THE EFFECT OF LOW TANNIN SORGHUM (TEGEMEO VARIETY) AS A REPLACEMENT OF MAIZE IN BROILER DIETS.

BY

ZAKAYO GRIFFIN GILBERT ALLEN

DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE

REQUIREMENT FOR THE DEGREE OF MASTERS OF SCIENCE (AGRICULTURE)

OF SOKOINE UNIVERSITY OF AGRICULTURE.

1994

ABSTRACT

A study was carried out to investigate the possibility of replacing maize with low tannin sorghum (Tegemeo variety) as an energy source in broiler diets. Three hundred and twenty, week old broiler chicks were fed on four diets in which maize was replaced by sorghum at 0, 33.3, 66.7 and 100% levels, for dietary treatment A, B, C and D, respectively. The control diet contained maize as the only cereal grain.

Twenty birds per group were randomly assigned to the four dietary treatments. Liveweight, daily gain, cumulative feed intake and feed gain ratio(FGR) were measured weekly. At eight weeks of age, sixteen birds from each treatment were picked at random and slaughtered for the analyses of their carcass characteristics. Dressing percentage, gizzard, heart, liver and abdominal fat as proportions of carcass weight were determined. At six weeks of age, sixteen male birds were used in the balance trial to determine the metabolizable energy.

Mean proximate composition of low tannin sorghum for crude protein, crude fibre, ether extract, nitrogen - free extracts and ash was 12.1, 5.4, 3.0, 65.3 and 1.6%, respectively. Calcium and phosphorus content were 0.03

and 0.2%, respectively.

Liveweight gains, feed gain ratio and dressing percentage were not significantly affected by the dietary treatments. Substitution of sorghum for maize significantly decreased the proportionate weights of internal organs. Proportionate weights of liver and abdominal fat increased with increasing level of sorghum in the diets, whereas that of gizzard and heart decreased.

Mean metabolizable energy values not corrected for nitrogen retention were 9.6, 10.9, 8.9 and 8.0 MJ/kgDM, whereas the mean nitrogen - corrected metabolizable energy values were 8.8, 10.0, 8.1 and 7.1 MJ/kgDM, for diet A, B, C and D, respectively. Mean true metabolizable energy values were 9.6, 11.0, 8.9 and 7.8 MJ/kgDM, respectively.

From these findings it can be seen that, low tannin sorghum (Tegemeo variety) can entirely replace maize in the broiler diets, without causing any adverse effects on performance.

DECLARATION

I, ZAKAYO GRIFFIN GILBERT ALLEN do hereby declare to the senate of Sokoine University of Agriculture that this dissertation has not been submitted for a degree award in any other University.

Signature:........................

Date: 29/03/1996

COPYRIGHT

ACKNOWLEDGEMENTS.

I would like to acknowledge the Norwegian Agency for International Development (NORAD) for financing this research work.

I owe a great deal of thanks to my supervisors Dr Mutayoba, S.K (Mrs) and Professor Lekule, F.P for their tireless assistance, guidance and constructive criticisms extended to me up to the end of this work.

Special thanks are due to Dr Katule, A. for his assistance in data analyses. The help extended to me by Mr Mndolwa, R; Mr Moses, A. and other workers in the department of animal science and production (DASP), poultry unit during data collection is highly appreciated. Workers in the DASP Nutrition laboratory, Mr Mufui, G., Mr Mnyipembe, F.M., Mrs Mbwana, M. and others are also acknowledged for their assistance in analyses of the feedstuffs and diets.

My heartiest thanks and appreciation are to my wife Mrs Eunice Matari Zakayo, for her patience, encouragement and to the great task she took in taking care of our daughters and to my daughters Veronica and Elice for their patience during my study. My thanks are due to my late father, mother, sisters, brother and relatives for their moral support throughout the study period.

Lastly, I am grateful to my fellow students and all the members of staff at DASP - Sokoine University of Agriculture who in one way or another contributed towards the completion of this work.

DEDICATION.

To my daughters Veronica Winnie and Elice Usu

and my father and mother.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

1.0 INTRODUCTION.

In developing countries, there is competition between human population and livestock in the use of agricultural land so that the use of grain as animal feed when human requirements are not fully met is difficult to justify. Consequently, only small amounts of grains are used for animal feeding. Furthermore, in most of these countries, there is still no distinction between food and feed grains, both being consumed as feed when necessity demands (Dale, 1979).

In Tanzania, maize form the major portion of the monogastric feeds although its production is not high enough to meet both human and animal requirements. Bhargava (1974) reported that about 80% of total maize produced is consumed on farm as human food and only 20% is marketed in urban areas. However, according to Food security unit (FSU) during 1992/93 Tanzania expected food deficit of 270,000 tonnes of maize, 137,000 tonnes of rice and 75,000 tonnes of wheat which was to be imported (MALD, 1992). Consequently the low production of maize affects feed availability to pigs and poultry, leading to high prices of their products.

In Tanzania, the average per capita intake of protein of animal origin per person per day in 1988 was 7g. This constituted only 64% of the recommended level (FAO, 1984). The intake of animal protein increased marginally to 9g per day by 1990. This value was still lower than the level of 21g which was recommended by FAO in 1990. This means that for the 1990 recommended level to be achieved effort must be towards increasing the productivity of animal protein sources in Tanzania.

Poultry production, among other animal species stands a better chance in contributing to animal protein supply. This is because chickens have high fecundity, early maturity, short generation interval, and small space requirement. In Tanzania poultry production has not been fully exploited, one of the reasons being poor quality and inadequate supply of feeds for poultry (Mchechu, 1983). The situation is made worse by the dependency on cereal grain, in particular maize as the chief source of energy. Since energy constitute the largest component of poultry diet, it is therefore important to look for a cereal grain that ranks low in competition between human and poultry.

Sorghum could suitably be used as a substitute for maize due to its agronomic and nutritional properties. It is considered as a drought tolerant crop and adapted to a wide range of ecological conditions which are unfavourable to other cereals (Acland, 1979). Wall and Ross (1970) reported that feeding value of sorghum grain is estimated to be approximately 92% that of corn.

In Tanzania, sorghum can be grown in all regions, but most commonly in areas with marginal rainfall such as Dodoma, Singida, Tabora and some parts of Shinyanga, Morogoro, Mwanza and Mara regions. According to FAO (1979) next to maize, sorghum is the second important cereal grain produced in Tanzania.

The problem of sorghum utilization in poultry industry is the presence of tannin. Some sorghum varieties have high tannin content and others have low tannin content. Those with tannin content about 1% catechin equivalent are referred to as high tannin sorghum varieties (Radhakrishnan and Swaprasad, 1980) and those with less than 0.3% catechin equivalent are referred to as low tannin sorghum varieties (Banda-Nyirenda and Vohra, 1990). Tannins are water soluble polyphenolic compounds which bind to the sorghum proteins and reduce dry matter and protein digestibility and hence depress growth of poultry and other animals (Mayer and Gorbet, 1985).

Studies have shown that the nutritional status of high tannin sorghum could be improved by reducing the tannin content level in the grain sorghum (Price et al. 1977). Following this, several methods have been employed including: dehulling (Reichert and Youngs, 1977), use of inexpensive chemicals such as Magadi Soda (Muindi and Thomke, 1983; Mutayoba, 1985), cooking, soaking and anaerobic storage of moistened grain (Mitaru et al. 1983) and germination (Shem et al. 1990).

Nonetheless, all these methods with exception of dehulling, involve wetting the grain. These methods are difficult to apply in developing countries because of the problems associated with the control of microbiological growth, expenses involved in redrying and uncontrolled loss of nutrients during drying.

Abrasive dehulling of sorghum grain removes the outer layer (pericarp) of the seed, thereby reducing the fibre and tannin content and improving the appearance, cooking quality, functional properties, palatability and digestibility of the grain (Reichert and Youngs, 1977). The process reduces the tannin content by up to 98% (Chibber et al. 1978).

Despite the above mentioned advantages, dehulling removes protein up to 45% and also is associated with some loss of nutrients found in the outer layer of the grain (Reichert and Youngs, 1977).

In view of the above mentioned problems, it is therefore important to look for the possibility of using sorghum varieties with low tannin content. Therefore the objectives of this study were:

a. To evaluate the nutritive value of low tannin sorghum (Tegemeo variety) compared to maize.

b. To evaluate the possibility of replacing maize by low tannin sorghum (Tegemeo variety) in broiler diets.

c. To evaluate the effect of level of low tannin sorghum (Tegemeo variety) in the diet on feed intake, growth rate, feed utilization efficiency and carcass characteristics of broiler chickens.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Sorghum grain.

Sorghum grain is of African origin. It was first domesticated in Ethiopia by people of Caucasoid origin. It came to East Africa in about the 12th century A.D as a result of migration of the Caucasoid people who came to settle in the altitude areas of East Africa (Doggett, 1970).

Sorghum is drought resistant and is adaptable to a wide range of ecological conditions which are unfavourable to other cereals. It grows successfully even in the areas where average rainfall is as low as 300 to 400mm and between 900 - 1500m above sea level, although in some cases different varieties are adapted to different altitudes (Acland, 1970). Sorghum tolerates medium to high pH conditions in the soils (Ross and Webster, 1970), and usually does well in areas where wheat, rice, and maize cannot thrive (Doggett, 1970). Streeter et al. (1993) reported that sorghum is the third most prevalent grain produced in the world.

Sorghum is grown in a wide diversity of cropping patterns including monocropping, intercropping with legumes, oil seeds and other cereals, and in many rotational sequences (IDRC, 1977).

2.2 Sorghum production in Tanzania.

In Tanzania, sorghum is grown in marginal (low rainfall) areas like Dodoma, Tabora, Morogoro, and Arusha regions and in other dry parts of southern Tanzania (Fig 1) (Matemu, 1987). There are about nine cultivated varieties of sorghum grown in Tanzania (Doggett, 1970), giving a wide choice for selection of variety suited to different regions of the country. The varieties include: Dobs bora, Lulu tall, Lulu dwarf, Sandala, Serena, Imani, Tegemeo and two local varieties. Table 1 shows the area (hectare), production (tonnes) and yield per hectare of sorghum and maize in Tanzania between 1981 - 1988.

Doggett (1970) observed that good quality, and palatable types of sorghum were planted only in areas where birds were scarce, as in the southern provinces of Tanzania towards the coast which lies outside the Quelea zone. In these regions the grain ripens while the birds are away nesting.

Utilization of sorghum in Tanzania is far below the level of its production. Significant quantities of sorghum are utilized for subsistence consumption in the form of soft porridge, hard porridge and for traditional beer making in rural areas where its production is predominant. However, this crop has failed to gain popularity amongst the urban consumers and has not been utilised significantly in the supply of raw materials for animal production (Runyoro, 1988).

Increased utilisation of sorghum in commercial animal feed production could reduce the existing competition for maize as the source of raw materials and human food.

2.3 Nutritive value of sorghum.

The protein in sorghum like other cereal grains is composed of albumins, globulins, prolamines and glutamines. These four classes of protein are distinguishable in all cereal grains on their solubility in water (albumins), salt solution (globulins), alcohol (prolamines), and alkaline detergents (glutamines) (Jambunathan and Mertz, 1973). Sorghum proteins serve as enzyme, structural and storage components (Rooney et al. 1972).

The highest concentration of protein in the sorghum kernel are located in the germ, followed by the endosperm and then the bran (Hubbard et al. 1950).

Figure 1: A map of Tanzania showing sorghum growing areas: (S=Sorghum)

Source: Matemu. (1987)

Table 1: Area, production and yield per hectare of sorghum and maize in Tanzania.

	Crop					
	Sorghum			Maize		
Year	A	P	Y	A	P	Y
1981/1982	315.92	233.41	740	1293.87	1401.97	1080
1982/1983	372.89	253.64	680	1231.55	1739.89	1410
1983/1984	476.22	301.18	630	1279.62	1711.71	1340
1984/1985	459.80	441.93	960	1411.83	2012.98	1428
1985/1986	445.88	383.64	860	1576.28	2670.77	1690
986/1987	416.38	367.30	860	1326.46	2787.33	1710
1987/1988	492.73	423.51	860	1675.15	2429.33	1450

A = Area -Thousand hectares

P = Production - Thousand metric tons

Y = Yield per hectare -Kgs

Source: 1981/1988: Basic Data Agriculture and Livestock Sector, Planning and Marketing Division, MALD 1988.

Proteins in sorghum grain are deficient in lysine and other essential amino acids such as methionine and threonine and these need to be supplemented from other sources (Guiragossian et al. 1978; Eggum et al. 1981).

Mukuru (1974) reported that the chemical composition, physical properties, endosperm texture and type of grain sorghum differ considerably. There is also a tremendous variation in colour and taste of food products made from grain sorghum. White sorghum grains are low in tannin content and are normally sweet and palatable whereas red sorghum grains are of bitter taste and have high tannin content.

Shepherd et al. (1971) reported the proximate composition, protein (Kjeldah, N X 6.25), crude fat (petroleum ether extract), crude fibre and ash of sixty one varieties of sorghum grown in East Africa. The ranges were:

Crude protein(%)	8.9 - 16.6
Crude fat(%)	2.5 - 5.1
Crude fibre(%)	1.3 - 3.5
Ash(%)	1.1 - 2.7

Reed (1988) conducted a study on the phenolics, fibre and fibre digestibility in high tannin sorghum and low tannin sorghum grain. He observed that high tannin sorghum varieties had higher acid detergent fibre, lignin, soluble and insoluble procyanidins, soluble phenolics, soluble red pigments and neutral detergent fibre than the low tannin sorghum varieties.

Nwokolo (1988) analyzed proximate constituents, fatty acids, minerals, amino acids and their availability in some tropical grains (sorghum and bulrush millet) and oil seeds (sesame and oil beans). Phosphorus content was found to be high in both grains and oil seeds whereas calcium, sulphur containing amino acids and lysine were found to be low in sorghum grain. Sorghum and millet were similar in the proximate constituents, but their amino acids availability was lower than that of sesame seed and oil bean seeds.

Metayer et al. (1993) studied the variability in French cereals. They determined physical characteristics, chemical composition and poultry metabolisable energy. They observed that maize composition was on average 73.6 ± 0.7%, 9.9 ± 0.4% and 15.7 ± 0.1 MJ/kg for starch, crude protein and metabolizable energy, respectively. For sorghum (Tannin free varieties), starch, crude protein content and metabolizable energy were found to be 73.0 ± 1.1%, 12.5 ± 0.7% and 16.1 ± 0.1 MJ/kg, respectively. For the other parameters the findings are as shown in Table 2 and 3.

Douglas et al. (1990) observed that ether extract content of yellow corn was 1 to 2% higher than that found in sorghum grain. Ash, calcium, phosphorus and neutral detergent fibre levels showed minor differences between the two grains. Sorghum grain contained higher levels of acid detergent fibre than did yellow corn. The metabolizable energy content of the low tannin sorghum was found to be similar to that of yellow corn.

Deyoe et al. (1970) observed little difference in crude protein content of mature and immature grain sorghum. As the grain matured, lysine and tryptophan contents decreased. Leucine and methionine increased from the early milky to the mid milky stage and at maturity it was intermediate between the early milky and the mid milky levels.

2.4 Sorghum feeding in animals.

Sorghum grain is one of the major cereal grains used in diets of poultry and swine (Waggle et al. 1967; Madacsi et al. 1988). Mohamed and Ali (1988) reported that

Table 2 : Characteristics of maize

	N	Mean	SD	Min	Max
Starch (%DM)	115.0	74.1	0.8	72.4	75.9
Crude protein (%DM)	115.0	10.0	0.5	9.0	11.9
Ether extract (%DM)	115.0	4.4	0.3	3.7	5.2
Crude fibre (%DM)	115.0	2.4	0.2	2.1	2.8
Gross energy (MJ/kg)	40.0	18.7	0.1	18.5	19.0
Poultry ME, (MJ/kgDM)	40.0	15.6	0.1	15.3	16.0

SD = Standard deviation

N = Number of samples

Min = Minimum

Max = Maximum

Source: Metayer et al. (1993)

Table 3 : Characteristics of sorghum

	N	Mean	SD	Min	Max
Starch (%DM)	10.0	73.0	1.1	70.6	74.3
Crude protein (%DM)	10.0	12.5	0.7	11.5	13.7
Ether extract (%DM)	10.0	3.8	0.1	3.6	3.9
Crude fibre (%DM)	10.0	2.2	0.1	1.9	2.4
Tannin (DM%)	68.0	0.1	0.03	0.02	0.4
Cell wall (%DM)	10.0	9.7	0.8	8.2	10.7
Sugar (%DM)	10.0	0.9	0.1	0.7	1.1
Gross energy, (MJ/kgDM)	10.0	18.9	0.1	18.8	19.0
Poultry ME, (MJ/kgDM)	10.0	16.1	0.1	15.8	16.3

SD = Standard deviation

N = Number of samples

Min = Minimum

Max = Maximum

Source: Metayer et al. (1993)

sorghum is regularly used in some parts of the world to furnish a large proportion of energy and protein requirements of human beings and livestock.

2.4.1 Tannin in sorghum.

The presence in some cultivars of significant levels of polyphenols or tannin (Mayer and Gorbert, 1985) is the limiting factor of sorghum utilization by monogastric. All sorghum cultivars contain phenols which affect the colour, appearance and nutritional quality of the grain sorghum and its products. The phenolic compounds can be divided into phenolic acid, flavonoids and tannin (Hahn et al. 1984).

Tannins are water soluble polyphenols having molecular weights between 500 and 3000 and have the ability to bind to protein (Hahn et al. 1984). They are classified into two distinct groups, hydrolysable and condensed tannin on the basis of their structure (Sarkar and Howarth, 1976; Hahn et al. 1984). These two groups can be distinguished by their chemical structure and reactivity with hydrolysable agents (Hahn et al. 1984)

2.4.1.1 Hydrolysable tannin.

These are esters of sugars and phenolic acids or their derivatives. The sugar is usually glucose, but in some cases polysaccharides have been identified. Hydrolysable tannins are readily hydrolysed by acid, alkali or some hydrolytic enzymes (tannase) into a carbohydrate (usually glucose) and phenolic carboxylic acid (Ribereau-Gayon, 1972).

2.4.1.2 Condensed tannin.

These have no carbohydrate core in their structure and are usually derived by condensation of flavonoid precursors. These are not readily degraded by acids or alkalis but polymerised to form amorphous phobaphenes or tannin reds (Jambunathan and Mertz, 1973). Condensed tannins are mainly found in brown sorghum (Strumeyer and Malin, 1975; Hahn et al. 1984).

Tannin occur mainly on the pericarp or testa. The presence of tannin in sorghum cultivars apart from being bird resistant, gives the grain other agronomic advantages such as resistance to fungal and bacterial attacks and pre-harvest germination (Shayo, 1988)

Sorghum varieties containing about 1% catechin equivalent are designated as high tannin sorghum varieties (Radhakrishnan and Swaprasad, 1980; Muindi and Thomke, 1981; Banda-Nyirenda and Vohra, 1990) and those with less than 0.3% catechin equivalent are referred to as low tannin sorghum varieties.

2.4.2 Limitations of using HTS in feeding of animals.

The increasing concern over the nutritionally harmful effects of tannin in sorghum is creating strong pressure for the sorghum industry to provide grain of low tannin content (Price and Butler, 1977).

Nutritionally high tannin sorghum is inferior when compared to the low tannin sorghum of similar composition. Studies have shown that high tannin sorghum grains are associated with low digestibility, reduced protein utilization, low feed efficiency, low weight gain per unit intake, low egg production and leg abnormalities (Rogler and Sell, 1984; Cao et al. 1985; Halley et al. 1987; Elkin et al. 1990).

Utilization of diets containing high tannin sorghum result in low growth rate in chicks (Chang and Fuller, 1964; Vohra et al. 1966) and rats (Jambunathan and Mertz, 1973). The depression in overall performance in chicks is observed when dietary level of tannin exceeds 0.6% (Armstrong et al. 1974). High tannin sorghum has also been associated with incidence of oesophageal cancer in humans (Maxson and Rooney, 1972).

Ducks fed on high tannin sorghum based diets, exhibited reduced weight gain and feed efficiency values compared to ducks on low tannin sorghum based diets. However, the difference in growth between ducks fed high tannin sorghum based diets and low tannin sorghum based diets was lower than that observed in chicks fed identical diets (17% versus 33%, respectively) (Elkin et al. 1991). It was speculated by Elkin et al. (1991) that, ducks might be less affected by dietary tannin when compared to chickens, possibly due to the fact that the pH of the digestive tract contents of the ducks was slightly more alkaline than that of chickens, thus making ducks less susceptible to the effect of tannin compared to chickens.

Tannins in sorghum are also associated with reduced digestibility and/ or increased excretion of endogenous nitrogen and energy because of its ability to conjugate with digestive enzyme proteins (Deiber, 1975; Hagerman and Butler, 1980; and Oh et al. 1980). Thakur et al. (1985) reported that egg weight and pigmentation were adversely affected when high tannin sorghum based diets were fed to laying hens.

Banda-Nyirenda and Vohra (1990) reported that body weights of chickens fed diets containing high tannin sorghum were significantly lower than those of chickens fed diets containing corn. Studies in rats have shown that consumption of high tannin sorghum based diets may result in lower mineral concentrations in the bone (Ali and Harland, 1991). Additionally, weight gains and feeding efficiency were lower in rats fed high tannin sorghum based diets compared to rats fed low tannin sorghum based diets. Increased weight gain observed when small amounts of soyabean meal were added to grain sorghum based diets was probably due to the increase in protein availability (Schaffert et al. 1974).

2.4.3 Methods of reducing tannin content in HTS.

Nutritional value of sorghum containing tannin may be improved by treatment with polyethyleneglycol (Ford and Hewitt, 1977; Savage et al. 1980), Magadi soda ($Na_2Co_3.NaHCo_3.H_2O$) solution (Muindi and Thomke, 1983; Mutayoba, 1985), germination (Reichert et al. 1980; Chavan et al. 1981; Shem et al. 1990), high moisture reconstitution (Mitaru et al. 1983; Teeter et al. 1986; Elkin et al. 1990), or by supplementing diets with orthophosphoric acid , dicalcium phosphate or amino acids (Azcona and Bonino, 1988; Ibrahim et al. 1988; Smith and Waldroup, 1988; Banda-Nyirenda and Vohra, 1990).

Any treatment that involves ensiling, soaking or sprouting of sorghum has a limitation because of a need to dry the grain before it is fed to chicken and other animals. This implies an additional expenditure in terms of fuel which is costly. The most practical method is to supplement the diet with some relatively inexpensive and easily available chemical belonging to the category GRAS (generally recognised as safe)(Banda-Nyirenda and Vohra, 1990).

Banda-Nyirenda and Vohra (1990) comfirmed the observations of Muindi et al. (1981) that antinutritive properties of tannin-containing sorghums are overcome by treatment with $NaHCO_3$. However, Muindi et al. (1981) detoxified sorghum grain by soaking it in $NaHCO_3$ for three days. Banda-Nyirenda and Vohra (1990), suggested that supplementation of the diets containing high tannin sorghum with $NaHCO_3$ is much simpler than soaking the grain in $NaHCO_3$.

Processing of the grain sorghum by pelleting has also been reported to detoxify the tannin content of the sorghum grain (Madacsi et al. 1988; Elkin et al. 1991)

2.5 Replacement studies.

A number of studies have shown that maize can entirely be replaced by low tannin sorghum in broiler rations (Rogler and Sell, 1984; Cao et al. 1985; Blaha et al. 1985; Kim et al. 1986; Lucbert and Castaig, 1988). But in some other studies it has been reported that low tannin sorghum could only replace up to 50% of maize in broiler diets (Thakur et al. 1985; Rostagno, 1988; Gaffar et al. 1990).

Thakur et al. (1984) observed that low tannin sorghum could replace 50% of dietary maize without affecting the weight gain of the broilers. However, the intensity of leg colour decreased with increase in the level of replacement of maize. Contrary to this Rostagno (1988) used sorghum in the diets of poultry and pigs and concluded that low tannin sorghum could completely replace maize in pigs and up to 50% in poultry diets, whereas high tannin sorghum could replace up to 50% and 25% of maize in pigs and poultry, respectively. Chickens fed diets containing low tannin sorghum had higher weight gains than those fed diets containing maize, but feed conversion was better with maize diets. Health of chickens and carcass characteristics were not affected in chickens given low tannin sorghum but had pale skin, legs and beaks.

Elzubeir and Jubaral (1993) observed that 2% of the birds fed on diets in which low tannin sorghum had replaced maize at 100% level, showed leg abnormalities and abdominal fat reduction. The latter was attributed to the dilution of the feed with dietary fibre, which also reduced liveweight gain.

Gaffar et al. (1990) replaced maize with sorghum in broiler diets at the rate of 0, 50, 75, and 100%. They observed that broilers fed on a diet containing 50% maize and 50% sorghum gained significantly more and consumed more feed than broilers fed other diets. Feed conversion and protein efficiency ratio in broilers fed 50% sorghum diets were comparable to the maize control diets.

However, their findings were slightly different from those of Syed Ali and Yeong (1977) who showed that low tannin sorghum could replace up to 60% of maize in broiler diets and 75% in layer diets. Despite good growth rate, paler egg yolk colour and shank colour were observed in chickens fed low tannin sorghum based diets, probably due to the low xanthophyll pigment in low tannin sorghum grain. Bornstein and Bartov (1967), reported that, this could greatly affect the acceptability of broiler meat in some parts of the world thus limiting the use of sorghum grain in finishing diets.

Azcona and Bonino (1988) reported that although low tannin sorghum grains could considerably replace maize in poultry diets, ingredients containing pigments should be added where good pigmentation of skin and egg-yolk is required. Furthermore, they observed that sorghum grain containing more than 1% tannin could replace maize completely in the diet of pullets 6 - 20 weeks old and about 50% of maize in the diet of laying hens provided supplementary proteins and methionine were added.

The need for protein and methionine supplementation was also noted in broilers fed high tannin sorghum based diets (Azcona and Bonino, 1988). Furthermore, supplementation of methionine and choline in high tannin sorghum based diets was shown to alleviate the depressing effect of tannin, consequently resulting into improved performance of broilers (Chang and Fuller 1964; Armstrong et al. 1973). However, on the contrary Glick and Joslyn (1970) reported that supplementation with choline or methionine had no effect, but supplementation with casein improved growth when rats were fed diets with tannic acid.

Adding sorghum grain to broiler diets significantly increased feed intake, probably due to the low energy density of the sorghum grain as compared to maize (Kim et al. 1986). Castro et al. (1985) observed no differences among groups in laying percentage, mean weight of eggs or feed intake [kg/ egg production (g)] when maize was replaced by low tannin sorghum in the diet of laying hens.

2.6 Metabolic studies.

Studies to compare the apparent digestibilities of amino acids, gross energy and starch in corn, sorghum, wheat, barley, oat groats and wheat middlings for growing pigs (Lin et al. 1987) showed that gross energy digestibility for corn, low tannin sorghum and oat groats were similar, whereas wheat had slightly lower digestibility followed by barley and wheat middlings was the least digestible.

Digestibility averages of dry matter, gross energy, and nitrogen for the low tannin sorghum grains were found to be higher than the corresponding digestibility averages for pigs fed on the high tannin sorghum grains (Cousin et al. 1981).

Cohen and Tanksley (1973) determined energy and protein digestibility of sorghum grain with different endosperm texture and starch type by growing pigs. They observed that digestibility coefficients for dry matter, organic matter, and gross energy and the concentration of digestible energy and metabolizable energy were essentially the same for the normal and waxy starch diets. Protein digestibility and nitrogen retention did not differ significantly among the three endosperm textures and the two starch types.

Grain containing endosperm with an intermediate texture appeared to have a nutritional advantage in digestible energy and metabolizable energy over those with flory or corneous texture. However, slight but insignificant weight gains were observed in pigs fed the waxy starch. A slight reduction in protein digestibility was observed in growing chicks fed diets containing high tannin sorghum (Vohra et al. 1966), and they concluded that tannin in diet caused reduction in feed intake and nitrogen retention.

Lucbert and Castaig (1988) compared sorghum with different concentrations of tannin to maize as the dietary cereal source in broiler diets. Low tannin sorghum was substituted for maize without problems of utilization, but poor performance was observed in medium tannin sorghum based diets. The poor performance obtained with medium tannin sorghum was related to its lower metabolizable energy content. Dry matter digestibility and metabolizable energy as well as the percentage of gross energy metabolised in chickens were also decreased with increasing levels of tannin content in sorghum grain (Halley et al. 1987).

Studies on the digestibility of protein and availability of amino acids in sorghum with low (0.11%) and medium tannin (0.88%) content were recently reported by Rigoni and Meggiolari (1993). In these studies the apparent and corrected digestibility of protein and apparent and real availability of amino acids were estimated. The corrected digestibility of low tannin sorghum was found to be similar to that of maize. Histidine, threonine, and arginine were found to be less available in medium tannin sorghum than in low tannin sorghum.

Studies on digestibility and nitrogen - balance conducted in poultry given maize and sorghum of similar proximate composition (Seidler, et al. 1964) showed that protein, fibre and nitrogen-free extract were more digestible and nitrogen - value was lower in sorghum based diets than in maize based diets.

Albino et al. (1989) determined the true and apparent metabolizable energies of some feedstuffs by roosters. The apparent metabolizable energy for maize and low tannin sorghum were 3.04 and 2.90 Kcal/g and the mean true metabolizable energy values were 3.65 and 3.47 Kcal/g, respectively. The metabolizable energy content corrected for zero nitrogen retention (ME_n) of low tannin sorghum did not differ significantly from that of yellow maize but the ME_n of high tannin sorghum was lower than that of yellow maize and low tannin sorghum (Douglas et al. 1990).

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 Experiment 1 (growth study)

3.1.1 Experimental animals and management.

Three hundred and twenty day old broiler chicks were obtained from Interchick hatcheries in Dar-Es-Salaam, which is about 200 km from Sokoine University of Agriculture (SUA), Morogoro. On arrival, the birds were housed at the poultry unit of the Department of Animal Science and Production in two brooding pens, each with floor area of 2.5 m^2. The chicks were fed on ration A (Table 4) for the first seven days. Feed and water were supplied on ad-libitum basis using metal feeders and drinkers, respectively.

On the fourth day of age, the birds were wing banded using plastic tags and were medicated with coccidiostats and antibiotics to control coccidiosis and bacterial infections and also were vaccinated against New Castle disease. Sexing was not done on the birds.

On the seventh day of age the chicks were weighed and randomly allocated to the four dietary treatments (Table 4), each replicated in four pens. Each pen had twenty birds.

The brooding period lasted for four weeks during which two 100-watt electric bulbs in each pen were used. One bulb was removed at the end of the brooding period while the other was left to provide light in order to encourage feed intake. At the end of the brooding period, the birds were kept in the same pens up to the end of the experiment (i.e. eight weeks of age). Feed and water continued to be supplied on ad-libitum basis throughout the experimental period.

Replacement of the litter was done as a control against coccidiosis. Inspite of this control measure, coccidiosis was diagnosed and treatment was done using Esb_3 30% powder at a rate recommended by the manufacturer (i.e. 2g / litre of drinking water). The medicated water was provided to all the birds for seven days. This was given on a skip a day basis where one day of medicated water was followed by a day on plain water. The medicated water was freshly prepared each day of the drug administration.

3.1.2 Diet formulation.

Four dietary treatments A to D were used in the experiment. These were locally compounded with diet A as a control. Ration A had maize as the main source of energy. In the remaining three diets B to D, White sorghum (Tegemeo variety) replaced maize by 33.3, 66.7, and 100%. Fish meal was used as the animal protein source, cotton seed cake and sunflower cake as plant protein sources. The four rations were formulated to be as isocaloric as possible. The formulation of rations and their calculated analyses are shown in Table 4.

3.1.3 Data recording.

3.1.3.1 Liveweight and feed intake.

The birds were individually weighed weekly. The amount of feed in each pen was recorded and at the end of each week, the remaining feed in the feeder was also weighed. Feed intake per pen was obtained as the difference between the total weight of feed and weight of residual.

3.1.3.2 Feed efficiency.

Feed conversion ratio was computed by dividing the total cumulative feed intake by the total gains of all the birds in each pen. This was calculated from the 2^{nd} week to the 8^{th} week of age.

3.1.3.3 Mortality and leg abnormalities.

Mortalities and cases of leg abnormalities were recorded throughout the experimental period. Leg abnormalities were determined by subjective evaluation of each bird. Only birds showing a medium or severe degree of bowing

Table 4: Composition of the experimental diets.

Ingredients	Content in rations (%) A	B	C	D
Maize	60.00	40.00	20.00	0.00
Sorghum	0.00	20.00	40.00	60.00
Cotton seed cake	17.00	17.00	17.00	17.00
Sunflower cake	7.20	7.20	7.20	7.20
Fish meal	10.00	10.00	10.00	10.00
Ground limestone	4.00	4.00	4.00	4.00
Dicalcium phosphate	0.60	0.60	0.60	0.60
DL-Methionine	0.15	0.15	0.15	0.15
L-lysine	0.05	0.05	0.05	0.05
Broiler premix	0.50	0.50	0.50	0.50
Salt	0.50	0.50	0.50	0.50
Total	100.00	100.00	100.00	100.00
Calculated analyses				
Metabolizable energy (kcal/kg)	2780.80	2741.40	2701.80	2664.20
Crude protein (%)	20.57	20.57	20.57	20.57
Crude fibre (%)	5.12	6.32	6.92	7.52
Lysine (%)	1.03	1.01	0.99	0.97
Methionine (%)	0.53	0.52	0.51	0.50
Cystine. (%)	0.25	0.25	0.24	0.23
Meth.+Cystine (%)	0.78	0.77	0.75	0.73
Calcium (%)	1.54	1.54	1.53	1.53
Available phosphorus (%)	0.48	0.48	0.49	0.49
Total phosphorus (%)	0.80	0.81	0.81	0.82

were considered to be abnormal.

3.1.3.4 Growth rate

Growth rate was calculated from liveweight at two week intervals as follows.

$$W = Wt_2 - Wt_1/t_2 - t_1$$

where:

W = Average daily weight gain (g/d) (i.e. growth rate)

Wt_1 = Liveweight at time t_1

Wt_2 = " " " t_2

3.1.3.5 Carcass characteristics.

At the end of the eighth week, four birds were randomly picked from each replicate pen (i.e. sixteen birds per treatment) for slaughter. Slaughtering was done by severing the neck at the base of the head and the occipital bone. Plucking was done after scalding in hot water (about 100^0C). The legs were severed at the tibio-metatarsal joint. Evisceration was done through a transverse incision of the abdominal wall about 1 cm caudal to the distal end of the keel. The internal organs (i.e. intestines, gizzard, liver, heart and abdominal fat) were carefully removed and weighed. The gizzard was separated from the rest of the gut and longitudinally incised so as to remove and discard its contents and the horny layer. The internal organs were expressed as a percentage of the carcass weight of the birds.

Dressing percentage was calculated using the following formula:

DP = CW/LW X 100

Where:

DP = Dressing percentage

CW = Carcass weight

LW = Live weight

3.1.4 Chemical analysis of feedstuffs and rations.

Ingredients and rations were analyzed for their content of dry matter, crude protein, crude fibre, ether extract, ash and nitrogen free extract according to AOAC (1990) procedure.

3.2 Experiment 2: (Metabolic study).

3.2.1 Metabolizable energy determination.

A complete randomized design (CRD) with four replicate male birds in each of the four dietary treatments was employed. The six weeks old birds were transferred to the individual metabolism cages and randomly assigned to the dietary treatments. Adequate separation of the birds between the adjacent cages was provided by leaving a cage unoccupied on either side. A polythene sheet was laid below each cage to collect the droppings. The birds were fed on the treatment diets for five and six days during the preliminary and collection periods, respectively and droppings were quantitatively collected as outlined by Sibbald et al. (1960). Feed and water were provided ad-libitum.

Droppings from each cage were collected every 24 h. After careful separation of unwanted particles, the samples were weighed, placed in sealed containers and then frozen immediately. Successive collections were added to their respective plastic containers making a single frozen composite for each lot.

3.2.2 Chemical analysis of poultry excreta.

At the end of the collection period the frozen composites were thawed, weighed, homogenised thoroughly and then dried in a forced air oven at 60^{0}C for 48 h. The dry samples were ground to pass through a 1 mm sieve and then allowed to equilibrate with the air moisture for 12 h before they were transferred into the screw cap sample bottles for storage for further analysis.

Analysis for nitrogen content was done by Kjeldah procedure, gross energy by using a bomb calorimeter, ether extract, ash, crude fibre, and nitrogen free extract were done according to AOAC (1990) procedures.

3.2.3 Computation of metabolizable energy.

The Apparent metabolisable energy (AME) values were calculated from the gross energy figures of the feeds and excreta (Chemi et al. 1980) as follows:

$$AME\ (Kcal/kg) = \frac{(GE\ intake - Excreta\ energy) \times 1000}{Gram\ test\ ingredient\ intake}$$

The nitrogen - corrected metabolizable energy (ME_n) was obtained using the following formula:

$$ME_n (MJ/kg) = AME - \frac{(Total\ N\ consumed - Total\ N\ excreted) \times 34.4}{Feed\ input}$$

The value 34.4 MJ/kg retained nitrogen used in the calculation of nitrogen - corrected metabolizable energy value (ME_n) is a correction factor according to Hill and Anderson (1958). This factor is the mean energy per kg nitrogen excreted by the chick in the form of uric acid.

The true metabolizable energy (TME) was obtained through the relationship between the N - corrected AME (ME_n) and the TME according to Sibbald (1977) as follows:

$$TME = ME_n \times 1.097$$

ME and ME_n values of sorghum were derived by difference using the formula given by Sibbald et al. (1960) as follows:

ME,MJ/kg test material = 100 x

$$\frac{[\text{ME,MJ/kg T.D} - \text{ME,MJ/kg B.D} \times (\%\text{basal in T.D})/100]}{\%\text{Test material in Test diet}}$$

where:

T.D = Test diet

B.D = Basal diet

3.3 Data analysis.

3.3.1 Statistical analysis.

Analysis of variance was carried out using complete randomized design (CRD) incorporating nested pen effects, as outlined by Snedecor and Cochran (1989).

$$Y_{ijk} = \mu + T_i + P_{ij} + E_{ijk}$$

where:

Y_{ijk} = Observation on the j^{th} bird on the i^{th} dietary treatment.

μ = The general mean.

T_i = The effect of the i^{th} dietary treatment.

P_{ij} = Effect of the j^{th} pen within the i^{th} treatment.

E_{ijk} = The random error peculiar to each bird.

For the second experiment the analysis of variance was carried out using complete randomized design (CRD), as outlined by Snedecor and Cochran (1989).

$$Y_{ij} = \mu + T_i + E_{ijk}$$

where:

Y_{ij} = Observation on the j^{th} bird on the i^{th} dietary treatment.

μ = The general mean.

T_i = The effect of the i^{th} dietary treatment.

E_{ij} = The random error.

All the data in the study were analyzed on a computer using the statistical package SAS (1990). General linear model (GLM) procedure was used to compute the least square means for the main effects and the probabilities for any pair of least square means.

3.3.2: Economic analysis of the diet formulations.

Based on the current prices (1993/94) of the feed ingredients used in formulation of the diet treatments, the economic analysis of the diets was conducted.

CHAPTER 4

4.0 RESULTS

4.1 Proximate chemical composition of feed ingredients and diets.

The nutrient content of feed ingredients used in the experimental diets is summarised in Table 5. The crude protein levels of the protein sources were 63.6, 33.8 and 23.3% for fish meal, cotton seed cake and sunflower cake, respectively. Fish meal had the highest values of ether extract, ash, calcium and phosphorus. Cotton seed cake and sunflower cake had almost similar ash, ether extract and phosphorus content. Sunflower cake had the highest crude fibre content followed by cotton seed cake and fish meal had the lowest. Dry matter content was highest in sunflower cake and lowest in fish meal.

For the two energy sources used in the experiment, sorghum was found to have a higher crude protein content than maize (12.1 and 8.3%, respectively). The ash and phosphorus content were similar in both grains (1.6 and 0.2%) for ash and phosphorus, respectively. Ether extract was found to be higher in maize (4.1%) than in sorghum (3.0%). The calcium levels were 0.05 and 0.03% for maize and sorghum, respectively. Dry matter content was higher in maize (91.3%) than in sorghum grain (87.3%).

The chemical composition of diets used in the experiment is presented in Table 6. Substitution of sorghum for maize significantly lowered the dry matter content in the diet whereas the effect of the level of sorghum was insignificant. Substitution of sorghum for maize resulted in a significant (P<0.05) decrease in crude protein content whilst significant increases in crude protein content with increasing sorghum levels were observed. Replacing maize with sorghum had no effect (P>0.05) on crude fibre content but crude fibre was found to increase with increasing levels of sorghum in the diet. Substitution of sorghum for maize in the diet resulted in significant decreases (P<0.01) of ether extract, nitrogen-free extract, calcium and phosphorus.

4.2 Health status of the birds.

The experiment started with 320 day old broiler birds. Eight birds died during the experiment, making an overall mortality of 2.5%. Two birds in treatment A (maize based diet) died on the third week of age due to coccidiosis and three each from treatment B and C (33.3 and 66.7% substitution of sorghum for maize) due to leg abnormalities.

Leg abnormality was characterised by reluctance to walk, swollen hocks and lateral deviation of the metatarsal

Table 5: Chemical composition of the ingredients used in the experiment.

Feedstuff	DM %	CP %	EE %	CF %	ASH %	Ca %	P %	NFE %	GE MJ/kgDM
Maize	91.3	8.4	4.1	2.1	1.6	0.05	0.2	75.2	17.8
Sorghum	87.3	12.1	3.0	5.4	1.6	0.03	0.2	65.3	16.6
Cotton seed cake	90.8	33.8	0.7	15.2	5.6	0.3	0.6	35.5	
Sunflower cake	92.4	23.3	0.7	26.5	5.3	0.3	0.6	36.6	
Fish meal	88.6	63.6	14.1	0.5	15.5	3.0	2.6		

Table 6: Chemical composition of treatment diets.

Nutrients (%)	Treatments A	B	C	D
Dry matter	96.0 ± 0.09^{a}	93.1 ± 0.12^{d}	93.6 ± 0.06^{c}	93.9 ± 0.01^{b}
Crude protein	19.8 ± 0.05^{c}	18.6 ± 0.03^{d}	20.1 ± 0.02^{b}	21.1 ± 0.02^{a}
Crude fibre	6.1 ± 0.29^{b}	6.7 ± 0.20^{b}	7.5 ± 0.11^{a}	8.1 ± 0.17^{a}
Ether extract	3.8 ± 0.03^{a}	3.3 ± 0.01^{b}	2.8 ± 0.04^{c}	2.8 ± 0.01^{c}
Ash	9.0 ± 0.04^{a}	9.1 ± 0.37^{a}	9.2 ± 0.20^{a}	9.8 ± 0.14^{a}
Nitrogen free extract	57.3 ± 0.36^{a}	55.5 ± 0.04^{b}	54.0 ± 0.10^{c}	52.1 ± 0.30^{d}
Calcium	1.3 ± 0.01^{a}	1.3 ± 0.01^{ab}	1.3 ± 0.01^{bc}	1.3 ± 0.01^{c}
Phosphorus	0.6^{a}	0.5^{b}	0.5^{c}	0.5^{d}

1. a, b, c, and d = All means in the same row with the same superscript are not significantly different ($P>0.05$)

for one or both limbs. Severely affected birds lost weightand finally died due to starvation for failing to reach the feeders and drinkers. Less severely affected birds survived up to the end of the experiment and their growth rates were not very much affected. The incidences of leg problems were 1.3, 2.5, 2.5 and 1.6% of the birds on 0, 33.3, 66.7 and 100% substitution of sorghum for maize respectively.

4.3 Liveweight.

The mean body weights of the birds at different ages are shown in Table 7. The summary of analyses of variance for the mean body weights of birds at various stages of growth is presented in Appendix Table II.

The mean body weights at the second, third and fourth week of age, were not significantly affected by the dietary treatments. No consistent trend was observed during this period.

From the fifth to the eighth week of age, no clear trend was shown. Insignificant increase in body weights with increasing level of sorghum in the diet were observed during this period.

Table 7: Mean (±SEM) body weights of birds at different ages fed diets containing different levels of sorghum.

	Body weights (g)/ Treatments			
Age (Week)	A	B	C	D
2	89.5 ± 1.62^{a}	91.1 ± 1.71^{a}	90.1 ± 1.54^{a}	90.2 ± 1.61^{a}
3	219.5 ± 3.67^{a}	222.0 ± 3.71^{a}	214.0 ± 3.76^{a}	217.8 ± 3.80^{a}
4	451.0 ± 6.34^{a}	433.1 ± 5.72^{a}	443.8 ± 6.33^{a}	439.3 ± 6.53^{a}
5	801.9 ± 9.25^{a}	771.1 ± 8.96^{b}	769.3 ± 9.26^{b}	777.4 ± 10.00^{ab}
6	1055.9 ± 11.45^{a}	1016.7 ± 12.46^{b}	1045.8 ± 12.46^{ab}	1050.9 ± 13.60^{ab}
7	1351.1 ± 13.33^{a}	1301.3 ± 15.61^{b}	1340.4 ± 14.23^{ab}	1345.8 ± 17.23^{ab}
8	1618.0 ± 17.22^{a}	1518.6 ± 21.21^{b}	1534.7 ± 15.05^{b}	1608.3 ± 21.22^{a}

1. a and b = All means in the same row with the same superscript are not significantly different ($P>0.05$)

4.3.1 Growth rate

The average daily gains of birds fed different dietary treatments are presented in Table 8. Appendix Table III shows the summary of analysis of variance for daily gains during the experimental period.

The results in Table 8 and Appendix II show that there were considerable variation between weeks with respect to growth rate throughout the experiment. Generally, the substitution of sorghum for maize caused no significant difference in growth rate throughout the experiment.

4.3.2 Carcass parameters.

The dressing percentages and mean weights of internal organs are shown in Table 9. The analysis of variance is summarised in Appendix IV.

Dietary treatments had no significant effect on dressing percentage whereas, mean weights of the internal organs were significantly (P<0.001) affected by dietary treatments. There was a significant (P<0.05) difference in the mean weights of gizzard between treatments.

Table 8: Treatment effect on the daily liveweight gain (g).

	Average daily gain(g) / Treatments			
Age (Week)	A	B	C	D
2	18.6 ± 0.36^{a}	18.7 ± 0.35^{a}	17.7 ± 0.41^{a}	18.2 ± 0.37^{a}
3	33.1 ± 0.55^{a}	30.2 ± 0.53^{b}	32.8 ± 0.56^{a}	31.6 ± 0.50^{a}
4	50.1 ± 0.63^{a}	48.3 ± 0.76^{ab}	46.5 ± 0.66^{b}	48.3 ± 0.78^{ab}
5	36.3 ± 0.72^{b}	35.1 ± 0.97^{b}	39.5 ± 0.81^{a}	39.1 ± 0.95^{a}
6	42.2 ± 0.96^{a}	40.7 ± 0.85^{a}	42.1 ± 0.86^{a}	42.1 ± 0.88^{a}
7	38.1 ± 1.54^{a}	31.0 ± 1.63^{b}	27.8 ± 1.30^{b}	37.5 ± 1.70^{a}
Overall	36.4 ± 0.40^{a}	34.0 ± 0.49^{b}	34.4 ± 0.34^{b}	36.2 ± 0.49^{a}

1. a and b = All means in the same row with the same superscript are not significantly different ($P>0.05$)

Birds on maize based diet had significantly higher gizzard weights than the birds fed other diets. Changes in mean weights of hearts, liver and abdominal fat followed the same trend as that observed for the gizzard weight.

The overall observation showed that birds fed maize based diet had significantly ($P<0.05$) higher weights of gizzard, heart, liver and abdominal fat than the birds fed other diets.

When internal organs were expressed as percentage of carcass weight the proportionate weights of all organs were found to be significantly ($P<0.05$) influenced by the dietary treatment except for the proportionate weights of liver.

The proportionate weights of gizzard and heart for birds on sorghum based diet (treatment D) were significantly ($P<0.05$) lower than those fed the other diets, whereas the proportionate mean weights of abdominal fat for the birds fed maize based diet were significantly ($P<0.05$) higher than those fed other diets.

Table 9: Means (±SEM) for liveweights of birds slaughtered and their caracas characteristics.

	Mean weights / Treatments			
Parameter	A	B	C	D
Liveweight, g	1650.4 ± 24.54^{a}	1511.6 ± 62.99^{a}	1556.3 ± 51.14^{a}	1639.7 ± 42.34^{a}
Carcass weight, g	1120.8 ± 16.89^{a}	997.9 ± 48.75^{b}	1075.0 ± 36.70^{ab}	1126.9 ± 32.79^{a}
Dressing percentage	68.5 ± 0.71^{a}	66.0 ± 1.31^{a}	69.3 ± 1.62^{a}	68.6 ± 0.57^{a}
Gizzard, g	45.7 ± 1.88^{a}	37.4 ± 1.90^{b}	37.0 ± 2.04^{b}	35.8 ± 1.13^{b}
Heart, g	10.6 ± 0.55^{a}	8.8 ± 0.54^{b}	7.9 ± 0.43^{bc}	6.6 ± 0.32^{c}
Liver, g	45.6 ± 1.62^{a}	36.9 ± 1.37^{b}	40.4 ± 1.30^{b}	41.1 ± 1.42^{b}
Abdominal fat, g	14.3 ± 1.93^{a}	6.1 ± 1.23^{b}	6.6 ± 1.10^{b}	8.1 ± 1.57^{b}

1. a, b and c = All means in the same row with the same superscript are not significantly different ($P>0.05$)

4.3.3 Feed intake and feed conversion efficiency.

Cumulative feed intake, liveweight gain and feed/gain ratio for birds in each pen (replicate) per week are presented in Appendix V.

The mean treatment effects on the cumulative feed intake and feed/gain ratio are shown in Table 10. Feed intake was not significantly (P>0.05) influenced by the dietary treatments during the second week to the fifth week of age, however, a significant difference between dietary treatments was observed thereafter. Birds fed sorghum based diet had a significantly higher feed intake from the fifth to the eighth week of age, whereas those on 33.3% substitution of sorghum for maize had a significantly lower feed intake.

Feed/ gain ratio (FGR) was not significantly (P>0.05) influenced by the dietary treatments during the first five weeks (i.e. Feed/ gain ratio in first and second period) of the experiment. A significant effect was observed from the sixth week onwards, but the trend was not clear.

4.4 Metabolizable energy of the diets and the low tannin sorghum grain.

Gross energy (GE), uncorrected for nitrogen metabolizable energy (ME_c), nitrogen-corrected metabolizable energy (ME_n)

Table 10: Mean (±SEM) cumulative feed intake (g) and feed conversion ratio of birds as affected by treatments.

	Treatment			
Age (week)	A	B	C	D
Feed intake				
2^{nd} – 3^{rd}	9497.0 ± 210.28^{a}	9299.0 ± 118.46^{a}	9217.5 ± 250.15^{a}	9520.0 ± 81.24^{a}
4^{th} – 5^{th}	21794.8 ± 475.01^{a}	20695.0 ± 598.52^{a}	21014.0 ± 396.78^{a}	21850.0 ± 315.12^{a}
6^{th} – 7^{th}	31156.8 ± 616.15^{ab}	29228.0 ± 1268.17^{c}	29831.0 ± 907.94^{bc}	31795.0 ± 432.08^{a}
Overall	62448.5 ± 1233.61^{ab}	59222.0 ± 1960.43^{b}	60062.5 ± 1529.84^{ab}	63165.0 ± 785.55^{a}
Feed gain ratio				
2^{nd} – 3^{rd}	1.4 ± 0.01^{ab}	1.4 ± 0.03^{a}	1.4 ± 0.02^{b}	1.4 ± 0.01^{ab}
4^{th} – 5^{th}	1.8 ± 0.01^{a}	1.9 ± 0.07^{a}	1.8 ± 0.05^{a}	1.8 ± 0.04^{a}
6^{th} – 7^{th}	2.7 ± 0.12^{b}	3.1 ± 0.10^{ab}	3.2 ± 0.20^{a}	2.8 ± 0.02^{b}
Overall	2.1 ± 0.03^{a}	2.2 ± 0.04^{a}	2.1 ± 0.01^{a}	2.1 ± 0.02^{a}

1. a, b and c = All means in the same row with the same superscript are not significantly different ($P>0.05$)

and true metabolizable energy (TME) content of the diets are summarized in Table 11. The analysis of variance is summarised in Appendix Table VII. Gross energy of the diets decreased significantly ($P<0.001$) with increasing level of sorghum in the diet.

Increasing sorghum levels significantly ($P<0.01$) affected the metabolizable energy values in the diets. The ME_c, ME_n and TME values were significantly higher at 33.3% level of substitution of sorghum for maize than in the other diets, but were similar at 0 and 66.7% level of substitution. The ME_c, ME_n, and TME content were lowest at 100% substitution of sorghum or maize.

The ME_c, ME_n and TME values of sorghum were obtained by the difference between the values of diets at 33.3, 66.7 and 100% level of substitution of sorghum for maize and those of control diet (0% substitution). Decrease in ME_c, ME_n and TME with increasing level of sorghum in the diet were observed (see Table 12).

The overall means of the derived values of sorghum were 10.3, 9.4 and 10.3 MJ/kgDM for ME_c , ME_n and TME, respectively as summarized on Table 12.

Table 11: Mean energy values of treatment diets.

Energy parameter MJ/kgDM	Treatments			
	A	B	C	D
Gross energy	18.2 ± 0.15^{a}	17.6 ± 0.10^{b}	16.7 ± 0.05^{c}	16.1 ± 0.15^{d}
ME, uncorrected (ME_c)	9.6 ± 0.40^{b}	10.9 ± 0.07^{a}	8.9 ± 0.05^{b}	8.0 ± 0.19^{c}
ME, corrected (ME_n)	8.8 ± 0.4^{b}	10.0 ± 0.07^{a}	8.1 ± 0.05^{b}	7.1 ± 0.19^{c}
True metabolizable energy	9.6 ± 0.44^{b}	11.0 ± 0.08^{a}	8.9 ± 0.06^{b}	7.8 ± 0.21^{c}

1. a, b and c = All means in the same row with the same superscript are not significantly different ($P>0.05$)

4.5: Economic evaluation of diet treatments.

The economic analyses of the diets used in this study based on 1993/94 price of ingredients are presented on Table 13 and Appendix Table VIII.

Substitution of sorghum for maize significantly ($P<0.05$) influenced the cost of producing a kg of feed, feed cost per kg gain and weight of saleable meat per bird. The cost of producing a kg of feed decreased significantly with substitution of sorghum for maize in the diet and the cost decreased further with increasing level of sorghum in the diet.

Table 12: Uncorrected for N - metabolizable energy, N-corrected metabolizable energy and true metabolizable energy of low tannin sorghum.

Energy parameter MJ/kgDM	Treatment			
	B	C	D	Mean
Metabolizable energy:				
Uncorrected for N (ME_c)	15.9	8.0	6.9	10.3
N - Corrected (ME_n)	15.1	7.1	6.0	9.4
True metabolizable energy(TME)	16.5	7.8	6.6	10.3

The cost of feed per kg gain increased significantly with increase in the level of substitution of sorghum for maize to 66.7%. However, at 100% substitution (i.e. diet D) there was a significant decrease in the feed cost per kg gain.

Substitution of sorghum for maize significantly increased the cost of feed per kilogram of saleable meat. However, the cost decreased with increase in level of sorghum in the diet.

Table 13: Economic evaluation of diet treatments.

	Diets			
Item	A	B	C	D
Feed cost per kg (Tsh)	92.4[a]	91.4[b]	90.4[c]	89.4[d]
Feed consumption per bird(kg)	3.1	3.1	3.2	3.2
Feed cost per bird (Tsh)	286.4	280.2	282.9	276.5
Weight gain per bird (kg)	1.5	1.4	1.4	1.5
Feed cost per kg gain (Tsh)	190.9[c]	200.1[b]	202.1[a]	184.3[d]
Saleable meat per kg gain (Tsh)	1.3[a]	1.0[c]	1.1[b]	1.1[b]
Feed cost per kg meat (Tsh)	238.7[d]	280.2[a]	257.2[b]	251.4[c]

1. a, b and c = All means in the same row with the same superscript are not significantly different (P>0.05)
2. 1 US $ = 500 Tsh

CHAPTER 5

5.0 DISCUSSION

5.1 Health of the birds.

Leg abnormalities was the major problem encountered in this study. The mortality rate due to leg abnormalities was 1.9% of the birds and 7.8% of the birds continued with the experiment but under poor health condition. This might have contributed to the poor results for the birds on treatment B and C in which maize was replaced by sorghum by 33.3 and 66.7% respectively. The birds on these two treatments were mostly affected.

Slightly higher calcium levels and low phosphorus levels in the diet might have contributed to this problem. Calcium levels were 1.3% and phosphorus levels ranged from 0.5 to 0.6%. Since most of phosphorus in the sorghum grain is bound in organic form such as phytic acid which reduces its nutritional bio-availability, these levels of phosphorus are lower than the recommended levels for broilers, as given by Blair et al. (1983) and NRC (1984). Therefore, it is very likely that the imbalance between calcium and phosphorus levels in the diets might have resulted into higher Ca/P ratio associated with incidence of leg abnormalities as reported by Hulan et al. (1985).

Premix supplemented to the diets could not be analyzed before use due to lack of facilities. This premix probably did not adequately meet all the requirements for vitamins such as Biotin, Choline, Folacin and Niacin, which were reported by Summers et al. (1978) to cause leg abnormalities in broilers.

5.2 Proximate composition of ingredients and diets.

The crude protein, ether extract and ash content of the low tannin sorghum grain observed in the present study were within the ranges reported by Shephered et al. (1971); Eggum et al. (1981) and Metayer et al. (1993). However, the crude fibre level of 5.4% observed in the present study was much higher than the levels (1.3 to 3.5% and 1.9 to 2.4%) reported by Shephered et al. (1971) and Metayer et al. (1993), respectively. The reason for such high value are equivocal and in contrast to reports by Almond et al. (1979) i.e. low tannin sorghum varieties have lower crude fibre content than the high tannin sorghum varieties. The calcium content of 0.05% obtained in the study was within the acceptable levels (Wall and Ross, 1970 and Eggum et al. 1981) whereas phosphorus content was slightly lower (Wall and Ross, 1970).

Ether extract content of the maize used in this study was 1.1% higher than that of low tannin sorghum but ash content was similar for the two cereal grains. These observations compare well with the observations reported by Douglas et al. (1990). Ether extract was found to be 1 to 2% higher in maize than that of sorghum, whereas minor differences were observed between the two grains with respect to the ash content.

The low ether extract content (0.7%) of cotton seed cake used in the present study was within the range (0.3 - 2.5%) reported by Phelps (1966) for the pre-press solvent extracted cotton seed cake. However, crude protein level of 33.8% was much lower than the value of 41.0% reported by Phelps (1966). The reason for this is not clear. The higher levels of crude protein, crude fibre and lower ether extract in the diets containing higher levels of low tannin sorghum than the control diet were a reflection of the differences in the chemical composition between maize and sorghum. These findings are in agreement with other studies which showed that sorghum had higher crude protein, crude fibre and lower ether extract than maize grain (Douglas et al. 1990).

Formulated diets where maize was replaced by low tannin sorghum, had significantly higher crude protein content. This was due to high crude protein content of low tannin sorghum (12.1%) as compared to that of maize (8.4%).

Significant increases in crude fibre content with increasing levels of low tannin sorghum grain in the diets, was probably due to the higher levels of crude fibre content in the low tannin sorghum as compared to that of maize. Ether extract content of the diets decreased with increase in the level of low tannin sorghum in the diets. This is due to the fact that ether extract content in maize was 1.1% higher than that of low tannin sorghum. Similar observation was reported by Douglas et al. (1990).

5.3 Growth performance.

There was no significant difference in the liveweight gain for the first four weeks of age. Yeong and Syed Ali (1976) and Hew (1978), made similar observations for chicks and pigs respectively when maize was substituted by low tannin sorghum. The probable cause for the lack of significant difference between treatments could be explained by a slight variation in nutrient content of the dietary treatments.

Similar observation was reported by Vanschoubroek et al. (1964) on pigs i.e. as the pigs grew, their protein requirements were reduced and the maize based diet which was compounded to contain 18% crude protein became optimal so that the higher protein from the higher sorghum diets were superfluous, and the rate of growth and feed conversion ratio of pigs were no longer different for all the treatments.

Significantly lower liveweight gains observed from the fifth week onwards in birds fed low tannin sorghum based diets than those fed the maize based diets, were probably due to the dilution of the feed with the dietary fibre which was high in the low tannin sorghum. This is in agreement with the observation made by Elzubeir and Jubaral (1993), that the increase in crude fibre in the diet may affect the weight gain and feed utilization which interact with feeding levels and digestibility of nutrients. The main reason for the similarity can be explained by the higher feed intake of the birds fed on the sorghum diets, a phenomenon which is common in monogastric animals as a way of maintaining a constant metabolizable energy intake.

In this study, analysis for tannin content in the low tannin sorghum was not done due to lack of facilities required for this analysis. A number of studies have indicated that low tannin sorghum contain very low levels of tannin if any. Relatively higher feed intake observed in this study for the birds on sorghum based diet (treatment D) which had the highest inclusion level of low tannin sorghum, could be an indication of presence of insignificant amount of tannin in low tannin sorghum (Tegemeo variety) and probably lower energy content. This is based on the findings of Vohra et al. (1966), that the presence of higher tannin content in diet reduces feed intake and N - retention in growing chicks.

From the present findings, it could be seen that the tannin content in sorghum had no major effect on the performance of broilers. However, all the experimental diets were supplemented with 0.15% DL-methionine and 0.05% L-lysine which according to Chang and Fuller (1964); Armstrong et al. (1973) and Azcona and Bonino (1988), alleviate growth depressing effects of tannin.

5.4 Carcass yield and composition.

As expected birds which were heavier at slaughter had also heavier carcasses. Higher growth rate is linked to the higher dressing percentage (Hayse and Marion 1973; Marion, 1976; Pesti and Fletcher, 1984). The birds fed on the maize based diet had similar carcass weight as birds on the high levels of sorghum based diets. This might have been due to the similarity in the growth rate and efficiency of feed utilization observed in these diets (Bornstein and Bartov, 1967).

The weights of abdominal fat, were significantly lower for the birds fed the low tannin sorghum containing diets, as compared to birds fed the maize based diet. This might have been due to the low calorie - protein (C/P) ratio of diets containing low tannin sorghum. This is in agreement with the findings of Donaldson (1985), who observed that body fat content increased with increasing C/P ratio.

Since in this study low tannin sorghum had low caloric value and high protein content than maize, the C/P ratio was lower in low tannin sorghum containing diets than that of the maize containing diets. Decrease in the weight of abdominal fat resulting from utilization of sorghum in poultry diets, has also been attributed to the dilution of the feed with dietary fibre in sorghum (Elzubeir and Jubaral, 1993).

Liver weights for the birds on a maize based diet were significantly higher as compared to the liver weights in birds on sorghum based diets. This might have been caused by the low dietary fat in the low tannin sorghum containing diets. As reported by Marion and Edwards (1963) deficiency in dietary fat produces enlarged and fatty liver during early life of chicks which extends throughout the growing period. Streeter et al. (1993), attributed the increase in liver weight to enhanced metabolic functions such as digestion, nutrient transport and excretion of metabolic products due to feeding of sorghum gluten meal.

Gizzard weights decreased with increasing level of low tannin sorghum in the diets. This might have been caused by the increased coarseness of the diets containing maize as compared to the low tannin sorghum containing diets which were relatively fine in texture. This is in agreement with a study by Wyllie and Kinabo (1980), who reported that increased coarseness of the diet, increases gizzard weight due to increased muscular activity of the gizzard in response to the coarse diets.

5.5 Feed intake and feed/ gain ratio.

Overall feed intake for the birds on diet containing higher levels of sorghum (i.e. treatment D) was slightly (although insignificant) higher as compared to that of birds on the other treatments. Kim et al. (1986) and Roth et al. (1994) observed higher feed intake when maize was replaced by sorghum in broiler diet. The possible reason for this might be the low energy density in low tannin sorghum as compared to maize, making the birds to eat more so as to meet their energy requirement.

The overall observation shows that feed gain ratio in this study was insignificantly affected by the dietary treatments. Bornstein and Bartov (1967) and Gaffar et al. (1990), observed no difference between maize and sorghum as far as growth rate and efficiency of food utilization of broilers were concerned . The birds fed on the diets containing highest level of sorghum (i.e. treatment D) showed a feed gain / ratio similar to that of the control diet. The possible reason for this could be the high protein content in sorghum based diet. The performance of birds fed on these diets probably were influenced by this factor affecting the calorie/protein (C/P) ratio which in turn could have affected the growth rate and body composition of broilers as reported by Donaldson (1985).

5.6 Metabolizable energy of diets and low tannin sorghum.

The higher metabolizable energy values observed (i.e. in diet B) as a result of substitution of sorghum for maize was not expected. The reason for this is not clearly known. The possible reason could be variations among cereals in their proximate composition, particularly in crude fibre and ether extract fractions as suggested by Fetuga (1977).

Another possible reason for this variation in metabolizable energy value, could be due to the change in protein quality in the diet after mixing the two grains together. This is according to Sibbald et al. (1960) that the protein quality or the profile of bioavailable amino acids may affect the apparent metabolizable energy values of the diet.

The nitrogen - uncorrected metabolizable energy (ME_c), nitrogen - corrected metabolizable energy (M_n) and true metabolizable energy (TME) values for diets containing high levels of sorghum (i.e. diet D), were significantly lower. The probable reason is the higher crude fibre and low ether extract content in sorghum based diets (Sibbald, 1975).

The uncorrected for nitrogen metabolizable energy (ME_c) value for the low tannin sorghum used in the study (10.3 MJ/kgDM) was lower than the values reported by Albino et al. (1989) and Fetuga (1977) (12.1 and 14.0 MJ/kgDM, respectively). Nitrogen - corrected metabolizable energy (ME_n) (9.4 MJ/kgDM), was also lower as compared to the values reported by Connor et al. (1976) and Fetuga (1977), (15.7 and 13.3 MJ/kgDM, respectively). True metabolizable energy (TME) of 10.3 MJ/kgDM observed in this study was also lower as compared to that of 14.5 MJ/kgDM reported by Albino et al. (1989). The cause for these variations may be due to variation in climatic conditions and soils where the crop was grown as suggested by Douglas et al. (1990).

5.7 Economic analysis of the diets.

Substitution of sorghum for maize significantly increased the cost of producing a kg gain and that of a saleable meat. This was due to the fact that maize based diet (control) produced more saleable meat per kg of feed than sorghum based diets.

Taking into consideration that the liveweight gain and dressing percentage did not differ significantly ($P>0.05$), (Table 9), between the birds fed sorghum and maize based diets, it may be economical to feed sorghum to broilers as a source of energy where sorghum is much cheaper than maize. Therefore, it is important to note that in areas where the price of sorghum is higher than that of maize, it will not be economical to substitute sorghum for maize.

CHAPTER 6

6.0 CONCLUSION AND RECOMMENDATIONS

High protein content, low tannin content and low demand as human food, are the important factors which make low tannin sorghum a good replacement for maize in poultry feeds. Various studies have shown that low tannin sorghum can partially or totally replace maize in poultry rations resulting in a reduction in the cost of poultry production.

From this study, it can be concluded that low tannin sorghum (Tegemeo variety), can entirely replace maize as a sole carbohydrate source in broiler diets. Replacement can go to a level as high as 60% of the diet without causing any adverse effect in broiler performance. However, the substitution was not cost effective.

Based on the findings from this study, it is recommended that low tannin sorghum be used in place of maize in broiler production in ares where sorghum is cheaper than maize or is abundantly available. This is due to the fact that apart from reducing the competition for cereal grain between human and livestock due to its agronomic advantages, it as well improves the carcass composition of the commercial broilers.

Since low tannin sorghum is relatively low in energy and fat content as compared to maize, it can reduce the problem of excessive energy intake above the broiler's normal metabolic needs, which is associated with fat deposition.

Fat deposition which occurs in considerably high proportion in the abdominal area is essentially a waste product in the carcass of commercial broiler. Moreover the accumulation of excessive fat is associated with decrease in feed efficiency.

Area for further study: The analytical determination of tannin is very important in the evaluation of the nutritional value of sorghum. Therefore a study should be conducted to determine the tannin content of sorghum (Tegemeo variety) and its negative correlation between metabolizable energy and protein utilization in poultry.

7.0 REFERENCES

Acland, J.D (1979). East African crops, FAO/ Longman pp 252

Albino, L.F.T; Rutz, F; Brum, P.A.R. De and Coelho, M.D.G.R (1989). True and apparent metabolizable energy of some feedstuffs determined by roosters. Nutrition Abstract and Review (Series B) 1991 Volume 61 no 7: 3552.

Ali, H.I and Harlard, B.F (1991). Effect of fibre and phytate in sorghum flour on Iron and Zinc in weanling rats: A pilot study. Cereal Chemistry. 68(3): 234 - 238

Almond, C; Smith, W.C; Savage, G.P and Lawrence, T.L.J (1979). A comparison of two contrasting types of grain in the diet of growing pigs. Animal production. 29: 143 - 150

AOAC (1990). Association of Official Agricultural chemists. Official methods of Analysis. 15th edition, Washington, DC.

Armstrong, W.D; Featherstone, W.R and Rogler, J.C (1973). Influence of Methionine and other dietary additions on the performance of chicks fed bird resistant sorghum grain diets. Poultry Science. 52 (4): 1592 - 1599

Armstrong, W.D; Rogler, J.C; and Featherstone, W.R (1974) Effect of Bird resistant sorghum grain on various commercial tannin on chick performance. Poultry Science. 53: 2137 - 2142

Azcona, J and Bonino, M.F (1988).Utilization of grain sorghum as forage grain. Grain sorghum in poultry nutrition. Nutrition Abstract and Review (series B) 1988 (58) 2: 924.

Banda-Nyirenda, D.B.C and Vohra, P (1990). Nutritional improvement of tannin - containing sorghum (sorghum bicolor) by sodium bicarbonate. Cereal Chemistry. 67 (6) : 533 - 537

Bhargava, S.C (1974). Preliminary investigation on maize protein in Tanzania. In: Proceeding of the fifth East African cereal research conference held in Malawi, March 10 - 15, 1974 pp 199 - 207

Blaha, J; Salah, El Din; H.M, Christodoulou, V and Mudrik, Z (1985). The possibility of replacing maize by sorghum in broiler chick feed mixtures. Nutrition Abstract and Review (series B) (55) :5848

Blair, R; Daghir, N.J; Morimoto, H; Peter, V and Taylor, T.G (1983). International nutrition standards for poultry. Nutrition Abstract and Review 53: 669

Bornstein, S. and Bartov, I (1967). Comparison of Sorghum grain (milo) and maize as the principal cereal grain source in poultry rations. British Poultry Science. 8: 213 - 231

Bullard, R. W; Garrison, M.V; Kilburn, S.K and York, J.O. (1980). Laboratory comparison of polyphenols and their repellent characteristics in bird resistant sorghum grain. Journal of Agriculture Food Chemistry. 28:1006

Cao, Z.C; Jiang, Y.X; Jin, Y.Y; Liu, and J.X (1985). Comparison of using high and low tannin content sorghum as broiler feed. Nutrition Abstract and Review (series B) (55):6307.

Castro, L.F.V; De and Costa, J.S.P. Da (1985). Replacement of maize by sorghum in the diet of laying hens. Nutrition Abstract and Review (Series B) 55 (7): 3616

Chang, S.I and Fuller, H.L (1964). Effect of tannin content of grain sorghum on their feeding value for growing chicks. Poultry Science. 43:30

Chavan, F.K; Kadm, S.S and Salunhke, D.K (1981). Changes in tannin F.A.A; reducing sugar and starch during seed germination of low and high tannin cultivars of sorghum. Journal of Food Science. 46:632

Chemi, D. B; Vohra, P and Kratzer, F.H (1980). Evaluation of true metabolizable energy of feed ingredients. Poultry Science 59: 569 - 571.

Chibber, B.A.K; Mertz, E.T and Axtell, J.D (1978). The effect of dehulling on tannin content, protein distribution and quality of high and low tannin sorghum. Journal of Agriculture Food chemistry. 26: 679.

Cohen, R.S and Tanksley, J.T.D (1973). Energy and protein digestibility of sorghum grain with different endosperm textures and starch types by growing swine. Journal of Animal Science. 37 (4): 931 - 935

Connor, J.K; Neil, A.R and Barram, K.M (1976). The metabolizable energy content for the chicken of maize and sorghum grain hybrids grown at several geographical regions. Australian Journal of experiment Agriculture and Animal Husbandry. 16: 699 - 703

Cousins, B.W; Tanksley Jr, T.D; Knabe, D.A and Zebrowska, T (1981). Nutrient digestibility and performance of pigs fed sorghum varying in tannin concentration. Journal of Animal Science. 53(6): 1524 - 1537

Daiber, K.H (1975). Enzyme inhibition by polyphenols of sorghum grain and malt. Journal of Science Food Agriculture. 23: 1399 - 1411

Dale, M.B (1976). The utilization of grain in animal feed. World Animal Review. Number 32: 42 - 48.

Douglas, J.H; Sullivan, T.W; Bond, P.L and Struwe, F.J (1990). Nutritive composition and Metabolizable energy value of selected grain sorghum varieties and yellow corn. Poultry Science. 69 (7): 1147 - 1155

Deyoe, C.W; Shoup, F.K; Miller, G.D; Bathurst, J; Liang, D; Sanford, P.E and Murphy, L.S (1970). Amino acid composition and energy value of immature sorghum grain. Cereal chemistry. 47: 363-368

Doggett, H (1970). Sorghum. Longmans, Green and Co LTD, London and Hallow pp 1 - 49

Donaldson, W.E (1985). Lipogenesis and body fat in chickens: Effect of calorie - protein ratio and dietary fat. Poultry Science. 64: 1199 - 1204

Eastoc, J.E and Taylor, R.H (1974). Composition of protein of sorghum grown in Botswana. Journal of science Food Agriculture. 25: 563 - 569.

Eggum, B.O; Bach Knudsen, K.E; Munck, L; Axtell,J.D and Mukuru, S.Z (1981). In: Proceeding of the International symposium on sorghum grain quality. ICRISAT centre, Patancheru, India. 28 - 31 october, 1981

Elkin, R.G; Rogler, J.C and Sullivan, T.W (1990). Comparative effects of dietary tannin in ducks, chicks and rats. Poultry Science. 69: 1685 - 1693

Elkin, R.G; Rogler, J.C and Sullin, T.W (1991). Differential response of ducks and chicks to dietary sorghum tannin. Journal of Science Food Agriculture. 57: 543 - 553

Elzubeir, A.E and Jabaral, S.K (1993). Nutritional evaluation of sorghum germ meal as a substitute for sorghum in broiler diets. Animal Feed Science and Technology. 44: 93 - 100.

FAO, Food and Agriculture Organisation (1976). Production year book. Italy Rome volume 29.

FAO, Food and Agriculture Organisation (1984). Production year book. Italy Rome

FAO, Food and Agriculture Organisation (1988). Production year book. Italy Rome volume 42.

Fetuga, B.L (1977). The metabolizable energy value of some cereals and cereal byproducts for chickens. West African Journal of Biology and Applied Chemistry. 20: 3 - 15

Ford, J.E and Hewitt, D (1979). Protein quality in cereals and pulses. Bioassays with rats and chickens on sorghum (Sorghum vulgar pers), Barley and field beans (vicia faba L.) Influence of polyethylene, glycol on digestibility on the protein in high tannin grain. British Journal of Nutrition. 42:325

Gaffar, M.A; Seshmukh, S.V; Shah, A.A (1990). Replacement of maize by sorghum in broiler rations. Nutrition Abstract and Review (series B) (60) 10: 5546

Glick, Z and Josylin, M.A (1970). Food intake depression and other metabolic effects of tannic acid in the rat. Journal of Nutrition. 100: 509 - 515

Guiragossian, V.C; Chibber, B.A.K; Vascoyoc, S; Jambunathan, R; Mertz,E.T and Axtel, J.D (1978). Characteristics of proteins from normal, high lysine and high tannin sorghum. Journal of Agriculture Food Chemistry. 26: 219

Hagerman, A.E and Butler, L.G (1980). Determination of protein in tannin protein precipitates. Journal of Agriculture Food Chemistry. 28: 944 - 947

Hahn, D.H. Rooney, L.W and Earp, C.F (1984). Tannin and phenols of sorghum. Cereal Food World. 29(12): 776

Hahn, D.H and Rooney, L.W (1985). Effect of genotypes on tannin and phenols of sorghum. Cereal Chemistry. 63 (1): 4 - 8

Halley, J.T; Nelson, T.S; Kirby, L.K and York, J.O (1987). The effect of tannin content of sorghum grain in poultry rations on dry matter digestion and energy utilization. Nutrition Abstract and Review (series B) 57 (2): 761

Hayse, P.L and Marion, W.W (1973). Eviscerated yield , component parts and meat, skin and bone ratios in the chicken broiler. Poultry Science. 52: 718 - 722

Hew, V.F (1978). A comparison of the feeding value of sorghum and corn. Malaysian Agricultural Journal. 51 (2): 167 - 172

Hill, J.H and Anderson, D.L (1958). Comparison of metabolizable energy and productive energy in growing chicks. Journal of Nutrition. 64: 587 - 603.

Hubbard, J.E; Hall, H.H and Earle, F.R (1950). Composition of the component parts of the sorghum kernel. Cereal Chemistry. 27: 415

Hulan, H.N; DeGroote, G; Foritaine, G; De Munier, G; McRae, K.B and Proudfoot. F.G (1985). The effect of different totals and ratios of dietary calcium and phosphorus on the performance of leg abnormalities of male and female broiler chickens. Poultry Science. 64: 1157- -1169

Hulse, J.H; Laing, E.M and Pearson, O.E (1980). Sorghum and millets: Their composition and nutritive value. Academic press, London.

Ibrahim, S; Fisher, C; Alaily, H.E; Soliman, H and Anwar, A (1988). Improvement of the nutritional quality of Egyptian and Sudanese sorghum grains by the addition of phosphates. British Poultry Science. 29:721

IDRC (1977) Agriculture, Food and Nutrition Science Division: The first five years International Development Research Centre, Box 8500, Ottawa, Canada K1G 3H9.

Jambunathan, R and Mertz, E.T (1973). Relationship between tannin levels, rat growth and distribution of protein in sorghum. Journal of Agriculture Food Chemistry. 28: 1191

Kim, K.S.; Han, I.K.; Han, J.K.;and Kwack, C.H (1986). The effect of substituting sorghum grain for corn and supplementation of methionine and lysine on the performance of broiler chicks. Korean Journal of Animal Science 28 (11) 732-735

Lichtenwalner, R.E; Glover, G.I and Show, C.C (1979). Protease activity of water and acid-reconstituted grain sorghum. Journal of Agriculture Food Chemistry. 27: 359 - 362

Lin, F.D; Knabe, D.A; and Tanksley Jr, T.D (1987). Apparent digestibility of amino acids, Gross energy and starch in corn, sorghum, wheat, barley, oat groats and wheat middlings for growing pigs. Journal of Animal Science 64: 1655 - 1663

Lucbert, J and Castaig, J (1988). Utilization of sorghum with different concentration of tannin in the feeding of broiler chickens. Nutrition Abstract and Review (series B) 58 (5): 2431

Madacsi, J.P; Parrish, F.W and McNaughton, J.L (1988). Treatment of low tannin sorghum grain for broiler feed. Animal Feed Science and Technology. 20 (1): 69 - 78

MALD, Ministry of Agriculture and livestock Development (1988). Basic data agriculture and livestock sector. Planning and marketing division.

MALD, Ministry of Agriculture and livestock Development (1992). Basic data agriculture and livestock sector, Planning and marketing division.

Marion, J.E and Edwards, H.M Jr (1963). Effect of age on the response of chickens to dietary protein and fat. Journal of Nutrition. 79: 53 - 61

Matemu, L.J.H (1987). Plant water studies and grain yield of sorghum (sorghum bicolor (L) Moench) in relation to soil water status at Morogoro, Tanzania. Msc Thesis - Sokoine University of Agriculture. Morogoro, Tanzania.

Maxson, D.E and Rooey, L.W (1972). Evaluation of methods for tannin analysis in sorghum grain. Cereal Chemistry. 49: 719

Mayer, R.O; and Gorbet, D.W (1985). Waxy and normal sorghum with varying tannin content in diets of young pig. Journal of Animal Feed Science and Technology. 12:179-186

Mchechu,J.E.U (1983). Present status of livestock Industry in Tanzania. In: Proceeding of the 10th Scientific conference of Tanzania Society of Animal Production, 18 - 21, October 1983 Arusha. 10: 8 - 43

Metayer, J.P; Grosjean, F and Castaig, J (1993). Study of variability in French cereals. Animal Feed Science and Technology. 43(2/2): 87 - 108.

Mitaru, B.N; Reichert, D.M and Blair, R (1983). Improvement of the nutritive value of high tannin sorghum for broiler chickens by high moisture storage (reconstitution). Poultry Science. 62:2065

Mohamed, T.A and Ali, O.M (1988). Effect of wood ash excreta treatment on the feeding value and utilization of high tannin sorghum by broiler chicks. Animal feed Science and Technology. 22: (1 - 2) 131 - 137.

Moran, E.T (1976). Growth and meat yield in poultry. In: Growth and meat production. Editors, Boorman, K.N and Wilson, B.J, British Poultry Science Ltd; Edinburgh, pp 145 - 173

Muindi, I. P and Thomke, S (1981). The nutritive value for rats of high and low tannin sorghum treated with magadi soda. Journal of Science Food Agriculture. 32:139

Muindi, I.P; Thomke, S and Elkin, R (1981). Effect of Magadisoda treatment on the tannin content and in-vitro nutritive value of grain sorghum. Journal of Science Food Agriculture 32:25

Muindi, I.P and Thomke, S (1983). Metabolic studies with laying hens on Tanzania sorghum grain of different tannin content. Swedish Journal of Agricultural Research. 2: 17 - 21.

Mukuru, S.Z (1974). Sorghum improvement in East Africa. In: Proceedings of the fifth East African cereals research conference held in Malawi, March, 10 - 15, 1974 pp 219 - 223

Mutayoba, S.K (1985). The effect of reducing tannin content in sorghum on performance of broiler chicken. Msc Thesis Agriculture, Sokoine University of Agriculture, Tanzania.

National Research Council (1984). Nutrient requirements of poultry. National Academy of Sciences, Washington DC.

Nwokolo, E (1988). Composition and availability of nutrients in some Tropical grains and oil seeds. Nutrition Abstract and Review (series B) 58 (4): 1599

Oh, H.I; Hoff, J.E; Armstrong, G.S and Haff, L.A (1980). Hydrophobic interaction in tannin protein complexes. Journal of Agriculture Food Chemistry. 28: 394 - 398

Pesti, G.M and Fletcher, D.L (1984). The response of male broiler chickens to diets with various protein contents during the grower and finisher phases. British Poultry Science. 25: 415 - 423

Phelps, R.A (1966). Cottonseed meal for poultry. From research to practical application. World's Poultry Science Journal. 22: 86 - 112

Price, M.L and Butler, L.G (1977). Rapid visual estimation and spectrophotometric determination of tannin content of sorghum grain. Journal of Agriculture Food Chemistry. 26 (6): 1268 -1273

Rathakrishnan, M.R and Swaprasad. J (1980). Tannin content of sorghum varieties and their role in iron availability. Journal of Agriculture Food Chemistry

Ribereau-Goyan, P (1972). Plant phenolics. Heywood, ed. University reviews in botany. Oliver and Boyd. Edinburgh, England.

Reed, J.D (1988). Phenolics, fibre and fibre digestibility in bird resistant and non bird resistant sorghum grain. Nutrition Abstract and review (Series B) 1988 (58) 2:559

Reichert, R.D and Youngs, C.G (1977). Dehulling cereal grains and grain legumes for developing countries. II Chemical composition of mechanically and traditionally dehulled sorghum and millet. Cereal Chemistry. 54: 174 - 178

Reichert, R.D; Flemming, S.E and Schwab, D.J (1980). Tannin deactivation and nutritional improvement of sorghum by anaerobic storage of H_2O, - HCL - or NaOH - treated grain. Journal of Agriculture Food Chemistry. 28:824

Rigoni, M and Meggiolari, D (1993). Digestibility of protein and availability of amino acids on sorghum with low or medium tannin content. Nutrition Abstract and Review (Series B) 63: 5

Rogler,J.C.; and Sell,D.R. 1984. Effect of stage of maturity on tannin content and nutritional quality of low and high tannin sorghum. Nutritional Reports International (1984) 29 (6) 1281-1287.

Rooney, L.W and Pflugfelder, R.L (1986). Factors affecting starch digestibility with special emphasis of sorghum and corn. Journal of Animal Science. 63: 1607 - 1623

Rooney, L.W; Frayar, W.B and Cater, C.M (1972). Protein and amino acid content of successive layers removed by abrasive milling of sorghum grain. Cereal Chemistry. 49: 399

Ross, W.M and Webster, O.J (1970). Culture and use of grin sorghum Agriculture Handbook. Number 385, Agriculture research service, United States Department of Agriculture, Washington,DC.

Rostagno, H.S; Featherstone, W.R and Rogler J.C (1973). Studies on the nutritional value of sorghum grains with varying tannin contents for chicks. 1 Growth studies. Poultry Science 52:765

Rostagno, H.S; (1988). Use of sorghum in diets for poultry and pigs. Nutrition Abstract and Review (series B). 1988 (55) 4:1598.

Roth, F.X; Kirchgessner, M; Windisch, W (1994). Performance of male broilers fed on diets with varying energy content and energy/protein ratio in a prolonged finisher phase. Nutrition Abstract and Review (series B). 64:(1) 385

Runyoro, G.T (1988). Rational and strategies for promotion of sorghum and millet processing and utilization. In: Proceeding of National workshop on sorghum and millet processing and utilization in Tanzania. 19th - 20th November 1987.

SAS 1990. Statistical analysis System, Statistics 1990 Edition; SAS Institute, North Carolina, 27605.

Sarkar, J.K and Howarth, R.E (1976). Specificity of the Vanillin test for flavonoids. Journal of Agriculture Food Chemistry. 24:317

Savage, C.F; Smith, W.C and Briggs, P.A (1980). A note on the influence of micronizing and polyethylene glycol on the nutritional value of brown sorghum for growing pigs. Animal Production. 30:157

Schaffert, R.E; Oswalt, D.L and Axtel, J.D (1974). Effect of supplemented protein on the nutritive value of high and low tannin sorghum bicolor (L) Moench grain for the growing rat. Journal of Animal Science. 39 (3) 500 - 505

Seidler, S; Kotowski,J and Swierzynska, Z (1964). Digestibility and N - balance in poultry given maize and sorghum. Nutrition abstract and review 35, 4957.

Shayo, N.B (1988). Analysis of protein and tannin contents in sorghum (Sorghum bicolor (L) Moench) using near infrared reflectance spectroscopy. Msc Thesis: University of Saskatchewan, Canada.

Shepherd, A.D; Woodhead, A.H and Kapasi-Kakama, J (1971) Cereal processing. In Annual Report, 1972-72, East African Industrial Research Organisation pp 23-52.

Shem, M.N; Lekule, F.P, Zakayo G.G.A; Eggum, B (1990). Nutritive value of germinated and ungerminated high tannin sorghum for growing pigs. Acta Agriculture Scandinavica. 40 (3) 253-258

Sibbald, I.R (1975). The effect of feed intake on metabolizable energy value measured with adult roosters. Poultry Science. 54: 1990 - 1997

Sibbald, I.R (1977). The true metabolizable energy system Part II: Feedstuffs value and conversion data. Feedstuffs. 49: 23 - 24.

Sibbald, I.R (1982). Measurement of bioavailable energy in poultry feeding stuffs. Canadian Journal of Animal Science. 62: 983 - 1048

Sibbald, I.R; Slinger, S.J and Ashton, G.C (1962). 5. The level of protein and of test material in the diet 6. A note on the relationship between digestible and metabolizable energy value. Poultry Science 41: 107 - 116

Sibbald, I.R; Summer, J.D and Slinger, S.J (1960). Factors affecting the metabolizable energy content of poultry feeds. Poultry Science 39: 544 - 556

Smith, N.K.Jr and Waldroup, P (1988). Investigations of threonine requirements of broiler chicks fed diets based on grain sorghum and soybean meal. Poultry Science. 67(1): 108 - 112

Snedecor, G.W and Cochran, G (1989). Statistical methods. 7th edition. Iowa State University press. Ames, Iowa. pp 507

Streeter,M.N; Hill, G.M; Wagner, D.G; Hibberd, C.A and Owens, F.N (1993). Chemical and physical properties and invitro dry matter and starch digestion of eight sorghum grain hybrids and maize. Animal Feed Science and Technology. 44: 45 - 58

Strumeyer, D.M and Malin, M.J (1975). Condensed tannin in grain sorghum: Isolation, fractionation and characterization. Journal of Agriculture Food Chemistry. 23: 909

Summers, J.D; Leeson, S and Ferguson, A.E (1978). Performance and leg conditions of caged and floor reared broilers fed diets deficient in selected vitamins and minerals. Poultry Science. 57: 506 - 512

Syed Ali, A.B and Yeong, S.W (1977). Direct substitution of maize in layer diets. Malaysian Agricultural Journal. 51 (1) 50-55.

Teeter, R.G; Sarani, S; Smith, M.O and Hibbard, C.A (1986). Detoxification of high tannin sorghum grain. Poultry Science. 65:67

Thakur, R.S; Gupta, P.C; and Lodhi, G.P (1984). Feeding value of different varieties of sorghum in broiler rations. Indian Journal of Poultry Science. (1984) 19 (2) 103-107.

Thakur, R.S; Gupta, P.C; Sagar, V; Prasad, D.; and Lodhi, G.P. (1985). Different sorghum grain varieties as alterative to maize in layers. Indian Journal of Poultry Science. (1985) 20 (2) 85 - 88.

Thakur, R.S; Gupta, P.C and Lodhi, G.P (1985). Comparative efficiency in different sorghum varieties in broiler diets. Indian Journal of Animal nutrition. 2(2): 87 - 88

Vanschoubroek, F.X; Van Spaendonk, R.L; Nauwynck, W (1964). A comparison of the feeding value of maize and sorghum for fattening pigs. Animal Production. 6: 371

Vavich, M.G; Kemmerer, A.R; Bon Nimbkar and Stith, L.S (1959). Nutritive value of low and high protein sorghum grain for growing chicks. Poultry Science. 38: 36 - 40

Vohra, P; Kratzer, F.H and Joslyn, M.A (1966). The growth depressing and toxic effects of tannin to chicks. Poultry Science. 45: 135 - 151

Waggle, D.H; Deyoe, C.W and Sanford, P.E (1967). Relationship of protein level of sorghum grain to its nutritive value as measured by chick performance and amino acid composition. Poultry Science. 46: 655 - 659

Wall, J.S and Ross, W.K (1970). Sorghum production and utilization. AVI Publishing Co; Inc. Westport, Connecticut, USA. pp 534 - 572

Wyllie, D and Kinabo, A (1980). Cassava and maize meal for broilers and the effect of supplementation with methionine and sulphate in cassava based diets. Tropical Animal production. 5: 182 - 190

8.0 APPENDICES

Appendix I: Composition of broiler premix.

Ingredient	Inclusion level	Ingredient	Inclusion level
Vitamin A	2 500 000 iu/kg	Biotin	20 mg/kg
Vitamin D_3	600 000 iu/kg	Choline chloride	100 000 mg/kg
Vitamin E	3 000 iu/kg	Selenium	20 mg/kg
Vitamin K	800 mg/kg	Cobalt	100 mg/kg
Vitamin B_1	200 mg/kg	Iodine	200 mg/kg
Vitamin B_2	1 200 mg/kg	Zinc	10 000 mg/kg
Vitamin B_6	400 mg/kg	Manganese	16 000 mg/kg
Vitamin B_{12}	2 mg/kg	Copper	2 000 mg/kg
Vitamin C	2 000 mg/kg	Iron	16 000 mg/kg
Folic acid	200 mg/kg	Antioxidant	25 000 mg/kg
Nicotinic acid	6 000 mg/kg		
Cal. Pantothenate	3 000 mg/kg		

Appendix II: **Summary of analysis of variance for means of body weights of broilers fed on different rations.**

Age (weeks)	source of variation	DF	Sum of square	Mean square	F value	Significance of F
2	Treatment	3	2595.45	865.15	2.19	NS
	Pen(Treat)	4	11621.42	2905.36	7.36	***
	Initial wt	1	203984.26	203984.26	516.64	***
	Error	303	119632.55	394.83		
	Total	311	337833.68			
3	Treatment	3	132266.34	4422.11	2.62	NS
	Pen(Treat)	4	60850.25	15212.56	9.00	***
	Initial wt	1	364554.85	364554.85	215.62	***
	Error	303	512296.31	1690.75		
	Total	311	950967.74			
4	Treatment	3	52838.50	17612.83	4.24	NS
	Pen(Treat)	4	136063.45	34015.86	8.19	***
	Initial wt	1	723385.19	723385.19	174.19	***
	Error	303	1258326.53	4152.89		
	Total	311	2170613.68			

Appendix II continues

5	Treatment	3	71539.89	23846.63	3.01	*
	Pen(Treat)	4	317583.20	79395.80	10.02	***
	Initial wt	1	1057297.64	1057297.64	133.49	***
	Error	303	2399880.81	7920.40		
	Total	311	3846301.54			
6	Treatment	3	119144.01	39714.67	2.95	*
	Pen(Treat)	4	274300.69	68575.17	5.09	***
	Initial wt	1	1199473.68	1199473.68	89.08	***
	Error	303	4079954.28	13465.20		
	Total	311	5672872.65			
7	Treatment	3	597034.31	199011.44	8.82	***
	Pen(Treat)	4	312214.49	78053.62	3.46	**
	Initial wt	1	1437077.69	1437077.69	63.72	***
	Error	303	6833329.81	22552.24		
	Total	311	9179656.30			

1. NS = Not significant at P<0.05
2. *, **, *** level of significance at P<0.05, P<0.01 and P<0.001, respectively.

Appendix III: Summary of analysis of variance for daily gains.

Age (weeks)	source of variation	DF	Sum of square	Mean square	F value	Significance of F
2	Treatment	3	46.46	15.49	1.92	NS
	Pen(Treat)	4	141.19	35.30	4.38	**
	Initial wt	1	830.28	830.28	103.04	***
	Error	303	2441.48	8.06		
	Total	311	3459			
3	Treatment	3	413.57	137.86	7.27	***
	Pen(Treat)	4	651.68	162.92	8.59	***
	Initial wt	1	472.36	472.36	24.90	***
	Error	303	5749.07	18.97		
	Total	311	7286.69			
4	Treatment	3	508.35	169.45	5.40	**
	Pen(Treat)	4	1391.59	347.90	11.09	***
	Initial wt	1	1242.43	1242.43	39.59	***
	Error	303	9509.34	31.38		
	Total	311	12651.71			

Appendix III continues

5	Treatment	3	1067.96	355.99	6.54	***
	Pen(Treat)	4	934.71	233.68	4.29	**
	Initial wt	1	644.65	644.65	11.84	***
	Error	303	16495.70	54.44		
	Total	311	19143.02			
6	Treatment	3	126.31	42.10	0.70	NS
	Pen(Treat)	4	680.08	170.02	2.82	*
	Initial wt	1	91.49	91.49	1.52	NS
	Error	303	18297.26	60.39		
	Total	311	19195.15			
7	Treatment	3	5945.68	1981.89	11.27	***
	Pen(Treat)	4	4327.37	1081.84	6.15	***
	Initial wt	1	218.94	218.94	1.24	NS
	Error	303	53296.67	175.90		
	Total	311	63788.67			

Appendix III continues

Overall	Treatment	3	345.54	115.18	9.01	***
	Pen(Treat)	4	176.27	44.07	3.45	**
	Initial wt.	1	510.37	510.37	39.92	***
	Error	303	3873.77	12.78		
	Total	311	4905.95			

1. NS = Not significant at P<0.05
2. *, **, *** level of significance at P<0.05, P<0.01 and P<0.001, respectively.

Appendix IV: Summary of analysis of variance for slaughter characteristics.

Variable	source of variation	DF	Sum of square	Mean square	F value	Significance of F
liveweight	Treatment	3	214591.67	71530.56	8.81	***
	Error	60	2154828.31	35913.81		
	Total	63	2369419.98			
carcass weight	Treatment	3	170036.50	56678.83	8.34	***
	Error	60	1220110.50	20335.18		
	Total	63	1390147.00			
Dressing %	Treatment	3	0.00997538	0.00332513	1.61	NS
	Error	60	0.12424402	0.00207073		
	Total	63	0.13421939			
Gizzard	Treatment	3	981.17	327.06	6.49	***
	Error	60	3025.81	50.43		
	Total	63	4006.98			
Heart	Treatment	3	135.13	45.04	12.83	***
	Error	60	210.63	3.51		
	Total	63	345.75			

Appendix IV continues

Liver	Treatment	3	611.80	203.93	6.21	**
	Error	60	1969.19	32.82		
	Total	63	2580.98			
Abdominal fat	Treatment	3	678.38	226.13	6.34	***
	Error	60	2141.63	35.69		
	Total	63	2820.00			

1. NS = Not significant at $P<0.05$
2. *, **, *** level of significance at $P<0.05$, $P<0.01$ and $P<0.001$, respectively.

Appendix V: Cumulative feed intake, liveweight gain and feed/gain ratio.

			Feed intake(g)			Liveweight gain(g)			Feed gain ratio		
PEN	BIRDS	TRT	FI1	FI2	FI3	LWT1	LWT2	LWT3	FG1	FG2	FG3
7	20	A	9860	22220	32580	7193	12060	12120	1.37078	1.84245	2.68812
10	19	A	8892	20539	29906	6423	11210	11438	1.38440	1.83220	2.61462
11	20	A	9660	22760	31760	7054	12500	10560	1.36944	1.82080	3.00758
15	19	A	9576	21660	30381	7058	11894	9709	1.35676	1.82109	3.12916
3	19	B	9452	20520	29146	6942	10925	9424	1.36157	1.87826	3.09274
8	20	B	9480	21420	30740	6805	11600	10460	1.39309	1.84655	2.93881
12	18	B	8964	19080	25686	6464	9378	7776	1.38676	2.03455	3.30324
14	20	B	9300	21760	31340	6242	12880	10960	1.48991	1.68944	2.85949
1	20	C	9040	20640	29560	6660	11420	9560	1.35736	1.80736	3.09205
4	20	C	9300	21180	30800	6801	11680	10380	1.36745	1.81336	2.96724
9	20	C	9860	22040	31560	7200	11860	10880	1.36944	1.85835	2.90074
16	18	C	8670	20196	27404	6678	12438	7236	1.29829	1.62373	3.78718
2	20	D	9420	21280	31280	6787	11860	11120	1.38795	1.79427	2.81295
5	20	D	9420	21360	30900	7066	11100	10780	1.33314	1.92432	2.86642
6	20	D	9760	22200	32200	7191	12060	11300	1.35725	1.84080	2.84956
13	20	D	9480	22560	32800	6904	12980	12160	1.37312	1.73806	2.69737

Where:

FI1 = Feed intake in the first period (2^{nd} - 3^{rd} week)

FI2 = Feed intake in the second period (4^{th} - 5^{th} week)

FI3 = Feed intake in the third period (6^{th} - 7^{th} week)

LWT1 = Total liveweight gain in the first period.

LWT2 = Total liveweight gain in the second period.

LWT3 = Total liveweight gain in the third period.

FG1 = Feed gain ratio in the first period.

FG2 = Feed gain ratio in the second period.

FG3 = Feed gain ratio in the third period.

Appendix VI: Proximate composition of poultry excreta.

Treatment	DM%(Air dry basis)	CP%	CF%	EE%	Ash%	GE(MJ/kg)
A	40.2	9.2	25.4	2.9	16.6	16.4
B	34.2	8.2	25.4	2.3	16.7	15.7
C	38.8	9.4	25.7	2.3	17.8	15.4
D	39.1	8.8	25.1	2.0	18.1	14.8

Appendix VII: **Summary of analysis of variance for uncorrected for N - metabolizable energy, N - corrected metabolizable energy and true metabolizable energy.**

Variable	Source of variation	DF	Sum of square	Mean square	F value	Significance of F
ME_c (Uncorrected)	Treatment	3	8.69	2.90	28.91	**
	Error	4	0.40	0.10		
	Total	7	9.09			
ME_n (Corrected)	Treatment	3	9.07	3.02	30.17	**
	Error	4	0.40	0.10		
	Total	7	9.47			
TME	Treatment	3	10.92	3.64	30.17	**
	Error	4	0.48	0.12		
	Total	7	11.40			

1. *, **, *** level of significance at $P<0.05$, $P<0.01$ and $P<0.001$, respectively.

Appendix V111: Cost of the diet treatments.

	Ingredient cost in a diet (100kg) / Diets				
Feed ingredient	Price/kg	A	B	C	D
Maize	60.0	3600.0	2400.0	1200.0	-
Sorghum	50.0	-	1000.0	2000.0	3000.0
Cotton seed cake	32.0	544.0	544.0	544.0	544.0
Sunflower cake	30.0	216.0	216.0	216.0	216.0
Fish meal	300.0	3000.0	3000.0	3000.0	3000.0
Ground limestone	20.0	80.0	80.0	80.0	80.0
Dicalcium phosphate	500.0	300.0	300.0	300.0	300.0
DL-methionine	3540.0	531.0	531.0	531.0	531.0
L-lysine	2400.0	120.0	120.0	120.0	120.0
Broiler premix	1500.0	750.0	750.0	750.0	750.0
Salt	200.0	100.0	100.0	100.0	100.0
Diet cost per 100kg		9241.0	9041.0	8841.0	8641.0