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Effect of dietary substitution of maize meal with finger millet meal on fat deposition on broiler meat

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Abstract

The aim of this study was to investigate the effect of a finger millet-based broiler feed on the meat quality of chicken. Proximate nutrient composition was analyzed on the finger millet meal and a feed formulated with finger millet as the main energy source. The feed was formulated on percent crude protein (CP) basis using Pearson square method. An experiment was designed and conducted on Ross Hybrid chickens to determine the effect of the feed on lean tissue development. A two-tailed *t*-test statistical analysis was conducted at a significance level of 5% to determine the effect of the feed on fat deposition and lean tissue development in broiler muscle. The finger millet feed increased mean lean tissue mass by 3.47%. This study showed that use of finger millet feed reduced the fat deposition and favored protein deposition in broiler muscle (increased leanness). This study also showed that finger millet feed significantly enhanced broiler growth performance. We concluded that finger millet has the potential to replace maize meal in broiler feed formulation in order to produce lean and healthier meat for consumers.

Keywords: *Broiler, Fat deposition, Finger millet, Lean, Meat quality*

1. Introduction

Broiler meat consumers prefer a quality product that is healthy. A healthy product is one that is free from any form of hazard that has the potential of causing harm to consumers after its consumption. The quantity of fat in broiler meat is a major concern to consumers in Zimbabwe as well as the global world (Utta *et al*., 2015). Lean broiler meat is high in protein content and low in fat and calorie contents. Studies have shown that high fat broiler diet has significant effect on fat tissue deposition (Zelenka *et al*., 2006; Jiang *et al*., 2014; and Utta *et al*., 2015).

The percentage of fat in broiler meat determines its quality parameters as well as consumer preference. Broiler meat that has a high fat content could contribute to high levels of bad cholesterol that could lead to health problems such as severe obesity and heart related diseases (Ananthakrishnan *et al*., 2014; and Bastien *et al*., 2014). The studies conducted by John Hopkins Medicine University (2005) and Royal Melbourne Institute of Technology (RMIT) University (2005) identified a multiple of benefits from the consumption of lean meat from various sources, broiler meat being included. The studies concluded that lean meat enables achievement

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of optimal health (Li *et al*., 2005; and Barosh *et al*., 2014). It was also found to reduce nutrition related health problem such as cardiovascular diseases, high blood pressure, clinical diabetes, inflammation, anxiety and stress. Lean broiler meat has been found to be a rich source of selenium, complex-B vitamins, zinc, iron and omega3 fatty acids. Selenium possesses antioxidant properties essential in the prevention of cell damage from free radicals. Complex-B vitamins (B3 and B6), zinc and omega3 fatty acids have been found to offer protection against inflammation, reduce anxiety and aids in the relief of stress in people. The iron present in lean broiler meat is significant in the formation of healthy red blood cells, prevention of nutritional anaemia, increasing body energy production and minimization of fatigue, body weakness and irritability. Other studies have also shown that consumption of lean broiler meat reduces body weight and increases lean muscle mass (Walker *et al*., 2005; McAfee *et al*., 2010; and Brennan *et al*., 2012).

Soya bean and maize are the major ingredients in poultry feed. In contrast to maize and soybean production, finger millet yields are high in low soil fertility and the seed is not easily damaged by insects during storage. There is minimal use of fertilizers, pesticides and herbicides in finger millet production and storage that could minimize introduction of chemical hazards in poultry meat production if the cereal is used as poultry feed.

The fat deposition in poultry is determined by a multiple of variables that include genotype of broiler birds and crops used as source of poultry feed, environmental conditions under which crops for poultry feed are grown and the poultry feeding regime (Choct *et al*., 2005; and Wang *et al*., 2014). Poultry feed high in poly unsaturated fatty acids could increase rate of fat deposition. Inadequate nutrition in poultry could cause increased fat deposition. Poultry feed rich in polyunsaturated fats are correlated to increased development of lean tissue muscle and reduced fat tissue. Finger millet is nutritionally rich in essential amino acids, minerals, low in crude fat (1.6 g / 100 g) and low calorie content (333.6 kcal / g) making it a suitable ingredient for broiler feed with the potential to provide lean meat (Singh and Raghuvanshi, 2012; and Utta *et al*., 2015).

2. Materials and methods

2.1. Study setting

The feed nutrient concentration analysis were carried out at Scientific and Industrial and Development Centre (SIRDC), Harare.

2.2. Experimental animals

Twenty-two, one day old Ross Hybrid broiler chicks were bought from Charles Stewart Poultry Company and used in this study.

2.3. Animal housing and handling

The chicks were housed in cages under a deep litter system (Figure 1) and had *ad libitum* access to feed and drinking water. The chickens were housed in well-ventilated wire mesh cages. The housing were electrically heated during the first 14 days. The cage floors were made of wire mesh raised one meter from the ground. The

Figure 1: (a) Finger millet fed broiler cage. (b) Maize fed broiler cage

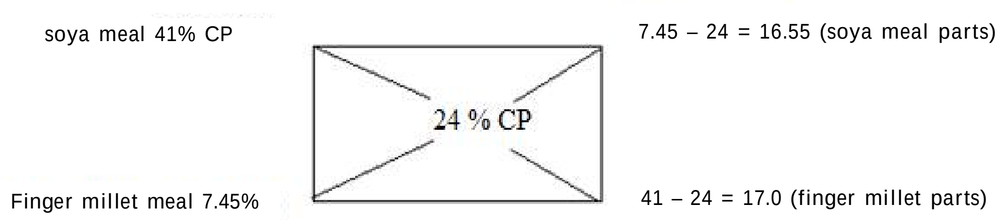
floors allowed passage of droppings to the ground. Bird droppings were removed from the ground each morning and the ground below the cages was wetted each morning to minimize dust as well as to keep the housing humid. Excess dust and feathers were removed from cage floors through regular brushing. Each cage had one plastic water trough and one galvanized feeder. Water troughs were cleaned and refilled each morning.

2.4. Plant material source and preparation

The finger millet and maize were bought from Kudzanayi market, Gweru. The finger millet was roasted at 115 °C for 15 minutes in an oven and then coarsely grounded before use. The roasting treatment was carried out to reduce levels of nutrient inhibitors and toxic substances normally present in finger millet such as trypsin inhibitor, phytates, cyanide, phenols and tannins. Roasting was also done to improve finger millet digestibility as well as enhancing iron bioavailability. The heat treated finger millet was ground to improve nutrient bioavailability (Devi *et al*., 2014; and Athawale *et al*., 2015). The maize was then milled into a coarse meal at Senga.

2.5. Formulation of broiler feed

The Pearson square technique was used to formulate the finger millet feed (FMF) and the maize feed (MF) as shown in Figure 2. Soya meal and finger millet meal were the ingredients used to formulate the finger millet feed while soya meal and maize meal were used for maize feed. The finger millet starter feed was made from mixing by mass 49.33% soya meal and 50.67% finger millet. Finger millet finisher contained 37.40% soya meal and 62.60% finger millet meal. The composition of maize starter were 46.20% soya meal and 53.80% maize meal. Maize finisher feed contained 31.65% soya meal and 66.46% maize meal. The Pearson square technique was used to calculate percentage ingredients that were targeted to produce 24% crude protein (CP) starter feed and 20% finisher feed. The Pearson square method was selected on the basis of its simplicity and quickness. The method was also appropriate since two ingredients were used per feed formulation (Wagner and Stanton, 2012; and Saxena and Khanna, 2014).



Note: CP – Crude Protein

Figure 2: An illustration of Pearson square method used calculate percent ingredients in broiler feed (Wagner and Stanton, 2012)

2.6. Determination of proximate composition of broiler feed

The formulated finger millet feed and maize feed were analyzed for crude protein, crude fat, ash, moisture content, iron, calcium, phosphorous and crude fiber levels as according to AOAC (2001). Each test analysis was replicated three times to minimize experimental errors.

2.7. Determination of iron, calcium and phosphorous in feed samples

The iron and calcium contents in feed samples were determined by flame atomic absorbance method using Flame Atomic Absorption Spectrometry (FAAS) model GBC Sens AA according to AOAC (2012). Briefly the feed samples were prepared for mineral analysis by wet digestion using 3.0M nitric acid and 30.0% hydrogen peroxide. The digested samples were filtered using Whatman No. 1 filter paper. UV-visible absorbance was read at 400 ηm using spectrophotometer model Shimadzu UV-160.

2.8. Experimental design

Twenty-two, one day old chicks were randomly allocated into two feed groups namely finger millet feed and maize feed. The chicks were fed for 49 days after which the experiment was terminated.

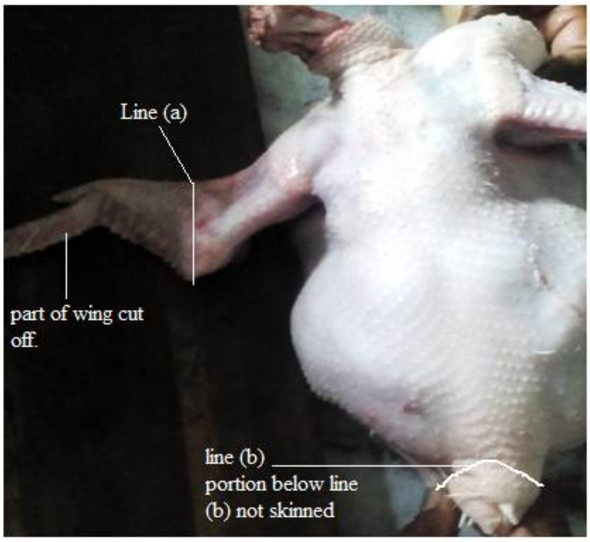


Figure 3: Line (a) along which wings were cut off. Portion below line (b) not included in the skin

2.9. Terminal procedures

On the 50th day all birds were weighed and decapitated, defeathered and eviscerated. The carcass mass of each bird was recorded. Each bird was sealed in labeled plastic bag and chilled overnight. Scapel blades were used for skinning the chilled birds. During skinning, each chilled bird was placed with its breast on a table. The wings were pulled away from the body and cut along line (a) as shown in Figure 3, in such a manner that the angle between the ulna and radius were equally divided. After cutting off of the wings the carcass were turned breast side up. Skin incision were made along the middle of the breastbone crest to the neck, along the wings and then along the legs. The incisions allowed easy pulling off of the skin.

2.10. Determination of lean tissue and fat tissue values

The broiler birds were first weighed at the age of seven days and then at a seven-day interval using an electronic balance (Model 2034986 V3. 47). The carcass mass (X1) and skin mass (X2) were measured. The X1 and X2 served as independent measurable traits that were used to calculate lean tissue mass ($\hat{Y}$) and fat ($\hat{U}$) tissue mass using Bochno regression Equations (6) and (7) shown below:

Bochno Equations (Bochno *et al*., 2005-2007)

$$\hat{Y} = 0.7672 * X1 + 10.4 \text{ (g)} \quad ...(6)$$

$$\hat{U} = 1.1158 * X2 + 6.7 \text{ (g)} \quad ...(7)$$

2.11. Statistical analysis

Data was analyzed using a two-tailed *t*-test method. The statistical analysis was carried manually since the results were not compatible with Graph Pad Prism 4 software. The results were analyzed at statistical significance level of 5.0% ($p = 0.05$).

3. Results and discussion

3.1. Nutritional composition of finger millet meal and maize meal

Results of the moisture content, crude protein, crude fat, ash content and crude fiber of maize meal and finger millet meal from proximate nutrient analysis are shown in Table 1. The results showed that maize meal and finger millet meal had different nutrient compositions. The maize meal and finger millet meal showed a moisture content difference of 0.21%. The low levels of moisture of both maize meal and finger millet meal were a preservation measure to prevent their biodegradation. Maize meal had 1.95% more crude protein and 3.04% more crude fat than finger millet meal. There was 2.97% more ash and 2.24% more crude fiber in finger millet meal than in maize meal. The finger millet meal had 198.20 mg / 100 g more calcium and 6.11 mg / 100 g more iron than maize meal while maize meal had 28.22 mg / 100 g more phosphorus than finger millet. The finger millet meal analysis results differed from the values given for The nutritional value of foods in Zimbabwe

Table 1: Nutritional composition of finger millet meal and maize meal

Parameter	Finger millet meal	Maize meal
Moisture content (%)	8.92 ± 0.02	8.71 ± 0.02
Ash (%)	4.28 ± 0.03	1.31 ± 0.01
Crude protein (%)	7.45 ± 0.03	9.40 ± 0.14
Crude fat (%)	1.62 ± 0.01	4.66 ± 0.03
Crude fiber (%)	3.98 ± 0.07	1.65 ± 0.01
Iron (mg/100 g)	8.77 ± 0.02	2.66 ± 0.03
Calcium (mg/100 g)	208.03 ± 0.04	9.18 ± 0.01
Phosphorous (mg/100 g)	184.18 ± 0.04	212.42 ± 0.03

Note: mg- milligrams

(Krishnan *et al*., 2010). The environmental conditions under which the cereal was grown such as temperature, soils and rainfall together with the varying species of the cereal are possible contributors to the noted variations. The higher ash content present in finger millet meal was an indication that it contained a higher mineral content than maize meal (Singh and Srivastava, 2006).

3.2. Nutrition composition of formulated broiler feeds

The analyzed nutritional composition of the formulated finger millet starter, finger millet finisher, maize starter and maize finisher feeds are shown on Table 2. The feeds constituents varied between finger millet and maize feeds, and between starter and finisher feeds. The starter feeds were formulated to have 24% crude protein while the finisher feeds were to have 20% crude protein. The maize meal and finger millet meal crude protein values that were used for feed formulation were based on the results from the feed ingredients proximate nutrient analysis conducted at SIRDC. The soya meal supplier's labeled crude protein value of 41.00% was used in feed formulation without verification. The starter feeds had higher protein content than finisher feeds since broiler chickens require more protein in the first 21 days of their age to achieve maximum growth performance (Leeson and Summers, 2009). The crude protein analysis results had slightly more crude protein than formulation values. The difference could have emanated from systematic and random experimental errors during feed mixing and nutrient analysis. There was 0.01% more crude protein in maize starter feed than finger millet starter feed. The finger millet finisher feed had 0.01% more crude protein than maize finisher.

The feeds had a mean moisture content of 7.90%. The low moisture content was a preservative measure to prevent fungal and bacterial feed decomposition. There was more ash in finger millet feeds than maize feeds. The higher ash content in finger millet feed could have stemmed from high ash content value of finger millet shown on Table 1. The finger millet starter feed had 2.23% more ash than maize starter. There was 2.67% more ash in finger millet finisher than in maize finisher. The amount of ash in a feed is a measure of the quantity of minerals present (Nielsen, 2003).

The amount of crude fiber varied from feed to feed. The finger millet feed had more crude fiber than maize feed. There was 1.33% more fiber in finger millet starter than maize starter and 1.00% more fiber in finger millet finisher than in maize finisher. The higher crude fiber contents in finger millet feeds is attributed to higher values of fiber in finger millet meal when compared to maize meal as shown on Table 1.

The maize feed contained more crude fat than finger millet feed. There was 2.69% more fat in maize starter than finger millet starter. The maize finisher contained 3.14% more fat than finger millet finisher. The difference in fat levels in feeds could have resulted from the different fat values in maize and finger millet as shown on Table 1 as well as from the different quantities of maize meal and finger millet meal that were used in feed formulation. A feed source with high fat content produces a feed with a high fat content. Reviewed literature has shown that a high fat content feed supplies more calories and has the potential to increase fat deposition in broilers (Wang *et al*., 2014)

The feeds were analyzed for calcium, iron and phosphorous and the minerals varied in the feeds. Calcium quantities were the most abundant in feeds and iron was the least mineral present. There were 2.41 mg/100 g iron, 192.22 mg/100 g phosphorous and 683.47 mg/100 g calcium more in finger millet starter than in maize starter. The finger millet finisher contained 1.84 mg / 100 g more calcium and 16.61 mg / 100 g more iron than maize finisher. The maize finisher contained 40.23% more phosphorous than finger millet finisher.

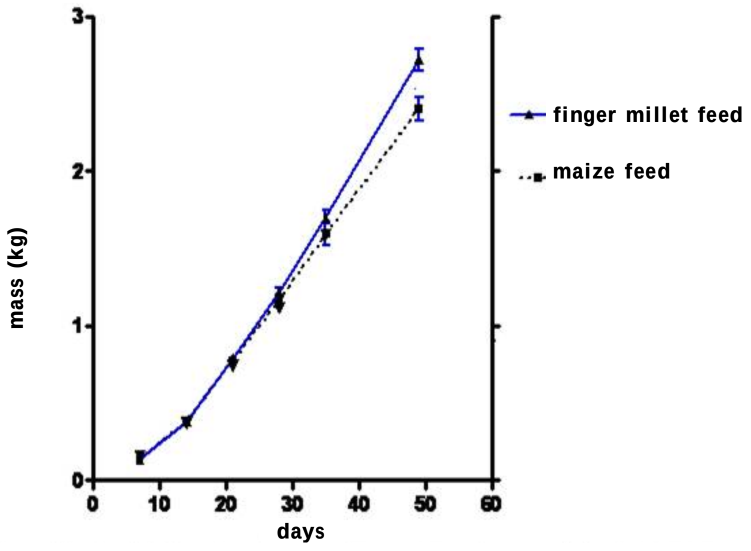
3.3. Mass –time curves of broilers fed on formulated feeds

Figure 4 shows the weekly gain in mass of broilers fed on formulated feeds during the rearing period of 49 days. The growth curves were drawn using Graph Pad Prism 4 software. The gain in mass was used as a measure of the growth rate. The growth rates of broilers fed on maize feed and finger millet feed were slow and even during the first 21 days. A significant difference in growth rates emerged after 21 days and it continued up to slaughter age. After the age of 21 days broilers fed on finger millet were growing faster than those fed on maize feed. At the age of slaughter broilers fed on finger millet feed had a mean mass of 0.34 kg more than their counterparts fed on maize feed. The finger millet feed significantly improved growth performance of broilers (t_c = 3.46, P_t = 1.31, p = 0.05). The enhanced growth performance was as a result of higher quantities of phosphorous, iron and crude fiber present in finger millet feed as shown on Table 2.

Table 2: Nutritional composition of formulated feeds

Parameter	Finger millet feed starter	Finger millet feed finisher	Maize feed starter	Maize feed finisher
Moisture content (%)	7.67 ± 0.09	8.06 ± 0.03	7.72 ± 0.01	8.15 ± 0.03
Crude protein (%)	24.28 ± 0.02	20.18 ± 0.02	24.29 ± 0.02	20.17 ± 0.06
Crude fat (%)	1.52 ± 0.04	2.24 ± 0.03	4.21 ± 0.03	5.38 ± 0.04
Ash (%)	8.42 ± 0.01	7.02 ± 0.02	6.29 ± 0.01	4.35 ± 0.04
Crude fiber (%)	4.32 ± 0.02	3.92 ± 0.04	2.99 ± 0.04	2.92 ± 0.01
Calcium (mg/100g)	1356.80 ± 0.18	673.33 ± 0.06	454.65 ± 0.04	452.81 ± 0.03
Iron (mg/100g)	32.66 ± 0.06	35.07 ± 0.04	28.48 ± 0.06	11.87 ± 0.02
Phosphorous (mg/100g)	378.69 ± 0.04	186.37 ± 0.03	299.52 ± 0.03	312.02 ± 0.04

Note: mg – milligrams

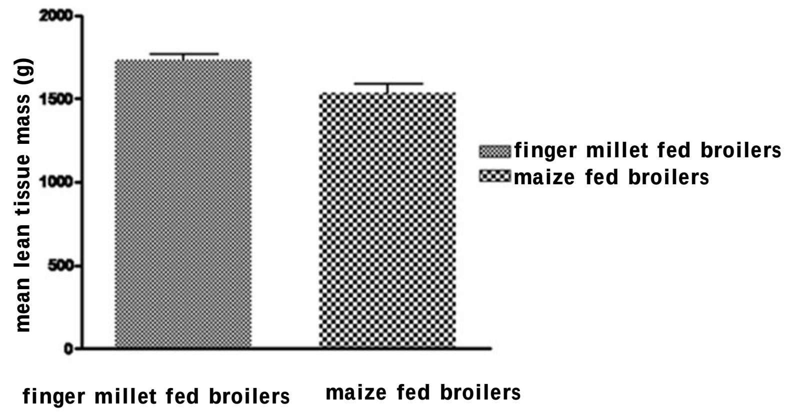


Finger millet feed significantly affected broiler growth performance (t_c (=3.46) > P_t (= 1.31), P = 0.05)

Figure 4: Mass – time curves of broilers fed on finger millet feed and maize feed

3.4. Mass of lean tissue of broilers fed on finger millet feed and maize feed at slaughter point (49 days)

Figure 5 shows the results of the mean lean tissue masses of broilers fed on finger millet feed and maize feed at the age of 49 days. Broilers fed on finger millet had a mean lean tissue mass of 204.19 g more than broilers fed on maize feed. The increase in lean tissue mass was attributed to higher levels of phosphorous and iron in finger millet feed that were required in protein synthesis and production of ATP energy molecule for releasing energy for cell metabolism. The finger millet fed had also low fat content that reduced fat absorption and deposition (Xie *et al*., 2010; and Fouad and El-Senousey, 2014).

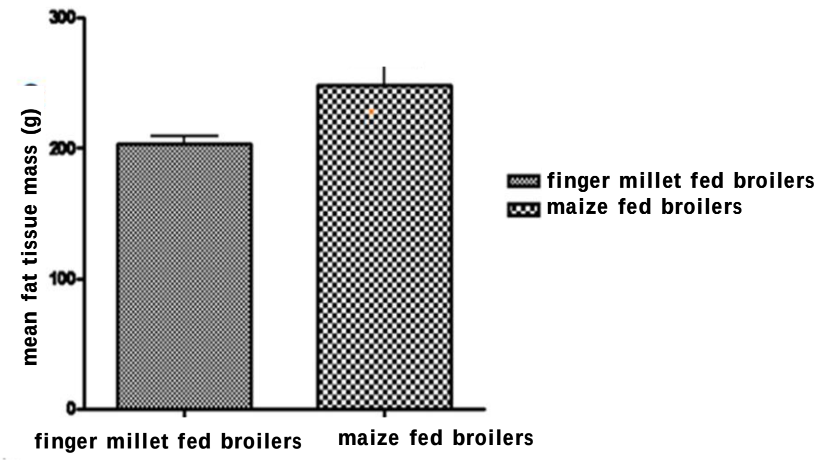


Finger millet feed significantly affected broiler growth performance (t_c (=3.63) > P_t ($\leq$ 1.75), P = 0.05)

Figure 5: Mass of lean tissue of broilers fed on finger millet and maize feeds at 49 days

3.5. Mass of fat tissue of broilers fed on finger millet feed and maize feed at slaughter point

Figure 6 shows masses of broilers fed on finger millet and maize feeds. Broilers fed on maize feed had a mean fat mass of 44.95 g more than their counterparts fed on finger millet feed. It has been reported in literature that feeding broilers with a diet low crude fat level inhibits fat absorption and causes fat deposition reduction in broilers. A low level dietary fat causes a decrease in the activity of enzyme linked to lipogenesis, a process that causes fat tissue production (Xie *et al*., 2010; and Fouad and El-Senousey, 2014). This study showed that the finger millet feed due to its low fat content increased lean tissue development in broilers and reduced fat deposition.



Statistically finger millet feed did not affect fat deposition in broilers (t_c = 2.61) < P_t (= 6.31), P = 0.05)

Figure 6: Mass of fat of broilers fed finger millet and maize feeds at 49 days

4. Conclusion

We conclude that finger millet can be used to replace maize meal in the formulation of broiler feed and has the potential to support growth of broilers and produce leaner meat which is favored by many health conscious consumers nowadays.

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Conflicts of interest

The authors declare that they have no conflict of interest.

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