d}$	$12.05±3.39^{b}$	$23.88±1.34^{a}$	$14.58±0.18^{a}$
		Tibia	$140.98±11.63^{c}$	$19.40±2.58^{b}$	$0.99±0.12^{b}$	$13.31±3.39^{b}$	$25.28±1.34^{a}$	$14.07±0.18^{a}$
Brown sorghum	Control	Femur	$137.15±11.63^{bc}$	$18.75±2.58^{b}$	$0.94±0.12^{b}$	$11.31±3.39^{ab}$	$23.75±1.34^{a}$	$14.44±0.18^{a}$
		Tibia	$135.74±11.63^{bc}$	$13.13±2.58^{a}$	$0.65±0.12^{a}$	$8.64 ± 3.39^{a}$	$25.21±1.34^{a}$	$14.01±0.18^{a}$
	25%	Femur	$118.34±11.63^{a}$	$20.24±2.58^{b}$	$1.85±0.12^{f}$	$11.20±3.39^{ab}$	$25.25±1.34^{a}$	$14.50±0.18^{a}$
		Tibia	$114.55±11.63^{a}$	$14.91±2.58^{a}$	$1.62±0.12^{ef}$	$9.33±3.39^{a}$	$24.71±1.34^{a}$	$13.65±0.18^{a}$
	50%	Femur	$110.71±11.63^{a}$	$21.32±2.58^{bc}$	$1.10±0.12^{cd}$	$9.69±3.39^{a}$	$24.37±1.34^{a}$	$14.04±0.18^{a}$
		Tibia	$108.39±11.63^{a}$	$19.92±2.58^{b}$	$1.03±0.12^{c}$	$8.91±3.39^{a}$	$24.84±1.34^{a}$	$14.06±0.18^{a}$
	100%	Femur	$125.15±11.63^{b}$	$19.39±2.58^{b}$	$1.31±0.12^{e}$	$12.40±3.39^{b}$	$25.57±1.34^{a}$	$14.72±0.18^{a}$
		Tibia	$134.50±11.63^{bc}$	$16.14±2.58^{b}$	$1.28±0.12^{e}$	$11.31±3.39^{ab}$	$26.83±1.34^{a}$	$14.73±0.18^{a}$

Values are means ± SE. Means with different superscript letters along the columns are significantly different at $p<0.05$.

IV. Discussion

In the present study Protein content of the feeds increased with increase in levels of substitution. Similarly a South African study reported that substituting maize with sorghum increased the protein content of quail grower diet by 4% [16]. Equally based on a study done in Ethiopian substituting 45% of maize with sorghum resulted to a high protein content in commercial broiler feeds [17]. In regards to fat content, the fat content in the feeds decreased with increase in levels of substitution. Conversely evidence shows that substitution of maize with sorghum resulted to a higher fat content in chicken feed as compared to findings of the present study [17]. Similarly, the findings of the present study conflicted with those of another study which reported that substitution of maize with sorghum resulted to a 10-44% increase in fat content [18]. These differences could be attributed to differences in sorghum varieties. The ash content of the feeds increased with increase in levels of substitution. These findings were in line with the results of a South African study which documented an increase in ash content with increase in substitution with white sorghum grains [18]. The fiber content of the poultry feeds ranged between 1.21 to 2.83% which was reported in slightly below the range of 3.50 to 5.50% reported by Alum et al., [19]. Similalry a study done in Nigeria documented the fiber contnet of poultry feed to range from 3.41% to 15.90%. studies suggests that inclusion of 3-5% of insoluble fiber in poultry diets aids in improving nutrient metabolism due to their ability to modulate gastric secretions [20,21]. Further evidence indicates that water soluble fiber found in cereals such as sorghum is antinutritial and thus poultry nutritionists have to consider during feed formulation [22].

The results on feed intake of the Kenya IIC in the present study conflicted with the results of Manyelo et al., whereby feed intake of starter diets (1-21 days) substituted with white sorghum were higher than that of 100% maize-based diets. However, for growers (22-42 days) feed intake was highest for the 100% maize-based diet and lowest for the diet substituted with 25% white sorghum [18]. Fagundes et al reported that at the age of 4-5 weeks, broiler chicken in Brazil did not exhibit a significant difference in feed intake between 100% maize-based diets and those substituted with sorghum [23].

A study in India showed that feed intake in broiler chickens during 0-3 weeks of age showed a decreasing trend with increasing levels of diet substitution with red sorghum [24]. On the other hand, Torres et al reported that feed intake among broiler chicken did not differ significantly with different substitution levels of sorghum [25]. A study on the effect of maize-substituted sorghum-based rations on IIC in Kenya showed that feed intake was highest among birds fed a diet with 50% substitution level [26]. These differences in observations could be attributed to difference in the chicken breeds, sorghum varieties and diet composition. Feed intake (FI) is the single most important factor influencing the growth rate of chicken. Higher FI increases the weight gain which in turn decreases the amount of energy used for the bird's maintenance in relation to gain [27].

The growth performance of Kenya IIC in the present study was in agreement with those reported by Torres et al whereby there was no significant difference in weight gain among birds aged 1-21 days fed on feeds with different substitution levels of sorghum [25]. The same study further observed a significant difference in weight gain in the 8th week with birds fed with feeds substituted with 0% and 50% sorghum having significantly higher weight gain as compared to those fed feeds substituted with 100% sorghum. Similarly a South African study reported that birds aged 22-42days exhibited higher body weights when fed on diets substituted with 50%, 75% and 100% white sorghum compared to the 25% and 0% substitution levels [28]. Conversely a study by Misiko, Ang'iyo & Rachuonyo reported a significant decline in weight gain with increase in sorghum substitution levels among IIC [29]. Additionally a study by Fagundes et al observed no significant differences in weekly weight gain between broilers fed on 100% maize diets and diets substituted with sorghum [23].

There was a positive significant correlation between feed intake and weight gain among the Kenya IIC. This implies that the chicken weight increases as feed intake increases. Ideally this is the norm and this further confirms that study protocols were followed when implementing the study. This finding was in alignment with the observations of Wen et al whereby the body weight gain of ducks increased with feed consumption level and force-fed birds exhibited significantly higher body weight gain [30]. Similarly, a significant positive correlation between feed intake and body weight was reported in broiler chickens in weeks 1 2 and 3 [31].

The feed conversion efficiency of the Kenya IIC was significantly affected by sorghum variety. In terms of variety, a converse trend was reported in broiler finishers whose feed conversion ratio was significantly better when fed diets substituted with red sorghum variety than their counterparts fed on diets with other varieties (yellow colored) or maize-based diets [32]. Similarly, a study by Selle et al showed that a white sorghum variety supported better feed conversion ratios than a red sorghum variety (1.49 versus 1.53) in broiler chickens[33]. The feed conversion efficiency of the Kenya IIC decreased with increase in levels of substitution. Similar findings were reported by Torres et al whereby feed conversion in broiler chicken was higher for birds fed low sorghum diet than those fed high sorghum diet [12]. Conversely, there was no significant effect of substitution levels on the feed conversion ratio among broiler finishers fed sorghum -based diets with up to 50% and 100% replacement levels [32].

Defined as the measure of how well a flock converts feed intake (feed usage) into live weight, feed conversion efficiency is determined by; the starting bird weight, feed intake and growth rate [34]. Studies have shown than white-sorghum based diets have more rapid protein digestion rate compared to red and brown colored sorghum which might enhance the feed conversion efficiency by synchronizing starch and protein digestibility as well as the availability of glucose and amino acids [35,36].

The calcium content of the chicken bones was not significantly influenced by the sorghum variety used in the formulation, level of substitution of maize with sorghum and the part of the bone (p>0.05). Similarly evidence have shown that substitution of maize with low tannin sorghum in feed formulation has no significant effect on the calcium levels of broiler chicken [18]. The calcium levels in chicken bones in the present study were comparable to a range of 30.42 to 49.01 g/kg reported in local chicken, broilers and old layers [37]. It is worth noting that the calcium levels of the chicken bones was significantly higher than 74.23mg/100g as reported by Ebeledike et al [38]. The differences observed in calcium levels could be attributed to differences in feeding regimes, age, sex and the body part analyzed [37]. The calcium levels were significantly higher than the phosphorus levels which validates the fact that calcium is more abundant in chicken bones as compared to phosphorus.

The phosphorus content of the chicken bones was not significantly influenced by the sorghum variety used in feed formulation, level of substitution of maize with sorghum and part of the chicken bone ($p>0.05$). In comparison to the findings of this study, the results reported by Manyelo et al indicated that substituting maize with a low-tannin white sorghum had no significant effect on the calcium and phosphorous contents and bone geometric analysis of broiler chickens [18]. The findings of this study conflicted with those reported by Chiripasi et al who observed a decrease in calcium and phosphorus contents of birds fed diets containing sorghum compared with those fed millet- or maize-based diets [40]. The phosphorus level in the chicken bones was comparable to a range of 17.67 to 19.23 reported by Okwonudulu et al[37]. In chicken, skeletal development is an important factor in terms of both welfare and production, with evidence that under- or oversupply of minerals such as phosphorous influence bird growth performance. Typically, therefore, chicken diets are supplemented with vitamin D, calcium and phosphorous to enhance skeletal development [41].

Sorghum grains have been known to contain ant nutritional factors like tannins and phytic acid which inhibit the availability and utilization of minerals in poultry. The findings of this study suggest that inclusion of sorghum in the diet improved the mineral content of the femur and tibia, with the white sorghum variety exhibiting superior qualities. This could be attributed to lower content of anti-nutritional factors in white sorghum variety as reported by other researchers [33,35].

V. Conclusion

Substitution of maize with sorghum in feed formulation significantly impacted on the feed intake of the IIC. The feed intake of feeds formulated using 25% white sorghum was similar to that of the control while feed intake of other formulations was significantly lower. Weight gain was constant between weeks 1 to 7 while at week 8 there was a significant increase in weight gain. Chicken fed using feed formulated using white sorghum showed significantly better feed conversion efficiency as compared to the control. Feeds formulated using 100% white sorghum resulted to significantly high levels of zinc and manganese in the chicken bones as compared to birds fed using the control. The iron and magnesium levels in bones of chicken fed using feeds formulated using 100% white sorghum were comparable to the control. There was no differences in Calcium and phosphorus levels among birds fed using the different diet regimes. However calcium levels in the birds was higher than phosphorus levels.

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