GRAIN SORGHUM AS AN ENERGY SOURCE IN BROILER CHICKEN DIETS

By

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DECLARATION

This is my original work and has not been presented for a degree in any other university.

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DEDICATION

To my children Eugene and Christine from whom I stayed for long hours.

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General

ABSTRACT

Three experiments were conducted to determine the effect of partly or wholly substituting high tannin sorghum (HTS) and low tannin sorghum (LTS) with maize in broiler chicken diets. In Experiment One, the chemical composition and the TME values of sorghum and maize were determined. In Experiment Two, day old chicks were randomly assigned to 7 dietary treatments consisting of a broiler starter diet upto 4 weeks of age followed by a broiler finisher diet upto 7 weeks of age. The 7 treatments fed had graded levels of the HTS and LTS (0, 20, 40, 60%). In Experiment Three, the procedure was the same as in Experiment Two except that the chicks were fed on two sets of sorghum grains. In one set of the sorghum grains, the HTS and LTS were treated with ash before incorporating in the diets while the other set of the sorghum grain was not treated and is referred to as untreated sorghum. Experiment Three had a set of 9 dietary treatments of untreated HTS, untreated LTS, treated HTS, and treated LTS graded as (0,40,60,%).

Chemical analyses showed that differences existed among the sorghum grains. The LTS generally had higher protein content (11.54%) than the HTS (9.34%) varieties, while the HTS had higher tannin content than the low tannin sorghums. Other aspects of chemical analyses were similar except that the HTS tended to have higher crude fibre (3.27%) than the LTS (3.07%) The proximate components of sorghum and maize also showed some differences. The crude protein content of sorghum was higher than that of maize while maize had higher ether extract (4.91%) than sorghum (3.38%). The crude fibre and ash content of sorghum and maize were similar. Maize had highest TME, followed by LTS and HTS.

In Experiment Two, chicks fed on HTS as the sole cereal component gave a ($p<0.05$) lower weight gain and poorer feed conversion efficiency at 0-4 and not 5-7 weeks of age compared to those on the control. Chicks on the 20% sorghum diet exhibited a significantly higher ($p<0.05$) body weight gain and better feed conversoin efficiency than those on 60% HTS. In Experiment Three, treatment of HTS with wood ash significantly reduced the amount of tannin. This reduction in the tannin content of the grain resulted in an increase, though not significant, in body weight gain and feed conversion efficiency. The chicks on the treated LTS diets showed slightly poorer performance than those on the untreated LTS.

Results of this study show that LTS of the type used in this study can completely replace maize in broiler chicken diets and upto 40% HTS can replace maize in the same diets. Ash treated HTS can also completely replace maize in broiler chicken diets.

1. Introduction.

Kenya has a land area of 569,646 square kilometers of which 75% is arid and semi-arid and only about 28% has the potential for arable farming. The estimated human population is well over 25 million implying that the amount of land available for grazing has been drastically reduced. As a result, livestock enterprises that require less land, and need concentrate feeding is, important.

Commercial production of livestock feeds is largely limited by availability of raw materials. The quality of manufactured feeds depends on the type of raw materials used. In the manufacture of feeds in Kenya, cereals used as energy sources include maize, wheat and barley. These same grains are important human foods whose prices, especially maize and wheat, are controlled by the government at a level that would motivate farmers to produce enough. These price levels, in most cases, are too high to allow the cereal to be economically used in animal feeds. For example, the price of maize increased from Ksh 855/ton in 1976 to Ksh 2233/ton in 1988 which in turn pushed the price of broiler mash from Ksh 1673 /ton to Ksh 4214/ton. Wheat and Barley command high market prices and any of it that is released into the feed industry is often composed of small grains that have been rejected by malters. Moreover, the domestic Wheat and Barley production does not even meet the human demand. This leaves maize as the major energy source although not completely free of competition between livestock feed and human food requirements. Despite the high prices of these cereals, as well as the prices of animal feeds, the amount of maize and wheat released to the livestock feed industry by the National Cereals and Produce Board (NCPB) has been declining since 1984 and is even uncertain during drought. Most of the grains released to the industry are those that have been damaged by weather or pests and therefore unfit for human consumption.

The demand for sorghum as a food requirement is lower than that for maize. Sorghum, by virtue of its chemical composition, is very similar to maize and is, therefore, worth investigating on as an alternative energy source in broiler chicken diets. Conservatively the potential land suitable for sorghum production in Kenya is 301,000 ha although this is not fully put to use. Sorghum grows fairly well in marginal areas where the competition with other food crops is negligible and where maize does not do well. Despite this potential to produce sorghum, production has been declining due to such factors as inadequate government support, poor pricing policy compared to other crops and poor marketing channels. With improvement of these factors, production of this grain can be expanded to supplement maize in the livestock feed industry.

Both white and brown varieties of sorghum are produced in Kenya e.g serena and 2KX17. The brown varieties are bird resistant but, contain condensed tannins which lower protein digestibility, and reduce metabolisable energy in poultry and pig diets. This problem can, however, be overcome through processing methods such as; dehulling, reconstitution and moist alkali treatment.

The main objective of this study was to evaluate the suitability of the commercially available grain sorghum and the varieties serena and 2KX17 in broiler chicken diets as an alternative energy source to maize. This study is justified by the above factors, and in addition, not so much work has been carried out in Kenya so that literature in this area is lacking.

The specific objectives of the study were; to characterise the commercially available varieties of sorghun grains from the National Cereals and Produce Board and the varieties serena and 2KX17 in terms of colour, chemical composition and the TME, to determine how much sorghum grain can replace maize in broiler chicken diets and finally to determine the effectiveness of wood ash to detoxify sorghum tannins and the effect of the ash on the nutritional value of the grain material when fed to broiler chicken.

2. LITERATURE REVIEW

2.1 Sorghum production in Kenya

Sorghum belongs to the tribe andropogoneae, family graminae, and the genus sorghum (Doggett, 1988). Cultivated sorghum (Sorghum bicolor (L) Moench) is drought tolerant and outyields maize in many of the drier parts of East Africa (Acland, 1971). It requires 300-380 mm of rainfall during its growing period, but an evenly distributed rainfall of only 175 mm has given yields of upto 1110 kg/ha (Acland, 1971). It is also more resistant to waterlogging and yeilds well on infertile soils. In East Africa yields vary between 550 and 1700 kg/ha under normal farming conditions (Acland, 1971). Sorghum grain constitutes a major source of energy for humans in Africa and Asia, while in the Western hemisphere the crop is grown mainly for animal feed. According to FAO (1988) statistics, the average annual global production amounted to 60-70 million tonnes making it the fifth largest cereal produced.

Sorghum and millet were the most important food crops for Kenyans until about the 16^{th} centuary when maize was introduced (Ministry of Agriculture, 1989). Maize growing was adopted because of its white colour and the bland flavour, higher yields, lower labour requirements and is less susceptible to bird damage.

Maize, however, does not tolerate low rainfall. On the other hand, the marginal lands of Kenya which receives an annual rainfall of 800mm or less are suitable for sorghum production (Ministry of Agriculture, 1989). The sorghum cultivars grown in Kenya include mainly the improved ones such as Serena, Seredo, IS8595 and 2KX 17 although small holders still grow local types. The production areas include Nyanza, Western, Eastern, Coast, Central and North Eastern provinces. Nyanza and Western provinces produce 91% of the total national sorghum output (Mbogo, 1982). The production of sorghum and millet in Kenya has declined but has not quite been abandoned. FAO (1988) reported that the national production of sorghum in Kenya decreased from 177,000 tonnes at the begining of the sixties (1961-1965) to some 120,000 tonnes in 1986/1987. This was due to the substitution of this crop with the Katumani composite maize. Production is further constrained by birds that attack the crop, striga weed infestation, poor government support, the absence of a well developed and efficient marketing structure like that for maize and low prices. The current government policy is that the National Cereals and Produce Board (NCPB) should purchase all available grain sorghum in order to promote its expansion and to stop farmers viewing sorghum merely as a subsistence crop.

2.2 Composition and structure of sorghum and maize grains

Although there are many similarities between sorghum and maize grains in terms of gross composition and structre Rooney et al. (1980), there are still some crutial differences. However, sorghum has slightly higher protein content but lower fat content than maize (Rooney, 1969). Major differences between maize and sorghum relate largely to the type and distribution of protein surrounding the starch in the endosperm. The endosperm of both maize and sorghum is made up of peripheral corneous and floury areas. Sorghum has much higher proportion of peripheral endosperm than maize (Rooney and Sullins, 1973 and Rooney and Miller, 1982). The peripheral endosperm region is extremely dense, hard and resistant to water penetration and digestion. Peripheral cells have a higher protein content and resist both physical and enzymatic degradation. This region also provides some protection to the endosperm cells which are richer in starch.

Hardness and corneousness in sorghum and maize is related to protein content and continuity of protein matrix (Rooney and Miller, 1982). The matrix may be continous or incomplete and consists of glutelins in which starch granules and prolamine rich protein bodies are embedded. In corneous endosperm, starch granules are smaller and the matrix nearly continous. Floury endosperm cells tend to have more larger starch granules surrounded by a discontinous matrix with fewer protein bodies. Scattering of light by the numerous voids in floury cells makes the floury endosperm opaque.

2.2.1 Carohydrates

Carbohydrates which include starch, cellulose, simple sugars and pentosans, comprise 80-85% of sorghum grain (Rooney and Clark, 1968). Starch is the major constituent of sorghum accounting for 56 - 75% of the total dry matter (Subramanian and Jambunathan, 1981). Most sorghum grain starches contain 20-30% amylose and 70-80% amylopectin. The physiochemical characteristics of starch are influenced by the amylose content in sorghum (Miller and Burns, 1970). Waxy sorghums have a low amylose content (Deatherage et al., 1955).

2.1.2 Proteins

The protein content of grain sorghum cultivars and large germplasm has been reported to show a wide range of variation, 5.8-20.9% (Axtell et al., 1974 and Salunke et al., 1977). This variation has been attributed to climate, soil, cultural practices, location and variety (Miller et al., 1964). The proteins in sorghum, like other cereal grains, are classified as albumins, globulins, prolamins and glutelins (Jambunathan and Mertz, 1973). The protein classes are distinguishable in all cereal grains on the basis of their solubility in water (albumins), salt solution (globulins), alcohol (prolamines) and alkaline detergents (glutelins) (Guiragossian et al., 1978). Fractionation studies indicated that the distribution of albumin-globulin, prolamin and glutelin in sorghum is about 15%, 26%, and 44%, respectively, of the total nitrogen in the grain (Jambunathan et al., 1975 and

Neucere and Sumrell, 1980). As in other cereals, lysine is the first limiting amino acid recorded in sorghum grain (Adrain and Saryerse, 1957). The prolamin fraction, which accounts for 26-43% of the total protein, is extremely low in these two amino acids while globulin and albumin, which account for 20% of the protein, are rich in lysine and tryptophan. A significant negative correlation between protein content and lysine content and a positive correlation between protein content and leucine has been reported (Deosthale et al., 1970). Sorhgum grain has an excess of leucine in comparison to isoleucine with no major deficiencies in other amino acids (Axtell et al., 1981). Vitamin B6 is involed in the metabolism of leucine, tryptophan and niacin. High leucine levels in the diet causes amino acid imbalance between leucine and isoleucine and also impairs the metabolism of niacin by increased excretion of N-methyl nicotinamide and vitamin B6 is hence preferencially used for the biosynthesis of tryptophan; and thus producing induced deficiency of niacin (Ghafoorunissa and Narasinga Rao, 1973). Dietary deficiency of niacin is a well accepted causative factor of pellagra a nutritional disorder in human biengs clinically manifested by dermatitis, diahrroea and dementia (Deossthale, 1970). These clinical and biochemical manifestations of excess leucine can be counteracted by increased intakes of niacine or tryptophan or supplementation with isoleucine (Belavady et al., 1973). The supplemented isoleucine counteracts the amino acid imbalance while the tryptophan and niacine spares the vitamin B6.

2.2.3 Ether extract

The lipid content of sorghum is reported to range between 2.2-4.9% (Neucere and Sumrell, 1980 and Subramanian et al., 1983). The fatty acid composition of sorghum grain is nearly the same as that of maize oil (Beldiumd and Sneigowski, 1951 and Kummerow, 1946). The fatty acids bieng composed primarily of linoleic, oleic, palmitic, stearic, mystric and hexadecenoic acids, in order of decreasing concentration (Kummerow, 1946).

2.3 Antinutritive factors

2.3.1. Tannins

The two groups of phenols that are widely distributed in the plant kingdom are the hydrolysable and the non-hydrolysable or condensed tannins (proanthocyanidin oligomers of flavan-3-ols) (Asquith et al., 1983). The principal tannin of sorghum has been reported as a proanthocyanin (Batesmith and Raspa, 1969). Tannins have been described as water soluble polyphenols having molecular weight of between 500 and 3000 and with the ability to precipitate proteins (Batesmith and Swain, 1962). Sorghum cultivars have been divided into three groups according to grain tannin content of the grain and the genes that control it (Price and Butler, 1977 and Rooney and Miller, 1982). Group I sorghums do not have condensed tannins, Group II sorghums have condensed tannins that are not extractable from the seed with methanol or aqueous acetone but are readily extractable with methanol to which 1% HCl has been added (Maxon and Rooney, 1972). Group III sorghums contain condensed tannins readily extractable with methanol without HCl.

Condensed tannins are phenolics of considerable agronomic and nutritional significance and may be present in sorghum seed upto 3% of the dry weight (Butler et al., 1980). High tannin content has resulted in several problems in the use of HTS grain in chicken feed such as lowered digestibility coefficients and lowered palatability due to astringency (Armstrong et al., 1974; Chang and Fuller, 1964; Connor et al., 1969; McGinty, 1968; Schaffert et al., 1975 and Batesmith and Raspa, 1969). Astringency has been described as that contracting or dry feeling in the mouth caused by precipitation of protein in saliva and mucosal surfaces (Joslyn and Goldstein 1964) and is considered to be the principal mode of bird repellancy in bird resistant sorghums (Bullard and Elias, 1980). Tannins have the ability to bind and coagulate proteinacious tissue. Under optimal conditions sorghum tannin is capable of binding and precipitating at least 12 times its own weight of protein (Hagerman and Butler 1980).

Because grain sorghum contains approximately 10% protein, the grain of high tannin sorghum contains more than enough tannin to bind all the seed protein (Neucere and Sumrell 1980). Indeed the name tannins is from their historical importance in tanning hides into leather by binding protiens such as collagen in animal skins (Butler and Riedle, 1984). Other explanations for the lower nutritive value of the brown seed grain sorghum include the formation of an insoluble tannin protein complex in the hard outer corneus endosperm and the insoluble nature of the glutelin matrix in the corneous endosperm due to presence of the disulphide bridges in the protein (Wall and Blessin, 1969). In both cases, the starch is encapsulated in the protein matrix and is less vulnerable to digestive enzyme action. Any processing method that either raptures or increases the solubility of the protein matrix enhances the digestiblity of the grain.

2.3.2 Phytic Acid

Phytic acid occurs primarily in the outer seed coat/bran and germ of the plant (Oberlease, 1973). It is the major storage form of phosphorous (De Boland et al., 1975). Phytate P constitutes 80-87% of total P in whole sorghum grain (Doherty et al., 1980).

The importance of phytic acid in nutrition lies in its ability to form chelates with di and trivalent cations particularly Ca, Fe, Mg, Zn and Co rendering them unavailable to monogastric animals by converting them into insoluble phytates Davies and Nightngale (1975) and Radhakrishnan and Sivaprasad (1980). Phytic acid also binds strongly with protein below the isoelectric point thus making it unavailable (Cosgrove, 1966).

2.4 Processing methods

Several methods have been utilised to reduce tannins toxic effects. Some of the methods used include:- Mechanical abrasion (dehulling) (Chibber et al., 1978), moist alkali treatments e.g Ammonium hydroxide, pottasium carbonate, sodium hydroxide, calcium oxide, hard wood ash filtrate (Price et al., 1979), wood ash slurry (Mukuru personal communication, Price et al., 1979 and Dogget, 1977) and raw magadi soda - a sodium sesquicarbonate salt (Muindi et al., 1981) and reconstitution (Mitaru et al., 1983,1984, and Teere et al., 1984)

Alkali treatment which involves mixing the grain and the alkali under moist conditions for a specified period of time in general reduces the chemically assayable tannins in high tannin sorghum grains and improves its nutritional quality. The mechanism by which the moist alkali conditions detoxify the tannins in sorghums is not known but it appears like the alkali solution reacts with the tannin making it unreactive both in the assay and nutritionally.

Reconstitution is the process of adding moisture back to the grain and sealing the moist grain from the environment so fermentation can occur. The mechanism by which this process deactivates tannins is also not clearly understood but it probably involves the polymerization of tannin monommers to higher oligomers that lose their activity in the assay as well as their protein binding activity (Mitaru et al. 1983)

Mechanical abrasion or mechanical dehulling is the removal of the outer coat of the grain. Although the process reduces the amount of tannin in the grain, it results in high grain losses (upto 37%) by weight and is not commonly recommended (Chibber et al., 1978).

2.5 Biological evaluation of grain sorghum with chickens and pigs

2.5.1 Chickens

Various investigators have reported differences in the feeding value of grain sorghum for non-ruminants. The presence of high tannins in some cultivars of sorghum has been associated with depression of growth rate, feed intake, protein digestibilities, and metabolisable energy and also with leg abnormalities in chicks and rats (Armstrong et al., 1973; Featherston and Rogler, 1975; Chang and Fuller, 1964 and Park et al., 1985). In a study comparing maize and sorghum as energy sources in chicken diets, the best growth rate was obtained with birds on 30% and 40% sorghum upto 37 days, 50:50 maize and sorghum combination, 30:30 combination (Finzi et al., 1970; Pieschel et al., 1976, and Park et al., 1985). All these workers reported a poorer performance with birds on sorghum diets alone. Better feed conversions were obtained with maize based diets and maize/sorghum mixtures (Blaha et al., 1984). Feed consumption of birds on high tannin diets decreased with increasing substitution level with the 60% sorghum diet having significantly lower feed intake

(Park et al., 1985). This is in agreement with the findings of Vohra (1966) who demonstrated a reduction in feed consumption with an increase in dietary tannin content.

In another trial where maize grain, sorghum, wheat, barley and oats were used in the diets, broilers fed on the diet containing maize or oats showed the highest live weight gains, while broilers fed on wheat diets and sorghum diets showed similar gains. However, those fed on sorghum plus tannin or barley showed the lowest gains (Petersen, 1969). The feeding of certain varieties of grain sorghum shown by field testing to be bird resistant did not depress either feed intake or body weight gain (Damron et al., 1968)

High incidences of leg abnormalities has also been reported in chicks fed on high tannin sorghum diets (Armstrong et al., 1973 and Rostagno et al., 1973). The leg abnormality is characterised by a bowing of the legs with swellings at the hock joint (Elkim et al., 1977; Armstrong, 1973 and Rostagno et al., 1973). The leg abnormality is believed to be due to the adsorption of the tannin to the gut and their subsequent deposition in the bone (Elkim et al., 1977). Other causes of leg abnormalities are high protein and energy contents of the diets (Sauver, 1984), biotin defficieny (Whitehead, 1977). Several dietary factors other than simple nutrient deficiencies appear responsible for the leg abnormalities in chicks.

Pale skin on the legs and beaks of younger chicks, dark pigmented skin on the legs and increased level of water and protein in the breast muscle have been reported in chickens fed on sorghum as compared to those fed on maize (Finzi et al., 1970; Blaha et al., 1984 and Saxena et al., 1978). Some authors noticed a bad flavour and fish like taste in the meat of birds fed diets with high tannin sorghum (Jensen, 1964 and Petersen, 1969).

Trials with layers demonstrated a reduction in egg production when hens were fed 1% tannic acid (Potter et al., 1967). They also reported an olive discolouration of the yolk and egg mottling at 2% level of tannic acid. Decreased egg production was also reported with 1% dietary tannic acid levels or when high and low tannin sorghum grains were compared (Weber, 1969). In an experiment with field beans (vicia faba L), an inverse relationship between egg weight per day and tannin content was reported (Guillaume and Bellec, 1976). Reduced laying rate and decreased egg weight of hens on high tannin horse bean diets have also been reported (Martin-Tanguy, 1977). These results do not agree with those of McClymont (1952) who reported that grain sorghum can be used successfully in the diets of laying hens but when used in the diets of growing chicks at levels between 28-63%, growth is depressed.

Differences in dressed weights by broilers fed om maize and sorghum diets has been reported (Geortz et al., 1961). These authors found that Turkeys fed on maize based diets had significantly higher dressed weights than those on sorghum based diets.

Available data shows inconsistent results of the inclusion of sorghum in broiler feed mixtures. Majority of authors ascribe these differences to tannin content, protein and amino acid availability with apparently different cultivars.

2.5.2 Digestibility in Farm and Laboratory Animals

Invitro digestibility studies with sorghum grain exhibited higher protein digestibility values for LTS compared with HTS varieties. Extraction of tannins from the HTS variety resulted in an increased invitro protein digestibility compared with the intact grain (Armstrong et al., 1974). Low apparent digestibilities of protein and energy have been reported in high than low tannin varieties fed to chicks (Vohra et al., 1966), rats (Glick and Joslyn, 1970) and pigs (Cousins et al., 1981) but protein digestibility is reportedly more depressed than energy digestibility (Featherstone et al., 1975; Nelson et al., 1975). Polyphenolic compounds adversely affect protein digestion and availability, cause a-amylase inhibition, reduces dry matter digestion and also denature proteins due to a non-specific tannin-protein binding (Jambunathan and Metz, 1973; Maxon et al., 1973 and Tamir and Alumot, 1969). Tannins reduce protein digestibility by inhibition of digestive enzymatic action and also by complexing dietary protein in the gastrointestinal tract rendering them resistant to enzyme breakdown (McLeod, 1974).

Contrasting reports with rats have, however, been reported when grain sorghums with varying tannin contents were used and digestible energy determined. No influence on utilizable energy content of grain sorghum was established (Ann and Nelson, 1973).

In a chicken study to determine the apparent and corrected amino acid digestibilities of sorghums with varying tannin contents, supplementation of a protein free diet with 1.41% tannic acid resulted in a four-fold increase in endogenous amino acid excretion. Apparent and corrected amino acid digestibilities of sorghums of intermediate and high tannin content were considerably lower than those of low tannin sorghum. Apparent digestibilities of all the amino acids of low, intermediate, and high tannin varieties was 73, 41, and 22%, respectively (Rostagno et al., 1973). Such wide differences in amino acids availability were also reported by Stephenson et al., (1970) and Mitaru et al. (1984). The large differences in amino acid digestibility reported by these workers do not agree with those of Chang and Fuller (1964) who reported only a slight depression in protein digestibility of high tannin sorghums compared to low tannin sorghums.

In trials with pigs to determine digestible energy, digestible protein and nitrogen retention, low tannin sorghum were significantly superior in digestibility than those with high tannin (Noland et al., 1976). They reported a range of 51.9%-64.7% in apparent nitrogen retention among pigs fed 10 different brown grain sorghum types. A negative dietary effect on protein digestibility, digestible energy and dry matter digestibility for high tannin sorghum diets and not low tannin sorghum diets or maize have further been reported by other workers (Almond et al., 1979, Cousins et al., 1981 and Kemm et.al 1984). Lower digestibilities for tryptophan, histidine, glycine and prolamin in high versus low tannin sorghum have also been reported (Cousins et al., 1981). It has further been reported that tannins have a higher affinity for hydrophobic amino acids such as isoleucine, valine and tyrosine (Mitaru et al., 1984).

3. NUTRITIONAL EVALUATION OF SORGHUM GRAIN VARIETIES WITH BROILER CHICKENS

3.1 EXPERIMENT ONE

3.1.2 Introduction

Knowledge of nutrient content, the relative nutrient availability to the animal and the variation in chemical composition of feedstuffs is as important as the knowldge of nutritional requirements of animals for successful application of the principles of nutrition to animal feeding. Sorghum is an important food grain in the semi-arid areas of Kenya, but its food and feed qualities have not been clearely defined. Studies cited in the literature review show that there exist chemical differences among the sorghum grain varieties. These are, however, studies carried out elsewhere and do not neccesarilly apply to our local conditions. This study, therefore, undertakes to determine the chemical compositon of the sorghum grain and its true metabolisable energy (TME).

The objective of this experiment was to characterise the commercially available varieties of sorghum grain from the NCPB and individual varieties, Serena and 2KX17 in terms of colour chemical composition and TME.

3.1.3 Materials and methods

3.1.3.1 Procedure

Two commercial batches of sorghum grain were obtained from the NCPB Nairobi in 1989. These batches were blends of several varieties from farmers all over the country and on the basis of visual appearance of the grain were simply classified as brown and white sorghums. The actual season when the crop was harvested was not precisely known. Another two varieties namely Serena (brown sorghum) and 2KX17 (white sorghum) were obtained from Kenya Seed Company from the 1989 crop season. Approximately 250 g of the grain sample was randomly taken from the different bags and milled using a willey mill to pass through a 1 mm screen. The milled samples were stored in airtight glass jars and later used for proximate analyses and tannin determination. Grain samples for tannin analysis were milled using a Udy Cyclotech sample mill attached with a vacuum to pass through a 0.4 mm screen. Analyses for proximate components were conducted in triplicates and at least five times for tannin analysis.

Proximate components were determined according to AOAC (1984) procedures. Tannin analysis was done using the vanillin assay method Burns (1971) as modified by Price et al. (1978).

3.1.3.2 <u>Determination of true metabolizable energy (TME)</u>

A total of forty, five month old Issa Brown hybrid roosters were obtained from a cockrel exchange program and allowed one week to acclimatise. During acclimatisation, all the birds were put on a similar diet with free access to water. They were then shaved around the cloaca, wing banded and starved for 24 hours. Each bird was then force fed 30 g of a feedingstuff and fitted with an excreta collection bag before being placed in individual cages. One lot of birds, the control, was fed absolutely nothing but allowed free access to water. Exactly 48 hours after force feeding, the excreta collection bags were removed. The collected excreta was oven dried, allowed to come to equilibrium with the atmospheric moisture and weighed. The experiment was a randomised block design with eight feedingstuffs each being assayed four times for TME by the method of (Sibbald 1976). The feedingstuffs consisted of maize (NCPB), maize (Kenya Seed Co.), HTS, LTS, serena, 2KX17, ash treated serena and ash treated 2KX17. Samples of the feedingstuffs were also assayed for gross energy (GE) content using a Parr adiabatic oxygen bomb calorimeter. All the feedingstuffs were assayed in the ground form.

3.1.4 Results and Discussion

3.1.4.1. Chemical analyses of the grains

Chemical analyses and the TME of sorghum grain and maize are shown in Table 1. Data on the chemical composition of sorghum indicated varietal differences. The mean protein content was highest for white sorghum from NCPB followed by brown sorghum from NCPB, 2KX17 (white sorghum) and Serena (brown sorghum). Factors such as climate, soils, cultural practices, location and variety have been associated with these differences in sorghum grain protein content (Miller et al.,1964). All the sorghum grains except Serena had a higher protein content than maize, while maize had higher ether extact than sorghum. This is in general agreement with the results of Rooney and Pflugfelder (1986) and Subramanian et al. (1983). The crude fibre content of sorghum grain ranged between 2.3% and 4.2%. This was within the range reported by Rooney and Clark (1968). However the level of crude fibre (4.2%) observed in brown sorghum was relatively high compared to that in white sorghum. It was observed that the brown sorghum had glumes attached to them. The lignin content of glumes is higher than that of the grain and this could account for the relatively higher crude fibre observed in brown sorghum. The crude fibre content of sorghum grain did not however differ significantly from that of maize (3.8-3.9%). The ash content of sorghum ranged between (1.4-2.7%). Although this was within the range reported by Rooney and Clark

Table 1: Chemical composition (%DM) and energy content (Kcal/g) of sorghum grains and maize .

Grain	DM	CP	EE	CF	ASH	TANNIN [1]	GE
B.sorghum	90.57±0.07	11.36±0.03	3.38±0.67	4.20±0.29	2.70±0.32	2.27±0.06	4.131±0.
W.sorghum	89.18±1.28	12.66±0.01	3.40±0.32	3.81±0.15	1.60±0.00	0.03±0.05	4.305±0.
Serena	87.39±0.14	7.24±0.07	3.13±0.05	2.56±0.07	1.40±0.02	2.25±0.16	4.061±0.
2KX17	88.31±0.21	10.42±0.03	3.62±0.22	2.34±0.03	1.39±0.07	0.00±0.00	4.200±0.
Maize (NCPB)	90.26±0.05	7.95±0.01	4.94±0.14	3.65±0.30	1.23±0.01	–	4.200±0.
Maize (KSCo.)	10.56±0.31	7.27±0.14	4.88±0.08	3.90±0.07	1.28±0.02	–	4.200±0.

[1] Catechine equivalent

NCPB - maize from National cereals and produce board

KSCo. - maize from Kenya seed company

B.sorghum - brown srghum

W. sorghum - white sorghum

G.E - gross energy

T.M.E - true metabolisable energy

(1968) the ash content of brown sorghum again tended to be somewhat higher than that of the other sorghums and maize.

The results of tannin analysis showed varietal differences in tannin content (0.0-2.28) among the sorghum varieties. Brown sorghum had the highest amount of tannin content (2.28%), followed by serena (2.25%), white sorghum (0.038%) and 2KX17 (0%). The presence or abscence of tannins in sorghum grain is genetically determined and is conditioned by the complementary genes B_1 and B_2 (Rooney and Miller, 1982).

The TME values of the grain are also shown in Table 1. The white sorghum and 2KX17 had consistently higher TME values as compared to brown sorghum and serena although no statstical analysis was done. Low apparent digestibility of energy has been reported in high than low tannin varieties fed to chicks (Vohra et al., 1966)

3.1.5.2. Conclusions

From this study, it is clear that sorghum varieties differ in terms of proximate components, TME and tannin content. Minor differeces in proximate components and TME also exist between sorghum grains and maize. These results further show that white sorghum and maize are similar in their chemical composition and that the only major difference between brown sorghum and maize is the presence of tannins in the soghum. Sorghum grains can therefore be tried as a substitute to maize in broiler chicken diets.

3.2 EXPERIMENT TWO:

3.2.1 Introduction

Competition between man and livestock for energy sources such as maize in Kenya, coupled with the rapidly increasing human population, diminishing per capita land holdings, and the unpredictable weather conditions have led to attempts to search for alternative energy sources particularly those crops that can do well in marginal areas. Results of Experiment I show that the chemical composition of maize and sorghum grain are almost similar except for a few differences. Successfull replacement of maize with sorghum in broiler chicken diets would spare substantial amount of maize for human consumption.

The objective of this study was to determine how much sorghum grain can efficiently replace maize as an energy source in broiler chicken diets.

3.2.2 Experimental diets

Equal amounts (w/w) of LTS and HTS analysed in Experiment One were added in boiler chicken diets and fed to the chicken. Two experimental diets were fed as shown in Table 2. The broiler starter and finisher diets were formulated such that sorghum substituted for maize at the following levels (0%, 20%, 40% and 60%). A 210 g/Kg CP and 2880 kcal of ME per Kg of diet starting ration was fed to the broilers until they were four weeks of age. Thereafter, the birds were fed on a 180 g/Kg CP and 2880 kcal of ME per Kg diet finishing ration until they were seven weeks old. A total of seven dietary treatments were fed. The diets were made isonitrogenous and isocaloric according to the specifications of NRC (1984).

Table 2. Composition of the starter and the finisher diets used in experiment two (%DM).

	Starter diets (0-4 weeks)							Finisher diets (5-7 weeks).						
Type of grain		B.sorghum			W.sorghum			B.sorghum				W.sorghum		
Diets	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Ingredients	0	20	40	60	20	40	60	0	20	40	60	20	40	60
Maize grain	61.85	40.20	20.54	0.00	41.20	20.40	0.00	61.37	40.20	20.40	0.00	40.27	21.01	0.00
B.sorghum	0.00	19.80	39.89	60.00	0.00	0.00	0.00	0.00	19.80	39.60	60.00	0.00	0.00	0.00
W. sorghum	0.00	0.00	0.00	0.00	20.29	39.60	59.41	0.00	0.00	0.00	0.00	19.80	39.60	60.00
Dried B. yeast	20.52	22.82	19.94	22.90	17.20	22.47	20.79	18.00	18.00	18.00	16.17	15.42	15.28	17.00
Fish meal	10.10	7.65	9.06	7.26	10.24	7.76	86.51	4.00	4.00	4.00	5.00	4.00	4.10	4.00
Maize gl. feed	2.06	2.00	2.01	2.00	2.04	2.00	1.98	7.91	9.16	9.36	9.07	10.07	10.74	12.59
Limestone	1.43	1.676	1.81	0.83	1.83	1.82	1.20	1.37	1.18	1.10	0.90	1.20	1.32	1.16
$DiCaPO_4$	0.93	0.53	1.18	0.75	1.10	0.63	1.99	1.00	1.08	1.17	1.20	0.86	0.75	1.28
Lysine premix	0.00	0.00	0.00	0.57	0.00	0.00	1.08	0.00	0.00	0.00	0.00	1.64	0.00	0.13
Methionine premix	0.00	0.00	0.00	0.37	0.42	0.00	2.79	0.00	0.00	0.11	0.11	0.49	0.00	0.29
Broiler premix	2.50	2.50	2.50	2.50	2.56	2.50	2.47	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Corn oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.83	1.06	1.46	2.03	1.00	1.46	2.96
Salt	0.51	0.30	0.50	0.30	0.51	0.30	0.29	0.50	0.50	0.38	0.50	0.30	0.50	0.40
Coccidiostat	2.57	2.50	2.51	2.50	2.56	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Vitamin mineral premix provided the following per Kg of feed:
vitamin A 12000 IU, D3 3000 IU, B12 0,008mg, nicotinic acid 0.02g, pantothenic acid 0.0625g, iodine 0.0015g, copper 0.00625g, selenium 0.0002g, salt 0.1kg

Chemical composition (%) of the diets

DM	87.75	87.95	88.01	87.87	87.70	87.69	88.24	88.01	88.29	90.10	87.83	89.40	87.35	87.56
Protein	20.99	21.11	20.71	20.59	20.84	20.26	20.63	17.88	17.91	18.01	17.95	17.84	17.72	17.93
Ether extract	4.08	3.65	3.45	3.07	4.07	3.50	3.33	5.12	4.57	4.43	4.01	4.07	4.50	4.33
Crude fibre	2.36	2.53	2.53	2.56	2.85	2.53	2.72	2.63	2.83	3.04	2.78	2.99	3.58	3.72
Ash	5.45	6.38	6.86	6.36	7.41	6.01	6.13	5.06	6.38	6.29	6.41	6.41	6.22	6.32

ME (KCal/Kg)

Starter	3047.89	2884.40	2789.30	2760.40	2955.80	2969.50	2922.27
Finisher	2958.80	2859.70	2939.70	2794.50	2863.10	2993.40	2987.50

3.2.2.1 The feeding trial

A total of two hundred and eighty day old shaver 'Star bro' broiler chicks were obtained from a commercial hatchery. The birds were initially pooled together in two pens. They were then sexed and separated into males and females for uniform distribution of the sexes among the treatments. A batch of 10 chicks of either sex was selected at random, weighed and put into each of the 28 experimental pens. Each treatment was replicated four times (two females and two males) in a completely randomised design.

The experiment was carried out in two houses in pens measuring 1 m x 1 m, providing a floor space of 0.1 m^2 per bird and covered with about 10 cm wood shaving litter. The pens were heated electrically using infrared bulbs to maintain a temparature of 26-32^oC in the first four weeks.

At seven weeks old, a total of 56 birds, 8 birds per treatment of similar weights within a sex, were withdrawn from the various treatments, starved for approximately 24 hours weighed and then slaughtered. The birds were killed by dislocating the cervical bone then cutting the jagular vein and carotid arteries. After the birds were thoroughly bled, they were scalded for 1 minute in hot water. Feathers were removed by hand picking and birds evicerated and chilled in a fridge for 24 hours. The birds were removed from the fridge, the legs cut off and the dressed weights taken. Dressing losses in percentage were determined by subtracting the chilled weight from the liveweight, dividing by liveweight and multiplying by a hundred.

3.2.2.2 Data Collection

Records of body weight and feed intake of the chicks per replicate were taken on a weekly basis from the first to the seventh week. Mean body weight gain per treatment was calculated as a mean of the four replicates. Weekly feed intake per replicate was obtained from the difference between feed offered and the left over at the end of every week. The mean body weight gain, feed intake and feed coversion efficiency per treatment were calculated as a mean of the four replicates. Feed efficiency was calculated as the ratio of feed consumed to body weight gain (feed:gain) while proximate composition of the diets was determined according to standard procedures (AOAC 1984).

3.2.2.3 Statistical Analysis

The data on body weight gain and feed intake at four, five to seven and seven weeks of age were subjected to analysis of variance (ANOVA) using the Least Square Model of analysis and treatment means were separated by Least Significant Difference (LSD).

3.2.2.4 Results and Discussion

3.2.2.4.1 Broiler performance

Table 3. shows the average body weight gain, feed intake, feed conversion efficiencies and carcass yields at the various ages. The mean body weight gain results at 4, 5-7 and 7 weeks of age were 720 g, 877.61 g and 1595.58 g, respectively. The mean feed intakes during the same ages were 1399.63 g, 2539.10 g and 3930.71 g respectively. Dietary treatments had a significant $(p<0.05)$ effect on weight gain at 4 weeks of age and not between 5-7 weeks of age.

Of the three energy sources, better weight gains and feed conversion efficiencies were observed from chicks fed the maize based diets followed by the white sorghum based diets and the brown sorghum based diets, respectively. Brown sorghum when compared to white sorghum at 60% levels produced poorer weight gains and feed intakes although the differences were not significant $(p>0.05)$ both in the starter and the finisher periods. Birds on the 60% brown sorghum treatment reflected significantly poorer weight gains in the starter period than those on the control diet in the same period. Weight gain results of this study are in agreement with those of Chang and Fuller (1964) and Connor et al. (1969) who observed that feeding sorghum with high tannin content reduced chick weight gains. When sorghum substituted maize in the diets at 20% and 40% levels, the best weight gain and feed coversion efficiency was observed from the birds on the 20% sorghum diets irrespective of whether it was high or low tannin sorghum though this did not differ significantly ($p>0.05$) from the control. The birds on the 40% sorghum diets performed the same as those on the control diet and did not also differ significantly ($p>0.05$) with birds on the 60% sorghum diet in weight gain in the starter period. In the finisher period there were no differences in weight gain for all the treatments including the control.

Six birds died during the experimental period due to latent coccidiosis and ascites. The dead birds were from the following treatments; control 3 birds, 20% HTS 1 bird, 40% HTS 1 bird, 20% LTS 1 bird. In period one and two, in terms of weight gain and feed intake. The rather superior performance of the birds on the 20% sorghum based diets is hard to explain. It however agrees with the results of Finzi et al., (1978) who reported better weight gains and feed efficiency with the chicks receiving maize sorghum mixtures in their diets.

Feed intakes for the various treatments were similar except for the 60% high tannin sorghum diet that showed an insignificant 3% lower feed intake than the control in the period 0-4 weeks. In the 5-7 weeks period, the kind of feed troughs used were rather wasteful resulting in inflated figures of intake. It was therefore dificult to establish the trend of feed intake during this period. The lowered feed intake for the 60% high tannin sorghum diet was possibly because of lowered palatability due to astringency. Armstrong et al. (1974) and Chang and Fuller (1964) reported lowered palatability in chicks receiving high tannin based diets due to astringency.

Although substitution of brown sorghum with maize in the diets lowered body weight gain, the growth depression effect appeared more severe during the starter phase 0-4 weeks of age than in the 5-7 weeks period of age, the birds seemed to have adapted to the adverse effects of the treatment and improved their performance to the same level as that of the birds on the control diet. Rostagno et al. (1973) reported that chicks adapted to the effects of tannin in their early stages of life, that is 1-3 weeks of age. This seems to have been the case in this study.

Table 3. Effect of dietary sorghum grain on broiler weight gain, feed intake and feed efficiency.

	maize	Brown sorghum			White sorghum			
Level of grain	0	20	40	60	20	40	60	SE
Weight gain (g/broiler)								
0-4 wks	724.52[b]	735.97[b]	719.92[ab]	680.70[a]	744.84[b]	716.10[ab]	711.57[ab]	10.08
5-7 wks	880.17	887.62	877.95	866.85	887.75	871.65	872.20	3.71
0-7 wks	1608.66[b]	1618.10[b]	1587.88[ab]	1547.76[a]	1633.68[b]	1586.85[ab]	1578.35[ab]	9.04
Feed intake (g/broiler)								
0-4 wks	1406.07	1420.42	1400.92	1362.87	1415.02	1373.45	1418.67	34.90
5-7 wks	2635.22	2610.30	2533.85	2500.60	2482.37	2532.80	2478.85	179.22
0-7 wks	4008.30	4030.65	3934.77	3863.62	3897.40	3906.22	3816.10	192.35
Feed efficiency								
0-4 wks	1.92	1.92	1.95	1.98	1.87	1.90	2.00	0.04
5-7 wks	3.00	2.95	2.85	2.87	2.80	2.90	2.82	0.20
0-7 wks	2.47	2.47	2.47	2.50	2.37	2.47	2.41	0.12
Carcass yield (g)								
Live weight (g)	1685.87	1630.00	1618.12	1569.87	1715.60	1621.62	1603.87	-
Dressed weight (g)	1091.06	1079.62	1052.72	980.87	1088.20	1082.00	1051.07	-
% Loss	35.29	36.54	36.18	37.52	36.57	36.28	35.81	-

[1]Means followed by the same supersript and those bearing no superscript are not significantly (p>0.05) different.

At the end of the seven weeks of the experiment, a leg abnormality characterised by an outward bowing at the hock joint was noted in a few birds. A subjective leg score was conducted in an attempt to evaluate the extent of the arbnomality. The evaluation revealed the following results :- treatment 1 with 0% sorghum - 2 birds with abnormal legs, treatment 2 with 20% brown sorghum - 2 birds, treatment 4 with 60% brown sorghum - 1 bird and treatment 5 with 20% white sorghum -1 bird. These were all mild cases and no definite pattern of this abnormality was established according to treatments. In total, 2.1% of the experimental birds exhibited this leg abnormality.

Birds on the control diet showed the lowest dressing weight losses, with the remaining treatments showing similar dressing weight losses although the 60% brown sorghum diet showed slightly higher losses than the birds on the 20% and the 40% sorghum diets These results support those of Finzi et al., (1970) and Saxena et al. (1978) who observed that birds on sorghum based diets tended to accumulate more water in the breast muscle which was subsequently lost during dressing resulting in higher dressing losses compared to maize based birds. On the contrary, Geortz et al. (1961) reported that turkeys on maize based diets had significantly higher dressing weight losses than those on sorghum based diets.

3.2.2.4.2 Conclusion

Results of this study show that white sorghum of the type used in this experiment can completely replace maize in broiler chicken diets and that brown sorghum can replace maize upto to 40% in broiler chicken diets without any adverse effects on weight gain or feed intake.

3.3 EXPERIMENT THREE:

3.3.1 Introduction

Results of Experiment Two indicated that high tannin sorghum can efficiently replace maize in broiler chicken diets upto 40% without any adverse effect on weight gain. High tannin sorghum as the sole cereal component in broiler chicken diets resulted in poorer weight gain and lowered feed conversion efficiency. Several techniques as outlined in the literature review have been utilised to reduce the toxic effects of tannins. However due to high costs majority of Kenyan farmers would be unable to adopt most of these techniques. This study, was therefore undertaken to determine the effectiveness of wood ash in detoxifying tannins in sorghum grain to be fed to chicken and to compare the energy digestibility of the treated versus the untreated grain sorghum.

The objective of this study was to determine the effectiveness of wood ash, in detoxifying sorghum tannins and the ashes' effect on the nutritional value of the grain material when fed to broiler chicken.

3.3.2 Material and methiods

3.3.2.1 Treatment of grain sorghum with wood ash

High tannin sorghum cultivar (serena) and a low tannin cultivar (2KX17) obtained from Kenya Seed

Company in 1990 were used in this study. The grain was from the 1989 crop season. Wood ash was used as the source of alkali. The sourse of the ash was burnt out wood charcoal.

1.5 kg of wood ash was dissolved in 1.5 l of tap water in a plastic bucket and thoroughly stirred to form a slurry, 10 Kg of whole grain sorghum was then added directly into the slurry and thoroughly mixed for 5 minutes using a wooden rod. The mixture was then transferred into a 90 Kg jute bag placed inside a plastic drum. Each jute bag carried 60 Kg of the grain/slurry mixture. The mouth of the jute bag was then tied with a sisal rope and emersed in tap water and the mixture allowed to soak for 13 hours. The water was then drained off and the grain /ash mixture thinly spread out on a concrete floor for 4 days to dry and equilibrate with the atmoshperic moisture. A dust blower was used to blow off the ash before milling and incorporating in the diets

3.3.2.2 Experimental diets

Both the treated and the untreated grain were milled and incorporated in the diets at 40% and 60% which comprised the treatments. A 210 g/Kg CP and 2880 kcal/Kg ME starting ration was fed to broiler chicks upto four weeks of age. Thereafter, the birds were fed on a 180 g/ Kg CP and 2880 kcal/Kg ME finishing ration until they were 7 weeks old. All the starter diets and the finsher diets were made isocaloric and isonitrogenous according to specifications of NRC (1984). Proximate components of the diets were determined according to standard procedures of AOAC (1984).

Table 4 Composition of the starter and finisher diets used in experiment three

	starter diets 0-4 weeks									finisher diets 5-7 weeks								
	raw serena		raw 2KX17		trt serena	trt 2KX1 7		raw serena		raw 2KX17		trt serena trt 2KX17						
Ingredients (%)	0	40	60	40	60	40	60	40	60	0	40	60	40	60	40	60	40	60
maize grain	58.00	19.40	-	20.40	-	19.40	-		-	-		60.00	20.40	0.00	20.40	-	20.40	-
serena	0.00	39.60	60.00	-	-	-	-	-	-	-	-	-	39.60	60.00	-	-	-	-
2KX17	-	-	-	39.60	60.00	-	-			-	-	-	-	-	39.60	60.00	-	-
Trt serena	-	-	-	-	-	39.60	60.00	-	-	-	-	-	-	-			39.60	60.00
Trt 2KX17	-	-	-	-	-	-	-	39.6	60.0	-	39.60	60.00	-	-	-			-
Dried B.yeast	28.00	24.60	26.00	15.00	16.00	24.60	25.00	15.00	16.00	13.98	14.99	15.09	16.09	10.99	13.98	14.99	16.09	10.99
F. meal	8.50	10.00	10.25	10.40	10.00	10.00	10.25	10.40	10.00	7.36	7.36	7.36	7.36	6.36	7.36	7.36	7.36	6.36
Maize gl. feed	0.00	4.00	1.00	8.00	7.00	4.00	1.00	8.00	7.00	11.59	10.96	10.59	9.59	10.57	11.59	10.96	9.59	10.57
Limestone	1.24	0.92	0.79	1.00	1.66	0.92	0.79	1.00	1.66	1.41	1.41	1.35	1.41	1.41	1.41	1.41	1.41	1.41
$DiCaPO_4$	-	-	-	-	-	-	-	-	-	0.35	0.41	0.52	0.52	0.52	0.41	0.52	0.52	0.52
Methionine prem.	1.00	0.65	0.50	2.27	2.05	0.65	0.50	2.27	2.02	-	-	-	-	-	-	-	-	-
Lysine premix	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Corn oil	-	-	-	-	-	-	-	-	-	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50.	0.50
Broiler premix	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Coccidiostat	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Salt	0.30	0.30	0.50	0.30	0.30	0.30	0.50	0.30	0.30	0.50	0.50	0.50	0.30	0.50	0.50	0.50	0.30	0.50
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Vitamin mineral premix provided the following per Kg of feed.

:

Vitamin A 12000 IU, D3 3000 IU, B12 0.008mg, nicotinic acid 0.02g, pantothenic acid 0.0625, iodine 0.0015g, copper 0.00625g, selenium 0.0002g, salt 0.1kg.

Chemical coposition of the diets (%)

DM	89.31	89.56	87.65	89.25	88.79	89.72	88.79	89.62	89.75	87.09	88.71	88.95	87.98	88.81	88.71	89.25	88.54	87.61
Protein	20.97	21.01	20.99	20.58	21.04	20.95	20.89	21.00	21.07	17.87	18.02	17.98	17.86	17.89	17.79	17.76	17.68	17.88
EE	3.61	3.34	3.48	4.50	3.63	3.21	3.28	4.50	3.68	4.56	4.01	3.71	3.87	5.23	4.56	4.01	5.70	4.93
CF	3.04	3.77	4.38	3.91	4.01	3.87	4.01	3.89	3.90	3.79	4.28	4.56	4.01	3.52	3.75	4.32	3.25	3.54
ASH	5.40	5.23	5.62	5.47	5.53	5.57	5.63	5.63	5.38	5.41	5.67	4.09	5.21	5.34	5.43	5.37	5.28	5.17

ME (Kcal/Kg)

Starter	3000.09	3047.80	2926.61	3113.80	3010.70	3113.80	3010.70	3032.80	3031.00
Finisher	3047.60	2906.10	2852.00	3052.80	2907.10	2932.40	2916.80	3009.10	2877.00

3.3.2.3. Feeding trials

A total of three hundred and sixty 4 day old chicks of the Shavers' starbro strain were obtained from a commercial hatchery. The birds were initially pooled together in two pens and later sexed and separated into males and females. A batch of ten chicks of either sex were selected at random, weighed and put into each of the 36 experimental floor pens. Each treatment was replicated four times (two female and two male) in a completely randomised design.

The experiment was carried out in two houses in experimental floor pens each measuring 1 x 1 m, providing a space of 0.1 m^2 per bird and covered with 10 cm deep of woodshaving litter. The pens were electrically heated using infrared bulbs to maintain a temperature of 26-32^{o} C in the first four weeks.

At seven weeks of age, a total of 72 birds, 8 birds per treatment, of similar weights within a sex were withdrawn from the various treatments, starved for approximately 24 hours and then slaughtered. The birds were killed by dislocating the cervical bone then cutting the jagular vein and carotid arteries. After the birds were thoroughly bled, they were scalded for one minute in hot water. Feathers were removed by hand picking and birds evicerated and placed in a fridge where they were chilled for 24 hours. The birds were removed from the fridge, their legs cut off and the dressed weights taken. Dressing losses in percentage were determined by subtracting the chilled weight from the liveweight, dividing by liveweight and multiplying by a hundred.

3.3.2.4 Data Collection

Data on body weight and feed intake of the chicks per replicate were taken on a weekly basis from the first to the seventh week. Mean body weight gain per treatment was calculated as a mean of the four replicates. Weekly feed intake per replicate was obtained from the difference between feed offered and the left over at the end of every week. The mean body weight gain, feed intake and feed conversion efficiency per treatment were calculated as a mean of the four replicates. Feed conversionefficiency was calculated as the ratio of feed consumed to body weight gain (feed:gain) proximate composition of the diets was determined according to standard proceedures (AOAC 1984).

3.3.2.5 Statistical Analyses

The data on body weight gain, feed intake and feed efficiency at 4, 5-7 and at 7 weeks of age to were subjected to analysis of variance (ANOVA) and treatment means were separated by least significant difference (LSD).

3.3.3 Results and Discussion

3.3.3.1 Effect of ash treatment on chemical composition of grain sorghum

The levels of the assayable tannins, the TME values and the proximate components of the grain after treatment with wood ash slurry are shown in Table 4. The pH of the ash slurry was 11-12 and the only visible treatment effects on the grain was the development of a much darker seedcoat most likely due to oxidation of the phenolic compounds. Compared with the values before the treatment, the tannin content of the high tannin grain was significantly reduced from 2.25% to 0.021% (93% reduction). Untreated 2KX17 sorghum variety had no tannin. The major mineral components of wood ash is calcium followed by potassium (Mukuru personal communication). Treatment of high tannin sorghum with potassium carbonate and calcium oxide are reportedly effective in reducing tannin content among other alkali sources (Price et al., 1979).

Table 4. Chemical (%) composition and TME (kcal/g) of the raw and treated sorghum.

Grain	DM	CP	EE	CF	ASH	TANNIN[1]	GE
Raw serena	87.39±0.10	7.24±0.07	3.13±0.05	2.56±0.07	1.40±0.02	2.25±0.16	4.20±0.01
Raw 2KX17	88.31±0.21	10.42±0.06	3.62±0.22	2.34±0.03	1.39±0.07	0.00±0.00	4.06±0.03
Trt serena	86.14±0.60	7.27±0.11	3.07±0.01	2.49±0.05	1.40±0.06	0.02±0.07	4.20±0.11
Trt 2KX17	86.41±0.33	10.24±0.14	3.45±0.16	2.80±0.07	1.95±0.08	0.00±0.00	4.23±0.14
Maize	89.44±0.31	7.27±0.14	4.88±0.08	3.90±0.07	1.08±0.02	-	4.20±0.05

[1] Catechine equivalent

TME - True metabolisable energy

GE - Gross energy

3.3.3.2 Broiler performance

The results of the feeding trial are shown in table 5. Diets containing 60% serena sorghum treated with wood ash resulted in a 4.19% increase in weight gain at four weeks and a 3.2% increase at 7 weeks of age repectively. This increament wasnot significantly different (P>0.05) from that of that of the birds on the untreated 60% high tannin sorghum diet. The birds on the other treatments reflected similar perfomance at all ages.

Treating high tannin sorghum with wood ash slurry seemed to influence mean body weight gain of broilers on the 60% ash treated high tannin sorghum diet. Since the treated high tannin sorghum and the untreated high tannin sorgum diets were similar in all aspects in terms of dietary protein and energy and all the other components, the improvement in body weight for the 60% treated high tannin sorghum diet must have been caused by the ash treatment of the high tannin sorghum before incorporating it in the diets. The performance in terms of weight gain of the chicks on the treated low tannin sorghum diets was suprisingly poorer copmpared to those on the untreated low tannin sorghum diet although again the difference was not significant (p>0.05). There was no reason for treating the low tannin sorghum grain and this was done purely for comparison purposes. That wood ash treatment significantly reduced tannin content of the high tannin sorghum and subsequently improved its nutritional value agree with the findings of (Mukuru personal communication and Price et al., 1979). These authors found that wood ash could effectively reduce the toxic effects of tannins in high tannin sorghum grain and subsequently improve its nutritive value.

There were no significant differences at (p>0.05) in feed intake among the treatments but there was a trend towards lowered feed intake levels for the 60% untreated high tannin sorghum diet. Decreased feed intake with increased levels of tannin in the diet has been reported in other studies (Featherstone et al., 1973). Wood ash slurry treatment improved feed conversion efficiency (p>0.05) but not significantly for chicks fed the 60% serena diet but had no influence on chicks fed the 60% low tannin sorghum diet. The other diets did not show improvements in weight gain or feed intake as a result of ash slurry treatment. In the period 5-7 weeks, the performance of the chicks was similar for all the treatments in terms of weight gain. The lowest weight gain was recorded for the chicks on the 60% untreated high tannin sorghum diet although this was not significantly (P>0.05) different from the weight gains of the other diets. In the finisher phase, the chicks seemed to have adjusted to the high tannin diets and this probably is why the weight gains in the period 5-7 weeks were not significantly different in all the treatments. This may also be due to the fact that birds in the finisher phase are nolonger rapidly growing and therefore may not demand as much protein as in the starter phase when they are growing very fast.

The weight gains reported in this study are generally lower than those reported by Scott et al. (1984) although the diets were formulated to meet the requirements of NRC (1984). The possible explanation is because of the high levels of dried brewer's yeast used in the starter diets. Growth trials with broiler chicks on diets containing upto 15% in all mash diets or upto 25% in pelleted diets showed that the chicks performed as well as those on the basal diet with no yeast (Waldroup et al., 1970). They however noted a reduction in weight gain at higher levels. They reported that this was due primarily to problems associated with feed intake as the bulkiness of the diet was markedly increased as the yeast level was increased and the reduction in weight gain at higher levels of the yeast feeding was more likely associated with reduced feed intake at higher levels of yeast incorporation.

Table 5. Effect of treating high tannin sorghum (serena) and low -tannin (2KX17) sorghum on broiler weight gain, feed intake, feed efficiency and carcass yield.

		High tannin sorghum(serena)				Low tannin sorghum (2KX17)				
		Untreated		treated		Unteated		treated		
Level of sorghum,%	0	40	60	40	60	40	60	40	60	SE
Weight gain (g/broiler)										
0-4 wks	736.80^{b}	747.80^{b}	687.29^{a}	757.76^{b}	726.62^{ab}	723.17^{ab}	717.09^{ab}	717.52^{ab}	706.75^{ab}	4.99
5-7 wks	929.00	929.25	876.60	907.90	902.90	907.50	891.21	899.55	888.00	18.12
0-7 wks	6165.80^{b}	1677.05^{b}	1583.97^{a}	1680.48^{ab}	1634.22^{ab}	1626.07^{ab}	1611.07^{a}	1617.07^{ab}	1594.30^{ab}	34.71
Feed intake (g/broiler)										
0-4 wks	1429.39^{a}	1506.16^{b}	1426.59^{a}	1530.91^{b}	1497.44^{ab}	1439.42^{a}	1485.91^{a}	1447.91^{a}	1431.04^{a}	29.80
5-7 wks	2037.68	2041.14	1996.67	2071.58	2029.99	2026.24	1976.71	1933.77	1944.78	36.22
0-7 wks	3487.07	3587.30	3423.26	3602.49	3577.43	3465.66	3416.13	3381.68	3375.82	39.41
Feed efficiency (gain/feed ratio)										
0-4 wks	1.93	2.01	2.07	2.01	1.92	1.98	2.31	2.01	2.02	0.03
5-7 wks	2.20	2.23	2.32	2.23	2.28	2.24	2.32	2.14	2.18	0.07
0-7 wks	2.09	2.09	2.19	2.14	2.12	2.23	2.11	2.08	2.11	0.04
Carcass yield (g/broiler)										
Live weight	1652.60	1654.20	1588.25	1681.50	1644.25	1626.50	1607.20	1635.00	1621.50	-
Dressed weight	1079.59	1074.64	1012.74	1077.84	1035.16	1054.21	1049.30	1051.21	1039.74	-
%Loss	35.06	36.06	36.74	36.22	36.52	35.98	35.96	36.00	36.98	-

[1]Means followed by the same superscript and those bearing no superscript are not significantly (p>0.05) different

Incidences of bowed legs was minimal and less than 1% of the birds fed 60% high tannin sorghum diet exhibited this abnormality. Other leg abnormalities were of a different nature and were probably due to some other unexplained reason.

The mortality rate was highest during the first two weeks and a total of 10 birds died giving a mortaliy rate 3.6%. There was no consistency in the mortalities regarding the diets and the postmorterm findings suggested a yolk sac infection which was a hatchery problem and had nothing to do with the treatments. The birds which died were from treatments:- trt 1 - 2 birds, trt 2 - 1 bird, trt 3 - 3 birds, trt 7 - 2 birds trt 8 - 1 bird, trt 9 - 2 birds.

3.3.3.3 Carcass yield

Table 5. also shows the effect of dietary treatments on carcass yield at 7 weeks of age. The birds on sorghum based diets showed higher dressing losses, with those on the 60% untreated high tannin diet showing the highest losses (36.74%) while birds on the control showed the lowest losses (35.05%).

3.3.3.4 TME values

The TME values for the untreated and treated high and low tannin sorghum are shown in Table 4. The TME values for the untreated low tannin sorghum were higher than those for untreated high tannin sorghum grain. Treated high tannin sorghum grain had higher TME values than treated low tannin sorghum. The tannin in the untreated high tannin grain interfered with the digestibility of the grain and hence lowered its true matabolisable energy value. Vohra et al. (1966) and Featherstone et al. (1975) also reported reduced apparent digestibilities of energy in high than low tannin sorghum varieties for chicks. The TME values of the diet containing high tannin sorghum grain must have improved as a result of the treatment hence the better performance of the birds on the 60% treated high tannin sorghum diet compared to that of the 60% untreated high tannin sorghum diet.

3.3.3.5 Conclusion

Wood ash slurry successfully reduced the effect of tannin content of high tannin grain and improved their nutritive value for broiler chicken but not for low tannin sorghum grain.

4. General Discussion

Much attention has been directed towards the possible use of sorghum grain as an alternative to maize in preparation of commercial livestock feeds in Kenya. This is because sorghum is available and there is potential to produce even more. This study was conducted to determine the performance of broiler chicks in terms of weight gain, feed intake and feed conversion efficiency, and carcass yield when sorghum replaced maize in part or wholly in broiler chicken diets and also to determine the effect of treating HTS with wood ash and the effect of the ash on the nutritional value of the treated grain. This section will try to link up the results of the three experiments.

In experiment one, chemical components and true metabolisable energy values of sorghum grain were determined while in experiment two and three, the parameters looked at were weight gain, feed intake and feed conversion efficiency, TME values and carcass yield when untreated and treated high and low tannin sorghum grain were incorporated in the diets of broiler chicken at various levels. In experiment one, most of the chemical components of maize and sorghum were similar although sorghum had higher protein content than maize but a lower ether extract content. Significant differences of 5.2% in terms of crude protein content were also noted among the sorghum grains.

The variation in certain parameters of the proximate componets in experiment one may be attributed to diversity in the varieties used in the experiment. The sorghums from NCPB were blends of varieties from farmers countrywide. These sorghums had been grown under diverse climatic conditions, different soils, different locations and were subjected to different cultural practices. Such factors have been implicated elsewhere to contribute to the differences in protein content (Miller et al., 1964). The use of hybrids with increased fertilization and irrigation has also been shown to increase yields but also resulted in general decrease in protein content (Rooney et al., 1968). Hybrids also tend to be lower in protein content than the standard varieties (Rooney, 1969). This and the effect of variety may explain why serena had lower protein content than 2 KX17 which also had a lower protein content than the blend of varieties from NCPB. The differences in protein content observed between maize and sorghum in experiment one were mainly due to differences in structure of the grain. Although the endosperms of both maize and sorghum are made of peripheral corneous and floury areas, sorghum has much higher peripheral endosperm than maize and these peripheral cells contain more protein (Rooney and Clark, 1968; Sullins and Rooney, 1973 and Rooney and Miller, 1982). This explains the higher content of proteins in sorghum as compared to maize. The brown sorghums also had higher tannin content than the white sorghums. The high tannin content in some sorghum varieties is genetic and is also an agronomic advantage in areas where there is severe bird damage. It is believed that tannins is the principle mode of bird repellancy in bird resistant sorghums (Bullard and Ellias, 1980). Besides these advantages, tannins have the antinutritional effects such as lowering digestibility coefficients and are nutritionally inferior to low tannin varieties. This explains the low TME values for the high versus the low tannin sorghums in this study. The enzyme a-amylase that pioneers the carbohydrate digestion may have been precipitated by tannins resulting in lowered carbohydrate digestibility for the high tannin sorghum hence lowered TME values. Polyphenolic compounds have been found to adversely affect protein availability and amino acid digestion, cause a-amylase inhibition and also reduce dry matter digestion (Jambunathan and Mertze, 1973; Maxon et al., 1973 and Tamir and Alumot, 1969). Reduced apparent digestibilities of protein and energy have also been reported in high than low tannin sorghum varieties (Vohra et al., 1966).

In experiment two where both low and high tannin sorghum grain were incorporated in the diets at 0%, 20%, 40% and 60% levels, the best performance was observed from the birds on the 20% sorghum irrespective of the tannin content. Birds on the other treatments displayed a similar performance to the birds on the control in the period 0-4 weeks except those on the 60% HTS that showed significantly lower weight gains ($p<0.05$) in the same period compared to those on the control. There were no differences in weight gain ($p>0.05$) in the period 5-7 weeks for all the treatments. A similar trend was observed in experiment three where both untreated and treated high and low tannin sorghum grain were incorporated in the diets. The birds on the 60% treated high tannin sorghum diet performed better than those on the 60% untreated high tannin sorguhm diet but the differences were not significant (p>0.05). Those on the 60% treated low tannin sorghum diet reflected an insignificant (p>0.05) poorer performance than those on untreated low tannin sorghum diet. In both Experiments Two and Three, reduced weight gain was observed from birds on the dietary treatments containing high tannin sorghum as the sole cereal component. This reduction in weight gain was more severe during the period 0-4 weeks of age. In the period 5-7 weeks of age, the birds seemed to have adapted to the adverse effects of the dietary treatments and gained as much weight as those on the other treatments.

The high performance and feed coversion efficiency obtained from birds on the 20% sorghum was hard to explain but probably the combination of the grains at those levels trigered off some synergistic effect in the diet resulting in higher weight gains. Scott et al. (1982) reported a synergistic effect which resulted in higher weight gains when oil was added to boiler chicken feeds. However the better feed coversion efficiency observed from the birds on this treatment agrees with the results of Blaha et al. (1984). On the other hand, the comparatively poorer performance obtained from the birds on the 60% high tannin sorghum in both experiments must have been due to increased tannin levels in the diets since the other aspects of the diets were similar in terms of composition. Although the dietary treatments containing 60% high tannin sorghums reflected reduced weight gains and feed intakes, the adverse effects of tannins were only severe enough to have a significant effect on the weight gain in the starter phase and not the finisher phase. During this phase the birds were growing very fast and required alot of proteins for body building. It is possible that the tannins in the 60% high tannin sorghum diet precipitated some of the dietary protein making it unavailable to the birds. This did not apply to the finisher phase because the birds had slowed down the growth rate and were laying down fat therefore did not need as much protein. The decreased feed intake in the treatment containing high tannin sorghum was likely due to astringency as the tannin to some extent precipitated the enzyme a-amylase in the mouth resulting in lower palatability. High tannin sorghum grain reportedly causes lowered palatability due to astringency (Scheffert et al., 1975).

Feed intake for both experiments were similar for all the dietary treatments but the treatment that had high tannin sorghum as the sole cereal componet showed insignificant ($p>0.05$) lower feed intakes. The best feed conversion efficiency was obtained from birds on the treatment that had 20% sorghum, followed by those on the control, 40% sorghum and 60% sorghum respctively with the treatment containing 60% high tannin sorghum exhibiting the highest values for feed conversion efficiency.

In both experiments two and three, the condition leg abnormality was mild and less than 2% of the birds showed this condition. No definite pattern of this abnormality was established among the treatments.

Wood ash treatment significantly reduced the amount of tannins in high tannin sorghum grain to levels of low tannin grain. This reduction in tannin levels resulted in improved nutritional value of the grain. Moist alkali conditions have been shown to reduce the amount of tannin in sorghum grain and to improve its nutritive quality (Price et al., 1979). The mechanism by which moist alkali conditions detoxify tannins in high tannin grain is not known. The major proportion of tannins is present in the proline and gluteline fractions of the grain (Neucere and Sumrell 1980). Studies involving dehulling of high tannin and low tannin grain suggested strong interactions between the proline protein and tannins (Chibber et al., 1978). It is possible that the tannins become permanently bound to these proteins or some other compound in the grain during the treatment rendering both insoluble and *nutritionally inert. The hypothesis that the* tannins become unreactive both nutritionally and in the assay perhaps by forming insoluble phlobaphenes has also been advanced (Swain, 1965). In this study, there was no need for treating the low tannin sorghum but the discovery was interesting and remain unexplained. For both experiments two and three, carcass yield was highest for the control while the other treatments reflected similar yields with the birds on the 60% untreated high tannin sorghums exhibiting slightly lower yields but the differences were not significant ($p>0.05$). Increased water content in the breast muscle has been reported for chicks fed sorghum grain based diets as compared with maize based diets (Finzi et al., 1970; Blaha et al., 1984 and Saxena et al., 1978).

4.1 Conclusion

The results of this study show that HTS of the type used in this study can replace maize in broiler chicken diets upto 40% and LTS can comletely replace maize in broiler chicken diets.

Wood ash slurry can successfully be used to reduce the toxic effects of tannins in high tannin sorghums to levels that are not deleterious to animal performance. If this is true for all sources of wood ash, then this would be a useful tool to farmers in the developing world who are not able to afford the expensive forms of commercial grade alkali but who are interested in making their home mixed feeds.

5. SCOPE FOR FUTURE RESEARCH

In this study, the effect of feeding various levels of both HTS and LTS on the performance of broiler chicken was investigated. However the sorghum grain used represented only a few varieties grown in the country. More studies with numerous varieties grown in the country would help in establishing the most suitable varieties with regards to broiler performance.

More studies also need to be carried out on the effectiveness of wood ash to reduce tannins in HTS and whether the source of the wood ash would influence the effectivness of the ash on the reduction of the tannin from the grain. This would help in coming up with a universally accepted method of using ash to reduce tannins in sorghum grain and would subsequently result in increased sorghum production and consumption especially in the third world.

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8. APPENDICES

1 EXPERIMENT ONE

Appendix 1.1 Tannin Analysis.

The vanillin assay (Burns 1971) is widely used for quantitative measurement of condensed tannins in sorghum grains. The chief advantage of the method is its specificity for a narrow range of flavanols, proanthocyanidins and dihydrochalcones (Sarkar and Horwarth, 1976 and Gupta and Haslam 1980). In contrast redox methods, for example the Folin Denis of (Burns 1963) or Prussian Blue (Price and Burtler 1977) assays detect any phenol present.

Price et al., (1978) modified the vanillin assay of (Burns 1973) to ensure accuracy and reproducibility. The modified assay procedure is as follows. Grain gound to pass through 0.4 mm sieve was extracted within one day after mixing with 10 mL of methanol in capped test tubes with susequent thorough shaking for 2-3 hours. Assays were performed on the supernatant at room temperature. Vanillin reagent was prepared by mixing equal volumes of 1% vanillin in methanol and 8% concentrated HCl in methanol was added (5mL) at one minute intrevals to 1 mL aliqoutes of samples. Five mL of 4% of concnetrated HCl in methanol was added to a second 1 mL aliqoute (the blank) also at one minute intervals. Absorbance at 500 nm was read after 20 min., and the absorbance of the blank was subtracted from the absorbance with vanillin. A Beckman-24 spectrophotometer was used to read the absorbance. A standard curve was constructed using catechin concentrations upto 0.5mg/mL

$$\% \text{ tannin} = \frac{5 \quad \text{x absorbance}}{\text{slope}}$$

Tannin analysis (%)

Sample	B.sorghum	W.sorghum	2KX17	Serena	Ash trt serena	Ash trt 2KX17
Absorbance	0.350	0.005	0.000	0.398	0.003	0.000
	0.356	0.006	0.000	0.348	0.005	0.000
	0.381	0.007	0.000	0.389	0.003	0.000
	0.371	0.007	0.000	0.326	0.004	0.000
% Tannin	2.250	0.025	0.000	2.400	0.002	0.000
	2.394	0.030	0.000	2.412	0.018	0.000
	2.158	0.036	0.000	2.109	0.030	0.000
	2.309	0.042	0.000	2.358	0.010	0.000
	2.240	0.042	0.000	1.976	0.018	0.000
% mean Tannin	2.279	0.036	0.000	2.250	0.021	0.000

Appendix 1.2 Proximate composition of the six sorghum grains (dry matter basis)

Ingredient	DM%	CP%	EE%	CF%	Ash %	Tannin%
B.Sorghum	90.57 ± 0.07	11.36 ± 0.08	3.38 ± 0.67	4.20 ± 0.29	2.70 ± 0.32	2.27 ± 0.06
W.sorghum	89.18 ± 1.28	12.66 ± 0.01	3.40 ± 0.32	3.81 ± 0.15	1.60 ± 0.00	0.08 ± 0.05
Serena	87.39 ± 0.14	7.24 ± 0.07	3.13 ± 0.05	2.56 ± 0.07	1.40 ± 0.02	2.25 ± 0.16
2KX17	88.31 ± 0.21	10.42 ± 0.08	3.62 ± 0.22	2.34 ± 0.08	1.39 ± 0.07	0.00 ± 0.00
Ash trt Serena	89.14 ± 0.60	7.27 ± 0.11	3.07 ± 0.00	2.49 ± 0.05	1.40 ± 0.06	0.02 ± 0.00
Ash trt 2kx17	90.41 ± 0.33	10.24 ± 0.00	3.45 ± 0.16	2.80 ± 0.07	1.95 ± 0.08	0.00 ± 0.00
Maize (KSC)	89.44 ± 0.31	7.27 ± 0.14	4.88 ± 0.08	3.90 ± 0.07	1.08 ± 0.02	–
Maize (NCPB)	90.26 ± 0.05	7.95 ± 0.00	4.94 ± 0.14	3.65 ± 0.30	1.13 ± 0.01	–

Appendix 1.3 True Metabolizable Energy Analysis

Assay procedure

1. Birds were fasted for 24 hours to empty their alimentary canals of feed residue.

2. A bird was selected and fed 30g of air dried test material.

3. The bird was fitted with an excreta collection bag attached to a harness and placed in a cage.

4. A similar bird was selected, fitted with a similar bag but is not fed and is returned to the cage.

5. Exactly at 48 hour after feeding the bird, the excreta is collected quantitatively, oven dried allowed to come to equillibrium with the atmospheric miosture and weighed.

6. Samples of the test materials and excreta are gound and then assayed for GE.

7. $$\text{TME/g of feed} = \frac{(Fi \times GEf) - (E \times GEe) + (FEm + UEe)}{Fi}$$

Each TME value is the mean of four replicated observations.

Fi = feed intake (g)

E = excreta output (g)

GEf = gross energy /g of feed

GEe = gross energy /g of excreta

FEm = metabolic feed energy

UEe = endogenous urinary energy

EXPERIMENT TWO

Appendix 2.1 Feed intake per broiler 0-4 weeks of age (g)

	Treatment						
	1	2	3	4	5	6	7
Rep 1	1376.40	1321.50	1374.80	1326.40	1369.20	1274.10	1398.61
2	1355.90	1365.50	1371.50	1335.30	1323.40	1320.20	1318.40
3	1470.60	1496.00	1409.00	1407.40	1489.50	1413.70	1430.40
4	1421.40	1498.70	1448.40	1382.40	1478.00	1486.80	1430.40
Mean	1406.07	1420.40	1400.92	1362.87	1415.02	1373.45	1418.67

Analysis of variance of feed intake

source of variation	df	sum of squares	mean sum of squares	F	P
Total	20	122982.984			
Treatment	6	12446.749	2074.458	1.702	0.198
Sex	1	83538.012	83538.012	68.551	0.000
House	1	490.565	490.565	0.403	0.536
Sex*treatment	6	10665.622	1777.603	1.459	0.266
Remainder	13	15842.034	1218.618		

Appendix 2.2 Feed intake per broiler 5-7 weeks of age (g)

	Treatments						
	1	2	3	4	5	6	7
Rep 1	2880.90	2846.50	2173.10	2218.60	2495.50	2530.60	2242.00
2	2446.70	2653.50	2450.60	2674.80	2382.10	2306.70	2339.40
3	2454.50	2330.60	2715.30	2657.10	2694.40	2680.10	2654.80
4	2658.80	2610.30	2796.40	2451.90	2357.50	2613.80	2679.20
Mean	2635.22	2610.22	2533.85	2500.60	2482.37	2532.80	2485.85

Analysis of variance of feed intake

source of variation	df	sum of squares	mean sum o squares	F	P
Total	28	10001988.449			
Treatment	6	90794.527	15132.421	0.471	0.818
Sex	1	117378.800	117378.800	3.654	0.0782
House	1	2287.843	2287.843	0.071	0.7938
Remainder	13	417599.691	32123.053		

Appendix 2.4 Mean weight gain per broiler 0-4 weeks of age (g)

	Treatments						
	1	2	3	4	5	6	7
Rep 1	696.20	724.00	707.40	654.80	712.50	692.68	692.20
2	695.80	712.10	696.20	653.20	719.70	696.60	675.30
3	736.60	749.50	736.00	705.50	766.90	734.60	729.00
4	769.50	758.30	740.10	709.30	780.30	740.60	749.80
Mean	724.52	735.97	719.92	680.70	644.85	716.11	711.57

<u>Analysis of variance of weight gain 0-4 weeks</u>

sources of variation	df	sum of squares	mean sum of squares	F	P
Total	28	30464.281			
Treatment	6	10449.588	1741.598	17.120	0.000
Sex	1	18008.643	18008.643	177.023	0.000
House	1	38.657	38.657	0.380	0.548
Sex*trt	6	644.894	107.482	1.057	0.439
Remainder	13	1322.497	101.730		

Appendix 2.4 Mean weight gain per broiler 0-4 weeks of age (g)

	Treatments						
	1	2	3	4	5	6	7
Rep 1	696.20	724.00	707.40	654.80	712.50	692.68	692.20
2	695.80	712.10	696.20	653.20	719.70	696.60	675.30
3	736.60	749.50	736.00	705.50	766.90	734.60	729.00
4	769.50	758.30	740.10	709.30	780.30	740.60	749.80
Mean	724.52	735.97	719.92	680.70	644.85	716.11	711.57

Analysis of variance of weight gain 0-4 weeks

sources of variation	df	sum of squares	mean sum of squares	F	P
Total	28	30464.281			
Treatment	6	10449.588	1741.598	17.120	0.000
Sex	1	18008.643	18008.643	177.023	0.000
House	1	38.657	38.657	0.380	0.548
Sex*trt	6	644.894	107.482	1.057	0.439
Remainder	13	1322.497	101.730		

Appendix 2.5 Mean weight gain per broiler 5-7 weeks of age (g)

	Treatments						
	1	2	3	4	5	6	7
Rep 1	879.40	873.80	864.30	862.30	874.70	851.80	868.50
2	847.00	874.60	861.90	849.30	877.70	851.40	852.30
3	895.99	901.50	894.20	880.00	899.60	889.20	880.90
4	898.40	900.60	891.40	875.80	899.00	894.20	887.10
Mean	880.17	887.62	877.95	866.85	887.75	871.65	872.20

Analysis of variance for 5-7 weeks

source of variation	df	sum of squares	mean sum of squares	F	P
Total	28	8195.201			
Treatment	6	1996.933	332.822	24.081	0.520
Sex	1	5780.188	5780.188	418.214	0.000
House	1	3.500	3.500	20.253	0.623
Sex*trt	6	234.903	39.150	2.833	0.054
Remainder	13	179.674	1382.821		

Appendix 2.6 Mean weight gain per broiler 0-7 weeks of age (g)

	Treatments						
	1	2	3	4	5	6	7
Rep 1	1571.10	1597.80	1569.00	1517.10	1587.20	1544.40	1560.70
2	1562.40	1586.70	1558.10	1502.30	1597.40	1548.00	1527.60
3	1632.50	1651.00	1630.20	1585.10	1666.50	1623.80	1609.90
4	1667.90	1658.90	1631.50	1581.50	1679.30	1634.80	1617.71
Mean	1608.47	1623.60	1597.20	1547.50	11632.60	1587.75	1578.97

Analysis of variance of weight gain 0-7 weeks of age (g)

source of variation	df	sum of squares	mean sum of squares	F	P
Total	28	62335.98			
Treatment	6	21453.50	3575.58	4375.75	0.000
Sex	1	39337.50	39337.50	481.33	0.000
House	1	116.44	116.44	1.42	0.253
Trt*sex	6	366.07	61.01	0.74	0.622
Remainder	13	1062.44	81.72		

Appendix 2.7 Feed conversion efficiency 0-4 weeks of age (g)

	Treatments						
	1	2	3	4	5	6	7
Rep 1	2.00	1.80	1.90	2.00	1.90	1.80	2.00
2	1.90	1.90	2.00	2.00	1.80	1.90	2.00
3	2.00	2.00	1.90	2.00	1.90	1.90	2.10
4	1.80	2.00	2.00	1.90	1.90	2.00	1.90
Mean	1.92	1.92	1.95	1.98	1.87	1.90	2.00

Analysis of variance of feed feed conversion efficiency

source of variation	df	sum of squares	mean sum of squares	F	P
Total	28	0.112223			
Treatment	6	0.042057	0.007010	2.871	0.0525
Sex	1	0.001406	0.001406	0.576	0.4615
House	1	0.000181	0.000181	0.74	0.7897
Sex*trt	6	0.036835	0.06139	2.514	0.0771
Remainder	13	0.031743	0.00242		

Appendix 2.8 Feed conversion efficiency 5-7 weeks of age (g)

	Treatments						
	1	2	3	4	5	6	7
Rep 1	3.30	3.30	2.50	2.60	2.90	3.00	2.60
2	2.80	3.00	2.80	3.10	2.70	2.70	2.70
3	2.90	2.60	3.00	3.00	3.00	3.00	3.00
4	3.00	2.90	3.10	2.80	2.60	2.90	3.00
Mean	3.00	2.95	2.85	2.87	2.80	42.90	2.82

Analysis of variance of feed conversion efficiency

sources of variation	df	sum of squares	mean sum of squares	F	P
Total	28	1.126768			
Treatment	6	0.566192	0.037746	0.875	0.6015
Sex	1	0.020487	0.020487	0.475	0.5028
House	1	0.002168	0.002168	0.050	0.8261
Sex*trt Remainder	13	0.560576	0.43121		

Appendix 2.9 Feed conversion efficiency 0-7 weeks of age (g)

	Treatments						
	1	2	3	4	5	6	7
Rep 1	2.70	2.60	2.30	2.30	2.40	2.60	2.30
2	2.40	2.50	2.50	2.70	2.30	2.30	2.40
3	2.40	2.30	2.50	2.60	2.50	2.50	2.60
4	2.40	2.50	2.60	2.40	2.30	2.50	2.34
Mean	2.47	2.47	2.47	2.50	2.37	2.47	2.41

Analysis of variance of feed conversion efficiency

source of variation	df	sum of squares	mean sum of squares	F	P
Total	28	0.362733			
Treatment	6	0.153458	0.010231	0.636	0.8009
Sex	1	0.001689	0.001689	0.105	0.7511
House	1	0.000718	0.00718	0.045	0.8361
Sex*trt	6	0.035044	0.005841	0.363	0.8897
Remainder	13	0.209275	0.016098		

Appendix 2.10 Live weights at seven weeks of age (g)

	Treatments						
	1	2	3	4	5	6	7
Reps 1	1683.00	1764.00	1599.00	1652.00	1712.00	1688.00	1510.00
2	1695.00	1680.00	1652.00	1630.00	1830.00	1670.00	1665.00
3	1625.00	1642.00	1660.00	1632.00	1843.00	1577.00	1565.00
4	1609.00	1650.00	1676.00	1586.00	1560.00	1570.00	1600.00
5	1692.00	1660.00	1635.00	1598.00	1643.00	1562.00	1651.00
6	1635.00	1725.00	1571.00	1550.00	1643.00	1590.00	1696.00
7	1600.00	1624.00	1577.00	1524.00	1643.00	1654.00	1590.00
8	1656.00	1635.00	1680.00	1698.00	1664.00	1665.00	1610.00
Mean	1649.37	1672.50	1631.00	1607.60	1692.75	1634.50	1610.87
Dressed weights							
Reps 1	1089.07	1135.32	1011.69	1041.10	1087.12	1069.86	958.10
2	1093.62	1077.05	1045.89	1027.72	1160.96	1067.47	1049.29
3	1041.30	1059.26	1047.63	1030.45	1166.81	1007.87	998.63
4	1046.02	1066.56	1060.75	999.03	992.63	1002.45	1011.36
5	1098.79	1064.23	1036.92	1019.93	1040.19	998.28	1041.95
6	1062.10	1008.14	995.23	978.36	1043.64	1065.55	1075.44
7	1040.32	1054.63	994.93	961.80	1045.12	1045.17	1003.77
8	1073.42	1059.98	1063.11	993.00	1056.31	1055.78	1017.24
Mean	1068.08	1078.14	1032.01	1073.48	1074.09	1039.05	1019.47
%weight lost	35.25	35.54	36.74	36.79	36.53	36.43	36.72

EXPERIMENT THREE

Appendix 3.1 Feed intake per broiler 0-4 weeks of age (g)

		Treatments								
		1	2	3	4	5	6	7	8	9
Reps	1	1379.56	1438.75	1398.40	1486.40	1431.89	1417.63	1396.40	1389.58	136
	2	1389.09	1431.68	1408.20	1482.70	1459.90	1398.41	1392.70	1365.80	13
	3	1436.42	1546.04	1450.27	1566.50	1568.20	1458.80	1566.50	1491.64	14
	4	1512.50	1608.20	1449.50	1588.04	1529.80	1482.86	1588.04	1544.60	15
Mean		1429.39	1505.16	1426.59	1530.91	1497.44	1439.42	1485.91	1447.90	14

Analysis of variance of feed intake

source of variation	df	sum of squares	mean sum of squares	F	P
Total	36	18980.61			
Treatment	8	44991.40	5623.92	6.332	0.057
Sex	1	119071.00	119071.00	134.059	0.000
House	1	572.80	572.80	0.640	0.433
Sex*trt	8	10125.97	1265.74	1.425	0.255
Remainder	17	3912.99	230.17		

Appendix 3.2 Feed intake per broiler 5-7 weeks of age (g)

	Treatments								
	1	2	3	4	5	6	7	8	9
Reps 1	1959.20	1989.27	1938.81	1981.17	2033.70	1992.59	1981.17	1907.41	
2	1979.11	1974.06	1995.45	2002.62	2015.43	1963.16	1883.39	2157.57	
3	2152.80	2174.52	2138.36	2115.05	2144.79	2062.57	2045.50	2172.23	
4	2139.61	2186.72	1987.11	2187.49	2126.04	2086.66	2057.49	1991.55	
Mean	2057.68	2081.14	2014.93	2071.58	2079.99	2026.24	2021.69	1933.77	

Analysis of variance of feed intake

source of variation	df	sum of squares	mean sum of squares	F	P
Total	36	291288.72			
Treatment	8	103150.18	12893.70	8.969	0.060
Sex	1	144543.16	144543.16	100.540	0.000
House	1	659.37	659.37	0.559	0.501
Sex*trt	8	18497.04	2312.13	1.608	0.195
Remainder	17	24438.95	1437.58		

Appendix 3.3 Feed intake per broiler 0-7 weeks of age (g)

	Treatments								
	1	2	3	4	5	6	7	8	9
Reps	3338.76	3428.02	3337.21	3468.10	3365.59	3410.26	3468.10	3296.99	3449.56
	3368.20	3405.74	3403.65	3485.32	3375.33	3361.57	3485.32	3249.21	3485.56
	3589.22	3720.56	3588.63	3681.55	3632.99	3621.37	3681.55	3444.40	3235.73
	3652.11	3794.74	3595.31	3775.53	3558.40	3569.52	3775.53	3536.15	3338.58
Mean	3487.07	3587.26	3481.20	3602.62	3483.07	3465.67	3602.62	3381.68	3377.35

Analysis of variance of feed intake

source of variation	df	sum of squares	mean sum of squares	F	P
Total	36	79049.94			
Treatment	8	218918.46	27364.80	17.61	0.067
Sex	1	7898.97	7897.97	5.085	0.038
House	1	7.2864	7.2864	0.005	0.096
Sex*trt	8	21225.86	2653.23	1.708	0.172
Remainder	18	24852.252	1553.2657		

Appendix 3.4 Mean weight gain per broiler 0-4 weeks of age (g)

	Treatments								
	1	2	3	4	5	6	7	8	9
Reps 1	695.70	718.30	668.70	719.50	688.30	692.50	687.00	684.51	666.10
2	707.80	720.10	660.60	735.00	669.60	693.60	684.80	691.48	675.90
3	766.10	773.60	726.40	786.10	758.00	747.60	750.50	748.10	742.00
4	776.60	779.20	724.00	790.47	766.80	759.00	746.10	748.54	741.50
Mean	736.80	747.80	707.29	757.76	726.62	723.17	720.32	717.52	706.30

Analysis of variance of weight gain 0-4 weeks

sources of variation	df	sum of squares	mean sum of squares	F	P
Total	36	49962.60			
Treatment	8	12454.82	1556.85	62.40	0.000
Sex	1	36627.58	36627.58	1468.13	0.000
House	1	219.533	219.533	8.80	0.087
Sex*trt	8	236.55	29.56	1.185	0.362
Remainder	17	424.12	24.94		

Appendix 3.5 Mean weight gain per broiler 5-7 weeks of age (g)

	Treatments								
	1	2	3	4	5	6	7	8	9
Reps 1	899.00	898.00	867.00	906.30	876.40	881.70	868.00	877.50	868.10
2	896.00	895.00	867.20	902 80	886.50	883.10	879.00	877.20	866.30
3	963.00	943.00	886.40	926.10	939.30	924.60	910.74	921.60	905.10
4	958.00	981.00	885.80	955.26	929.40	922.20	907.50	921.90	912.50
Mean	929.00	929.25	876.60	922.15	907.90	902.90	891.31	899.55	888.00

Analysis of variance of weight gain 5-7 weeks

source of variation	df	sum of squares	mean sum of squares	F	P
Total	36	25406.51			
Treatment	8	9535.94	1191.86	5.178	0.522
Sex	1	9363.46	9363.46	40.68	0.000
House	1	503.927	503.927	2.189	0.1573
Sex*trt	8	2091.18	261.39	1.136	0.38
Remainder	17	3912.99	230.17		

Appendix 3.6 Mean weight gain per broiler 0-7 weeks of age (g)

	Treatments								
	1	2	3	4	5	6	7	8	9
Reps 1	1594.70	1616.30	1502.80	1625.80	1564.70	1574.20	1555.00	1562.01	1534.2
2	1603.80	1615.10	1612.80	1637.80	1585.91	1576.70	1564.71	1568.68	1542.2
3	1729.10	1666.60	1612.80	1712.20	1697.30	1672.20	1661.24	1669.70	1647.1
4	1735.60	1760.20	1609.80	1745.70	1696.20	1681.20	1653.60	1670.44	1654.0
Mean	1665.80	1677.05	1583.97	1680.31	1634.22	1626.07	1611.85	1617.07	1594.0

Analysis of variance of weight gain 0-7 weeks

source of variation	df	sum of squares	mean sum of squares	F	P
Total	36	790490.94			
Treatment	8	218918.46	27364.80	17.618	0.023
Sex	1	467878.42	467878.42	301.22	0.000
House	1	7897.90	7897.97	5.085	0.035
Sex*trt	8	21225.86	2653.23	1.7	0.172
Remainder	16	24852.25	1553.26		

Appendix 3.7 Feed conversion efficiency 0-4 weeks of age (g)

		Treatments								
		1	2	3	4	5	6	7	8	9
Reps	1	1.98	2.00	2.15	2.06	1.93	2.04	2.16	2.03	2.05
	2	1.96	1.98	2.16	2.01	1.94	2.01	2.16	1.97	2.04
	3	1.87	1.99	1.99	1.99	1.96	1.95	2.08	1.99	1.97
	4	1.94	2.06	2.00	2.00	1.86	1.95	1.12	2.06	2.03
Mean		1.93	2.01	2.07	2.01	1.92	1.98	2.13	2.01	2.02

Analysis of variance of feed feed conversion efficiency

source of variation	df	sum of squares	mean sum of squares	F	P
Total	36	0.19863			
Treatment	8	0.13353	0.16690	4.581	0.0400
Sex	1	0.18810	0.18880	16.432	0.0088
House	1	0.00082	0.00082	0.072	0.7917
Sex*trt	8	0.02675	0.00334	2.922	0.0301
Remainder	17	0.01946	0.01145		

Appendix 3.8 Feed conversion efficiency 5-7 weeks of age (g)

	Treatments								
	1	2	3	4	5	6	7	8	9
Reps 1	2.23	2.30	2.41	2.28	2.28	2.23	2.32	2.11	2.18
2	2.23	2.22	2.24	2.28	2.28	2.26	2.41	2.16	1.16
3	2.17	2.21	2.28	2.18	2.32	2.25	2.28	2.17	2.15
4	2.20	2.20	2.35	2.21	2.27	2.22	2.27	2.14	2.25
Mean	2.20	2.23	2.32	2.23	2.28	2.24	2.32	2.14	2.18

Analysis of variance of feed conversion efficiency.

sources of variation	df	sum of squares	mean sum of squares	F	P
Total	36	0.73600			
Treatment	8	0.10652	0.012707	2.038	0.104
Sex	1	0.49670	0.496700	79.665	0.705
House	1	0.00114	0.001140	0.183	0.674
Sex*trt	8	0.03054	0.003818	0.612	0.755
Remainder	17	0.10600	0.006230		

Appendix 3.9 Feed conversion efficiency 0-7 weeks of age (g)

		Treatments								
		1	2	3	4	5	6	7	8	9
Reps	1	2.09	2.20	2.22	2.13	2.15	2.16	2.23	2.11	2.10
	2	2.10	2.10	2.11	2.12	2.12	2.13	2.22	2.07	2.16
	3	2.07	1.94	2.22	2.15	2.14	2.10	2.21	2.06	2.09
	4	2.10	2.15	2.23	2.16	2.09	2.12	2.28	2.11	2.10
Mean		2.09	2.09	2.19	2.14	2.12	2.23	2.08	2.11	2.28

Analysis of variance of feed conversion efficiency.

source of variation	df	sum of squares	mean sum of squares	F	P
Total	36				
Treatment	8	0.086468	0.01080	4.7120	0.051
Sex	1	0.000345	0.00345	0.150	0.703
House	1	0.001117	0.001117	0.487	0.495
Sex*trt	8	0.011911	0.01489	0.649	0.726
Remainder	16	0.036698	0.02294		

Appendix 3.10 Live weights

		Treatments								
		1	2	3	4	5	6	7	8	9
Rep	1	1721.00	1760.00	1555.00	1655.00	1710.00	1583.00	1667.00	1610.00	1650.0
	2	1708.00	1698.00	1670.00	1693.00	1632.00	1593.00	1682.00	1602.00	1596.0
	3	1681.00	1735.00	1641.00	1765.00	1578.00	1690.00	1574.00	1681.00	1665.0
	4	1622.00	1720.00	1626.00	1729.00	1592.00	1686.00	1666.00	1604.00	1572.0
	5	1619.00	1609.00	1565.00	1702.00	1639.00	1596.00	1560.00	1680.00	1578.0
	6	1607.00	1661.00	1534.00	1590.00	1676.00	1685.00	1692.00	1677.00	1592.0
	7	1709.00	1622.00	1586.00	1715.00	1611.00	1664.00	1572.00	1688.00	1661.0
	8	1634.00	1639.00	1629.00	1673.00	1606.00	1675.00	1695.00	1696.00	1678.0
Mean		1652.60	1654.20	1588.25	1681.50	1644.25	1626.50	1607.20	1635.00	1621.5

Dressed weights

		1	2	3	4	5	6	7	8	9
Rep	1	1114.70	1122.71	984.16	1060.52	1092.52	1012.97	1068.72	1036.84	1055.8
	2	1111.74	1087.06	1043.38	1081.32	1032.73	1019.21	1076.32	1023.36	1022.0
	3	1093.16	1108.84	1037.12	1124.31	1002.03	1087.52	1008.62	1012.00	1064.9
	4	1051.22	1099.94	1029.21	1106.39	1004.72	1079.72	1066.08	1026.40	1006.4
	5	1050.74	1030.25	992.37	1086.89	1045.39	1018.09	1000.12	1075.54	1015.1
	6	1044.88	1064.87	972.71	1019.35	1065.93	1077.73	1082.55	1071.04	1017.2
	7	1110.68	1033.06	1002.67	1093.99	1022.98	1066.80	1006.87	1078.30	1062.0
	8	1059.65	1050.44	1029.37	1050.27	1015.00	1071.67	1085.14	1086.29	1074.2
Mean		1079.59	1074.64	1012.74	1077.84	1035.16	1054.21	1049.30	1051.21	1039.7
% weight loss		35.06	36.06	36.74	36.22	36.52	35.98	35.96	36.00	35.9

APPENDIX 4: Nutrient composition of feed ingredients

	DM	CP	CF	EE	ASH
Ingredients	---	---	%	---	---
Maize grain	89.44	7.44	4.88	3.24	1.13
B.sorghum	90.57	11.36	5.14	3.30	2.71
W.sorghum	89.87	12.66	3.81	3.40	1.60
Serena	87.39	7.27	2.56	3.13	1.40
2KX17	88.31	10.81	3.81	3.62	1.39
Brewers yeast	93.64	34.84	2.70	1.00	1.43
Fish meal	94.46	71.45	1.20	4.97	14.32
Maize gluten fd	95.10	22.00	8.64	3.10	1.32
Limestone	100.00	-	-	-	-
DiclPO4	100.00	-	-	-	-
Lysine premix	94.00	23.10	6.93	3.65	-
Methionine premix	95.00	18.59	7.12	3.75	-
Broiler premix	95.00	7.15	1.98	3.63	-
Corn oil	-	-	-	-	-
Salt	98.00	-	-	-	-
Coccidiostat	-	-	-	-	-

APPENDIX 5: True Metabolizable Energy Analysis

Force feeding is a recently developed assay which measures the true metabolizable energy (TME) of poultry feedingstuffs (Sibbald 1976). The TME is a term used by Harris (1966) to describe an estimate of metabolizable energy (ME) if correction is made for metabolic feacal (FEm) and endogenuos urinary (EUe) energy The FEm is the energy of that portion of the feaces other than feed residues and is present as abraded intestinal mucosa, bile and digestive fluids. The UEe is that portion of urinary energy not of direct feed origin. Combined, the FEm plus UEe represent a maintenace cost that should not be charged against the feed. The concept of force feeding, a single rapid bioassay arose during an investigation of the effects of feed intake on apparent metabolizable energy (AME) value. AME values of variuos feedigstuffs demonstrated a linear relationship between gross energy (GE) and feed input (Sibbald, 19975, 1976, and Guillaume and Summers 1970). This linearity was because AME values are dependent of FEm + UEe while TME values were independent of this variable. When feed intake is large, the energy loss as FEm + UEe is relatively small but as feed intake is reduced this loss becomes increasinly significant and depreses AME. By assuming linearity hold for all feedingstuffs, it was possible to develop a simple bioassay on a single level of feed input. The force feeding bioassay has the advantagee of:- avoid need to recover waste feed, prevents feed selection and eliminates variation of feed intake among birds.

The assay has been performed with adult cockrels, laying hens, meat type hens and turkeys and meat type and egg type chicksof different a ges (Sibbald, 1976,1978). For routine assay work the adult white leghorn cockrell is preffered because it maintains steady state, does not become obese and has good liveability.