THE FEEDING VALUE OF COCOYAM (*Colocasia esculenta*) MEAL AS A SUBSTITUTE FOR TRADITIONAL ENERGY SOURCES IN BROILER STARTER DIETS AND ESTIMATION OF ITS METABOLISABLE ENERGY VALUE.

By

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A THESIS SUBMITTED IN PARTIAL FULFILMENT
FOR THE DEGREE OF
MASTER OF SCIENCE IN ANIMAL PRODUCTION
IN THE
FACULTY OF AGRICULTURE, UNIVERSITY OF
NAIROBI.

1981.

DECLARATION

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

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ACKNOWLEDGEMENTS

I am grateful to the Ministry of Livestock Development (Kenya) for sponsoring me for the M.Sc. Course in the University of Nairobi and granting me the study leave. Thanks also to the International Development Research Centre (IDRC) Ottawa, Canada for funding the Research work through their non-conventional feedstuffs project in the Department of Animal Production, University of Nairobi.

This work was carried out under the supervision of Dr. M. Gomez who was always ready to offer both technical and academic advice, to him I am greatly indebted. Many thanks to Dr. Schwartz who agreed to read through the manuscript and made valuable corrections and to Dr. P. Nyaga (Veterinary Pathologist) who took special interest in the work and gave valuable comments.

I am also thankful to the entire Animal Production Department who helped in one way or another. Special thanks in this respect go to F.C. Ndegwa (Senior Technician) who went out of his way to supervise the Laboratory analyses. Thanks also to Miss L. Mwanjumwa (Food Science Department) for the help offered during the oxalic acid and mineral determinations.

Finally I am grateful to my co-worker Miss. J. Nambi with whom I shared the facilities at the Poultry Unit and was always ready to offer physical assistance. To Miss V. Kingatua, thanks for your patience in typing this work.

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ABSTRACT

Three experiments were conducted with the objective of investigating the feeding value of raw and processed cocoyam (*Colocasia esculenta*) meal in broiler diets.
Another experiment was also carried out to establish the Metabolisable Energy value of cocoyams using the rapid procedure based on Farrel's (1978) method. The Metabolisable Energy value was compared to maize and cassava values.

Cocoyam tubers were obtained from the Machakos District. They were sliced, sun dried or oven dried and then coarsely milled. The cocoyam meal was formulated into insonitrogenous diets containing the meal at 0, 29 or 58 per cent. Similar cassava meal based diets were included as reference diets and these diets were compared to a 58 per cent maize control diet.
The diets were fed to 'Starbro' chicks for a period of four weeks. Chicks on the raw cocoyam meal diets showed severely depressed growth response as compared to those fed on the maize or cassava based diets. Weight gain for the maize control diet was 560 grams per bird compared to (520, 481) and (388, 261) grams

for the (29 and 58 per cent) levels of cassava and cocoyam meals respectively over the four week experimental period.

With a view to overcoming the anti-nutritional factor in raw cocoyam, methods of processing cocoyam were further investigated. One batch of the tubers was peeled, the other was sliced and soaked in hot water (80°C) for one hour while the third batch was sliced and dried whole and fed as the control or in a diet supplemented with two per cent calcium carbonate to overcome the effect of high levels of oxalates in the cocoyams. There were no significant ($P \geq .05$) treatment differences But the processed meal diets showed lower weight gains of 583, 586 grams per bird for the peeled cocoyam meal diet and hot water treated cocoyam meal diet respectively compared to the maize control diet (607 grams) over the four week experimental period. The calcium carbonate supplemented diet on the other hand, had a 4 per cent improvement on feed intake and a three per cent increase in weight gain (627 grams over the four week experimental period) compared to the control. This improvement with calcium carbonate supplementation was further investigated with a comparison of the levels, one two or three per cent calcium carbonate supplementation of the 29 per cent cocoyam diet. Unsupplemented and 4 per cent calcium carbonate supplemented 58 per cent cocoyam meal diets were also tested. Both levels of cocoyam meal inclusion in the diet supplemented or unsupplemented with calcium carbonate gave lower weight gains and feed intake compared to the maize control diet. These differences were highly significant ($P \leq .01$). The weight gain for the maize control diet was 536 grams per bird compared to 367 and 387 grams for the unsupplemented and calcium carbonate supplemented 58 per cent cocoyam meal diet respectively and (441, 471 and 479 grams) for the 29 per cent cocoyam diets supplemented with (3, 2 and 1 per cent) calcium carbonate respectively. Four per cent calcium carbonate supplementation of the 58 per cent cocoyam meal diet led to an insignificant ($P \geq .05$) increase in weight gain and feed intake. Treatment differences among the three levels of calcium carbonate supplementation of the 29 per cent cocoyam meal diet were insignificant ($P \geq .05$).

Adult Rhode Island Red roosters were used for Metabolisable Energy determination using a procedure based on Farrel's (1978) method. The values obtained were 1948 Kcal/kg for cocoyam, 2852 Kcal/kg for cassava and 3679 Kcal/kg for maize on DM basis. Rapid passage of feed was observed with the cocoyam meal and considerably more excreta was voided during the collection period. The low Metabolisable Energy value for cocoyam meal confirms the poor feed utilisation observed with the chick experiments.

Both levels of cocoyam meal inclusion with or without calcium carconate supplementation, peeling or hot water extraction of the oxalates gave lower weight gains and feed intake as compared to the maize control diet. Nevertheless, with an effective processing method like cooking to overcome the irritant and amino acid suppl mentation to compensate for any losses during processing, the cocoyam meal may form a substitute for maize at the lower level of inclusion.

1. INTRODUCTION

Edible roots and tuber crops form a component of the staple foods in Kenya as supplements for cereals. In Western and Coastal Provinces, sweet potatoes (*Ipomoea spp*) and cassava (*Manihot spp*) are widely grown while in Central and Eastern Provinces, sweet potatoes, cassava, cocoyam (*Colocasia spp*) and yams (*Dioscorea spp*) form part of the human diet. They are often referred to as famine crops since they are used when cereals are not available.

Unfortunately, these crops have received very little research attention because they have been over-shadowed by the more established cereal crops and cash crops which are apparently more important economically. They are mainly grown as subsistence crops and since they do not come into the cash economy they are marketed at free market prices.

This trend is now changing in many countries and improved methods of cultivation are being looked into. Some root crops are now grown on a large scale and cassava for example is grown as a cash crop in developing countries and forms a major export product for use in animal feeds. The recent formation of the International Society of Tropical Root Crops is another indication of the growing interest in root crops.

Fresh roots and tubers contain 65-90% moisture and their nutritional value is mainly in their carbohydrate content. Compared to cereals, they are low in fibre and hence more digestible. They are also lower in their protein and vitamin contents. No known antinutritional factors have been identified in cocoyam. There are however reports of unusually high levels of calcium oxalate.

Some tuber crops are known to produce high yields in some tropical areas where cereals grow with difficulty. They have the added advantage that they can be left in the ground during dry conditions. Tuber crops like cassava have the ability to shed leaves during drought to reduce water requirements. Cocoyam on the other hand can withstand waterlogging and requires water supply throughout the year. During the drought season, the plant continues to subsist but there is reduced expansion of the tuber giving it the characteristic dumb bell shape. When grown as a rainfed crop, cocoyam requires a minimum of 1250mm well distributed annual rainfall.

Tuber crops are grown over a wide range of altitudes. Cocoyam is grown at altitudes between 900-1800m, while cassava is grown at altitudes below 1500m. Sweet potatoes do well in both warm and cool areas and are therefore grown from sea-level to altitudes up to 2100m. Most of the tuber crops grow best under warm conditions with temperatures above 21°C and do no tolerate frosty conditions.

Soil requirements for cocoyams depend on the variety but generally they grow best in heavy soils with a high moisture holding capacity. Plants growing under waterlogged conditions are able to transport oxygen from the aerial parts to the roots to enable them to respire and grow normally. They prefer fertile soils which have not been exhausted by previous cropping. A soil pH of 5.5-6.5 is preferred and they can tolerate saline soils better than many other crops. Cassava on the other hand has low nutrient requirements and can yield well in soils of low fertility where the production of many other crops would be uneconomical. Very fertile soils lead to high vegetative growth and low tuber growth. Light, sandy loam soils of medium fertility and good drainage are preferred. Shallow and stony soils restrict tuber growth. Unlike cocoyam, it does not tolerate saline conditions and soil type also affects bitterness of the tubers.

Rainfed cocoyam is planted vegetatively shortly after the rains while under irrigation the crop can be planted at any time depending on when the first crop matures. The previous crop provides setts for planting. The crop is ready for harvesting when most of the leaves have begun to turn yellow. This time varies between 6-15 months.

The world acreage under tuber crops is low compared to the area under cereals. An increasing trend in area cultivated, yield per hectare and total production of root and tuber crops in the world is reported (FAO, 1975). In Kenya, yields are difficult to assess since the crops are grown at subsistence level and harvested irregularly. Expected yields for cocoyam are estimated at 15 tonnes per hectare while average cassava yields are in the range of 7.5-10 tonnes per hectare (Acland, 1975). The highest yield of cocoyam under improved methods of cultivation is 26 tonnes per hectare compared to 6 tonnes per hectare for maize (FAO, 1975). The high yield of cocoyam and other tubers may therefore compensate for their high moisture content.

Where cocoyams are harvested in bulk, they are best stored under cool, dry, well ventilated conditions. Field storage is more common where the crop is harvested as needed. Cocoyams can also be dried fresh or after cooking and then ground into flour which stores for a longer period compared to fresh tubers.

It is clear that, inspite of the low dry matter yield of tuber crops compared to cereals, their fresh yields per hectare are higher. In terms of calories per hectare, some like cassava have proved to be high yielders compared to cereals. There has also been an increasing trend in production and in future they might form suitable substitutes for cereals in animal feeds.

This study was designed to select and evaluate a suitable crop for poultry feeds in a selected region. A survey done in Machakos market showed cocoyam to be the most abudant tuber crop in the District. This unlike cassava which was available during the dry season only, was found to be available in the region throughout the year. Whole and half substitution of cocoyam for maize in broiler starter diets was studied. Some processing methods to improve the utilisation value of cocoyam were also tested and an attempt was made to determine the Metabolisable Energy values. Cassava which is widely studied in poultry diets was tested in comparison to cocoyam.

2. LITERATURE REVIEW

2.1. Introduction

Edible aroids belong to the Family Araceae and include Colocasia spp, Xanthosoma spp, Alocasia spp, Crytosperma spp and Amorphophallus spp. The first two are by far more important and widely cultivated in many parts of the world. Both Colocasia and Xanthosoma are referred to as Cocoyams especially in Africa (Onwueme, 1978). In Kenya they are called 'arrowroot' which is a misnomer. According to Acland (1975) and Kay (1973), arrowroot (Maranta arudinacea) is mainly grown in the West Indies for starch production. It has a more fibrous and smaller rhizome 2.5-5.0 cm in diameter as compared to over 10 cm in cocoyam.

2.1.1 Origin and Distribution

Colocasia orginated and was first cultivated in South Central Asia and then spread to the Pacific Islands and West Africa. It is now cultivated in many parts of West Africa (Onwueme, 1978). In Kenya, it is grown mainly in the Central Province and to a lesser extent in the Western and Eastern Provinces. In the latter it is mainly grown in the Embu, Meru and Machakos Districts (Acland, 1975). Xanthosoma on the other hand originated in Tropical America and spread to ther tropical areas where it arrived later than Colocasia (Onwueme, 1978). In Kenya it is grown in areas where Colocasia is found except in the Central Province (Acland, 1975). Both grow well in areas with annual rainfall of atleast 1250mm and they prefer wet heavy soils of good fertility. Xanthosoma is hardier and more productive and is replacing Colocasia in many parts (Oyenuga, 1968).

2.1.2 Classification and Botany

The Cocoyams (Colocasia and Xanthosoma) form the most important genera in the Monocotyledonous Family Araceae. The main distinguishing feature between the two is the shape of the leaves. In Xanthosoma commonly known as Tannia the leaf is saggitate, dark green with a pointed tip and the basal lobes are unjoined. In Colocasia commonly known as Taro, the leaf is peltate, pale green with lobes joined at the base (Cobley, 1976; Kay, 1973; Oyenuga, 1968; Onwueme, 1978). The two genera also differ in plant height, whereas Xanthosoma appears to be larger and grows to a height 1.8-2.1m, Colocasia grows to a height of 0.4-2.0m (Kay, 1973). Both produce cylindrical corms with cormels but the corms of Xanthosoma are relatively large than those of Colooasia, (Onwueme 1978). Flowering is rare and a distinguishing feature is the presence of a sterile appendage at the tip of the spadix in Colocasia and not in Xanthosoma. Cocoyams grown in Kenya have few small cormels and they conform to the description given for Colocasia..

The classification of Colocasia is controversial since some authorities recognise two species, Colocasia esculenta and Colocasia antiquorum as reported by Purseglove, (1972). In C. esculenta, the sterile appendage of the spadix is shorter than the male part and the reverse is true for C. antiquorum. Others maintain C.esculenta as the main polymorphic species with two varieties namely C. esculenta var esculenta and C. esculenta var antiquorum or globulifera (Kay 1973). The common names for the two varieties being Eddoe for C. esculenta var antiquorum and Dasheen for C. esculenta var esculenta. According to Onwueme (1978) and Purseglove (1972) it is preferable to recognise C. esculenta as the main species until further studies are carried out.

Colocasia spp is generally referred to as Taro or old Cocoyam to distinguish it from Xanthosoma spp which is known as Tannia or new Cocoyam. Colocasia is then divided into two varities on the basis of corm size, corm and leaves acridity. According to Kay, 1973 the Eddoe (C.esculenta var *antiquorum*) group bears a small central corm with large well developed cormels while the Dasheen (*C. esculenta* var *esculenta*) has a large central corm with fewer, compactly, clustered cormels. In Kenya, a large cylindrical corm with the characteristic dumb bell-like shape reflecting constrictions in growth during drought is common. Few small tubers represent the cormels and these are removed before the corms are brought to the market.

The Dasheen plant is a herb which grows to a height ranging between 1-2m above the ground and this part is made up of petioles and leaves. The petiole is attached to the middle of the lamina distinguishing it from *Xanthosoma spp*. The petiole is thicker near the base where it wraps round the apex of the corm. It has large air spaces which probably function as conduits for aeration of the underground parts when the plant is grown under flooded conditions (Onwueme 1978). The leaf lamina is large, thick, entire and globrous with rounded basal lobes. Flowering is rare but when it occurs, the flowers appear shortly after planting, from the leaf axils or from the centre of unexpanded leaves. The flower is borne on a short penducle with a spathe rolled inwards at the apex enclosing a cylindrical spadix with basal female flowers, above which are male flowers tipped by a short sterile appendage.

In an experiment carried out to evaluate seed set, it was shown that partial ovary development is possible with self pollination but not with cross pollination (International Institute of Tropical Agriculture, 1976). When fruits occur, they are clustered barries 3-5 mm in diameter at the base of the spadix and only germinate with difficulty (Onwueme, 1976).

The underground portion is made up of a superficial fibrous root system, a large cylindrical corm with cormels. The corm may be up to 30 cm. long and 15 cm in diameter. The outer periderm of the corm is thick and brownish and within it, is the parenchyma densely packed with starch. Scattered in the parenchyma are vascular bundles and cells containing rephides which cause irritation when the uncooked corm is eaten (Gohl 1975, Onwueme 1978). The corm represents the main stem while the cormels represent lateral branches of the stem. They are relatively thin at the point of attachment to the corm and thicker and rounded at the distal end. Both corms and cormels are edible.

2.1.3 Agronomy and Availability

In view of the difficult flowering and seed setting, cocoyams are vegatatively propagated. Dasheens are mainly propogated through setts from parent corms while the eddoes which produce numerous cormels are propagated from cormels. The setts are leaf bearing tops of mature corms spared after harvesting. In many parts of Kenya, the setts are planted immediately after the old corm is harvested or left to wither as this is said to improve rooting (Acland,1975). The time of planting is therefore determined by the maturity of the parent plant. In other parts of the world like in Hawaii, irrigation is a common practice and planting is done at any time of the year while rainfed cocoyam is planted shortly after the onset of the rainy season. The recommended spacing is 60cm x 60cm (Onwueme, 1978). Rainfed cocoyam is interplanted with other crops like pigeon peas, maize and sugar cane in West Indies (Purseglove, 1972). Intercropping is reported in some parts of East Africa where the crop is rainfed (Acland,1975). In the Machakos district, cocoyams are grown along the banks of rivers and streams and hence in pure stands. The leaves shade the soil and weeding is not necessary.

Corm formation commences three months after planting. The corms are ready for harvesting when most of the leaves begin to turn yellow and this varies with the cultivar, locality and method of cultivation. In Hawaii, upland cocoyam is ready for harvesting 12 months after planting while flooded cocoyam takes about 15 months (Onwueme,1978). In Nigeria, on the other hand, the corms mature in 6-8 months while the shortest maturity period is reported to be 3 months in Ceylon (Kay,1973). With planned planting, harvesting should coincide with the dry season when most of the roots are dry and lifting is easier. If the corms are left underground during the rainy season, new roots develop at the expense of stored food and yields are reduced (Onwueme,1978). Cocoyam is grown continously on fertile river bank plots but fertility should be maintained by manure or fertilizer application. Use of superphosphate is reported in Central Province (Acland 1975). A general application of 40-60 kg/ha for nitrogen 13-26 kg/ha for phosphorous and 48-96 kg/ha for potassium is recommended (Jacoby,1967). For flooded cocoyam, fertilizer application results in increased number and weight of cormels while in rainfed cocoyam, it increases the weight of the main corm (Pena,1967). Nitrogen fertilizer is thought to increase the protein content of the corm while potassium enhances water use by the plant (Cable, 1975).

The yields vary with the cultivar and method of cultivation. The average world yield of cocoyam (Taro) is 5520 kg/ha while the highest yield is 26,000 kg/ha reported in Egypt (FAO, 1975). Yields in Kenya are difficult to assess since the crop is not harvested in bulk and is only harvested when required. A yield of 15t/ha is considered reasonable (Acland, 1975) but this can only be achieved through improved methods of cultivation.

At 26^{o}C and 76 per cent Relative Humidity (RH) the corms can be stored for about 6 weeks while they can be stored for 18 months at 7^{o}C and 80 per cent RH (Purseglove, 1972). At lower temperatures below 2^{o}C the corms decay in 6-8 weeks (Kay, 1973). In Egypt and Samoa, underground storage in pits is reported by Onwueme (1978) to be common. Storage in dry processed or semiprocessed form is common and this is the most suitable form for animal feed. In Kenya, the corms are only harvested when required and this partly compensates for the poor storing ability of the corms after harvesting.

Inspite of the reported high yield values, the area under the crop is not extensive and hence the low availability. This is partly because the crop has not been given much attention by researchers and farmers still consider it as a 'marshland crop'. Lack of controlled price incentives is another factor contributing to the low production. In the Ministry of Agriculture Report (1977), total production in the Central Province is reported to have been 2800 tonnes from 529 hectares while a combination of Colocasia and yams (Dioscorea spp) is reported to have been 7,553 tonnes from 1790 hectares in the Eastern Province. In the Machakos market, cocoyam was found to be available throughout the year.

2.2 Nutritive value of Cocoyam

Tubers have a low dry matter content ranging from 10-35 per cent compared to cereals whose dry matter content is about 90 per cent. The main component of the dry matter is carbohydrate while crude protein, crude firbre, minerals and vitamins form a minor component. Kay (1973) reports chemical composition of cocoyams as 63-85 per cent moisture, 13-29 percent carbohydrate, 1.4-3.0 per cent protein 0.16-0.36 per cent fat, 0.60-1.18 per cent crude fibre and 0.6-1.3 per cent ash.

2.2.1 Cocoyam as a Carbohydrate Source

The major component of the cocoyam dry matter is carbohydrate. Oyenuga (1968) reports an analysis where the carbohydrate fraction had 77.91 per cent starch. The starch was found to contain 17.5 per cent amylose and 79.4 per cent amylopectin. In another report by Martinod and Aguirre (1974),the starch was found to consist of 83 per cent amylopectin and 17 per cent amylose. Amylopectin is made up of 22 glucose units per molecule while the large amylose molecule has 490 glucose units. It therefore follows that since cocoyam starch is largely made up of amylopectin, it is easily digested (Onwueme, 1978). The presence of a mucilage which on hydrolysis yields d-galactose and L-arabinose has been reported (Kay 1973). Most of the starch is concentrated in the fleshy portion while the dry matter concentration is higher at the base(next to the leaves) than at the apex (Onwueme 1978).

2.2.2 Amino acid, vitamin and mineral supply

Most of the non-starchy nutrients of the tuber are found in the outer peel. Oyenuga (1968) reports a crude protein value of 8.66 per cent on dry matter basis compared to 10.65 per cent for yellow maize. The protein is well supplied with most of the essential amino acids except for lysine, methionine, tryptophan and histidine (Onwueme, 1978).

Kay (1973) reports that there is an appreciable amount of vitamin C (7-9 mg/100 edible material). Thiamine and niacin are low compared to amounts found in maize while the riboflavin content is higher than in maize (Oyenuga 1968).

According to Oyenuga (1968), cocoyam is higher in calcium and iron than maize but lower in most of the other minerals. The same report indicates that calcium and phosphorous in cocoyam are 90 per cent readily utilised. The silica free ash is reported to be 2.79 per cent compared to 3.13 per cent in maize. The amino acid, vitamin and mineral contents are higher in the peel than in the fleshy part of the tuber (Oyenuga, 1968).

2.2.3 Other Chemical Constituents

There are reports of the presence of raphides in cocoyam (Kay 1973, Gohl 1975). These are needle-shaped crystals of calcium oxalate and most cultivars especially the Dasheens are reported to contain 0.1-0.4 per cent oxalic acid in the form of calcium oxalate,(Kay1973). In a study of the Araceae family (FAO 1969), it was found that crystals of calcium oxalate were "either short (3μm), non-irritating ones occurring in clusters or singly, or long (12μm) finely pointed occuring in compact bundles and causing severe irritation when eaten. In tubers of all genera only the non-irritating ones were present in the cortex while both types were present in the leaves and stems. This indicates that, the absence of the irritating effect does not rule out the presence of calcium oxalate in the tubers. In another study, the density of the crystals was found to increase as the plant developed and decreased in older and larger tubers. A higher concentration ofthe crystals was observed 2-3 mm from the outer edge of the tuber corresponding to a ring of vascular tissue from the surface (Sunnel and Healey 1979).

Onwueme (1978) reports small quantities of prussic acid, less than that found in cassava.

In another study where tubers including cocoyam, Irish potato, Sweet potato, Cassava, and yams were screened for inhibitory activity against trypsin and alpha-chymotrypsin, cocoyam was found to contain the highest anti-tryptic activity (2062 units/g DM) and this was more thermostable than that of the potato (Sumathi and Pittabiraman, 1975).

2.3 Energy Substitutes in Poultry Feeds

Cereal grains are the principal energy sources in poultry feeds and they form the largest proportion of the diet. Maize has been the principal grain used in poultry diets and to a lesser extent wheat, barley, grain sorghum and oats. Other non-conventional grains like the millets have aroused interest, more so because of their drought resistant ability. Of the available tubers, cassava has been widely studied while hardly any research has been conducted on others like sweet potato, yams and cocoyams as energy sources in poultry diets.

2.3.1 Cereals

The chemical composition of the different cereals does not vary greatly. The metabolisable energy however is affected by the crude fibre content which is not easily digested by birds. The crude fibre of barley is twice while that of oats is four times that of maize. This partly accounts for the lower metabolisable energy in barley and oats as compared to maize (Petersen, 1972). According to the same report, most of the cereals have about the same content of Nitrogen Free Extractives (NFE) and the main cause of variation in the metabolisable energy content is thought to be due to differences in the digestibility of NFE. This depends on the proportions of disaccharides, starch and other non-specified carbohydrates. The digestibility of NFE decrease with an increase in the amount of the non-specified carbohydrates.

Both wheat and barley are grown in Kenya but only the rejected grains find their way into animal feeds. Both have a higher protein content than maize but are lower in energy. Both are higher priced and therefore maize is preferred by feed manufacturers.

Sorghum and oats in Kenya are mainly grown for forage. Sorghum grain compares well to maize in terms of energy and protein and some varieties have been found to have higher protein content than maize (FAO, 1972). In addition, sorghum is drought resistant and can outyield maize in the dry parts (Acland, 1975). It has a high potential as an energy source but the major drawback is its high tannin content in some varieties and this limits its use in poultry diets.

Non-conventional cereals that have not been widely studied in poultry diets include bulrush and finger millets. Recent work (Abate 1980) showed that bulrush millet can be used in broiler diets to form up to 70 per cent of the diet. At this level and with not less than 0.3 per cent lysine it can serve as a part supplement for the protein.

3.2 Tubers

Tuber meals are used in poultry diets after slicing, drying and milling as substitutes for maize. Their high moisture content has been the limiting factor which necessitates artificial drying before incorporation into the rations. Methods of production have not been as mechanised as in grain production and this partly discourages farmers from large scale production of tubers. The fresh tubers do not store well after harvesting and need to be dried for long storage.

Hardly any literature is available on tuber meals as energy sources in poultry diets. Considerable work has however been done on cassava as an energy substitute for maize in poultry diets.

In Philliphines, Gerpacio et al (1974) conducted some trials in which sweet potatoes (Ipomoea batatas), cassava (Manihot utillissima), gabi (Colocasia esculenta), pongapong (Amorphallus campanulatus) and Ubi (*Dioscorea alata*) were evaluated as energy sources in broiler diets. It was shown that sweet potatoes and cassava could wholly replace yellow maize in broiler rations at levels of 50 per cent of the ration. The two meals were however inferior to maize in promoting weight gain. Birds fed on the other three meals performed poorly with significantly ($P \leq 0.05$) lower weight gains and feed conversion efficiencies. The tubers had been chopped and dried at 80°C before being mixed into isonitrogenous, isocaloric diets which were fed to day old chicks.

In another experiment, Szylit *et al.* (1979) examined starch grains from cassava (*Maninot utillissima*), taro (*Colocasia antiquorum*) canna (*Canna edulis*) and two species of yam (*Dioscorea dumentum* and *D. cayanensis*). Starch grains from *D. dumentum* were 1-2 μm, cassava 12 μm, canna 60 μm and *D. cayanensis* 75 μm. This was found to be related to weight gains where *D. cayanensis* gave the lowest weight gains while cassava with the smallest starch grains gave the highest gain per unit feed. The birds were fed on diets containing 57-70 per cent of the starches from 2-6 weeks of age.

The nature of the feed influences feed intake in the bird. Tuber meals tend to be dusty and fat inclusion and pelleting reduces the dsuty nature. However, work by Enriquez and Ross (1967) where a 50 per cent cassava diet was supplemented with a 4 per cent cane molasses or 3.7 per cent soybean oil, gave no beneficial effect, an indication that palatability and essential fatty acid deficiency were not responsible for the poor performance. Kharjaren and Kharjaren (1976) fed graded levels of cassava meal in isonitrogenous, isocaloric diets from 1-9 weeks of age. There was a decline in growth and feed conversion efficiency beyond the 30 per cent level of inclusion during 1-5 weeks of age. A level of up to 50 per cent was found suitable during 5-9 weeks of age, an indication that the level of inclusion is affected by the age of the bird.

Tuber meals have been found to be low in crude protein content compared to maize. On a dry matter basis, yellow maize has 10.66 per cent crude protein compared to 8.66 per cent for cocoyam, 2.38 per cent for cassava and 8.36 per cent for sweet potato (Oyenuga, 1968). Enriguez and Ross (1967) using day old broiler chicks concluded that, cassava root meal can be used up to 50 per cent in the diet provided it is balanced with respect to protein and methionine.

Cassava used in this experiment was from the sweet clone and the methionine response was associated with an increase in the level of supplemented soybean meal which is low in methionine and not with an increase in the level of hydrogen cyanide. On the other hand, in a report by Montilla (1977), 0.3 per cent methionine and 0.3 per cent lysine supplementation in a diet containing 54 per cent cassava flour had no beneficial effect on growth. Later, Yeong (1978) working with broiler finisher diets found that, with 0.2 per cent dl-methionine supplementation, tapioca meal could be included up to 50 per cent in the diet. Work on amino acids is inconclusive but it is clear that the amino acid balance in the diet affects the level of inclusion of the energy source. Cocoyam is deficient in lysine, methionine and tryptophan (Onwueme 1978) and these should be considered when evaluating levels of inclusion of cocoyam meal in broiler diets.

The metabolisable energy value of most of the tuber meals have not been established but their gross energy values compare well to those of maize. According to Oyenuga (1968), yellow maize has 409.65 calories per 100 grammes, cassava has 375.93 while cocoyam has 376.37. The ME value of maize is about

3.4 kcal/gram (NRC, 1971) while Shires et al. (1979) using adult cockerels found a value of 4.06 kcal/g (DM basis). Maust et al. (1972) using growing chicks reported an ME value of 4.31 kcal/g for cassava. This value was higher than the earlier value of 3.44 kcal/g (DM basis) reported by Olson (1969) and 3.20 kcal/g reported by Aguirre et al. (1979). Hardly any values have been reported for cocoyam.

2.4 Role of Metabolisable Energy (ME)

Metabolisable energy (ME) is the gross energy of the feed consumed minus fecal and urinary energy which are combined as single excreta energy in birds. The energy lost as gaseous products of digestion in poultry is insignificant and can therefore be ignored (Harris, 1966). The ME is therefore the energy that the bird can utilise for metabolic activities and is expressed in calories or kilocalories per gram.

The level of dietary ME determines the levels of inclusion of protein, amino acids and to a lesser extent, minerals and vitamins (Sibbald, 1979). The energy value of the feed influences the feed intake. Birds eat to satisfy their calorie requirements and raising the energy concentration in a ration lowers the feed intake and hence a reduction in the intake of the other nutrients (Ewing, 1963). It is therefore necessary to balance the energy content of a diet with respect to all the other nutrients to ensure that these are adequately supplied.

2.4.1. Determination of Metabolisable Energy

Metabolisable Energy can be expressed as Apparent Metabolisable Energy (AME) or True Metabolisable Energy (TME). Reports on ME values do not always indicate which value is being reported.

2.4.1. Apparent and True Metabolisable Energy Relationship

Apparent Metabolisable Energy (AME) is the difference between the consumed feed energy and fecal energy.

$$AME/g\ feed = \frac{(F \times GE_f) - (E \times GE_e)}{F}$$

Where F is the feed intake in grams,

E is the excreta output in grams;

GE_f is the gross energy per gram of feed;

GE_e is the gross energy per gram of excreta.

It is argued that some body nitrogen is catabolised and excreted as energy giving products.
The AME corrected for this nitrogen retention (NR) is referred to as Nitrogen Corrected Apparent Metabolisable Energy (AME_n). Nitrogen correction increases precision but the additional work of measuring nitrogen retention is of questionable value (Sibbald, 1979).

$$AME_n/g\ feed = \frac{(F \times GE_f) - (E \times GE_e) - (NR \times K)}{F}$$

where $NR = (F \times N_f) - (E \times N_e)$

N_f is the nitrogen per gram of feed

N_e is the nitrogen per gram of excreta

and K is a constant which is either

34.4 kJ/g N (Hill and Anderson, 1958) or

36.5 kJ/g N (Titus *et al*. 1959)

This constant represents the energy value of the nitrogen constituents of chicken urine. Both factors are under current use and this contributes to the variation in AME_n data.

True Metabolisable Energy (TME) describes an estimate of ME in which correction is made for Metabolic Fecal (FE_m) and Endogenous Urinary (UE_e) energy (Harris, 1966).

Where FE_m is the energy from digestive enzymes and abraded intestinal mucosa.

UE_e is the urinary energy which is not of feed origin.

The correction is necessary since the AME and AME_n values have been shown to vary with feed intake (Sibbald, 1975). It has been shown that as feed intake increases, the AME value approaches the TME value. This is because at high levels of intake, the $FE_m + UE_e$ energy loss is relatively small and insignificant. Feed intake is important where feedstuffs of low palatability are being assayed. Where AME is used as an estimate of TME, high feed consumption should be ensured for more accurate results. Nitrogen corrected true metabolisable energy (TME_n) like AME_n is corrected for nitrogen retention and again the additional work involved is questionable relative to the precision obtained.

$$TME_n/\text{g feed} = \frac{(F \times GE_f) - (F \times GE_e) - (NR \times K) + (FE_m + UE_e)}{F}$$

2.4.1.2. Conventional ME determination

This method was developed by Hill and Anderson (1958). Chicks are fed on a reference diet for two weeks before the commencement of the test period. Glucose is used in the reference diets and a known percentage is replaced by the test feedstuff. Chromic oxide is used as an index substance which is recovered in the excreta quantitatively. The excreta is collected during the last four days. Both the feed and excreta are analysed for chromic oxide and it is not necessary to feed a known amount of feed or collect the feaces quantitatively. Both feed and excreta are analysed for gross energy and the values used to compute metabolisable energy.

This method has several limitations. Results cannot be obtained within a short period since the birds are kept for two weeks on the reference diet prior to the two weeks test period. Total recovery of chromic oxide is usually not obtained and this is likely to give erroneous results.

Rao and Clandinin (1970) determined the ME value of rapeseed meal and obtained significantly different results. Lower ME values were obtained where semi-purified glucose is known to pass faster through the gut than a practical diet. The other disadvantage is that values using semipurified glucose are used to formulate practical diets. There could also be changes in the ME of the reference diet (Which is usually assumed to be constant) when it is mixed with the test material. These limitations have led workers to develop other methods for ME determination.

2.4.1.3 Recent Development in ME determination

Sibbald (1976) suggested a method for the bioassay of ME using adult roosters. In this method, correction is made for the endogenous excreta and the ME so obtained is TME. The birds are starved for 24 hours to empty their alimentary canals, they are then force fed with a known amount of pelleted feed and total excreta collection follows for 24 hours. Subsequent tests can be done after allowing one day ad libitum feeding but a longer period is preferred (Sibbald 1978a). Birds have been used for as many as 30 assays spaced 14 days apart with no adverse effects (Sibbald 1979). Force feeding in this method is the major limitation since it is tedious and the amount force fed is limited by the size of the bird. The greater the intake the smaller the effect of experimental errors, but as feed intake rises, the incidence of regurgitation increases (Sibbald 1977).

Farrel (1978) has developed a rapid method for ME determination. Unlike Sibbald's method, the birds are trained to consume about 70 grams of feed in one hour. The test ingredient is mixed with a basal ration whose ME value is also determined.

Chami et al (1980) are of the view that the ME values are influenced by toxicants such as guar gum, tannic acid and gossypol. A longer excreta collection period is recommended as a modification of the first two methods.

2.4.1.4 Factors that affect ME values

The age, level of feed intake, duration of starvation and previous diet are the major factors that are thought to influence the ME values.

Sibbald (1978b) observed no significant differences between TME values obtained with broiler chicks and roosters. It was however noted that TME values on the same diet with adult birds were less variable than those for chicks. Shires et al (1980) found no significant differences between TME values obtained with adult roosters and with chicks. It was therefore confirmed that, with the exception of high glucosinolate rapeseed, the TME values obtained with adult roosters can be used to formulate diets for young birds.

The energy voided as excreta has been found to increase linearly with an increase in the intake of wheat. It has been observed that the metabolic fecal and endogenous nitrogen excretion is constant 144 mg/kg/24 hours (Sibbald, 1975). With low feed intake, this value is relatively significant and it is reported by the same worker that while the TME value of wheat was constant, the AME value varied with intake.

The starvation period between assays should be long enough to eliminate all the previous material from the digestive tract. This is influenced by the nature of feed. Sibbald (1978) observed that when Soybean was assayed following a bioassay of maize, the TME values were not affected by the duration of the rest period. But when wheat was assayed following a bioassay of rapeseed meal, a 48 hour delay was required since some of the rapeseed meal failed to clear from the digestive tract within 24 hours. Shires et al

(1979) found a significant decrease in the TME of maize when birds were only starved for 12 hours but no significant difference in the values when birds were starved for 24 or 48 hours. The rest period should not be less than 24 hours but a longer period for the bird to regain its body weight is recommended by the same workers.

The dietary level of protein in the previous diet has been found to have no significant ($P \geq .05$) effect on the TME value of maize (Shires et al 1979).

2.5. Presence of oxalates in feedstuffs

Oxalic acid has the ability to bind calcium and other divalent ions to form oxalates. Mugerwa and Stafford (1976) reported the presence of both calcium and protein bound oxalates. Plants such as rhubarb (*Rheum rhapanticum*) are known to contain high levels of oxalic acid. Humans show a remarkable ability to adapt to low levels of calcium, and according to Fasset (1966) it would require a combination of a high intake of oxalate containing food plus low calcium and vitamin D intake over a long period of time for chronic effects to be noted. The trend may be different for birds and other monogastrics and precautions may be prequired when feeding oxalate containing feedstuffs.

2.5.1 Methods of oxalic acid determination

The earlier method by Moir (1953) is still being used especially where dry samples are involved. The AOAC (1975) method is designed for tinned products and may not be applicable for dry samples. Both methods involve hot aqueous extraction of oxalic acid so obtained titrated with potassium permanganate. The AOAC method includes the use of atomic absorption spectroscopy.

2.5.2 Effects of oxalates on performance

There is lack of information on the effects of oxalates on broiler performance. Much work has however been done with ruminants and reports by (Talapatra *et al*.(1948) and Negi (1971) indicate that rumen microorganisms destroy the oxalates producing alkaline carbonates and bicarbonates which inhibit fermentation and hence rumen dysfunction. The microorganisms can destroy over 70 per cent of the plant oxalates (Mugerwa and Stafford, 1976). Lynn *et al*. (1967) working with sheep found that cellulose fermentation was inhibited when 240, 180, 120 mg of oxalate was added to 100 ml fermentation medium containing rumen liquor.

Later work (Lynn and Butcher, 1972) showed that up to 6 per cent soluble oxalate caused no ill-effect on yearling wethers other than slight hypocalcemia, increased serum phosphorous, decreased serum magnesium and reduced daily feed and water intake. The lethal dose was found to be between 0.99-1.06g/kg body weight.

2.5.3 Processing to overcome the effect of oxalates

Extraction of the oxalates or calcium supplementation are two ways in which the effects of oxalates may be overcome.

Cooking is reported to overcome the irritant (calcium oxalate crystals) in cocoyam (Gohl, 1975). In an earlier report by Watts (1959) it was shown that sheep can tolerate high oxalate levels if the diet contains lucerne, calcium or strontium Later work by Lynn et al (1967) showed dicalcium phosphate ($CaHPO_4$) to be the most effective ($P<.01$) followed by calcium carbonate ($CaCO_3$), magnesium sulphate ($MgSO_4$) and bonemeal.
The calcium supplements lower the concentration of free oxalates in the rumen. This ranking is in order of solubility, where dicalcium phosphate is the most soluble.

3. MATERIALS AND METHODS

3.1 Experiment I

3.1.1 Objective

The feasibility of using cocoyam (*Colocasia esculenta*) as a substitute for maize or cassava in broiler starter diets.

3.1.2 Experimental Design

A completely randomised design was used. There were five treatments with three replicates of ten birds each.

3.1.3 Experimental Birds

One hundred and fifty, three-day old 'Starbro' broiler chicks were used. They were individually weighed and placed in fifteen groups of similar weights. The groups were randomly allocated to the different treatments in a wire floored electrically heated brooder maintained at 35°C. Fifteen pens of 142.5 x 32.5 cm floor space were used for the experiment. Feed and water were provided *ad libitum* throughout the four-week experimental period.

3.1.3 Experimental Diets.

Cocoyam (*Colocasia esculenta*) tubers were obtained fresh from a market in Machakos District. They were sliced into about five millimeter chips and dried in a locally improvised, simple polythene covered solar drier. The chips were spread thinly on four wire mesh trays (46 x 102 cm each) each holding about two kilograms of the chips. On a clear cloudless warm day the solar drier temperatures rose from 21^{o}C at 8 am to 49^{o}C by 2 pm and decreased to 27^{o}C by 6 pm. Under these conditions, the moisture content of the chips decreased from 60 per cent to 7 per cent in a period of 28 hours. Dry cassava chips for comparison with cocoyam were obtained from the Coast Province and the two feedstuffs were coarsely milled using a 4mm diameter sieve. The protein contents of the meals were determined and isonitrogenous diets were formulated using the values on 'as is basis'. Sixty kilograms of feed were mixed for each treatment and the batch divided into three for each replicate and stored in covered plastic buckets. Table I shows the composition of the diets and the calculated crude protein and metabolisable energy values.

3.1.5 Parameters Recorded

Initial and weekly liveweights were recorded for each replicate. Initial weight of the feed and subsequent weekly weights were recorded and feed

Table 1: COMPOSITION OF THE EXPERIMENTAL DIETS FED TO BROILER CHICKS IN EXPERIMENT I

Feedstuffs	Experimental Diets				
	01	02	03	04	05
	%	%	%	%	%
Maize	58	29	0	29	0
Cassava	0	29	58	0	0
Cocoyam	0	0	0	29	58
Lard	2	2	2	2	2
Wheatbran	10	5	1	5	1
Soybean meal	18	22	25	22	25
Sunflower meal	1	2	3	2	3
Fish meal	7	7	7	7	7
Meat and bone meal	3	3	3	3	3
Salt	0.5	0.5	0.5	0.5	0.5
Premix[1]	0.5	0.5	0.5	0.5	0.5
Total	100.0	100.0	100.0	100.0	100.0
Calculated Crude Protein (%)	20.62	19.92	19.01	20.35	19.79
Calculated ME (Kcal/kg)	2967	3029	3082	3029	3082

1 The premix provided the following per kilogram of feed; Vitamin A 20,000 IU, Vitamin D_3 4,000 IU, Vitamin E 16 mg, Vitamin K 4 mg, Vitamin B_2 12 mg, Vitamin B_{12} 0.02 mg, Choline Chloride 0.30mg, Folic acid 2mg, Niacin 60mg Pantothenic acid 20 mg, Cobalt 2mg, Copper 28mg, Iodine 4mg, Iron 48mg, Manganese 134mg, Zinc 134 mg, Selenium 0.20mg BHT (antioxidant) 240 mg.

consumption was obtained by difference between initial weekly weight and the weight of remaining feed. Mortality and morbidity were also recorded. Weight gains per bird were calculated by subtracting initial weekly liveweights from the final weekly liveweights. Feed conversion efficiency was calculated to give feed consumed per unit body weight gain.

3.1.6 Feed analyses

Proximate composition of the feedstuffs and diets were determined using methods outlined in AOAC (1975). Wet ashing was done to prepare diet samples for calcium and phosphorous determinations. Calcium analysis was done using Atomic Absorption spectrophotometer (Perkin-Elmer 303) and Ultra Violet Spectrophotometer (Beckman, Model 24) was used for phosphorous determination.

3.1.7 Statistical analysis

Analysis of variance and Duncan's New Multiple range test (Steel and Torrie, 1960) were used to test treatment differences.

3.2. Experiment II

3.2.1 Objective

To observe effect of simple processing methods and calcium carbonate supplementaion on improving utilisation value of cocoyam in broiler diets.

3.2.2 Experimental Design

A completely randomised design was used. There were five treatments with three replicates of eight birds each.

3.2.3 Experimental Birds

Ninety six, three-day old 'Starbro' broiler chicks were used in the feeding trial.
The chicks were individually weighed and divided into twelve groups of similar weights. The groups were randomly allocated to the four treatments and placed in an electrically heated brooder and the temperature was maintained at 35°C. Feed and water were provided *ad libitum* throughout the experimental period.

3.2.4 Experimental Diets

Fresh cocoyam tubers from the same source as in Experiment I were subjected to three treatments. Whole tubers in one batch were sliced and dried while a batch was sliced and soaked in hot water at 80^{o}C for one hour, drained and dried. The sliced cocoyams were dried under direct sunlight (open drying) on polythene sheets. Under clear, warm, windy conditions with temperatures ranging between 21^{o}C and 35^{o}C, the moisture content was reduced from 60 per cent to about 7 per cent in 30 hours. The dry slices were then ground coarsely as in Experiment I. Isonitrogenous diets were then formulated to contain the same levels of the various feedstuffs except for the calcium carbonate supplemented diet where wheat bran and soybean meal were varied to compensate for the nutrients forgone by adding two per cent calcium carbonate. Twenty nine per cent cocoyam meal was included in all the diets to replace half the content of maize. The per cent composition of the diets is shown in Table 2. Thirty six kilograms of feed were mixed for each treatment and this was divided into three and stored in covered plastic buckets.

3.2.5 Parameters Recorded

Initial and weekly liveweights were recorded and used to calculate weekly liveweight gains. Initial weight of the feed and weekly weights were recorded, from which weekly feed intakes were calculated.

TABLE 2: COMPOSITION OF THE EXPERIMENTAL DIETS FED TO BROILER CHICKS IN EXPERIMENT II

Feedstuffs	Experimental Diets			
	01	02	03	04
	%	%	%	%
Maize	29.0	29.0	29.0	29.0
Cocoyam	29.0	29.0	29.0	29.0
Lard	2.0	2.0	2.0	2.0
Wheat bran	5.1	5.1	5.1	2.0
Soybean meal	22.0	22.0	22.0	23.1
Sunflower meal	2.0	2.0	2.0	2.0
Fish meal	7.0	7.0	7.0	7.0
Meat and bone meal	3.0	3.0	3.0	3.0
Salt	0.5	0.5	0.5	0.5
Premix [1]	0.4	0.4	0.4	0.4
Calcium carbonate [2]	0	0	0	2.0
Total	100.0	100.0	100.0	100.0
Calculated Crude Protein(%)	20.34	20.34	20.34	20.36
Calculated ME (Kcal/kg)	3002	3002	3002	2987

1 The premix provided the following per kilogram of feed: Vitamin A 16,000 IU, Vitamin D 3,200 IU, Vitamin E 12.8mg, Vitamin K 3.2mg, Vitamin B_2 9.6mg, Vitamin B_{12} 0.016, Choline chloride 240mg, Folic acid 1.6mg Niacin 48mg, Pantothenic acid 16mg, Cobalt 1.6mg, Copper 22.4mg, Iodine 3.2mg, Manganese 107.2mg, Zinc 107.6mg, Selenium 0.16mg, Iron 38.4mg, dl-methionine 240mg, L-lysine 800 mg, BHT (antioxidant) 192mg.

2. Feed grade calcium carbonate containing 40 per cent calcium.

Feed conversion efficiency was also calculated to give feed consumption per body weight gain.

3.2.6 Feed analyses

Proximate analysis, calcium and phosphorous determinations were carried out as outlined in AOAC (1975) for the cocoyams and diets. Oxalic acid was determined using Moir's (1953) method which was designed for dry samples and has essentially three parts. First, the oxalates are extracted using 0.25N hydrochloric acid in a 70^{o}C waterbath for one hour. After filtering, 5 ml of the filtrate is used in the precipitation. The precipitating reagent used is made up of sodium acetate and calcium acetate. Precipitation is done overnight, and this is repeated after dissolving the precipitate in hydrochloric acid. In the final stage, the precipitate is washed with a solution of 96 per cent alcohol and concentrated ammonia in distilled water. After centrifuging the precipitate is heated in an oven at 100^{o}C for 30 minutes and then cooled and dissolved in 2N sulphuric acid. This is then titrated under boiling conditions (the tube is placed in a beaker of boiling water) with a fresh

solution of 0.02 N potassium permanganate.
Oxalic acid per cent is obtained by multiplying the titration in millitres by 1.801 which is a constant.

3.3.7 Statistical Analysis

Analysis of variance and Duncan's new multiple range test (Steel and Torrie, 1960) were used to test differences in treatment means.

3.3. Experiment III

3.3.1 Objective

To investigate further the improvement of cocoyam utilisation with a view to optimising calcium carbonate supplementation.

3.3.2 Experimental Design

A completely randomised design was used. There were six treatments with three replicates of seven birds each.

3.3.3 Experimental Birds

One hundred and twenty six, three-day old 'Starbro' broiler chicks were used. They were individually weighed and allocated to eighteen groups of similar weight. These were then allocated to different treatments at random and housed in an electrically heated brooder and the temperature was maintained at 35°C. Feed and water were provided ad libitum throughout the experimental period.

3.3.4 Experimental Diets

Fresh Cocoyam tubers, again from the same source as in Experiment 1, were sliced and dried at 40°C in a forced-air draught oven for 24 hours to lower the moisture content to 7 per cent. Isonitrogenous diets were formulated containing different levels of calcium carbonate and two levels of cocoyam meal as shown in Table 3. Twenty four kilograms of feed was mixed for each treatment and stored in covered plastic buckets.

3.3.5 Parameters Recorded

Initial weekly and final weekly liveweights were recorded and these were used to calculate weekly liveweight gains. Feed was weighed into the troughs at the beginning of each week and feed consumption calculated. Feed consumption efficiency was calculated to give feed consumed per unit body weight gain.

3.3.6 Feed analyses

Proximate analysis, calcium and phosphorous determination were carried out as outlined in AOAC (1975).

3.37 Statistical Analysis

Analysis of variance and Duncan's new multiple range test (Steel and Torrie, 1960) were used to test differences in treatment means.

TABLE 3: COMPOSITION OF THE EXPERIMENTAL DIETS FED TO BROILER CHICKS IN EXPERIMENT III

Feedstuffs	Experimental Diets.					
	01	02	03	04	05	06
	%	%	%	%	%	%
Maize	58.0	0	0	29.0	29.0	29.0
Cocoyam	0	58.0	58.0	29.0	29.0	29.0
Wheat bran	17.5	6.0	0	7.0	8.7	10.2
Soybean meal	11.6	23.1	25.1	18.9	18.4	17.9
Fish meal	8.0	8.0	8.0	8.0	8.0	8.0
Meat and Bone meal	4.0	4.0	4.0	4.0	4.0	4.0
Salt	0.5	0.5	0.5	0.5	0.5	0.5
Premix [1]	0.4	0.4	0.4	0.4	0.4	0.4
Calcium carbonate [1]	0	0	4.0	3.0	2.0	1.0
Total	100.0	100.0	100.0	100.0	100.0	100.0
Calculated Crude Protein (%)	19.58	19.60	19.58	19.59	19.59	19.60
Calculated ME (Kcal/kg)	2794	2902	2868	2823	2832	2840

1 Premix and calcium carbonate composition as in Table 2.

3.4 Experiment IV

3.4.1 Objective

Estimate the metabolisable energy values of the cocoyam and cassava meals with a view to establishing their energy constitution.

3.4.2 Methodology

A rapid metabolisable energy determination procedure based on Farrel's (1978) method was used. The birds were trained to consume about fifty grams of feed in one hour. This was done by gradually reducing the time allowed for feed intake. The birds were then starved for 24 hours and then offered a basal diet with the test feedstuff (1:1) for one hour. The feed troughs were then removed and the remaining feed weighed. A weighed polythene sheet was placed on a metal tray under the cages and excreta collected for 24 hours. The polythene sheet and contents were then placed in an oven at 60°C for 24 hours. The sheet and contents were then left for three hours to equilibrate with the atmosphere and then weighed. The excreta was milled finely, mixed thoroughly and stored in sealed polythene bags for gross energy determination.

3.4.3 Experimental Design

The test material was allocated to the birds at random with five replicates per feedstuff.

3.4.4 Experimental Birds

A batch of six Rhode Island Red adult roosters and a second batch of eight Rhode Island Red roosters were used in the experiment.
The birds were weighed at the beginning and end of the experimental period. They were housed in individual cages 31.25x38.75x42.50cm raised 45 cm above the floor.
During the training period, the birds were fed for 24 hours, 12 hours, 6 hours, 3 hours and finally for one hour per day, each period lasting one week. Water was provided *ad libitum* throughout the training period and test period except for the one hour when the test feed was given. This was found necessary to minimise feed wastage and avoid spillage into the water troughs. One day of *ad libitum* feeding was allowed between the test days.

3.4.5 Test Diets

Sixty kilograms of the basal diet was mixed as outlined by Farrel (1978). The composition of the diet is shown on Table 4A. This was used during the

TABLE 4A: COMPOSITION OF THE BASAL DIET USED IN METABOLISABLE ENERGY DETERMINATIONS

Feedstuff	%
Maize	90.0
Fish meal	8.0
Meat and bone meal	1.0
Salt	0.5
Premix[1]	0.5
Total	100.0
Calculated Crude Protein	13.13
Calculated ME (Kcal/kg)	3344

1 Pramix Composition as in Table 1

TABLE 4B: COMPOSITION OF TEST FEEDS IN USED IN METABOLISABLE ENERGY DETERMINATIONS

Feedstuff	%
Basal	50
Test feedstuff	50
Total	100

test period. The basal diet was tested alone or mixed with cocoyam, cassava or maize.

3.4.6 Parameters Recorded

The initial and final liveweights of the roosters were recorded. Feed intake during the training period and test day were recorded. Weight of the excreta voided per bird was also recorded.

3.4.7 Laboratory Analysis

Proximate Composition of the diet was determined (AOAC 1975) and the gross energy of the feed and excreta were determined using an Automatic Adiabatic Bomb Calorimeter (Gallenkamp) and moisture determined by drying the samples in an oven set at 105°C for 4 hours.

3.5 Location of the Experiments

3.5.1 Laboratory analyses

These were conducted at the Nutrition Laboratory of the Animal Production Department, University of Nairobi.

3.5.2 Feeding Trials

The feeding trials were conducted at the Poultry Unit of the Department of Animal Production, University of Nairobi.

4. RESULTS

4.1 Experiment I

The average chemical composition of the feedstuffs and diets used are shown in Tables 5A and 5B respectively. The average weight gains and feed conversion efficiency over the four week experimental period are shown in Table 6. Figure 1 shows the weight gain trend over the experimental period.

Both the control birds and those fed on 29% cassava based diets were over 500 grams at the end of the fourth week. Birds fed on the cocoyam based diets had significantly ($P \leq .01$) lower weight gains than those fed on the maize control diet. The weight gain from the 29 per cent cocoyam meal diet was 31 per cent lower than the control diet while the weight gain for birds fed 58 per cent cocoyam meal was 53 per cent lower than that for the control diet birds. At both levels of cocoyam meal inclusion, there was a reduction in feed intake. At the 29 per cent level of cocoyam meal inclusion there was a 14 per cent reduction in feed intake which was not significant ($P \geq .05$). The reduction in feed intake at 58 per cent level of cocoyam meal inclusion was 20 per cent and this was significantly ($P \leq .01$) different from the control. The difference in feed

TABLE 5A: CHEMICAL COMPOSITION (AS IS BASIS) OF FEEDSTUFFS IN THE EXPERIMENTAL DIETS

Feedstuff	Chemical Composition				
	Dry Matter	Crude Protein	Crude Fibre	Ether Extractives	Ash
	%	%	%	%	%
Maize	88.25	8.56	3.38	2.96	1.03
Cassava	89.82	1.97	1.92	0.34	3.01
Cocoyam	92.34	3.24	3.06	0.67	1.65
Wheat bran	86.62	15.67	12.41	3.50	10.48
Soybean meal	89.97	43.19	6.83	1.04	6.17
Sunflower meal	91.90	37.90	14.43	2.13	6.29
fish meal	90.11	60.26	0.30	9.56	16.37
Meat and bone meal	93.43	49.29	3.28	10.28	24.08

TABLE 5B: CHEMICAL COMPOSITION (AS IS BASIS) OF THE EXPERIMENTAL DIETS USED IN EXPERIMENT I

Experimental Diet	Chemical Composition						
	Dry Matter %	Crude Protein %	Crude Fibre %	Ether Extractives %	Ash %	Calcium %	Phosphorous %
58%MZ[1]+0%CS[2]+0%CY[3]	88.53	19.62	4.11	7.00	4.63	0.87	0.51
29%MZ+29%CS+0%CY	88.93	19.58	4.20	5.87	4.68	0.92	0.50
0%MZ+58%CS+0%CY	88.91	19.52	4.99	5.83	5.06	1.07	0.55
29%MZ+0%CS+29%CY	88.90	19.68	4.56	5.28	5.07	0.92	0.53
0%MZ+0%CS+58%CY	90.57	19.70	5.15	5.88	5.13	0.92	0.51

MZ[1] - MAIZE
CS[2] - CASSAVA
CY[3] - COCOYAM

TABLE 6: MEAN WEIGHT GAIN (g) AND FEED CONVERSION EFFICIENCY (FCE) OF BROILER CHICK FED 0, 29 or 58 PER CENT MAIZE, CASSAVA OR COCOYAM DIETS FROM THREE DAYS TO FOUR WEEKS OF AGE IN EXPERIMENT 1.

Experimental Diets	Weight gain	FCE
58%MZ+0%CS+0%CY	560.33^{a}	1.99^{a}[1]
29%MZ+29%CS+0%CY	519.55^{ab}	2.09^{ad}
0%MZ+58%CS+0%CY	480.56^{bc}	2.37^{ad}
29%MZ+0%CS+29%CY	388.10^{c}	2.47^{b}
0%MZ+0%CS+58%CY	261.30^{d}	3.40^{c}

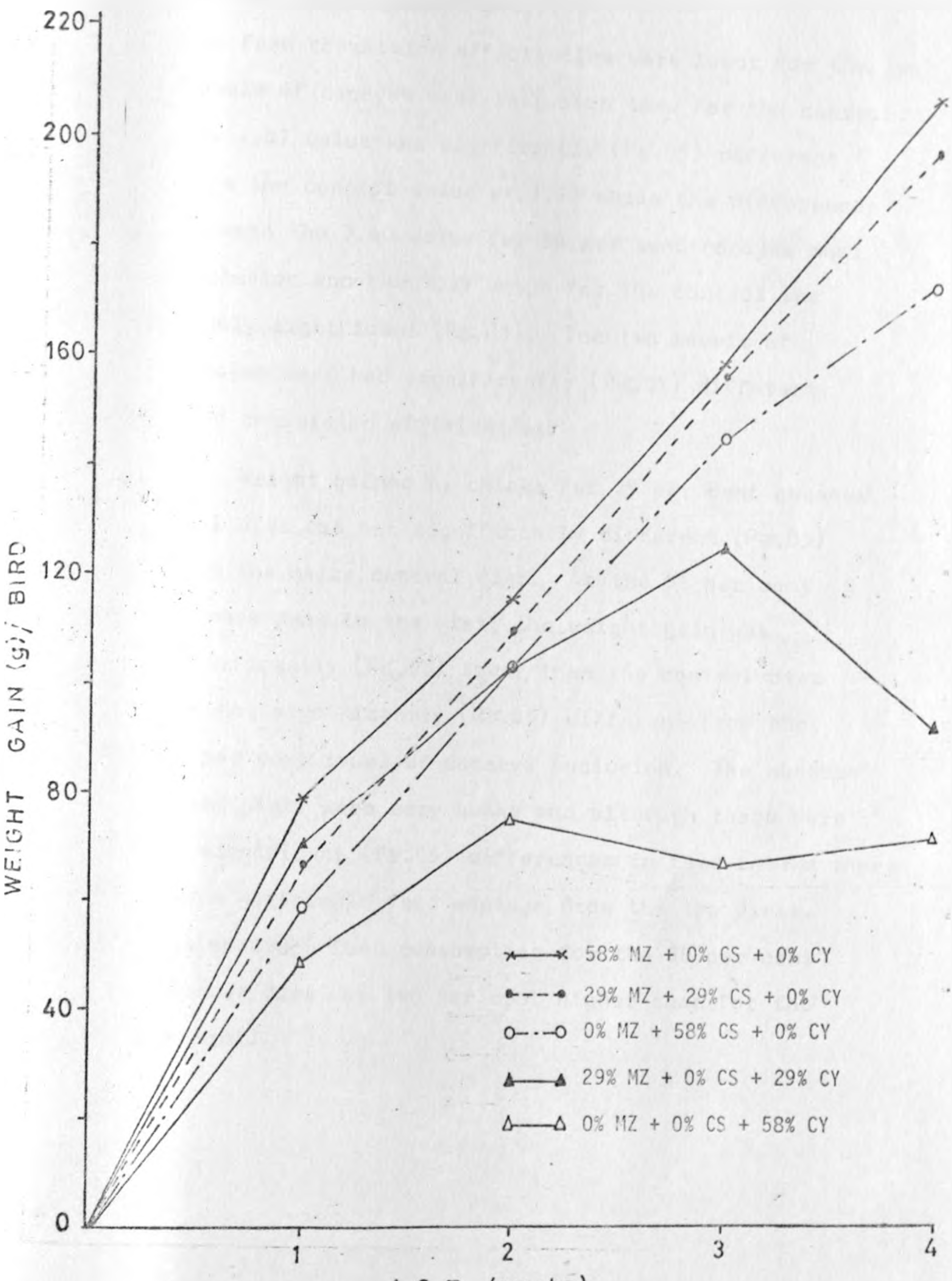
1 means bearing similar superscripts are not significantly different.

ANOVA

	Source	df	ss	mss	f
<u>Weight gain</u>					
	Total	14	183345.12		
	Treatment	4	170554.12	42638.53	33.33**[1]
	Residual	10	12791.00	1279.00	
<u>FCE</u>					
	Total	14	4.2605		
	Treatment	4	3.7524	0.9381	18.47**[1]
	Residual	10	0.5081	0.0508	

** Significant treatment difference (P≤.01)

Fig. 1: Weight gain (g) per broiler chick fed starter diets in Experiment 1.



intake between the two levels of cocoyam meal inclusion was not significant ($P \geq .05$).
The feed conversion efficiencies were lower for the two levels of cocoyam meal inclusion than for the control. The 2.47 value was signficantly ($P \leq .05$) different from the control value of 1.99 while the differences between the 3.40 value for 58 per cent cocoyam meal inclusion and the 1.99 value for the control was highly significant ($P \leq .01$). The two levels of cocoyam meal had significantly ($P \leq .01$) different feed conversion efficiencies.

Weight gained by chicks fed 29 per cent cassava meal diet was not significantly different ($P \geq .05$) from the maize control diet. At the 58 per cent cassava meal in the diet, the weight gain was significantly ($P \leq .05$) lower than the control diet but not significantly ($P \geq .05$) different from the 29 per cent level of cassava inclusion. The cassava-based diets were very bulky and although there were no significant ($P \geq .05$) differences in feed intake there was a noticeable feed wastage from the two diets. The apparent feed consumption for the 58 per cent cassava diet was two per cent higher than for the control.

Four birds from different treatments died during the course of the experiment but none died from the 58 per cent cocoyam meal diet. In this treatment, the birds were generally smaller, with normal feathering but they were not as active as the birds from the other treatments. They also showed signs of pasty diarrhoea during the last week of the experiment but pathological reports gave negative results. There were no apparent organ abnormalities observed in the sacrificed birds.

4.2 Experiment II

Cocoyam used in this experiment was processed with the objective of removing the oxalates. The chemical composition of the raw and treated cocoyam is shown in Table 7A, and the chemical compostition of the diets is shown in Table 7B. The crude protein values for the processed cocoyam are slightly lower than for the unprocessed cocoyam. This is also true for the ether extractives, crude fibre and ash. The diets were formulated on the assumption that processing did not alter the crude protein content of the cocoyam, but on analysis the diets with processed cocoyam had lower crude protein values than those with unprocessed cocoyam.

The weight gains and feed conversion efficiencies are shown in Table 8 and figure 2 shows the weight gain trend There were no apparent differences among the treatments. However, the peeled cocoyam diet had a 4 per cent lower weight gain than the control and there was a similar reduction in feed intake. There was an improved trend with the calcium carbonate supplemented diet, where the weight gain was 3 per cent higher than for the control and a 4 per cent increase in feed consumption. These differences were however not statistically significant ($P \geq .05$).

TABLE 7A: CHEMICAL COMPOSITION ('AS IS BASIS') OF COCOYAM MEALS USED IN EXPERIMENT II

Cocoyam	Chemical Composition							
	Dry Matter	Crude Protein	Crude Fibre	Ether Extractives	Ash	Cal-cium	Phos phorous	Oxalic acid
	%	%	%	%	%	%	%	%
Unprocessed	92.44	3.24	3.06	0.65	1.70	0.08	0.08	0.05
Peeled	92.28	3.19	1.42	0.30	1.59	0.07	0.07	0.05
Hot water treated	93.08	3.19	2.83	0.31	1.48	0.11	0.07	0.05
Peel	92.84	6.69	21.24	0.88	8.07	0.47	0.10	1.97

TABLE 7B: CHEMICAL COMPOSITION ('AS IS BASIS') OF THE EXPERIMENTAL DIETS IN EXPERIMENT II

Experimental Diets	Chemical Composition						
	Dry Matter	Crude Protein	Crude Fibre	Ether Extractives	Ash	Calcium	Phosphorous
	%	%	%	%	%	%	%
29%MZ+29%CY[1]	89.36	20.53	5.01	5.61	5.14	1.03	0.53
29%MZ+29%CY[2]	89.15	19.74	4.84	5.49	5.09	1.01	0.53
29%MZ+29%CY[3]	90.10	19.68	5.08	5.21	5.48	1.19	0.60
29%MZ+29%CY[1]+2%$CaCO_3$	89.74	20.48	4.60	5.07	7.53	1.57	0.50

CY[1] - Unprocessed Cocoyam
CY[2] - Peeled Cocoyam
CY[3] - Hot water treated Cocoyam

TABLE 8: MEAN WEIGHT GAIN (g) AND FEED CONVERSION EFFICIENCY (FCE) OF BROILER CHICKS FED 29 PER CENT UNPROCESSED OR PROCESSED COCOYAM MEAL DIET OR WITH TWO PER CENT CALCIUM CARBONATE SUPPLEMENTATION IN EXPERIMENT II

Experimental Diets	Weight gain (g)	FCE
29%MZ+29%CY[1]	606.66	1.74
29%MZ+29%CY[2]	583.33	1.80
29%MZ+29%CY[3]	586.66	1.74
29%MZ+29%CY[1]+2%$CaCO_3$	627.26	1.75

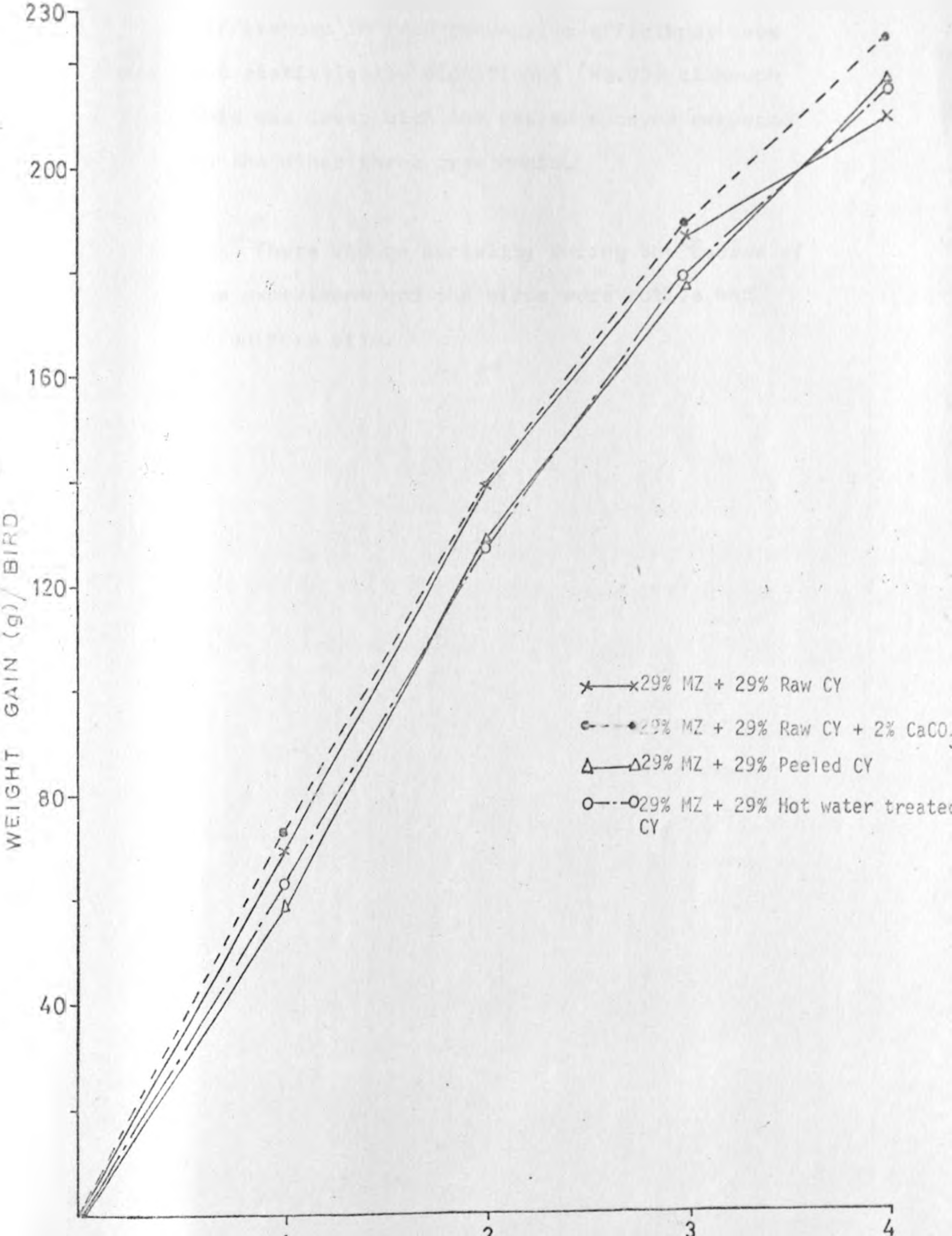
Superscripts as in Table 7B.

ANOVA

	Source	df	ss	mss	f
Weight gain					
	Total	11	6300.71		
	Treatment	3	3717.53	1239.18	3.84 NS[1]
	Residual	8	2583.18	322.90	
FCE					
	Total	11	0.0165		
	Treatment	3	0.0080	0.0027	2.25 NS[1]
	Residual	8	0.0085	0.0012	

NS[1] Treatment differences not significant ($P \geq .05$)

Fig. 2: Weight gain (g) per broiler chick fed starter diets in Experiment II.



Differences in feed conversion efficiency were not statistically significant ($P \geq .05$) although this was lower with the peeled cocoyam compared to the other three treatments.

There was no mortality during the course of the experiment and the birds were active and of uniform size.

4.3 Experiment III

The chemical compostion of the diets is shown in Table 9. The average weight gains and feed conversion efficiency over the whole experimental period is shown in Table 10. As in experiment 1 the cocoyam inclusion at both 29 and 58 per cent in the diet caused a marked reduction in weight gain and feed consumption. Weight gained by birds fed the 58 per cent cocoyam meal diet was again 31 per cent lower than that gained by birds on 58 per cent maize control diet and thus confirming the observations in Experiment 1. An inclusion of 4 per cent calcium carbonate in the diet with 58 per cent cocoyam meal gave a 6 per cent improvement on weight gain as compared to the unsupplemented 58 per cent cocoyam meal. There was a 23 per cent reduction in feed intake with the 58 per cent unsupplemented cocoyam meal diet compared to the control. On the other hand, there was no change in feed intake with 4 per cent calcium carbonate supplementation on the 58 per cent cocoyam meal diet. The weight gain and feed conversion efficiency differences between the control and the 58 per cent supplemented and unsupplemented cocoyam

TABLE 9: CHEMICAL COMPOSITION (AS IS BASIS) OF THE EXPERIMENTAL DIETS USED IN EXPERIMENT III

Experimental Diets	Chemical Composition						
	Dry Matter	Crude Protein	Crude Fibre	Ether Extractives	Ash	Calcium	Phosphorous
	%	%	%	%	%	%	%
58%MZ+0%CY+0%$CaCO_3$	88.24	20.92	5.24	4.34	5.65	0.93	0.59
0%MZ+58%CY+0%$CaCO_3$	91.19	20.48	4.92	2.58	6.21	1.04	0.55
0%MZ+58%CY+4%$CaCO_3$	91.92	20.48	4.83	2.35	10.57	2.46	0.52
29%MZ+29%CY+3%$CaCO_3$	90.38	20.04	5.02	3.21	7.71	2.15	0.55
29%MZ+29%CY+2%$CaCO_3$	90.46	20.22	5.01	3.28	6.73	1.58	0.57
29%MZ+29%CY+1%$CaCO_3$	90.32	19.87	4.90	2.62	7.08	1.24	0.59

TABLE 10: MEAN WEIGHT GAIN (g) AND FEED CONVERSION EFFICIENCY (FCE) OF BROILER CHICKS FED ONE, TWO THREE OR FOUR PER CENT CALCIUM CARBONATE SUPPLEMENTED DIETS FROM THREE DAYS TO FOUR WEEKS OF AGE IN EXPERIMENT III

Experimental Diets	Weight gain	FCE
58%MZ+0%CY+0%$CaCO_3$	535.86[a][1]	2.29[a]
0%MZ+58%CY+0%$CaCO_3$	366.91[b]	2.57[b]
0%MZ+58%CY+4%$CaCO_3$	387.38[b]	2.48[bc]
29%MZ+29%CY+3%$CaCO_3$	441.18[c]	2.35[ac]
29%MZ+29%CY+2%$CaCO_3$	470.61[c]	2.17[a]
29%MZ+29%CY+1%$CaCO_3$	479.19[c]	2.23[a]

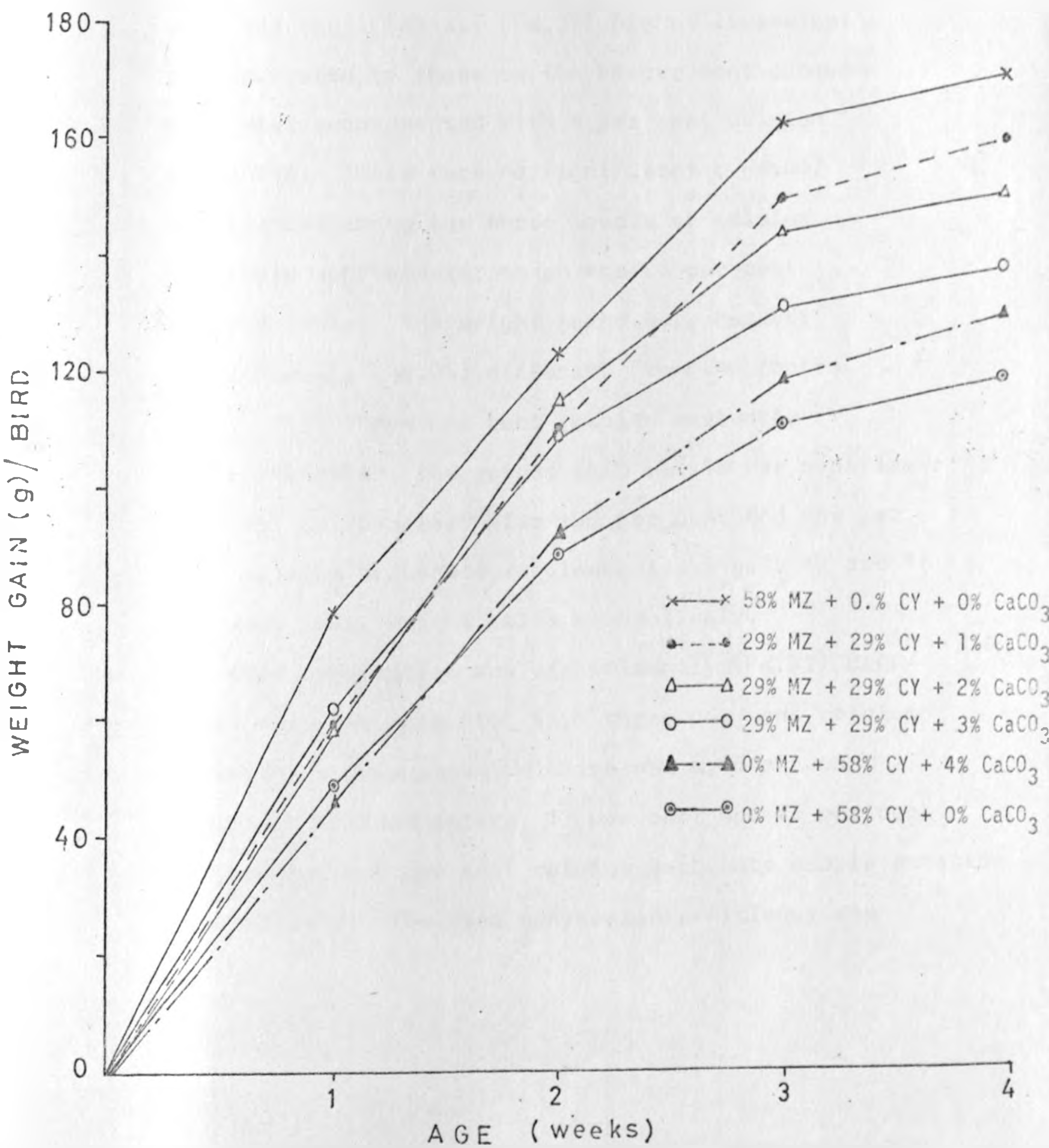
1 Means with similar superscrips are not significantly different

ANOVA

Source				
Weight gain				
Total	17	64597.40		
Treatment	5	58412.51	11682.50	22.31**[1]
Residual	12	6284.89	523.74	
FCE				
Total	17	0.4588		
Treatment	5	0.3375	0.0675	6.68**[1]
Residual	12	0.1213	0.0101	

1** Significant ($P \leq .01$) treatment differences

Fig. 3: Weight gain (g) per broiler chick fed starter diet in Experiment III.



meal diet were significant ($P \leq .01$). Two per cent calcium carbonate inclusion in the 29 per cent cocoyam meal diet improved weight gain compared to the unsupplemented 29 per cent cocoyam meal diet in Experiment II. In this experiment, chicks, on the two per cent calcium carbonate supplemented diet had significantly ($P \leq .01$) higher liveweight gain compared to those on the 58 per cent cocoyam meal diet supplemented with 4 per cent calcium carbonate. There were no significant ($P \geq .05$) differences among the three levels of calcium carbonate supplementation on the 29 per cent cocoyam diets. The weight gains were however significantly ($P \leq .05$) different from the control diet. With three per cent calcium carbonate supplementation, the weight gain was 18 per cent lower than for the control while two per cent and one per cent calcium carbonate supplementation gave 12 and 11 per cent lower weight gains respectively.

The feed consumption was significantly ($P \leq .01$) different from the control. With three per cent calcium carbonate supplementation there was a 15 per cent reduction in feed intake, 17 per cent and 13 per cent for two and one per cent calcium carbonate supplementation respectively. The feed conversion efficiency was significantly ($P \leq .01$) different between the control and the unsupplemented 58 per cent cocoyam meal diet. Four per cent calcium carbonate supplementation on the diet did not improve the feed conversion efficiency significantly ($P \geq .05$) compared to the unsupplemented diet. With the 29 per cent cocoyam meal diets, there were no significant ($P \geq .05$) differences in feed conversion efficiency between the control and the three levels of calcium carbonate supplementation. Within the three levels of calcium carbonate supplemenation there were no significant differences in the feed conversion efficiencies.

Two birds died during the last week of the experiment, one from the maize control diet and the other one from the unsupplemented 58 per cent cocoyam meal diet. There was normal feathering in all the birds but those from the supplemented and unsupplemented 58 per cent cocoyam meal diet were smaller and less active than all the others. There were signs of pasty diarrhoea with birds fed 58 per cent cocoyam meal diet during the fourth week and again pathological reports showed negative results.

4.4 Experiment IV

The basal diet used in this experiment had 90.27 per cent dry matter, 12.95 per cent crude protein, 2.90 per cent crude fibre, 2.97 per cent ether extractives and 3.40 per cent ash. The average Metabolisable Energy values obtained are shown in Table 11.

The body weight of the first batch ranged between 3.0-3.5 kg at the beginning of the experiment and 3.0-3.2 kg at the end of the experiment. The second batch of younger birds had a weight of 1.94-2.44 kg at the beginning and 2.01-2.40 kg at the end of the experiment. Generally, all the birds lost weight during the experimental period and feed consumption varied with individual birds. However, the second batch had a higher feed consumption inspite of their lower body weights.

There was a noticeable contamination of the excreta with feathers and separation of these from the excreta was necessary before drying. Roosters fed the cocoyam test diet voided considerably more bulkier excreta than roosters fed other feedstuffs. The gross energy values of the excreta were similar within the same test feedstuff (S.e = 0.01) and there

TABLE 11: MEAN METABOLISABLE ENERGY (Kcal/kg) OF FEEDSTUFFS USED AS ENERGY SOURCES IN THE BROILER STARTER DIETS.

	Metabolisable energy (DM basis)
	Kcal/kg
Test feed	
Basal	3257 (6)[1]
Basal + Cocoyam	2602 (3)
Basal + Maize	3468 (5)
Basal + Cassava	3054 (5)
Test feedstuffs	
Cocoyam	1948
Cassava	2852
Maize	3679

1 Value in parenthesis indicate the number of replicates used.

was no apparent relationship between feed intake and metabolisable energy values.

5. DISCUSSION

Birds fed the 58 per cent cocoyam meal diet gained 30 grams per bird less than the birds fed on the control diet during the first week. This trend continued to the fourth week when the birds fed 58 per cent cocoyam meal gained 70 grams compared to 200 grams gained by birds fed on the control diet. With the 29 per cent cocoyam diet the weight gain per bird during the first week was only 10 grams less than that gained by the birds on the control diet. There was a rising trend in weight gain to the third week after which the birds gained less than during the previous week. A similar decline in weight gain occured during the third week with the 58 per cent cocoyam meal diet. This could probably have been due to a cumulative effect of the anti-nutritional factors in the cocoyam meal.

The experimental diets were formulated to be isonitrogenous but since the metabolisable energy values were not available for cocoyam meal the value was estimated to be similar to that of cassava. This was later proved to be erroneous and the cocoyam based diets must have been very low in energy compared to the maize and cassava based diets, and this must have greatly contributed to the lower weight gains. Both the cocoyam based diets and the 58 per cent cassava diet had slightly higher (4.56 and 5.15% crude fibre for 29 and 58% cocoyam meal diet respectively) compared to the 4.11 per cent crude fibre for the control diet. On the other hand the maize control diet had 7.00 per cent ether extractives compared to about 6 per cent for the 58 per cent cocoyam meal diet and 5 per cent for the 29 per cent cocoyam meal diet. According to Petersen (1972) a high crude fibre value and low ether extractives value correspond to a low metabolisable energy value and thus the cocoyam meal based diets were obviously low in metabolisable energy in all the experiments.

Feed consumption during the first week was similar for the control and the two diets containing cocoyam meal inspite of the lower weight gains. This is a clear indication of the poor feed utilisation of the cocoyam meal based diets compared to the maize control diet. During the latter weeks, birds on the cocoyam meal diets consumed less than the birds on the control diet. Feed consumption during the fourth week was 154 and 142 grams per bird less than the control diet for the 58 per cent and 29 per cent cocoyam meal diets respectively. This depression in feed intake was very likely due to the irritating effect on the gastro-intestinal tract of the calcium oxalate crystals (raphides) found in the cocoyams. The per cent reduction in weight gain was considerably more than the per cent reduction in feed consumption and therefore the reduction in feed consumption did not fully account for the red- cution in weight gain. Feed utilisation as reflected by the feed conversion efficiency was very low with the cocoyam meal based diets and this was subsequently confirmed to be as a result of the low metabolisable energy values. Earlier work (Gerpacio et al 1975) showed similar results where weight gain and feed conversion efficiency was 11.78 grams per day and 3.87 respectively for birds fed a 50 per cent cocoyam meal diet as compared to 16.16 gramsper day and 2.09 for birds fed a 50 per cent yellow maize meal diet.

There are reports (Fasset, 1966; Kay 1973; Gohl, 1975; Onwueme, 1978 and Sunnel and Healey, 1979) on the presence of calcium oxalate crystals in cocoyam and that these exert an irritating effect when the coco- yam is fed raw. Kay (1973) reports a value of between 0.10-0.40 per cent on fresh weight basis and Gohl (1975) and Kay(1973) suggest boiling in water to overcome this effect. In adopting this procedure, no positive effect was seen, some of the irritants could have been washed away during the hot water treatment since the water exerted an irritating effect on the hands. In Moir's (1953) method of oxalic acid determination, the meal is treated with hydrochloric acid and allowed to stand in a hot water bath at 70°C for one hour. Water alone therefore may not have been as effective in extracting any reasonable amount of oxalic acid and perhaps the use of a mild organic or inorganic acid may have proved more effective. On analysis, there were no differences between the amount of oxalic acid in hot water treated and the untreated cocoyam meal. Perhaps a more sensitive method with the ability to detect lower levels would have shown some differences. Soaking of the cocoyam slices in hot water could not have been as effective as boiling.

At the same time water soluble nutrients like simple sugars and some of the amino acids were also obviously expected to have been washed out. The presence of other nutrients in the cooking water was evidenced by the slimy feel in the water. On analysis, the water treated cocoyam was found to have three per cent lower crude protein, 50 per cent lower ether extractives and 13 per cent lower ash as compared to the unprocessed cocoyam meal. Consequently, the diet had a 4 per cent lower crude protein and 7 per cent lower ether extractives compared to the unprocessed cocoyam based diet. There could also have been an amino acid imbalance in the hot water treated cocoyam meal diet as a result of the extraction of some of the amino acids.

The performance between the hot water treated cocoyam meal diet and the control was not significantly ($P \geq .05$) different but there was a three per cent reduction in both weight gain and feed intake compared to the control. A higher feed consumption was expected with the complete extraction of the irritating effect if this was fully responsible for the reduced feed intake. On the contrary there was a three per cent reduction in weight gain. Feed utilisation was however better with the hot water treated cocoyam meal diet considering that it had a lower crude protein content than the control diet.

The oxalates are known to have a binding effect on divalent ions and on protein (Talapatra et al 1948; Negi, 1971; Lynn and Butcher, 1972, Mugerwa and Stafford, 1976). Experiments with sheep (Lynn et al 1967) indicated that the oxalate effect is best overcome with dicalcium phosphate followed by calcium carbonate. This was followed in an attempt to counteract the binding effect of the oxalates by increasing the available calcium ions for metabolism. The ash content of the supplemented diet was 32 per cent higher than in the control diet, while crude protein values were essentially similar. The crude fibre and ether extractives were higher in the control than in the

calcium carbonate supplemented diet and this could have contibuted to differences in metabolisable energy values between the two diets.
The three per cent improvement on weight gain and the four per cent increase in feed intake were significant ($P \leq .05$). The improvement was however an indication that calcium was in great demand to compensate for the bound calcium with the oxalates. Perhaps the 0.08 per cent calcium in cocoyam as compared to 0.02 per cent in maize is found in a bound unavailable form.

The 58 per cent cocoyam meal diet supplemented with 4 per cent calcium carbonate was designed to give a ratio of calcium supplementation to level of cocoyam meal in the diet similar to the 29 per cent cocoyam diet supplemented with two per cent calcium carbonate. The 58 per cent cocoyam meal diet had a lower perfomance compared to the 29 per cent cocoyam meal diet supplemented with 4 per cent and 2 per cent calcium carbonate respectively. This confirmed the presence of higher anti-nutritional effects not counteracted by calcium supplementation. This could be a higher level of oxalates in the 58 per cent cocoyam meal diet causing a more intense irritation and hence a reduction in feed intake. The 58 per cent diet supplemented with 4 per cent calcium carbonate had a 6 per cent improvement on weight gain as compared to the unsupplemented 58 per cent cocoyam meal diet. There was no significant ($P \geq .05$) difference in feed intake between the two diets and the improvement on weight gain is therefore not a result of increased feed intake but could have been a result of increased calcium ions available for metabolism. The 58 per cent cocoyam meal diet gave a significantly ($P \leq .05$) lower feed intake and weight gain as compared to the control. Again the reduction in weight gain did not correspond to the reduction in feed intake, an indication of poor feed utilisation. The 29 per cent level of cocoyam inclusion with the three levels of calcium carbonate supplementation gave significantly ($P \leq .05$) lower weight gains as compared to the control but there were no significant ($P \geq .05$) differences in feed conversion efficiencies. The lower weight gains could be partly explained by the reduction in feed intake while the similar feed conversion efficiency values indicate improved utilisation of the feed due to the additional calcium ions. There were no significant ($P \geq .05$) performance differences among the three levels of calcium carbonate supplementation on the 29 per cent cocoyam meal diets. The oxalate levels in the three treatments must have been similar and perhaps they caused similar adverse anti-nutritional effects and hence a similar reduction in feed intake. There was however a slight improvement on performance with one per cent calcium carbonate supplementation compared to the two and three per cent level of calcium carbonate supplementation. At the higher levels of calcium carbonate supplementation the recommended (NRC, 1971) 2:1 ratio for calcium to phosphorous was probably disturbed and hence the depressed performance. Earlier work (Lynn et al, 1967) with sheep, showed dicalcium phosphate to give the best counteracting effect on the oxalates arising from the solubility compared to calcium carbonate and probably it provided phosphate ions to maintain the ratio. Although this comparison is made, the mechanism may be different with monogatrics.

When formulating the diets, no reported metabolisable energy values were available for cocoyam and the diets were therefore formulated with the estimated values. These estimates finally proved to be grossly in error since the determined metabolisable energy value for cocoyam was found to be very low as compared to that of maize or cassava. The determinations were based on the rapid method developed by Farrel (1978) and the Metabolisable Energy value of 3247 Kcal/kg for maize was comparable to the reported value of 3430 Kcal/kg (NRC, 1971) (as is basis). Inspite of the efforts made to keep feed wastage to a minimum during feeding, there could have been some unavoidable wastage which may have contributed to the low Metabolisable Energy values. Most of the birds consumed more than 40 grams of feed and there was no apparent relationship between feed intake and Metabolisable Energy values to that reported by Sibbald (1975). The report showed that, as feed intake increased the apparent Metabolisable Energy value increased and because of this, a high feed intake was later recommended (Sibbald 1979) to minimise the errors. No noticeable feed reduction was observed when the cocoyam test diet was fed but the birds voided considerably more excreta than the others. This indicated a rapid passage of the feed through the gastro-intestinal tract probably caused by the irritating effect of the calcium oxalate crystals. The digestibility of the cocoyams was also affected probably by the nature of carbohydrates or by other unknown factors.

Additionally the method involved gross excreta collection and this could have contributed to the low Metabolisable Energy values since different feedstuffs may have different passage rates as reported for other feedstuffs like rapeseed meal (Chami et al 1980). Contamination of the excreta was also apparent and this could have been another factor contributing to the low energy values inspite of the efforts made to remove the feathers.

The low Metabolisable Energy values confirms the poor performance of chicks in the treatments with the cocoyam meal diets. Other factors like the dusty nature of the feed arising from the fine particle size and perhaps the possible presence of anti-trypsin inhibitors reported by Sumathi and Pitta-biraman, (1975) may have also contributed to the depressed growth.

6. CONCLUSIONS

In comparing cocoyam meal in broiler starter diets with maize or cassava, there was observed poor performance with the cocoyam based diets and cocoyam ranked third compared to the other two energy supplements. The higher level of oxalates in the peel compared to the inner starchy portion did not appear to have a more adverse effect on performance and therefore peeling did not improve the utilisation of cocoyam meal. Hot water extraction of oxalates was not very effective and if it was, then the effect was counteracted by the loss from drainage of other nutrients together with the oxalates. Both peeling and hot water treatment are tedious methods and since they were unable to improve performance in comparison with raw cocoyam, they cannot be recommended at this stage.

Calcium carbonate supplementation led to a positive improvement in performance at both levels of cocoyam meal inclusion in the diet. The improvement was better at the 29 per cent level of cocoyam meal in the diet but this was still not near the performance with the maize control diet. It was also shown that supplementing the 29 per cent cocoyam diet with more than one per cent calcium carbonate had no beneficial effect. Raw cocoyam at a high level even when supplemented with calcium carbonate did not seem acceptable.

The Metabolisable Energy Value of cocoyam was found to be 1799 Kcal/kg compared to 2561 Kcal/kg for cassava and 3247 Kcal/kg for maize on 'as is basis', whether this is due to the high oxalate content causing rapid passage and hence low digestibility or the quality of the raw starch needs to be further investigated.

7. SCOPE FOR FURTHER STUDIES

Hardly any reports are available on the use of cocoyam in broiler diets. More investigations are therefore required for any reasonable recommendation to be made on the feasibility of using cocoyams as a substitute for maize in broiler diets.

There is need to improve on the cocoyam carbohydrate availability by cooking or by chemical treatment. It is also necessary to study the toxic levels of the oxalates and determine methods of extraction. The binding effects on calcium and the optimal level of calcium supplementation should be further investigated.

Lower levels of cocoyam meal in the diets should be looked into and the diets should be fed in the finishing stage to find the effect of age on the level of cocoyam in the diet.

There are different varieties of cocoyams grown in Kenya and these should be investigated to establish yield differences, environmental requirements, chemical composition and also the stage of maturity on the performance of the birds.

The feed energy contributes greatly to the performance of birds and hence the Metabolisable Energy methodology needs to be refined further. Different excreta collection periods should be studied to find out their effect on Metabolisable Energy and the effect of the previous assay feedstuff on the Metabolisable Energy value of the cocoyams.

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APPENDIX

TABLE AI: PROXIMATE ANALYSIS OF FEEDSTUFFS IN THE EXPERIMENTAL DIETS

Feedstuff	Proximate Composition (%) 'As is basis'						
	DM	CP	CF	EE	ASH	Ca	P
Raw)	92.33	3.22	2.95	0.65	1.58	0.08	0.08
Cocoyam)	92.35	3.26	3.17	0.69	1.72	0.08	0.08
Mean	92.34	3.24	3.06	0.67	1.65	0.08	0.08
Peeled)	92.19	3.24	1.48	0.30	1.57	0.07	0.08
Cocoyam)	92.37	3.15	1.36	0.30	1.61	0.07	0.07
Mean	92.28	3.19	1.42	0.30	1.59	0.07	0.07
Hot water treated) Cocoyam)	93.12	3.24	2.66	0.29	1.49	0.11	0.07
	93.04	3.15	3.00	0.33	1.47	0.11	0.07
Mean	93.08	3.19	2.83	0.31	1.48	0.11	0.07
Cassava	90.17	1.93	1.96	0.30	2.96	0.20	0.10
	89.46	2.01	1.89	0.39	3.07	0.26	0.10
Mean	89.81	1.97	1.92	0.34	3.01	0.23	0.10
Maize	88.41	8.56	3.51	2.88	1.02		
	88.10	8.56	3.26	3.04	1.04		
Mean	88.25	8.56	3.38	2.96	1.03		
Wheat bran	86.76	15.67	12.09	3.48	10.46		
	86.49	15.67	12.74	3.52	10.51		
Mean	86.62	15.67	12.41	3.50	10.48		
Sunflower	91.72	37.38	15.60	2.20	6.14		
Meal	92.08	38.43	13.26	2.06	6.44		
Mean	91.90	37.90	14.43	2.13	6.29		
Soybean	89.98	43.25	6.72	1.01	6.16		
Meal	89.96	43.07	6.95	1.07	6.19		
Mean	89.97	43.16	6.83	1.04	6.17		
Fish meal	90.25	60.30	0.64	9.71	16.27		
	89.98	60.23	0.95	9.42	16.48		
Mean	90.11	60.26	0.80	9.56	16.37		
Meat and	93.30	49.29	3.56	10.20	24.02		
bone meal	93.56	49.11	3.00	10.36	24.14		
Mean	93.43	49.20	3.28	10.28	24.08		

TABLE A2: PROXIMATE ANALYSIS OF STARTER DIETS FED TO CHICKS IN EXPERIMENT I

Diet	Proximate Composition (%) 'As is basis'						
	DM	CP	CF	EE	ASH	Ca	P
58%MZ+0%CS +0%CY	88.50	19.50	4.13	6.99	4.57	0.80	0.50
	88.57	19.74	4.10	7.00	4.70	0.95	0.52
Mean	88.53	19.62	4.11	6.99	4.63	0.87	0.51
29%MZ+29%	88.90	19.60	4.30	5.94	4.67	0.90	0.47
CS+0%CY	88.97	19.56	4.10	5.80	4.70	0.95	0.53
Mean	88.93	19.58	4.20	5.87	4.68	0.92	0.50
0%MZ+58%CS	88.90	19.56	4.99	5.82	5.24	1.20	0.57
+0%CY	88.92	19.48	4.99	5.84	4.88	0.95	0.53
Mean	88.91	19.52	4.99	5.83	5.06	1.07	0.55
29%MZ+0%CS	88.97	19.59	4.48	5.12	5.05	0.90	0.51
+29%CY	88.83	19.77	4.64	5.45	5.10	0.95	0.56
Mean	88.90	19.68	4.56	5.20	5.07	0.92	0.53
0%MZ+0%CS	90.59	19.62	5.16	5.93	5.12	0.90	0.47
+58%CY	90.56	19.78	5.14	5.84	5.13	0.95	0.56
Mean	90.57	19.70	5.15	5.88	5.12	0.92	0.51

TABLE A3: PROXIMATE ANALYSIS OF STARTER DIETS FED TO CHICKS IN EXPERIMENT II

Diet	Proximate Composition (%) 'As is basis'						
	DM	CP	CF	EE	ASH	Ca	P
29%MZ+29%CY[1]	89.35	20.55	4.80	5.68	5.12	0.95	0.56
	89.36	20.57	5.22	5.54	5.16	1.12	0.51
Mean	89.35	20.56	5.01	5.61	5.14	1.03	0.53
29%MZ+29%CY[2]	89.86	20.06	4.87	5.45	5.16	1.01	0.53
	89.77	19.42	4.81	5.53	5.02	1.01	0.53
Mean	89.81	19.74	4.84	5.49	5.09	1.01	0.53
29%MZ+29%CY[3]	90.02	19.20	5.09	5.15	5.42	1.20	0.62
	90.18	19.56	5.07	5.27	5.55	1.18	0.59
Mean	90.10	19.68	5.08	5.21	5.48	1.19	0.60
29%MZ+29%CY[4]	89.70	20.55	4.68	5.16	7.63	1.62	0.52
	89.79	20.41	4.76	4.99	7.43	1.53	0.49
Mean	89.74	20.48	4.60	5.07	7.53	1.57	0.50

1 Raw Cocoyam
2 Peeled Cocoyam
3 Hot water treated Cocoyam
4 Raw Cocoyam + 2% Calcium Carbonate.

TABLE A4: PROXIMATE ANALYSIS OF STARTER DIETS FED TO CHICKS IN EXPERIMENT III

Diet	Proximate Composition (%) 'As is basis'						
	DM	CP	CF	EE	ASH	Ca	P
58%MZ+0%CY	88.23	21.01	4.12	11.77	5.62	0.89	0.60
+0%$CaCO_3$	88.24	20.84	4.56	11.76	5.69	0.97	0.59
Mean	88.23	20.92	4.34	11.76	5.65	0.93	0.59
0%MZ+58%CY	91.20	20.66	2.59	8.80	6.05	1.10	0.57
+0%$CaCO_3$	91.18	20.31	2.58	8.82	6.37	0.98	0.54
Mean	91.19	20.48	2.58	8.81	6.21	1.04	0.55
0%MZ+58%CY	91.94	20.31	2.41	8.06	10.53	2.51	0.52
+4%$CaCO_3$	91.89	20.66	2.30	8.11	10.61	2.45	0.52
Mean	91.91	20.48	2.35	8.08	10.57	2.46	0.52
29%MZ+29%CY	90.36	19.96	3.28	9.64	7.84	2.15	0.57
+3%$CaCO_3$	90.39	20.13	3.14	9.61	7.58	2.15	0.54
Mean	90.37	20.04	3.21	9.62	7.71	2 15	0.55
29%MZ+29%CY	90.28	20.31	3.25	9.72	7.21	1.56	0.57
+2%$CaCO_3$	90.63	20.13	3.32	9.37	7.01	1.60	0.57
Mean	90.45	20.22	3.28	9.54	7.11	1.58	0.57
29%MZ+29%CY	90.24	19.96	2.65	9.76	6.96	1.20	0.59
+1%$CaCO_3$	90.40	19.78	2.60	9.60	6.45	1.29	0.60
Mean	90.32	19.87	2.62	9.68	6.70	1.24	0.59

TABLE A5: PROXIMATE ANALYSIS OF BASAL DIET FED TO COCKERELS IN EXPERIMENT IV

	Proximate Composition (%) 'As is basis'				
	Dry Matter	Crude Protein	Crude Fibre	Ether Extract-ives	Ash
	90.26	13.13	3.15	9.74	3.27
	90.28	12.78	2.64	9.72	3.54
Mean	90.27	12.95	2.90	9.73	3.40

TABLE A6: BODY WEIGHT GAIN (g) PER BROILER CHICK FED STARTER DIET IN EXPERIMENT I

Treatment	Age in weeks			
	1	2	3	4
58%MZ+0%CS+0%CY	75.00	117.50	154.50	213.00
	86.00	122.00	157.00	165.00
	75.00	105.50	164.50	246.00
Mean	78.67	115.00	158.67	208.00
29%MZ+29%CS+0%CY	66.00	124.00	184.50	165.00
	76.00	107.00	151.50	203.00
	59.00	98.00	135.00	188.86
Mean	67.00	110.00	157.00	185.63
0%MZ+58%CS+0%CY	62.00	101.94	136.11	191.12
	50.00	98.50	132.50	149.00
	64.00	108.50	167.50	180.00
Mean	58.83	102.98	145.37	173.37
29%MZ+0%CS+29%CY	69.00	103.50	127.50	90.00
	72.50	104.00	138.50	108.89
	67.50	99.00	108.50	75.00
Mean	69.67	102.17	124.83	91.30
0%MZ+0%CS+58%CY	47.00	67.00	51.00	68.89
	52.00	77.00	86.00	70.00
	47.00	81.50	61.50	75.00
Mean	48.67	75.17	66.17	71.30

TABLE A7: BODY WEIGHT GAIN (g) PER BROILER CHICK FED STARTER DIET IN EXPERIMENT II

Treatment	Age in weeks			
	1	2	3	4
29%MZ+29%CY[1]	70.62	136.87	190.00	215.00
	64.37	136.62	188.75	211.25
	70.62	144.37	185.00	207.50
Mean	68.54	138.95	187.92	211.25
29%MZ+29%CY[2]	44.37	127.50	172.06	216.07
	65.00	125.62	179.37	215.00
	65.00	133.75	163.75	222.50
Mean	58.12	128.96	178.39	217.86
29%MZ+29%CY[3]	61.25	126.25	175.00	215.00
	61.25	125.00	180.00	223.75
	65.62	131.25	184.37	211.25
Mean	62.71	127.50	179.79	216.67
29%MZ+29%CY[4]	72.50	158.75	190.00	235.54
	71.87	126.87	192.50	216.25
	71.87	130.62	190.00	225.00
Mean	72.08	138.75	190.83	225.60

Superscripts as in Appendix Table A3.

TABLE A8: BODY WEIGHT GAIN (g) PER BROILER CHICK FED STARTER DIET IN EXPERIMENT III

Treatment	Age in weeks			
	1	2	3	4
58%MZ+0%CY+0%$CaCO_3$	75.00	127.14	167.14	164.29
	73.57	138.57	171.43	178.29
	87.14	103.57	151.43	170.00
Mean	78.57	123.10	163.33	170.86
0%MZ+58%CY+0%$CaCO_3$	49.29	84.29	108.57	117.14
	53.57	97.14	111.43	118.57
	43.57	81.43	114.29	121.43
Mean	48.81	87.62	111.43	119.05
0%MZ+58%CY+4%$CaCO_3$	52.14	98.57	117.14	120.00
	40.00	90.71	120.71	135.00
	47.14	86.43	118.57	135.71
Mean	46.43	91.90	118.81	130.24
29%MZ+29%CY+3%$CaCO_3$	63.57	110.00	136.14	145.71
	62.86	103.57	121.43	137.14
	61.43	115.00	134.29	144.29
Mean	62.62	109.52	130.95	138.09
29%MZ+29%CY+2%$CaCO_3$	57.86	128.57	157.14	164.29
	56.43	110.00	130.00	135.71
	60.71	112.86	144.29	154.29
Mean	58.33	117.14	143.71	151.43
29%MZ+29%CY+1%$CaCO_3$	60.71	94.29	160.00	162.86
	62.86	125.00	151.43	165.71
	55.00	111.43	137.14	151.43
Mean	59.43	110.24	149.52	160.00

TABLE A9: FEED CUNSUMPTION (g) PER BROILER CHICK FED STARTER DIET IN EXPERIMENT I

Treatment	Age in weeks			
	1	2	3	4
58%MZ+0%CS+0%CY	117.00	205.00	294.00	520.00
	127.00	235.00	340.00	427.00
	117.00	195.00	310.00	444.44
Mean	120.22	211.67	314.66	463.81
29%MZ+29%CS+0%CY	122.00	215.00	387.00	535.00
	117.00	200.00	315.00	445.00
	102.00	185.00	240.00	400.00
Mean	113.67	200.00	314.00	460.00
0%MZ+58%CS+0%CY	112.00	222.22	338.89	488.39
	107.00	205.00	330.00	445.00
	117.00	200.00	340.00	495.00
Mean	112.00	209.07	336.30	476.30
29%MZ+0%CS+29%CY	127.00	210.00	280.00	305.00
	112.00	200.00	311.11	390.00
	117.00	200.00	340.00	280.00
Mean	118.67	203.33	310.67	325.00
0%MZ+0%CS+58%CY	122.00	200.00	245.00	275.00
	117.00	185.00	260.00	290.00
	127.00	200.00	295.00	335.00
Mean	122.00	195.00	266.67	300.00

TABLE A10: FEED CONSUMPTION (g) PER BROILER CHICK FED STARTER DIET IN EXPERIMENT II

Treatment	Age in weeks			
	1	2	3	4
29%MZ+29%CY[1]	120.62	193.75	360.62	360.00
	121.25	233.12	354.37	359.37
	120.00	225.00	356.25	367.50
Mean	120.62	217.29	357.08	362.29
29%MZ+29%CY[2]	112.50	210.00	352.14	362.50
	110.62	208.75	355.00	362.50
	129.37	220.62	362.50	371.25
Mean	117.50	213.12	356.55	365.42
29%MZ+29%CY[3]	108.75	209.37	333.75	351.87
	126.25	224.37	347.50	357.50
	112.50	193.75	346.87	353.12
Mean	115.83	209.16	342.71	354.16
29%MZ+29%CY[4]	131.25	245.62	386.87	382.86
	128.12	210.00	362.50	363.75
	128.75	221.25	359.37	377.50
Mean	129.37	225.62	369.58	374.70

1,2,3,4 as in a Appendix Table A3.

TABLE A11: FEED CONSUMPTION (g) PER BROILER CHICK FED STARTER DIET IN EXPERIMENT III

Treatment	Age in weeks			
	1	2	3	4
58%MZ+0%CY+0%$CaCO_3$	107.86	231.43	416.43	470.00
	126.43	245.71	432.14	467.14
	132.14	190.71	405.00	460.00
Mean	122.14	222.62	417.86	465.71
0%MZ+58%CY+0%$CaCO_3$	110.71	182.14	238.57	302.14
	110.71	207.86	290.00	415.71
	100.71	185.00	282.14	405.00
Mean	107.38	191.57	270.24	374.29
0%MZ+58%CY+4%$CaCO_3$	105.00	206.43	292.86	384.29
	94.29	192.86	274.29	362.14
	103.57	185.71	289.29	387.14
	100.95	209.52	316.86	406.67
29%MZ+29%CY+3%$CaCO_3$	116.43	235.71	331.43	417.86
	117.14	190.00	300.00	400.00
	114.29	202.86	319.29	402.14
Mean	115.95	209.52	316.86	406.67
29%MZ+29%CY+2%$CaCO_3$	101.43	221.43	349.29	426.43
	100.71	192.14	289.29	357.14
	99.29	217.86	319.29	396.43
Mean	100.48	210.43	319.29	393.33
29%MZ+29%CY+1%$CaCO_3$	129.29	191.43	333.57	418.57
	114.29	236.43	338.57	415.71
	101.43	211.43	305.00	414.29
Mean	115.00	213.10	325.71	416.19

TABLE A12: FEED CONVERSION EFFICIENCY OF BROILER CHICKS FED STARTER DIET IN EXPERIMENT I

Treatment	Age in weeks			
	1	2	3	4
58%MZ+0%CS+0%CY	1.56	1.74	1.90	2.44
	1.48	1.93	2.17	2.59
	1.56	1.85	1.88	1.81
Mean	1.53	1.84	1.98	2.28
29%MZ+29%CS+0%CY	1.85	1.73	2.10	3.24
	1.54	1.86	2.08	2.19
	1.73	1.89	1.78	2.12
Mean	1.70	1.82	1.99	2.52
0%MZ+58%CS+0%CY	1.79	2.18	2.49	2.56
	2.14	2.08	2.49	2.99
	1.83	1.84	2.03	2.75
Mean	1.92	2.03	2.34	2.77
29%MZ+0%CS+29CY	1.84	2.03	2.20	3.39
	1.54	1.92	2.25	3.58
	1.73	2.02	3.13	3.73
Mean	1.70	1.99	2.53	3.57
0%MZ+0%CS+58%CY	2.60	2.98	4.80	3.93
	2.25	2.40	3.02	4.14
	2.70	2.45	4.80	4.47
Mean	2.52	2.59	4.21	4.18

TABLE A13: FEED CONVERSION EFFICIENCY OF BROILER CHICKS FED STARTER DIET IN EXPERIMENT II

Treatment	Age in weeks			
	1	2	3	4
29%MZ+29%CY[1]	1.87	1.43	1.91	1.70
	1.72	1.61	1.92	1.73
	1.70	1.64	1.87	1.71
Mean	1.76	1.56	1.90	1.71
29%MZ+29%CY[2]	2.53	1.65	2.05	1.68
	1.70	1.66	1.98	1.68
	2.00	1.65	1.97	1.67
Mean	2.08	1.65	2.00	1.68
29%MZ+29%CY[3]	1.78	1.66	1.91	1.64
	2.06	1.79	1.93	1.60
	1.71	1.48	1.86	1.67
Mean	1.85	1.64	1.91	1.64
29%MZ+29%CY[4]	1.81	1.55	2.04	1.62
	1.78	1.65	1.88	1.68
	1.79	1.69	1.89	1.68
Mean	1.79	1.63	1.94	1.66

1,2,3,4 as in Appendix Table A3.

TABLE A14: FEED CONVERSION EFFICIENCY OF BROILER CHICKS FED STARTER DIET IN EXPERIMENT III

Treatment	Age in weeks			
	1	2	3	4
58%MZ+0%CY+0%$CaCO_3$	1.43	1.82	2.49	4.86
	1.72	1.77	2.52	2.62
	1.52	1.84	3.04	2.70
Mean	1.55	1.81	2.85	2.72
0%MZ+58%CY+0%$CaCO_3$	2.25	2.16	2.78	2.58
	2.07	2.14	3.73	3.51
	2.31	2.27	3.54	3.33
Mean	2.20	2.19	3.36	3.14
0%MZ+58%CY+4%$CaCO_3$	2.01	2.09	3.28	3.20
	2.36	2.13	3.00	2.68
	2.20	2.15	3.26	2.85
Mean	2.17	2.12	3.18	2.90
29%MZ+29%CY+3%$CaCO_3$	1.83	2.14	3.05	2.87
	1.86	1.83	3.29	2.92
	1.86	1.76	2.99	2.79
Mean	1.85	1.91	3.10	2.94
29%MZ+29%CY+2%$CaCO_3$	1.75	1.72	2.71	2.59
	1.78	1.75	2.75	2.63
	1.63	1.93	2.74	2.57
Mean	1.72	1.80	2.74	2.60
29%MZ+29%CY+1%$CaCO_3$	2.13	2.03	2.62	2.57
	1.82	1.89	2.74	2.51
	1.84	1.90	3.02	2.74
Mean	1.93	1.93	2.78	2.60

TABLE A15: GROSS ENERGY (GE) OF FEED AND EXCRETA, FEED INTAKE, EXCRETA OUTPUT AND APPARENT METABOLISABLE ENERGY (ME) OF THE ENERGY FEEDSTUFFS.

Test Feed	Values on Dry Matter basis					
	Feed GE (Kcal /kg	Feed Intake(g)	Excreta GE (Kcal/kg)	Excreta Output (g)	Test Feed ME (Kcal /kg)	Feed stuff ME (K cal/kg)
BASAL	3972	85.75	3729	8.00	3625	
		63.18	3629	11.80	3294	
		49.65	3552	11.99	3114	
		54.61	3850	10.92	3202	
		36.11	3166	11.27	3059	
		63.18	3259		3257	
Mean			3531		3259	
BASAL + COCOYAM	3782	71.98	3765	25.88	2429	1602
		58.48	3922	16.61	2668	2080
		22.49	3710	18.84	-	-
		58.48	3947	44.08	-	-
		22.99	3394	28.97	2709	2162
Mean			3748		2602	1948[1]
BASAL + CASSAVA	3822	39.76	3718	7.54	3117	2978
		41.15	3430	8.50	3080	2904
		35.83	3623	7.37	3077	2898
		36.27	3360	8.48	3037	2818
		30.96	3340	8.80	2958	2660
Mean			3494		3054	2852
BASAL + MAIZE	4305	51.73	3662	11.76	3472	3688
		52.91	3524	12.91	3445	3634
		47.06	3671	10.81	3462	3668
		48.59	3754	9.22	3593	3930
		35.34	3420	10.65	3366	3476
Mean			3606		3468	3679

1 Mean of three values.

TABLE A16: INITIAL AND FINAL BODYWEIGHT (Kg) OF COCKERELS USED IN METABOLISABLE ENERGY DETERMINATION

Batch I	Bodyweight	
Cockerel	Initial	Final
1	3.2	3.0
2	3.5	3.1
3	3.3	3.2
4	3.1	3.0
5	3.0	3.0
6	3.0	3.0
Batch II		
1	2.33	2.40
2	2.09	2.20
3	1.94	2.01
4	2.44	2.35
5	2.02	2.20
6	2.14	2.30
7	2.36	2.35
8	2.40	2.40