EFFECTS OF FERMENTED WHOLE CASSAVA MEAL ON THE PERFORMANCE OF BROILERS.

By

Paul A. Onjoro

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Declaration

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

Signed ____________ Date 13-11-95

This thesis has been submitted with our approval as university supervisors.

1. Signed ____________ date 14/11/95.

   Dr. J. M. Ottaro

   Animal Science Department

2. Signed mBhattacharjee date 14.11.95

   Dr. M. Bhattarcharjee

   Department of Chemistry/Biochemistry

3. Signed ____________ date 14th Nov. 1995

   Dr. Z. Ali

   (Chairman, Animal Science Department)

DEPARTMENT OF ANIMAL SCIENCE
DATE..........................
EGERTON UNIVERSITY

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By Paul A. Onjoro

1995

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Paul Athans Onjoro
Egerton University,
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Dedication

I affectionately dedicate this thesis to my brother John N. Onjoro who paid my school fees and strictly followed my academic progress. To my wife Rosebella who tolerated the hard times when I was a student.

P.A.O

ABSTRACT

Initially an experiment was conducted to establish the effect of fermentation on the nutrient composition of whole cassava meal. In this experiment chopped whole cassava was fermented using different moisture conditions (aerobic, semi-aerobic and anaerobic) for varying time intervals (day 1, 2, 3, 4, 5, 6). The dried Fermented Whole Cassava Meal (FWCM) samples were analyzed for proximate, cyanide (CN) and soluble carbohydrate composition. The moisture condition and the duration of fermentation both affected the nutrient composition of the resulting cassava product. Anaerobic fermentation was the most effective in reducing cyanide content, while at the same time increasing the level of Crude (CP) ($P < 0.05$). By the fourth day cyanide and protein contents were 10, 28, 0 mg/kg; and 4.78, 4.01, 5.70 percent for aerobic, semi-aerobic and anaerobic fermentations, respectively. Aerobic and semi-aerobic fermentations did not fully eliminate the cyanide even by the sixth day. Crude protein (CP), CN, and glucose content for anaerobic fermentation were: 3.94%, 145 mg/Kg, and 5.62 g/Kg; 5.78%, 5 mg/Kg, 7.5 g/Kg; and 5.01%, 0 mg/Kg, and 9.12 g/Kg for fresh, three day fermentation and six day fermentation, respectively. Three day fermentation period was adequate to reduce the cyanide below the toxic level (10 mg/kg) in broiler diets. Anaerobic fermentation of cassava beyond three days results in excessive breakdown and leakage of nutrients rendering the product less nutritious.

A second experiment was set to ascertain maximum substitution levels of maize grain with FWCM in broiler diets. In this experiment 198 one day old broiler chicks were fed on six different diets over a period of eight weeks. In the diets used, maize was replaced with FWCM at the following levels: 0, 20, 40, 60, 80, and 100 percent. Fish meal and un-decorticated sunflower cake were used as the protein supplements at various levels to compound isonitrogenous starter and finisher diets. Weekly weight gains and feed intakes were recorded and Feed Conversion Efficiency (FCE) was calculated. Performance of broilers from the successive FWCM diets for the starter and finisher phases were: weight gains (g), 607, 488, 597, 674, 621, 582 ; and 1498, 1552, 1377, 1447, 1428, 1271 ; feed intake (g), 1028, 1065, 1112, 1097, 1039, 1113 ; and 2933, 2906, 2887, 2930, 2881, 2991; and FCE, 0.59, 0.46, 0.53, 0.61, 0.60, 0.53; and 0.51, 0.53, 0.48, 0.49, 0.50, 0.42, respectively. Final body weights and feed intakes were not statistically different ($P < 0.05$) although overall FCE for the 100% FWCM substitution level was lower ($P < 0.05$) than the others. Final body weights were, 2.14, 2.07, 1.99, 2.15, 2.09, and 1.89 Kg for the successive FWCM levels. Thus birds fed on FWCM diets consumed more feed than those fed on maize control. Among the substitution levels examined, broiler performance was best when maize was substituted by FWCM at the level of

60%. Diets where maize was replaced wholly by FWCM had lower weight gains, especially during the finishing period. However, total substitution did not adversely affect broiler health.

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CHAPTER ONE

1.0.0: INTRODUCTION

Cassava (Manihort esculanta Crantz) is a staple food and a valuable cash crop in many tropical countries. In Kenya, it is mainly grown in the Western and Coastal provinces (Acland, 1973). Cassava is fairly resistant to drought, and is capable of producing relatively high yields in soils of low fertility (Ravindran et al., 1983). Under such conditions, yields of cereals like maize would be low with high risks of crop failure. Most of the cassava produced in Kenya is used as a direct human food, although some farmers in certain parts of the country feed surplus cassava to pigs. Many Asian, European and some African countries use cassava for livestock feeding. This is however, not a common practice in Kenya. Since cassava is in most cases cheaper than maize in Kenya, the surplus could be processed and used for livestock feeding.

Unlike cassava pulp and cassava peel, the whole cassava root (unpeeled cassava root) has not been very popular in livestock feeding. Cassava in livestock rations serves mainly as an energy source since its protein content is very low and of poor quality, being particularly deficient in amino acids methionine and cystine. Various studies indicate that the presence of high levels of cyanide (CN) in cassava is the most detrimental factor affecting its nutritional quality as a livestock feed (Kharjerarn and Kharjerarn, 1985). In order to reduce CN content cassava can be sun- or oven-dried, boiled or fermented. Drying and boiling only remove free CN while fermentation reduces both free and bound CN in cassava tissues (Osei et al., 1990). During the fermentation process, protein, soluble carbohydrates and fibre, increase while ash and fats decrease due to microbial action (Han, 1988). However, the magnitude of these changes depends on the conditions (ie. method and time) of fermentation. Both aerobic and anaerobic fermentations are possible although the former results in mould growth - a potential source of aflatoxin contamination. Due to the magnitude of changes in the composition of cassava during fermentation and possible exposition to aflatoxicity, the quality of the product is not predictable. There is need for appropriate fermentation techniques that would yield a product of predictable quality.

Fermentation as a processing method was advanced, as a way of improving the protein of feedstuffs (single cell protein). It was eventually found to be one of the suitable methods of detoxifying CN content in cassava (Han, 1988; Bokanga, 1992). Fermentation periods ranging from three to eight days have been used with varied results. The amount of time required for total elimination of CN is unclear. Judging from the feeding trials carried out using Fermented Cassava Peel Meal (FCPM) in broiler diets, levels of incorporation still remain relatively low. Further studies on fermented cassava meals are therefore necessary to establish better fermentation guidelines with the objective of improving the utilization of whole cassava root in livestock rations.

The overall objective of this study was to determine the suitability of fermented whole cassava meal in broiler rations. Specific objectives being:

1. To determine the best fermentation method that effectively reduces the cyanide.

2 To determine the effect of fermentation time on the nutrient composition of cassava.

3. To assess the performance of the broiler chickens on the cassava meal using the best fermentation technique.

4. To determine the maximum substitution levels of maize grain with FWCM in broiler rations.

CHAPTER TWO

2.0.0: LITERATURE REVIEW

Following discovery of cassava in America, it was passed to tropical areas of Africa and Asia where it soon became a basic food. Cassava has been used for various purposes in different countries. About 60% of the cassava output of households in Nigeria is sold for processing of starch and cooking flour "gari" while the rest is consumed at home (Han, 1988). In East Africa it is used for brewing local beers or processed into cooking flour for "Ugali"and porridge flour ("Uji"). Many other people roast or boil over various meals.

It is reported that cassava was first utilized as an ingredient in poultry rations in 1935 (Tabayoyon, 1935). In this study, Tabayoyon (1935) evaluated a product derived from the extraction of cassava starch as a broiler feed. He incorporated this material at 30 and 60% in broiler rations replacing equal amounts of maize meal. Body weight and feed intake at 12 weeks decreased as cassava component increased. He attributed the poor performance on presence of a toxic substance which was later found to be hydrogen cyanide (Vogt and Panner, 1963; Wood, 1965 and Vogt, 1966). Since then a lot of work has been done to eliminate cyanide, to improve cassava utilization in livestock feeding (Nertey, 1963; Best, 1978; Gomez et al., 1983; Tewe, 1991; and Gomez et al., 1993). Total elimination of cyanide was not realized until the introduction of fermentation procedure of O'brien et al. (1992). During that time that scientists had not achieved total elimination of cyanide, they tried to improve cassava utilization by stimulating detoxification of cyanide through metabolism in the body (Hutagulang, 1973; Hutagulang, 1977; Gerbacio, 1979; and Delange, 1983). This improved cassava utilization by livestock. Animals were thus able to accommodate higher levels of cassava in the diets. At this time cassava could substitute up to 20% of maize in poultry rations (Omole, 1977). Higher amounts could not be used because cassava has very low and poor quality protein. Excessive amino acids deficiency made the choice of the protein supplement difficult (Tewe, 1984; Waldroup, 1984; and Tudor et al., 1985). Using higher cassava amounts in livestock diets requires high amounts of protein supplements, which makes the diets very expensive. Soyabean has been the most widely used protein supplement in the feeding trials so far reported. When cassava is used as a substitute for cereals, nutrients like methionine (Labier and Parrot, 1985), fats (Gomez et al., 1987), and minerals (Hutagulang, 1977) have been given above the animals' requirements to try and ameliorate cyanide detoxification in the body and therefore improve cassava utilization.

Cassava processing procedures are varied, from simple preparation (peeling and boiling) to complex processing into starch which involves many steps, peeling, grating, fermenting, roasting, and drying. Processing, particularly drying and roasting, increase shelf life of cassava product. Various processing methods have different effects on the products and the cyanide content.

2.1.0: **Shortcomings of Cassava as a Feed**

Presence of cyanogenic glycosides in cassava root and leaf tissues is a major limiting factor in its utilization as a feed. These toxic substances cause high mortalities when ingested by animals. Further shortcomings include dustiness and low specific density which reduce feed intakes. It is also inferior to cereals because of its low CP, mineral and vitamin deficiencies. These deficiencies and the presence of the CN affect health and performance of animals in various ways.

2.2.1 **Cyanogenic Glycosides**

The cyanogenic content of cassava products varies with age (Table 2.1), strain and variety, location, soil type and climate. Cassava varieties are generally grouped as "sweet" or "bitter" depending on the CN content in the root parenchyma tissue. The CN level also varies with the part in the tuber used. The peel normally has higher CN concentrations than the pulp (Iyayi and Tewe, 1989). The CN content of cassava tubers are higher (> 300 mg/Kg) in the "bitter" varieties than "sweat" varieties (Gomez et al., 1983). Cyanide content of cassava tubers slightly decrease with maturity and is lowest at 11 and 12 months (Table 2.1).

Cassava roots destined for animal feed market are commonly harvested, processed (peeled, fermented, chopped and or grated) and sun-dried from 9th to 12th months of plant age when the CN level is lowest. The peeled roots vary in CN content from 10 to 370 mg/Kg, whereas the whole roots may contain as much as 560 mg/Kg. The Cyanide in cassava roots and tissue is present either in bound form (linamarine and lotaustraline) and/or free form (Iyayi, 1991).

Structurally all the cyanogenic glycosides are related. They have a cyanide ion attached to a glucose molecule. Lotaustraline is different from linamarine because it has a methyl group attached to it. It is thus a methyl derivative of linamarine. As in lower plants such as bacteria, fungi and ferns, the cyanogenic glycosides in plants originate from amino acids. The amino acids that serve as precursors for the various cyanogenic glucosides are quite specific (Iyayi and Tewe, 1989). Linamarine and lotaustraline are synthesised from valine and isoleucine respectively. Generally Linamarine accounts for the bulk of cyanogenic glucosides in cassava tissues. It is a glucoside of acetone cyanohydrin. It is readily hydrolysed by an endogenous heat labile β-glucosidase (linamarase) enzyme to yield cyanohydrin, which can be split by a hydroxynitrile lyase, or non-enzymatically into acetone and hydrogen cyanide (HCN). HCN ionises to produce the CN^- which causes toxic effects in the body. Linamarine is only absorbed if hydrolysed into HCN and the respective glycosides.

However, the body is able to detoxify the cyanide through several ways (Adegbola, 1977). There is a renal adaptive mechanism in some animals which prevents the serum Cyanide level from increasing beyond some critical level above which detoxification mechanisms are triggered to remove it. These regulatory mechanisms increase with the cyanide level of the diet and length of feeding (Tewe, 1984).

Cyanide has toxic effects in the body in various ways. Most of which result when CN reacts with metallic ions like Cu, Fe, and Zn. If this happens the involved ion is bound and hence can not function in its normal way in the body. Metabolism, Feed intake and growth rates have been affected in various ways due to effects of CN toxicity. Lack of oxygen due to binding of Fe causes fatigue in the birds. This may be one of the causes of reduced feed intake. Cyanide binds the copper of the cytochrome oxidase system and interferes with energy metabolism which leads to reduced ATP production. This may also be a cause of reduced growth, efficiency of feed utilization, and productivity. Cyanide ion combines with the iron in haemoglobin to form cyanohaemoglobin which can not transport oxygen (Iyayi, 1991) resulting in reduced oxygen supply to tissues. The most vulnerable tissues in this case are central nervous system and reproductive organs. Poor oxygen supply due to CN toxicity drastically affects the energy metabolism. In laying hens the shell gland is most affected, thus the shell gland muscles may not be able to contract well and move the egg, or the active transport of calcium fails leading to poor calcification which results into weak shelled eggs, very vulnerable to cracking and unlikely to hatch.

Table 2.1: **Cyanogenic Composition of Cassava by Variety and Age**

Variety	age	Total CN mg/kgDM	Bound CN mg/kgDM	Free CN % of total
CMC 40	9	584	397	32
	10	459	351	24
	11	379	247	35
	12	355	208	42
CMC 84	9	980	802	18
	10	750	578	23
	11	723	551	24
	12	646	515	20

Source: Gomez et al., (1983)

CMC 40, sweet variety

CMC 84, bitter variety

2.2.2: Dustiness and low Specific Density

Dustiness is an undesirable characteristic of cassava based diets, as cassava root flour (CRF) is usually powdery. This dust irritates the birds leading to sneezing. It also prevents them from feeding and hence reduces feed intakes (Montilla et al., 1976). It is possible to reduce dustiness by adding oil or pelleting. Montilla et al. (1977) feeding up to 30% cassava flour, added to all diets 5% animal fat and 5% molasses and observed increased feed intakes in all diets. Pelleting also helps to reduce dustiness and improve feed intake. Chou et al. (1974) substituted pelleted CRF for maize flour up to level of 58% without any effects on feed intake. Pelleting is a relatively expensive process although it gives better performance than when vegetable oils and fats are used. Palm oil is one of those oils that have been used extensively (Hutagulang, 1977), which in addition is a good energy booster.

2.1.3: Mineral and Vitamin Deficiencies

Cassava root meal (CRM) is deficient in most minerals and vitamins. Pigs and chicken on CRM have thus been shown to require higher mineral supplementation particularly sulphur than those receiving diets based on cereals (Lisorets and Lipyenchik, 1982). Cyanide renders minerals in cassava-based diets less available.

Zinc deficiency is usually triggered by relatively high Ca in cassava and fish meal, and the presence of oxalic acid in the root. The high Ca content increases the pH in the stomach creating Ca-Zn-phytate complex which can not easily be absorbed. Deficiency of zinc also reduces glycogen deposition hence interferes with tissue building leading to poor growth rates and feed utilization as it is used to increase uptake of glucose by adipose tissue (glycogen synthesis). Cyanide has high affinity for metallic ions such as copper and iron (Iyayi, 1991). It binds Cu, Fe, and I causing their deficiencies. These deficiencies disrupt energy metabolism, and biosynthesis. This may be the cause of reduced growth rates at high levels of cassava supplementation, and reduced feed utilization efficiency. Cyanide leads to depletion of iodine (Tewe, 1983a). Cyanide has the same molecular weight as iodine hence it competes with iodine for uptake by the thyroid gland. Prolonged feeding on cassava also causes depletion of thyroidal iodine stores. This leads to hyperplasia and thyroid malfunction. Maximum toxicity is manifested when goitre shows.

Jackins et al. (1970) found that copper supplementation increased growth rate in chicks as it improved the energy metabolism. Deficiency of Fe reduces oxygen supply to tissues. These two when acting together destabilize energy metabolism. Cobalt (Co) reacts with CN^- to form a stable harmless ion, cobalt cyanide, during this process Co is bound and made unavailable. Mineral supplementation is critical and at least 0.35% P, 0.3% Ca and 16 ppm Mn are recommended.

The vitamin values of cassava root are nutritionally insignificant compared to maize. Therefore to substitute cassava for maize vitamins have to be supplemented, especially vitamin A and vitamin B_{12}.

2.2.4 Protein Content

The tuberous tissue is essentially a carbohydrate source and contains very little (1 - 3%) poor quality protein (Table 2.2; Tewe and Ebunike, 1988 and Ravindran et al., 1983). Because of the low poor quality protein in cassava, the quality and quantity of the protein supplement used is critical, especially the sulphur containing amino acids (Job, 1975). In cases where supplementary protein is deficient in these amino acids elemental sulphur is offered. Low CP, and especially deficiency in S-amino acids lower the feed utilization efficiency and hence growth rates since protein synthesis is reduced. under such succumstances methionine has to be supplemented (Hutagulang, 1977).

Soyabean meal and fish meal form an appropriate mixture in rectifying these deficiencies. 15% Soyabean meal and 11% fish meal in the diet are adequate (Manner and Gomez, 1973; Khajerern and Khajerern, 1985). Cassava/soyabean meal mixture contains adequate levels of most nutrients but slightly lower in methionine and ME required for poultry compared to maize/soyabean mixture.

Table 2.2: Proximate Composition by Cassava Variety

Variety	DM	CP	CF	ASH	EE	NFE
Sweat[a]	91.4	2.4	2.1	3.9	0.7	91.9
Sweet[b]	91.2	2.1	3.2	2.4	0.9	82.6
bitter[a]	91.1	2.6	5.6	6.1	0.6	85.3
Bitter[b]	91.1	3.1	3.4	2.1	0.9	81.3

Source: Gomez et al., (1983) and Iyayi, (1989).

a, b, different varieties

For cassava to be fed to livestock successfully, it has to be processed to reduce cyanide the main toxic substance usually present. Various processing methods, varying in effectiveness of reducing cyanide content in cassava root tissue, have been advanced.

2.2.0 The Effect of Various Processing Methods on the Nutritional Value of Cassava Meal

Peeling of the fresh tubers followed by boiling, fermenting or chopping and then sun-drying can reduce the cyanide in cassava root tissue (Ravindran et al., 1983 and Anon, 1987). For use in compound feeds, whole root cassava chips are commonly sun-dried on concrete flours (Gomez et al., 1983) or small scale wooden frame trays (Best, 1978); the concrete flour being the best (Gomez et al., 1983). Compared to other drying methods, sun-drying eliminates the highest percentage of the free cyanide because it allows hydrolysis to take place most efficiently (Ospina and wheatley, 1991). Drying in the sun for two to three days has been recommended depending on the climatic conditions. Length of drying depends on the chip size, intensity of the sunlight and loading. Longer drying periods lead to excessive protein losses. The recommended size of chips is 50-80 mm long, 25-30 mm wide, 4-7 mm thick. The loading on concrete flour should be 10 kg/m3 (Gomez et al., 1983).

Sun-drying of cassava is unlikely to remove all the cyanide. Fermentation in water before drying and feeding removes most residual cyanide (Osei, 1992). Fermentation destroys the glycosides which are the precursors from which cyanide is generated. It also destroys the enzyme linamarase. During the fermentation HCN dissolved in water which facilitates its evaporation. The end products of fermentation have negligible amounts of HCN. During the drying any HCN that would be remaining in the tissues evaporates. Fermentation in water appears to be a more efficient method for reducing the cyanide in roots (Ofuya and Obilor, 1993). Mahungu et al. (1988) showed a reduction of cyanide by a range of between 80 and 90% by fermenting a cassava product called "gari".

Drying also reduces cyanide but it depends on the amount of drying time. Fast drying methods only reduce little amounts (10-30%) as the time is not enough to allow effective hydrolysis of the glycosides (Iyayi, 1991). Mahungu et al. (1987) reported a reduction of up to less than 10 mg/100g after 7 day sun-drying. They found oven drying to be less effective. Boiling also reduces CN but it is limited (10%) (Han, 1988).

Fermented cassava products are less prone to disintegration and deterioration when stored (have longer shelf life) than those dried before fermentation. They are also superior in terms of transportability and acceptability (less toxic) than other dried products (Han, 1988).

2.2.1 Fermentation as a Form of Processing

In cassava fermentation, CN reduction is facilitated by micro-organisms. This process may be carried out under aerobic or anaerobic conditions. In the case of aerobic fermentation the peeled and chopped cassava roots are sun-dried for one day, heaped together and covered for three to eight days, during which time the cassava becomes mouldy. The cassava is then sun-dried with or without removing the mould. This process is common in Western Kenya where the flour from this type of cassava is used for "Ugali" or porridge preparation. Protein content is increased three to eight times in this type of fermentation (Han, 1988).

Anaerobic fermentation involves soaking of cassava chops under water for three to six days. During the first stage the bacterium, Corynebacteria manihort, attacks cassava starch producing various organic acids like lactic acid and formic acid. In the second stage, the acidic condition created stimulates the growth of a mould Geotrichum candida which produces a series of aldehydes and esters. Tissue disintegration in the presence of excess moisture during fermentation in water facilitates rapid hydrolysis of glycosides, reducing both free and residual cyanide in the product. Han (1988) reported that anaerobic fermentation reduced the cyanide by 70- 95% of the original level within three days. The fermentation removed 88% of the cyanide compared to acid hydrolysis which can remove up to 98%. Acid hydrolysis removes more cyanide, but it is rather expensive.

Strasen et al. (1970) used yeast (Candida utilis) in an enzymatic fermentation and produced a product containing 35% CP on DM basis. Gregory, (1977) using Aspergilus fumigatus 1-21A fermented whole cassava in a non-septic continuous fermentation system to produce single cell protein containing 37% CP and 27% true protein. This produced good results when fed to rats. They reported an increase in CP between 2 to 4% in peeled roots from 0 to 2%. Although moulding during fermentation enhances protein content of the product, it may also enhance building up of aflatoxin (Omole, 1977). Tewe and Egbonike (1988) reported that this may predispose young chicks to aflatoxicity.

In various parts of the world cassava is used in varying degrees in both ruminants and non-ruminants rations. Recommended levels of incorporation vary considerably depending on the CN content, and cassava processing technique employed.

2.3.0: **Utilization of Cassava as a Livestock Feed**

Cassava has for a long time been regarded as a subsistence crop for low-income families or as a "famine reserve crop". Advances have been made over time to use it as a livestock feed, but as discussed above it contains cyanogenic glycosides and is deficient in most essential amino acids, minerals and vitamins. Amino acids and minerals in the diet are bound and made deficient during the rodanase detoxification pathways (Hutagulang, 1977).

Both the tuber and the leaves may be used for livestock feeding. Currently the pulp is most widely used, possibly because it contains least cyanide and fibre as compared to the rest of the cassava plant tissues (Gomez et al., 1983). However, cassava pulp has less CP and EE compared to the leaves and the peel (Iyayi and Tewe, 1989). It is also deficient in essential fatty acids (Omole, 1977). In cassava producing areas particularly in Western Kenya, cassava is sold at the market in the form of dry chips. The fresh roots are peeled, cut into chips and fermented before sun-drying, or dried without fermentation. Fermentation followed by sun-drying substantially reduces the content of cyanogenic glycosides (Ravindra et al., 1983).

Cassava peel is a major by-product of the tuberous root processing industry. In most parts where cassava is grown, and used for feed, the peel is under-utilised especially as a livestock feed whereas it constitutes in most cases about 20% of the tuber (DM basis). Cassava peel meal is a good source of energy for ruminants, serving as either the basal diet or as supplement (Smith, 1988). Sun-drying, ensiling and fermentation are used to reduce cyanide concentration to tolerable levels (below 100 mg/Kg). Rumen degradability in cattle, sheep, and goats is 83% in 48 hours (Smith, 1988). Supplementation with protein-rich feeds or even cassava leaf meal has been shown to improve its feeding value. Cassava peel meal could make up to 40% of the ration for pigs and freyer rabbits without any deleterious effects on their performance. In this respect either fish meal (Omole, 1988) or methionine (Job, 1975) are effective supplements. Using cassava peel meal as a feed also requires vegetable oil supplementation especially palm oil. Hutagulang (1977) attributed improved performance with feeding palm oil in cassava based diets to increased energy intake by the animals. The oil also delays HCN decomposition in the stomach, which prevents absorption of cyanogenic glycosides (Omole, 1988).

Unlike other livestock species chicken can not tolerate high cyanide and fibre as is found in peels. This is why levels of cassava peel meal currently incorporated in broiler feeding trials are generally low. Fortification with methionine, minerals and vitamins are necessary. Osei and Duodu (1988) found that fermentation could increase inclusion level from 7.5% to 15% of the diet, without any effects on performance, and carcase characteristics.

Cassava leaf meals are rich in protein (17.8 to 34.8 percent) (Rogers and Miller, 1983) and can be easily processed, but their digestibility is low (Gomez et al, 1988). Cassava leaf meal is a valuable forage which can be used for feeding cattle (Seerely, 1972). Cassava leaf meal (CLM) can serve as a good source of protein, fibre, minerals and vitamins in rations for layers (Omole, 1977). Its percentage composition is: CP 17.8 -34.8, CF 7.6 -10.5, Ash 5.7 - 8.8, CF 4.8 - 7.9, NFE 50 -51, on DM basis. Although CLM is inferior in terms of amino acid composition (Devendra, 1977), it is useful for rabbit nutrition and it compares favourably with alfalfa and _Aspilia_ _african_ meals which have been proved to be desirable feed for rabbits (Omole, 1988). Moore (1976) evaluated the feeding value of cassava foliage for ruminants in a trial in which steers weighing 250 Kg were fed with Pennisetum purpureum with varying levels of cassava foliage, and found that feed intake, growth rate, and feed efficiency were improved in diets containing cassava foliage supplements. Smith (1988) in his review, showed cassava leaf to be comparable to alfalfa meal even though it performed 96% lower than alfalfa. Beef and dairy cattle respond well to wilted cassava foliage, with digestibility of 66.6% (Smith, 1988). Rumen degradability of cassava foliage is higher than that of leucaena, palm leaves, bamboo and Citricum sepium meals in goats and cattle. Cassava leaf meal can be used as protein supplements in poultry feeds. Its feeding value decreases with age (Muller, 1974) (three to four months are optimal in reference to nutrient composition).

Cassava and its by-products can therefore, be profitably used in the feeding of livestock, but the feeding levels for various livestock species will vary depending on cyanide tolerance, supplementary protein source and purpose for feeding.

2.3.1: **Cassava as a Feed for Ruminants**

Cassava root meals are currently being used in ruminant rations including those for sheep, goats and cattle, in many countries. Cassava can adequately substitute maize at low levels (below 30%) in ruminant rations (Devendra, 1977). Feeding trials indicate that cassava chops are most efficiently utilised when incorporated at the levels between 20-30%. Higher levels, are poorly utilized due to reduced digestibility probably because amylolytic activity in intestinal track decrease.

Cassava when used as a feed at levels of up to 30%, does not affect weight gain performance and milk yield in cattle (Anon, 1984, Tudor et al., 1985 and Smith, 1988). Levels above this may lead to reduced growth rates especially for young calves. Abate, (1981) noted a decrease in the growth rate of beef calves offered concentrate diets containing cassava as main source of energy. However, some experiments indicate that Cassava Root Meal (CRM) can fully replace cereals such as oats and barley in dairy cow concentrates. Sanda and Methu (1988), noted comparable performance in milk yield, butterfat and live weight gains when they used CRM as a dairy concentrate. They concluded that total substitution of maize with cassava was possible.

2.3.2: **Cassava as a Feed for Non-ruminants**

Generally results of studies on feeding cassava roots to non-ruminants indicate that cassava is comparable to other energy sources but requires protein, mineral and vitamin fortification when fed to pigs and poultry (D'mello, 1987).

Rabbits can tolerate up to 30% of cassava root meal in their diets (Omole, 1988). In this review, Omole, (1988) observed that above 4% cassava meal supplementation of 0.26 methionine and 2%

palm oil is desirable. Pigs however, can tolerate higher levels of CN in their rations than rabbits and poultry.

2.3.2.1 Cassava as a Feed for Pigs

It is generally agreed that cassava root products (pulp, peel) can be successfully used as an energy source for pigs. These once properly prepared, may be used at levels of 40-75% in diets for growing and finishing pigs without adverse effects on performance or carcass characteristics (Kharjerarn and Kharjerarn, 1985). Toxicity has been reported (Iyayi, 1991), especially when the cyanide levels exceed 100 g/kg. Hormonal imbalances (especially testosterone), goitre and reproductive failures are among the symptoms of toxic effects. Both the roots and leaves have been successfully used in various proportions as long as the rations are balanced for minerals, vitamins and supplemented for methionine.

Apart from dried cassava, pigs can also be fed on fresh cassava tuberous roots, a common practice with the subsistence pig farmers in Busia District of Western Kenya. Chopped cassava roots either fresh or parboiled, are fed to pigs although deaths among piglets are common. To overcome this problem (toxicosis in cassava) some farmers now sun-dry the grated cassava with or without fermentation before feeding them to pigs.

Levels of cyanide above 500 mg/kg in the diets of pigs results in histological lesions in the liver, lungs, spleen and gastrointestinal tract (Iyayi and Ngodida, 1991). It also leads to increased serum testosterone in growing male pigs. Excess of these lesions may lead to death (Iyayi, 1991). Cassava peel-based diets increased serum oestradiol of growing young female pigs (Iyayi and Tewe, 1991). Similarly cassava may be incorporated in rations for other non-ruminants eg. chicken.

2.3.2.2 **Cassava as a Poultry Feed**

Cassava root meals, and Cassava Peel Meal (CPM) can be used as feed for poultry, although performance is not comparable with the traditional cereal-based diets. Cyanide is believed to be responsible for poor performance obtained when CRM is used as poultry feed ingredient. Current recommendations on the levels of incorporation of CRM in poultry rations are not in unison. Experiments so far conducted using cassava flour give contradictory results. Muller et al (1974) and Stevenson and Jackson (1983) demonstrated that levels of up to 50% of cassava in the diet by no means depressed growth in poultry, whereas Longe and Oluyemi, (1977) and Wyllie and Kinabo, (1980) observed a decrease in the weight at lower levels. Patterson et al. (1994) comparing different cereals (barley, wheat middlings and maize) using soyabean and poultry by-products (broiler offals and condensed carcass) noted no difference in body weights and feed intakes, although, the control had better feed conversion ratios.

Satisfactory growth is obtained if young growing chicks are fed on diet having 10% cassava flour (Obuobi, 1974; Wyllie et al, 1984; Gomez et al., 1987). Reduced laying percentages, hatchability, and high mortalities have been reported in layers (Omole 1977) especially if fed on diets that contain more than 5 mg/kg residual cyanide. Depending on the cyanide level and type of protein supplements, higher levels (up to 50% CRM) can give favourable responses (Lopez, 1984). In cases where the cyanide levels in cassava exceed 5 mg/Kg, levels above 40% cassava flour can only be given to broilers because they are more tolerant to high levels of cyanide than the layers (Omole, 1977).

2.3.2.3 **Cassava as a Feed for Broilers**

Cassava root meal (CRM) can be fed to broilers, although with varying performance at various cassava inclusion levels. Differences in performance of broilers given the same amounts of CRM in the various trials reviewed seem to change depending on diet composition (Adegbola, 1977) and form of processing (Osei and Duodu, 1988). Although drying reduces cyanide, it does not completely eliminate it. Ofunya and Obilor, (1993) using Rhizopus sp. fermented cassava and noted it had more protein of better amino acid composition. Performance of the birds also improved. Osei and Duodu, (1988) reported improved performance (live weights, feed intakes and carcase parameters) with fermented cassava peel meals compared to non-fermented peel meal (Osei, 1990). Fermentation therefore improves the nutritional quality of cassava and eliminates the cyanide leading to improved performance of the birds.

2.4.0: Effects of CRM on the Performance of Broilers

Using equal amounts of cassava root meal in broiler diets has produced varied results. Variations occurring due to either the variety, part of the tuber used or processing technique.

2.4.1: Feed Intake

Cassava-based diets tend to lower feed intake, when fed to poultry and pigs. This may be due to CN which cause the birds to refuse the feed in fear of poisoning (Mcmillan and Dudley, 1941). Dustiness may also be responsible for the low feed intakes. Dustiness occurs due to low specific density of cassava flour which reduces its pick value (amount taken per pick) (Gomez et al 1987). Both poor feed intake and feed utilization efficiency lead to reduced growth rates and productivity. However, this needs further investigation. In cases where the cyanide levels were high histological lesions were reported (Manner and Gomez, 1973), this causes ill health which reduces the appetite of the birds, feed utilization and growth rates as it increases maintenance requirements.

2.4.2: **Weight Gains**

It has been observed that live weight gains decrease with increasing cassava levels in poultry diets. Maust et al. (1972) found that cassava based diets depressed growth rates in broiler chicks. This was associated with the presence of cyanide and low feed intakes in cassava based diets. As mentioned earlier the body always tries to remove CN^- through detoxification. During detoxification of cyanide in the body, energy metabolites such as pyruvate are used. Key minerals in energy metabolism like copper and iron are also bound. This reduces efficiency of energy metabolism, and therefore the biosynthesis of tissue. This is the cause of reduced growth rates at high levels of cassava feeding especially for the "bitter" varieties of cassava (Montilla, 1977).

Poor growth rates observed when cassava is used as a broiler feed ingredient has limited its use to low (limited) amounts in the diet. The maximum level one can use depends on the cyanide level of the product used. Some results, however, are contradictory. According to Vogt (1966) 10% tapioca meal in broiler feeds produced results which were equivalent to normal rations (maize based) while 20% and 30% tapioca caused depressed growth. He was working with a bitter cassava variety. The final diets had HCN levels less than 100 mg/Kg, 300 mg/Kg and > 300 mg/Kg for 30, 20 and 10 percent levels. But, Enriguez and Ross (1967) using similar cassava found that cassava meal produces inferior growth rates compared to equivalent amounts of maize unless the diet was supplemented with

0.15% of methionine, when a level of 50% of the chick ration satisfactorily replaced maize. Methionine, as seen above, improved CN detoxification in the body and therefore does not interfere with other metabolites. Methionine supplementation caused increased weight gains, as it improved feed conversions (Larbier and Perrot, 1985). Feeding "bitter" varieties of cassava up to 60%, Bahri et al. (1985) found significant reductions in mean daily body weights at all substitutions above 30% cassava.

Low levels should be used if residual cyanide is above 30 mg/Kg especially for young chicks. Vogt, (1966) recommended for broiler diets levels above 10%, only after the fourth week, because Yoshida et al. (1966) noted that HCN present in the flour (36 ppm), was responsible for the low level of growth, among the young chicks. To the contrary Gomez et al. (1983) working with low and high cyanide cultivars incorporated at 10% or 20%, with a commercial control diet, found the performance of chickens similar to that of the controls. The cyanide content of the dried cassava chips was below 100 mg/Kg. Using cassava root meal (CRM) as a substitute for wheat in broiler diets, Stevenson and Jackson (1983) reported no significant effect on body weights, even with diets fed to day old chicks. The maximum inclusion was 50%, although they recommended a maximum of 30%.

Low energy in cassava based diets, and certain deficiencies reduce growth rates due to low feed utilization efficiency. Rendon et al. (1969) incorporated up to 45% CRF in broiler diets and reported poor growth rates and feed efficiency for all the levels studied. He recommended the 15% level. Olson et al. (1969) incorporated up to 45% and made the diets isocaloric and isoproteineous by adding animal fat. He found that weight gains were slightly reduced by increasing the level of CRF. Significant differences occurred above 34.5%. Feed efficiency was similar in all diets. Animal fat may have assisted in eliminating the deficiency in essential fatty acids, boosted the energy and reduced dustiness. Waldroup et al. (1984) using full-fat soyabean diets found adverse effects on body weight gains, growth rates with higher substitution levels being reasonably good, although required slightly more feeding periods (2 weeks).

Cassava peel meal produce poor growth rates when used in broiler diets because of its high CN. Fermentation, however, reduces the CN and improves its feeding value. Anaerobic fermentation under water is a better technique as the resulting product produces higher weight gains (even at 56% cassava inclusion level) than when Rhizopus sp. is used as the fermenting agent (Wyllie et al., 1984). Osei et al. (1990) reported increased live weight gains in a linear trend with fermented CPM substituting equal amounts of maize up to 75 g/Kg, with no changes in feed intake whereas sun-dried CPM reduced weight gains and feed intakes, at all levels (Osei and Twumasi, 1989). Although in using sun-dried CPM as feed, Osei (1992) found no significant differences in live weight gains. Feed intakes increased insignificantly with increasing levels of sun-dried CPM but FCE did not vary.

2.4.3: Feed Conversion Efficiency

High feed utilization efficiency (FUE) ratios have been reported when cassava is fed to broilers, and especially bitter cassava. This may be partly due to the presence of CN, or poor digestibility of nutrients in cassava especially protein (Waldroup et al., 1984). This may be the reason why feed utilization efficiency (FUE) detoriorates with increasing levels of cassava in the diet. Waldroup et al. 1984 using cassava flour blended with extruded full-fat soyabean diets found digestibility of protein to decrease and that of fat to increase with the increase in percentage CRF. Feed conversion efficiency, however, detoriorates with increase in cassava level.

The processing method seems to affect both FUE and FCE. The latter improved with fermentation, and more so anaerobic fermentation under water (Wyllie et al., 1984). They suggested that although no significant differences were found in chicks, the boiled cassava gives better conversions than sun-dried or the roasted cassava. Boiling breaks bonds between nutrients, and causes them to be available to enzymes. Mineral, amino-acid or vitamin supplementation also improve digestibility, hence FUE and FCE.

Presence of CN also affects FCE. Cyanide as explained earlier binds some minerals (Co, Fe and Cu). This is a possible cause of reduced FCE as they are involved in energy metabolism and active transport or uptake of metabolites into the tissues and cells. If iron is bound it reduces oxygen uptake impairing the efficiency of metabolism, causing weakness in the animal and poor growth rate. Copper being a co-factor in the cytochrome oxidase, if bound impairs oxidative phosphorylation, and B-oxidation of fats. This in poultry reduces ATP production therefore interfering with the whole process of energy metabolism. In layers as stated earlier, interference with metabolism is more prominent in the shell gland where active transport of calcium fails, therefore affecting egg shelling. Thus, eggs produced have low hatchability, and marketability because of their weak shells. Iodine deficiency results in goitre due to failure in the functioning of the thyroid gland. The thyroid gland has an effect on the reproduction of the chicken. Failure of this gland may be the main cause of reduced egg production, and general infertility.

Zinc deficiency discussed earlier decreases the utilization of glucose. Zinc normally assists in the uptake of glucose by adipose tissue (glycogen synthesis). Deficiency will lead to reduced glycogen deposition therefore reducing tissue building ability of the bird. Reduced tissue deposition results in poor feed utilization efficiency hence poor growth rates.

Varying inclusions of CRM as substitutions for wheat grains in broiler chick diets had no effect on FCE, except, in one experiment, after 4 weeks, when the diet with 100 g/Kg CN (lowest) improved the values (Stevenson and Jackson, 1983). Feed conversion indices were comparable to maize based diets, in substitution levels varying from 33.33% to 100%, although other parameters varied (Brum et al., 1990). Using sun-dried CPM at levels up to

15% Osei and Doudu (1988) found no significant differences. Weight gains and feed intakes increased with the increase in the inclusion level. Using fermented CPM at levels of up to 75 g/Kg in layers diets, Osei et al. (1990) reported poor FCR. Feed intakes were not significantly different from the maize control. Feed intakes and FCE decreased when Osei and Twumasi, (1989) substituted equal amount of maize with oven dried CPM. Osei, (1992) feeding sun-dried CPM reported significant effect on feed intake, and FUE, even at 150 g/Kg. Daguro and Rivas (1987) working with dried cassava, had found the same even at 100% substitution. Muinga and Mbugua (1991) reported the FCE of cassava to be higher than maize, in the experiment to test cocoyam inclusion levels.

Obioha et al. (1984) working with layers, substituted maize with equal amounts of CPM, and reported an increase (detorioriation) in FCR, a decrease in protein efficiency ratio, but no change in feed intake and digestibility. The feeding was done for 70 days, during the laying period.

Elimination of CN and dustiness can improve feed intake, FCE, health and growth rates of broilers fed on cassava-based diets. Fermentation is a potential tool in improving the protein and reduction of cyanide in cassava based diets. Two experiments were set to determine the effect of fermentation on whole cassava meal, and to establish the maximum level FWCM can replace maize in broiler rations.

CHAPTER THREE

3.0.0: MATERIALS AND METHODS

3.1.0: Introduction

Use of cassava as a broiler feed is limited by the presence of cyanide and deficiencies in amino acids and minerals compared to traditional cereal alternatives. Elimination of CN can improve its feeding value and hence performance of the broiler chicks fed on cassava based diets. To establish this, two experiments were designed to determine the effect of time on three types of fermentation, and to use the best resulting cassava product, in a feeding trial to establish the maximum substitution level of maize with FWCM.

3.2.0: Cassava Source and Site of the Experiment

Fermentation, analysis of the samples and the feeding trials were done at Egerton University. It is approximately 27 Km south of Nakuru town. Egerton University is situated in an agro-economic zone with a bimodal rainfall distributed with the long rains from March to May, and the short rains from mid September to November with four months of dry period, in between. There are monthly temperature variations, ranging from 18 °C during the period of June to August (coldest), to 28 °C during the period of December to

February (warmest), with the rest of the months averaging 24 °C. The mean annual rainfall is about 1000 mm. The fermentation experiment was carried out during the month of July, when the temperatures were gradually decreasing (averaged 22 °C). On the other hand the feeding trial was carried out over a period of two months (December 1994 to January 1995).

The cassava used in the fermentation experiment was collected from Rongai near Nakuru and was delivered to the laboratory on the same day. Rongai has the same rainfall pattern as Egerton, although the temperature regimes vary. They range from 22 °C, at night to 34 °C during the day.

The cassava used in the feeding trial was collected from Nambale in Busia District of Kenya. Nambale experiences long rains during the period of March to May, then a dry spell up to September. This is followed by short rains in October and November. The temperature fluctuates between 26 and 34 °C, averaging at 30 °C.

3.3.0: **Fermentation Procedure**

Cassava (Variety 2000 or " Nabwire") was harvested by hand. This was done at 10 months when the cyanide level is expected to be lowest (Cooke and Cruz, 1982). It was thoroughly washed and the dark corky cover (pericarp) was removed. The whole cassava was chopped into small pieces, and fermented. Fermentation was done in the laboratory under various water levels in plastic pails for different periods.

1. Cassava used for aerobic fermentation was put in three pails which were loosely covered with cassava leaves and left for six days.
2. In semi-aerobic fermentation cassava was put in three different pails and water was filled half way (1 Kg of cassava to $^1/_2$ l of water),
3. In anaerobic fermentation experiment, the cassava was put in three pails in which water was filled till all the cassava chips were totally submerged (ie. 1 Kg : 1 l of water). For comparison some cassava was fermented in one pail (6 Kg) and three samples were taken every day for six days.

Fermentation was done for one to six days, the zero day being the control. Duration of fermentation in this experiment represented the treatments while the water levels represented the various blocks.

3.4.0: **Analysis of Cassava Samples**

Three samples from each pail were taken at a similar time every day and dried on concrete floor for 7 days. Dried samples (N = 60 samples) were ground and passed through a 2 mm sieve. Each was analyzed for hydrogen cyanide (Cooke, 1982), proximate composition (AOAC, 1975), and glucose (Meloan and Pomeranz, 1980).

3.4.1: Cyanide Analysis

Before every analysis of cyanide the spot test analysis (Jungreis, 1976) was done. The samples were moistened in a test tube, a wet test paper put, and a few drops of chloroform added. Cyanogenic glycosides were indicated by gradual appearance of an orange to brick red colour on the test paper.

For the cyanide analysis, dry samples each weighing 1g were ground in acidified sand, 100 ml of water added, and incubated with enzyme linamarase for 8 hours in an incubator at 40 °C. An aliquot was prepared as described by Cooke, (1982), distilled over NaOH, and the resulting solution assayed over the standard NaCN in an electrophotometer.

3.4.2: Soluble Carbohydrates

Total soluble carbohydrates were estimated using the phenol-sulphuric acid method for total carbohydrate analysis (Meloan and Pomeranz, 1980). This was based on the fact that they give orange yellow colour when treated with phenol and concentrated sulphuric acid. Standard sugar (glucose) solutions were prepared by titrating 0, 10, 20, 30, 40 and 60 ug sugar into colorimetric tubes and adding 1 ml of phenol solution, and 5 ml concentrated acid and comparing them using a spectrophotometer.

3.5.0 Feeding Trial

3.5.1 Preparation of Experimental Diets

After harvest, the cassava roots were washed, and the thin brown corky outer bark removed. The cassava was then fermented for three days then sun-dried for seven days. Dried FWCM chips were then ground in a hammer mill without a sieve. Fresh fish "Omena" from Lake Victoria was dried and ground in a hammer mill using a 2 mm sieve and used in the diets as shown in Tables 3.1 and 3.2. Sunflower cake from manually operated ram press was collected from Bungoma District of Western Kenya and was also used as protein supplement. It was ground then sieved through a 2 mm screen using a powered shaker. The husks were removed and the cake incorporated into the diets. The diets were formulated according to National Research Council (1986) recommendations using a lotus formulation program. The diets were all isoproteinous and balanced for all other nutrients. The feeds were analyzed for proximate composition.

Six rations were formulated in which FWCM replaced maize at 0, 20, 40, 60, 80 and 100 percent, each representing a single treatment.

Table 3.1: Composition of the Broiler Starter Diets.

	Cassava substitution level (%)					
	0	20	40	60	80	100
Ingredients						
Cassava	0.0	9.0	17.0	26.0	31.0	38.0
maize	45.0	36.0	26.0	17.0	8.0	0.0
sunflower	22.4	23.8	26.0	28.6	31.6	35.0
fishmeal	31.8	31.3	30.4	28.6	28.9	28.0
premix	1.0	1.0	1.0	1.0	1.0	1.0
CP(%)	23.4	23.1	23.1	23.2	23.1	23.0
ME(Kcal)	3249.0	3208.0	3207.1	3038.0	2901.0	2964.0
Ca(%)	0.8	1.5	1.3	1.2	1.0	1.7
P (%)	0.6	0.7	0.8	0.9	1.0	1.2
Cost[2]	977.5	925.7	884.0	826.2	795.5	766.2

Ca = Calcium, P = Phosphorus,

[2] Cost per 70 Kg bag in Ksh.

Table 3.2: Composition of the Broiler Finisher Diets.

	Cassava substitution level (%)					
	0	20	40	60	80	100
Ingredients						
cassava	0.0	12.0	25.0	36.0	47.0	58.0
maize	64.0	52.0	38.0	25.0	12.0	0.0
sunflower	20.0	21.0	22.0	23.0	26.0	26.0
fishmeal	15.0	15.0	15.0	15.0	15.0	15.0
premix[1]	1.0	1.0	1.0	1.0	1.0	1.0
CP (%)	19.1	19.1	19.0	19.1	19.1	19.1
ME(Kcal)	2991.0	3006.0	2942.0	2957.0	2829.0	2820.0
Ca (%)	0.6	1.2	1.8	1.5	1.4	1.1
P (%)	0.5	0.5	0.6	0.6	0.8	0.9
Cost[2]	840.4	797.0	742.4	689.2	647.2	613.6

Ca = Calcium, P = Phosphorus

1 The premix (A-D-VIT-25 Kolfolk, Israel) used had the following composition; Vit A 7,000,000 IU, Vit D 1,000,000 IU, Vit E 2,500 IU, Vit K 2,000 mg, Riboflavin 4,000 mg, Nicotinic acid 10,000 mg, Pantothenic acid 5,000 mg. Fe 25,000 mg, Mn 40,000 mg Co 2,000 mg, Cu 200 mg, I 1,100 mg, Se 75 mg per Kg mixed with salt

[2] Cost of a 70 Kg bag in Kshs.

The experiment involved two phase feeding of broilers. In the first phase the starter diets in Table 3.1 were used. The experiment was continued into the second phase using the same chickens and same design from the age of five weeks and fed to eight weeks. The finisher diets as shown in Table 3.2 were used.

3.5.2: **Experimental Design**

A total of one hundred and ninety eight one day old chicks from the Kenchic hatchery were randomly allocated into various treatment pens. Three replicates (11 chicks each) were used for each treatment. A completely randomized design was used to allocate the birds randomly into pens.

Model $Y_{ij} = U + T_i + E_{ij}$

where Y_{ij} = The ijth observation

U = The overall mean

T_i = Treatment effect

E_{ij} = random error

The data were analyzed using the linear model analysis of SAS computer package (SAS/STAT, 1986). Regression and correlation analyses were done for live weights and feed intakes, and for the various parameters over the FWCM levels. Separation of means was done using LSD, to determine which means were different from the others. Two way ANOVA was done for the fermentation experiment's data.

3.5.3: Experimental Procedures

The poultry house was thoroughly cleaned and disinfected before the start of the feeding trial which was conducted over a period of eight weeks. The chicks were fed ad libitum. Fresh feed was added as necessary. The feed was weighed before and after every feeding. Polythene sheets were put below the feeders once a week and left for two days to collect feed waste (spill). Clean water was available all the time using automatic plastic drinkers. The drinkers were cleaned every evening at 5.00 pm. Lighting and heating were provided for 24 hours during the first four weeks of brooding using 150 Watt bulbs (one bulb for each pen). The chicks were allowed lighting over night for the whole experimental period to allow continuous feed intake.

To evaluate growth performance of the various treatments; the chicks were weighed when one day old, and weekly there after. A two phase laboratory scale (Avery Scale) was used. The weekly weights were obtained as a difference in weight between the preceding weeks. To ascertain the feed acceptability the feed intakes were measured. This was done by recording weekly feed intakes. Feed conversion efficiency was calculated as gain to feed ratio. Mortalities and deformities were monitored on a daily basis. Post mortem examination was carried out on all dead birds.

CHAPTER FOUR

4.0.0: RESULTS

4.1.0: Effects of Fermentation on the Nutritional Value of Whole Cassava Meal

4.1.1: Cyanide and Protein

Fermentation using various water levels had variable results. The cyanide decreased while protein increased with time, changes being significant ($P < 0.05$) on the fourth day (Table 4.1). The fresh and non-fermented sun-dried cassava had 145 mg/Kg and 28 mg/Kg cyanide; and 3.94% and 3.76% CP, respectively (Table 4.2). Cyanide and protein contents after four days fermentation were: 10, 28, 0 mg/Kg; and 4.78, 4.01, 5.86 per cent for aerobic, semi aerobic, and anaerobic fermentations, respectively. These results show that cyanide content decreased while CP increased. The decrease in CN and increase in CP were higher ($P < 0.05$) in anaerobic fermentation than the others, semi aerobic being the lowest. Semi aerobic and aerobic fermentations did not fully eliminate cyanide even by the fifth day. Although total bacteria in both cassava and the fermenter was not estimated, the hard texture of cassava chops in the semi aerobic fermentation even after six days indicated poor degradation and bacterial action.

Aerobic fermentation resulted in intensive moulding, and oxidation causing the cassava tissue to be very soft.

Anaerobic fermentation produced the highest CP (5.70%) and totally eliminated cyanide (0 mg/Kg) (Table 4.1). It was thus adapted for evaluation and ultimately used in the preparation of various of diets. The results of anaerobic fermentation for the different days are shown in Table 4.2 and 4.3. Cyanide level decreased as fermentation time increased, and there was no CN detectable by the fourth day. Cyanide content was: 145 mg/Kg (fresh), 28 mg/Kg (non-fermented), 5 mg/Kg (after three days), and 0 mg/Kg (after four days) mg/Kg. Sun-drying reduced cyanide from 145 mg/Kg to 28 mg/Kg in this experiment, an equivalent of 80% reduction.

4.1.2: **Proximate Composition**

Proximate composition changed with fermentation time (Table 4.2). Nutrient contents were as follows: crude protein (%), 3.94, 3.76, 5.76, 5.01; ash (%), 2.82, 2.98, 3.13, 2.73; EE (%), 1.12, 0.89, 0.76, 0.69; and CF (%), 4.3, 4.4, 5.0, 9.12 for fresh, zero day , three day, and six day fermentation periods, respectively. The results show that fibre and glucose increased, while fat decreased significantly ($P < 0.05$). Ash and Crude Protein increased during the first three and four days respectively, and then dropped.

Table 4.1: Effects of fermentation using various water levels on CN and CP Composition of Whole Cassava Tuber.

	Cyanide level (mg/Kg)			Crude Protein (%)		
	Aerobic	S-a	An	Aerobic	S-a	An
day						
0	28	45	37	3.76	3.76	3.70
1	22	40	32	4.64	3.81	3.70
2	22	35	25	5.16	3.84	3.61
3	5	28	10	5.78	3.80	4.30
4	-	28	10	5.86	4.01	4.78

S-a = Semi-aerobic; An = Anaerobic

Table 4.2: Changes in the Nutritional Composition of Whole Cassava Tuber During Anaerobic Fermentation.

	Composition							
day	moist %	CP %	ASH %	EE %	CF %	NFE %	CN mg/Kg	GLUCOSE g/kg
F	63.97	3.94^b	2.82	1.12^a	4.30^b	23.85	145^a	5.62^c
0	6.55	3.76^b	2.98	0.89^a	4.40^b	81.41	28^b	5.60^c
1	6.55	4.64^b	3.08	0.82^a	4.70^b	80.26	22^b	5.68^c
2	7.22	5.16^b	3.01	0.84^a	5.10^b	78.63	22^b	6.62^c
3	6.87	5.78^a	3.13	0.76^b	5.00^b	78.46	5^c	7.50^b
4	6.85	5.86^a	3.04	0.61^b	5.62^a	78.02	2^c	7.30^b
5	6.24	4.90^b	2.94	0.68^b	6.01^a	79.23	0^d	7.80^b
6	6.87	5.01^b	2.73	0.69^b	6.12^a	78.58	0^d	9.12^a
SEM	0.6	0.22	0.31	0.05	0.71	1.98	2	1.70

Values within the same column with different superscripts are significantly different at ($P < 0.05$)

F fresh

SEM Standard error of means

Table 4.3: Composition of Cassava used in the Feeding Trial

	CN mg/Kg	MOIST %	EE %	CP %	CF %	Ash %	CHO %
Fresh	150	66.7	1.0	2.6	4.9	3.3	88.2
1day	40	nd	nd	nd	nd	nd	nd
2day	10	nd	nd	nd	nd	nd	nd
3day	0	7.0	0.7	5.7	4.0	5.0	75.7

nd = analysis not done

CHO = Carbohydrates

4.2.0: Effects of FWCM as a Substitute for Maize in Broiler Diets

Nutrient levels for the various components and diets are summarised in Tables 3.1 and 3.2. Metabolizable energy of the rations was calculated using the estimations of Jansen and Carre (1989). Calculated ME decreased with increase in FWCM level, from 3249 to 2964 and 2991 to 2820 Kcal starter and finisher respectively. Calculated ME values and analyzed proximate composition of maize, sunflower cake, fish meal, and cassava are shown in Appendix Table 1.

Feed intakes, liveweight gain and FCE were compared under one way ANOVA linear model of SAS computer program, for significance (F) tests. The findings are presented in Tables 4.3 and 4.4 and App. 3 - 6.

4.2.1: Feed Intake

The results of feed intake of the six treatments are presented in Table 4.4, Table 4.5 and App. 5 and 6. Means of the total feed intakes (Kg) were 3.95, 3.97, 4.00, 4.01, 3.92, and 4.11 for the successive FWCM substitution levels. Total feed intake was highest at 100% FWCM level (4.11 Kg), and lowest for 40% level (3.94 Kg). Eighty percent FWCM level had very low feed intakes corresponding to low growth rates. The higher FWCM diets had significantly ($p < 0.05$) higher feed intakes over the starting period (Table 4.3), although the 80% had lower intakes which were comparable to the ones of the control diet. During the finishing phase the control, 60% FWCM and 100%FWCM diets had higher ($p < 0.05$) feed intakes than the rest. Thus substitution of maize with cassava did not affect feed intake ($p < 0.05$) of chickens, although, at higher levels of cassava inclusion, feed intakes slightly increased.

4.2.2: Weight Gains

The chicks used in this trial were raised from a weight of 41.0, 41.2, 40.9, 41.0, 41.1 g, and 41.1 to 2.14, 2.07, 1.99, 2.15, 2.09, and 1.89 Kg for the successive FWCM levels over a period of eight weeks. Overall analysis showed no significant difference ($P < 0.05$) in the final body weights. The broilers from treatments which had lower weight gains over the brooding stage increased weight over the finishing stage (Table 4.4) such that there was no difference ($p < 0.05$) in their final body weights.

Average mean liveweight was 2073.1 ± 130 g after eight weeks. These results showed that the chickens fed on 60% FWCM had the highest final body weights, while the ones on 100% FWCM had the lowest over the same period. The results of the birds' weekly live weights and weekly daily gains are shown in Table 4.3 and Table 4.4, respectively.

Live weight gains for the starter and finisher periods ranged from 488.1 to 674.5 g and 1377.3 to 1552.7 g, respectively (Table 4.4). The 20% FWCM substitution level had lower ($p < 0.05$) than the others, during the starter period, but the highest ($p < 0.05$) weight gains during the finishing stage. There was no difference in weight gain ($p < 0.05$) between the control and the 60 and 80% FWCM diets during the two experimental phases. The 100% FWCM diet had lower body weight gains over the finishing period compared to the other cassava-based diets.

4.2.3: Feed Conversion Efficiency

Feed Conversion efficiencies ranged from 0.46 to 0.61; and 0.42 to 0.53 for the starter and finisher periods, respectively. The high FWCM based diets had similar FCE with the control over the two feeding phases except the 100% FWCM substitution level which had low ($P < 0.05$) FCE over the finishing phase (Table 4.4). The 0% and 20% levels had similar FCE while the 40%, 60% and 80%FWCM diets also had similar FCE.

4.2.4: Health Aspects

Generally mortality rate was very low (Table 4.4). Deaths were mainly due to injuries, developmental problems (especially with the liver). Three birds from the 60% and 100% died from mixed microbial infections during the sixth week.

Deformities showed in a few birds during the first three weeks. Most heavy chicks (those weighing 190 g) by the end of week two from all pens showed leg deformities. This were not treatment dependent.

4.2.5: **Cost of Production**

The cost of producing 1 Kg live weight ranged from Ksh. 23.60 to 18.78. There was a decrease in cost of production with the increasing cassava inclusion levels, the 80% FWCM level being the cheapest (Table 4.4).

Table 4.3: Performance of Broilers Fed on FWCM over the Starter and Finisher Periods

	Treatment					
	0%	20%	40%	60%	80%	100%	SEM
WT^s	607.40^{ab}	488.00^{c}	597.90^{b}	674.50^{a}	621.30^{a}	582.40^{b}	± 7.76
FI^s	1028.80^{b}	1065.60^{b}	1112.90^{a}	1097.90^{a}	1039.00^{b}	1113.80^{a}	± 7.16
FCE^s	0.59^{a}	0.46^{c}	0.53^{b}	0.61^{a}	0.60^{a}	0.53^{b}	± 0.01
WT^f	1498.70^{ab}	1552.70^{a}	1377.30^{c}	1447.10^{bc}	1428.30^{bc}	1271.30	±25.46
FI^f	2933.00^{a}	2906.20^{b}	2887.00^{b}	2930.40^{a}	2881.00^{b}	2991.10^{a}	± 5.32
FCE^f	0.51^{ab}	0.53^{a}	0.48^{c}	0.49^{bc}	0.50^{bc}	0.42	± 0.01

Values within the same row with the same superscript are not significantly different ($p < 0.05$)

^{s} starter ^{f} finisher

WT = weight gain (g) FI = Feed intake (g)

FCE = Feed conversion efficiency (ratio)

Table 4.4: Overall Performance of Broilers Fed on FWCM

	FWCM level					
	0%	20%	40%	60%	80%	100%
Parameter						
Initial body weight(g)	41.0	41.2	40.9	41.0	41.1	41.1
final body weights(Kg)	2.14	2.07	1.99	2.15	2.09	1.89
Mean feed intakes(Kg)	3.95	3.97	4.00	4.01	3.92	4.11
Feed Conv. Eff.	0.53	0.51	0.49	0.53	0.52	0.45
Mortality totals	2.00	4.00	2.00	2.00	4.00	4.00
Cost[p] per bird	23.60	23.22	22.94	19.75	18.78	20.81

p = production; Conv = Conversion; Eff= Efficiency

LW = Liveweight

CHAPTER FIVE

5.0.0: DISCUSSION

5.1.0: Effects of Fermentation on the Nutritional Value of Whole Cassava Meal

5.1.1: Cyanide Content

Sun-drying reduced cyanide from 145 to 28 mg/Kg (about 80%) in this experiment. This is because sun-drying provides adequate warmth for effective action of linamarase on cyanogenic glycocydes releasing the free HCN which is also adequately evaporated. Levels of CN reduction under sun-drying however, vary with the climatic conditions and the loading capacity (Gomez et al., 1983). In their paper Gomez et al. (1993), found cyanide levels below 100 mg/Kg in sun-dried whole cassava roots from low cyanide cultivars (CMC-40 and Llanera). Sun-drying, however, does not allow complete elimination of bound glycocyanides. Sun-drying was found by Panigrahi et al. (1992) to reduce cyanide by 92% within three days. Although the percentage loss seem to be high, the residual cyanide was 38 mg/Kg which was composed of mainly the bound form of cyanide. Thus, sun-drying alone can only remove free cyanide, leaving the bound cyanide (toxic) intact.

Fermentation followed by sun-drying effectively helps to eliminate the bound glycocyanides.

Anaerobic fermentation reduced cyanide by over 96%, within three days and totally by the fourth day in this experiment. This is in agreement with Han, (1988) who reported a reduction of between 70-90% within three days. Fermentation followed by sun-drying has also been shown to reduce cyanide by more than 75% (Ravindran et al., 1983, Osei, 1992). Sun-drying on the concrete floor being the best (Gomez et al., 1983). During fermentation, the micro-organisms that feed on cassava produce B-glycosidase enzymes which act on the gylcocyanides to release CN and a glucose molecule. This destroys the bound cyanide which can not be removed through hydrolysis and sun-drying. The micro-organisms also destroy the enzyme Linamarase that liberates HCN from linamarine, hence no HCN remains (Han, 1988).

Although moulds produce B-glucosidase which hydrolyse cyanogenic glycosides, its effect is not much. Anaerobic fermentation in this experiment reduced cyanide effectively more than aerobic fermentation. Gidamis et al. (1993) in a similar experiment reported 11.3 and 5.6 mg/ Kg total cyanide after eight days aerobic and anaerobic fermentations, respectively. This differs with the 10.0 and 0.0 mg / kg total cyanide (aerobic and anaerobic fermentations, respectively) reported in this study after four days. The difference may be the drying periods used. Seven days sun-drying period was used in this experiment unlike the three days oven drying period used by Gidamis et el. (1993). Slow drying eliminates more cyanide than fast drying (Panigrahi et al., 1992). Un-peeled roots require more drying periods as the peel seems to physically hold some cyanohydrins (Gidamis et al. 1993). Oven drying is also not an efficient method of eliminating cyanide (Han, 1988).

It is evident from the results of this experiment that cyanide was fully eliminated by the fourth day. There was a significant decrease between the second and the third day, but no statistical difference ($P < 0.05$) between the fourth and the third day. For the cassava which was used in the feeding trial, the cyanide level was 0 mg/Kg on the third day (Table 4.3). This may be due to difference in the daily temperatures between Nakuru and Busia (22 and 32 degrees respectively). Higher temperatures increase enzyme activity.

It is also evident from this experiment that fermentation using the naturally occurring micro-organisms in water can fully eliminate cyanide from cassava roots. O'brien et al., (1992) reported that traditional water fermentation, followed by pressing and sun-drying reduced the amounts of cyanide in fresh roots (from 91 - 515 mg/Kg to 0 - 11.3 mg/Kg) within two days. In this experiment cyanide was reduced from 145 -150 mg/Kg to 0 - 5 mg/Kg on the third day and 0 - 2 mg/Kg within four days.

5.1.2.0: Proximate Composition

5.1.2.1: Crude Protein

The crude protein increased with the time of fermentation for all the fermentation techniques observed and it was found to be highest in anaerobic fermentation on the fifth day, even though significant increase was realised on the third day. The average CP in the dry pulp has been reported to be 2.0 -2.6% on DM basis (Vogt, 1966) and 4.1% for the peel. The peel generally has more CP than the pulp. The whole root has been found to have 3.0- 4.0% CP (Iyayi, 1989). The CP level in the current experiment was 3.94% for the fresh whole cassava tuber, and 3.76% for the dry non-fermented tuber.

The increase in protein could be coming from the micro-organisms that feed on the cassava starch. Micro-organisms were reported to attack the starch in water and multiply (Oyewole and Odunfa, 1989). The micro-organisms contributed the protein increase (Single Cell Protein). Total protein increased from 3.76% (non fermented cassava to 5.78% on the third day and 5.86% on the fourth day. This increase was significant ($P < 0.05$). There was no difference ($p > 0.05$) in the CP increase between the third and the fourth day.

Guo and Guo (1989) produced a bacterial protein "4320" in a culture using mainly cassava or sweat potato, fermented for 24 h in a solid medium. The original culture had 5.67% CP, while the refined culture produced CP of 22.82%. This experiment shows a slightly lower figure as a total protein of 5.16% was achieved on the second day and 5.78% on the third day. The highest protein percentage was obtained on the fourth day. On the other hand Oyewole and Odunfa, (1989) reported a reduction in protein by 20% within the first 3 days, then a rapid increase within the fourth day. Antai, (1990) using 1 g yeast cells per 30 g cassava mash, noted an increase in CP and a decrease in carbohydrates and lipids. This shows that carbohydrates and lipids may have been utilised by the microbes in protein synthesis.

Under anaerobic fermentation regime more protein was produced than the aerobic one (5.86% and 4.78%, respectively), possibly because the respiratory rate of the micro-organisms is higher in the aerobic one, that could cause oxidation at a faster rate than microbial transformation into protein. Anaerobic fermentation condition is such that there is no oxygen so all the metabolites convert to alanine, a protein. This is not the case with aerobic fermentation. During sun-drying the fungus which was the major agent involved in aerobic fermentation broke off from the cassava. There was thus less of them to be assessed for CP. In semi-aerobic fermentation, it appears that each time it was turned the fungus and the bacteria became dormant whenever they were turned to the surface. This may be the reason why the CP remained low.

The aerobic fermentation results on CP does not agree with Han's, (1988) review. His review reported an increase of up to 8% on CP while this study realised an increase of CP from 3.76% to 4.78% on the fourth day of aerobic fermentation. This variation may be because in the papers Han (1988) reviewed, specific special micro-organisms and fungus were used. It is not possible in our conditions to use specific commercial fungus or yeast as used by Gregory (1977), and Strasen et al. (1970) because they are not available.

5.1.2.2: **Lipids**

The lipid content of cassava is generally low (Serely, 1972). The fresh whole tuber had an average of 1.12% EE. Fermentation reduced the lipid significantly on the third day in this study indicating that perhaps the micro-organisms used lipids to some extent for their nourishment. There was significant difference in lipid reduction between the third and the fourth days.

5.1.2.3: **Soluble Carbohydrates (Glucose)**

The micro-organisms seemed to be feeding on complex carbohydrates and breaking them into soluble carbohydrates. There was an increase in soluble carbohydrates from 5.62 fresh tuber to 9.12 g/Kg on sixth day. The results agree with those of Oyewole and Odunfa, (1989). They found a reduction in starch, and an increase in reducing sugars concentration during the first 36 hours, which decreased for the remainder of the four days. Results from the current study indicate an increase in reducing sugars with fermentation time. The main source of these may be the starch and cyanogenic glycosides that are being broken down.

5.1.2.4: **Ash and Fibre**

There was leakage of inorganic ions during fermentation. This may be the reason of the insignificant decrease in ash content during fermentation and increased ash in fermenter. Other materials may have also leached out leading to increased viscosity of the fermenter (water) and increased CF of the fermented products with time. The CF is in this case increased proportionally because of leakages of ash. The water had a soapy feeling on touch a characteristic of microbe presence. Microbe action caused the texture of the cassava to soften with the time of fermentation which could have caused the leakage. Ash content increased to an appreciable extent after three days of fermentation. This increase in mineral content (as a percentage) may be due to the decrease in carbohydrates present. Individual minerals were however not analyzed. Oyewole and Odunfa, (1989), analyzed individual minerals and noted an increase in Ca, and a decline in Mg, K, Na, Mn, Fe, Cu, Zn, and P as time of fermentation increased, up to the fourth day.

5.2.0: Effects of FWCM as a Substitute for Maize in Broiler Diets

5.2.1: Feed Intake

Birds on the cassava diets consumed more feed than the birds on the control diet. The differences in the feed intake may be due to the differences in ME of the diets as cassava had lower ME than maize (Table 3.1). Birds on higher cassava diets fed more in an attempt to meet their energy requirements. This experiment showed increase in feed intakes with increasing cassava levels, similar with Osei (1992). These results disagree with Gomez (1977) who reported a decrease in the feed intake. He attributed his results to dustiness of the cassava flour.

Dustiness has been reported to reduce feed intakes and acceptability of CRM. The European Economic Community (EEC) has fixed maximum inclusion level at 20% in poultry rations for satisfactory poultry production (Tewe and Egbunike, 1988). The reason given for this includes dustiness of the feedstuffs which causes irritation of the respiratory tract of the chickens unless the feed is pelleted. Some oil is normally added. Pelleting is also recommended as powdery starch has been reported to produce ulcerogenic effects in the gastric mucosa. Dustiness can reduce feed intake in poultry which adversely affects productivity.

Dustiness in this experiment was reduced by the residual oil of the sunflower cake, which may have led to high feed intakes and hence performance. High feed intake in this experiment may also be attributed to the un-decorticated cake that was used. The cassava - fish meal mixture is lower than maize in energy density (Kharjeran and Kharjeran, 1984). They recommended that fat supplement at 2.5 to 3.0% of rations containing over 40% cassava was necessary. This was mainly because they used soyabean cake which has lower residual oil due to its extraction method. To compensate for the inferiority of sunflower to soyabean, more fish meal was used in starter diets. Tewe and Ebunike, (1988) had suggested increased fish meal to make up for methionine in soya based diets.

5.2.2: **Liveweight Gains**

Higher live weights for chicks on FWCM diets in the starter phase (0 -4 weeks) contradicts the generally known facts that cassava based diets reduce growth rates, and produce low live weights (Fetuga and Tewe, 1985 and Maust et al., 1972). Such performance of chicks on higher FWCM diets, also contradicts the results of Vogt (1966) and Yoshida et al., (1966) who recommended that levels of cassava above 10% of the diet should only be used after the fourth week.

Elimination of cyanide by fermentation in this experiment may be the cause of increased live weights. Cyanide has been reported to be a cause in reduction of weight gains (Ofuya and Obilor, 1993). The cassava used by Vogt (1966); Maust et al. (1972) and Fetuga and Tewe (1985), were not fermented and had varying cyanide levels. The peel has higher cyanide content than the pulp (Iyayi, 1991), and therefore likely to depress growth rates. Osei et al. (1990) using un-fermented cassava peel meal reported lower live weights for equal amounts of cassava substituting maize up to 7.5%. The peel meal thus depressed live weights at this low substitution level, with no change in feed intakes. Fermentation, however, improved performance of broilers, in a similar experiment by Osei and Duodu (1988). They found a slight increase (not significant) in the body weights up to 15% fermented cassava peel meal (FCPM) level in the diet.

The higher weight gains in this experiment is also in agreement with the results reported by Wyllie et al. (1984). The same authers using cassava from different fermentation techniques, reported that fermentation in water produced higher weight gains. He found weight gains comparable to the control with up to 56% cassava substitution.

Our results showed a positive correlation between live weight gains and FWCM level over the starter period. This shows that live weights increased with the FWCM level similar to that of Tiemeko (1988); Chou et al. (1974) and Stevenson and jackson, (1983). Lounge and Oluyemi (1977) on the other hand observed a negative correlation between the level of cassava in the diet and growth of broilers. They used a non fermented pulp. In their review they reported poor feed intakes. The poor performance therefore may have been due to the presence of cyanide which reduced feeding. This trial also showed a positive correlation between live weights and F1, unlike what they reported. The insignificant difference in live weights and the positive correlation of liveweight gains with the FWCM level are an indication that it is a comparable feed to maize.

The CP level in the starter diet may have also contributed to the higher performance of chicks in this study. Compared to other works, the protein level used in this trial was higher. Quite a number of trials used CP levels bellow 20%. Tiemeko (1988) used 19.08% for the control and 18.90% for the cassava-based diets. He used soybean meal, fish meal and cotton seed cake for the protein. Gomez et al., (1988) used 21.4% for the control and 19.25% for 30% cassava, Osei (1990) used 21.6% CP, Osei and Doudu (1988) used 21.0% for control and 21.2% for the 15% FCPM. Diets in this experiment were compounded to have 23% CP for the starter and 19% CP finisher, and were balanced for all nutrients. This variations may be because the other experiments varied in CP, with higher cassava levels being inferior in the protein content. The difference in the type and quantity of oil seed cake may also be a cause. The un-decorticated sunflower seed cake used had residual oil of 10.7% EE which boosted the energy in cassava-based diets, to let them compare well with the maize-based diets. Fermentation increased the CP which contributed to the balancing of CP in the diets. More work needs to be done to evaluate the quality of the protein in the fermented cassava. One can therefore use lower levels of cassava (38% of the diet), in the starter diet and higher levels (58%) in the finisher diets.

Increased feed intakes sometimes leads to increased growth rates especially when the FCE are similar. Even though the birds on cassava-based diets had higher feed intakes, the feed intakes may not have been very advantageous to their weight gains. The following regression model of weight over feed established in this experiment does not show much advantage

$$WT = 16.37(FI) - 395.24$$

Where; WT= body weight

FI= Feed intake

However, the results of the finisher phase show a decrease in weight gain as the FWCM levels increase. This negative trend could be due to the reduced FCE. Cassava has been reported to have lower FCE than maize (Chou et al., 1974). High FCE over the starter period were as a result of the high fish meal used, as fish meal contributes lysine and methionine, the most limiting amino acids in cassava-based diets. Low FCE in this case may also be due to the high sunflower oil, and glucose levels in this diets.

5.2.3: **Feed Conversion Efficiency**

Feed conversion efficiency for FWCM-based diets were similar to that of the control (Table 4.4). This may be because of fermentation. Cassava is known to have low digestibility which varies with processing (Montaldo, 1977). In this review cassava was reported to have digestibility of 48.3% in raw state and 77.9% when roasted. Effect of fermentation on digestibility was not studied in the current study. Poor FCE of cassava reported in the literature review, may be due to the poor protein quality of cassava, and lack of essential trace minerals (Adegbola 1975). They may also be attributed to the binding of metabolic electrolytes like Fe, Cu, I, and Zn. It may also be due to utilization of methionine, and/or pyruvate key energy metabolites during detoxification of cyanide in the body which lowers energy production. Supplementation of these minerals increases FCE and broiler performance. FCE in this experiment was similar to that of the control. This is contrary to Tiemoko (1988) who found a decrease in nutritional efficiency with increasing feed intake of diets high in cassava level ($\geq$ 30%).

Better FCE in this study compared to reported FCE of cassava-based diets may also be due to the increased soluble carbohydrates during fermentation. Soluble carbohydrates are easily assimilated and hence improve feed utilization efficiency. FCE ratios of non fermented peel meals were also found to be low compared to the FCE of the fermented peel meals in the experiments of Osei (1992). Reduction in the FCE during the finishing period may be due to the increased tendency to deposit fats, which takes more energy. Post mortem examination done on dead birds showed high fat on the carcase of the bird from the high cassava diets. This is contrary to reported fat characteristics of broilers fed cassava based diets (Ekpenyong and Obi, 1986). Abdominal fat has been known to decrease with increasing cassava levels.

6.0.0 CONCLUSIONS AND RECOMMENDATIONS

Three day fermentation period in this experiment was found adequate. At this time proximate composition was 6.87, 5.78, 3.13, 0.76, 5.0, 78.46 percent, moisture, CP, ash, EE, CF, and NFE respectively. Cyanide and glucose levels were 5 and 7.5 mg/Kg, respectively. Beyond the third day, EE and CP decrease ($P < 0.05$) and CF increase ($P < 0.05$)(Table 4.2). Compared to non fermented cassava, CP was higher ($P < 0.05$), and cyanide lower ($P < 0.05$). There was a significant increase in CP, and glucose accompanied with a decrease in EE, and cyanide between the second and the third day. Crude fibre on the third day had not significantly changed, but showed a significant change on the fourth day. To avoid further reduction in fats, and increase in fibre, it would be advantageous to stop fermenting on the third day. Osei et al. (1990) and Osei and Duodu (1988) under Canadian conditions (22 ^{0} C) in their experiments, quoted having fermented cassava peel meal for three days. No explanation was given for having chosen the third day. Fermentation for periods above three days would be a waste of time and would lead to loss of fats and minerals causing the cassava to become more fibrous. Even though cyanide is still decreasing, the remaining (below 5 mg/Kg) is below the critical levels (O'brien, 1992). For the cassava used in the feeding trial, the cyanide content was zero by the third day. The difference in CP and glucose between the fourth and the third day was not significant ($P < 0.05$).

Presence of cyanide has been the main limiting factor for use of cassava in livestock feeds. Use of low cyanide cultivars like "Nabwire" may to some extent improve cassava use. Gomez et al. (1983) using low cyanide, cultivars found performance to be similar to a commercial control. Age of harvesting is also very important (Gomez et al., 1983). Young cassava roots have very high CF, as the fibrous tissue is the first to form. As the plant matures it deposits more carbohydrates in the roots (feed reserves), which forms the pulp. After 12 months the feed resources are depleted and CF increase, and rotting is common (personal experience). The best harvest time is thus 10 to 12 months (Gomez et al., 1983). Cyanide levels also decrease with age and is lowest over this time. It is advisable, therefore, to harvest when the cyanide levels are lowest, because the higher the starting cyanide content, the more time it may require to totally eliminate it. There are different views on the maximum concentration at which cassava root meal of different cyanide content can be included in poultry diets without any adverse effects on production, recommendations varying from 100 mg/kg (Vogt, 1966). Gomez et al. (1988) reported that cyanide content of 83 mg/kg in finished diet did not affect chick growth, while Yoshinda (1966) observed adverse effects at 36 ppm cyanide concentration. In a feeding trial to determine toxicity Panigrahi et al. (1992), reported no adverse effects when using a diet with 38 mg/kg cassava at 500 g/kg replacing maize. He found the liver and pancreas weights abnormally higher than normal, and bile in the excreta. This was in a two week feeding period. This indicates that in a longer feeding period deaths would occur, and weight gains would be affected. Thus lower starting concentrations (10 mg/Kg total CN) are appropriate.

Fermentation seem to be the cause of the improved performance as non fermented cassava has been reported to always produce low live weight gains. The relative weekly live weights and FCE for the diets based on FWCM level used in this experiment are probably a reflection of the relative feeding values of these diets. The whole meal is a better diet than either the peel or the pulp separate. Tewe (1984) found the peel to increase feed intakes, reduce body weight gain, and reduce nutrient utilization when fed to broiler at levels between 0 and 30.5% replacement of equal amount of maize, even with addition of palm oil and groundnut cake. This experiment realised total substitution of maize. Earlier reports in the review, show low substitution levels of the pulp.

It is evident therefore that fermented whole cassava meal can fully substitute maize in broiler starter diets, even though total cassava will be lower than total maize, and more of the sunflower cake (oil seed cake) is required, to balance for the nutritional deficiencies in cassava flour. In evaluating feeds, economy of gain and final body weight must naturally receive most consideration. The advantage of high final body weight may be offset by high cost of production. Even though total substitution of maize with FWCM seemed to reduce the final live weights, these weights are within the acceptable market weights in Kenya. The Kenyan market buys chicken at between 1.2 to 1.6 kg dressed weights. The 1.8 kg live weight birds (Table 4.4) are within acceptable limits because they yield between 1.5 to 1.6 kg dressed weight. In cases where the farmers are interested in high weights at low cost of production, the 100% FWCM could be the best. But when early maturity is being considered, the 60%FWCM substitution level is the best as the broilers were ready at the end of six weeks (1750 g). This also lowers the cost of production. These results agree with Osei and Duodu (1992). They attributed their results to fermentation. The peels were fermented for three days. Total replacement of maize with FWCM produced diets which were more than KSh. 200 cheaper than the maize diet and Ksh. 300 cheaper than the commercial diets for each 70 Kg bag.

It has been demonstrated within the limits of this experimental conditions that:

a) Anaerobic Fermentation (under water) of cassava root tubers reduces cyanide and increases protein proportionately more than aerobic fermentation.

b) For maximum elimination of cyanide and achievement of suitable proximate composition, anaerobic fermenting of whole cassava for three days is adequate.

c) Total substitution of maize grains with FWCM is feasible, although a substitution of 60% FWCM appears to give the best results.

d) Further work is required to compare cost systems using varying combinations of various oil seed cake processed through the ram-press to establish if higher cassava levels can be used than was used in this study.

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Appendix 1: Proximate composition of the feedstuffs used in the feeding trial

	DM	CP	CF	EE	Ash	NFE	ME (MJ/KG)
Maize	86.2	9.5	2.5	3.6	1.4	83.6	14.9
Fish meal	83.0	58.3	4.2	4.2	9.4	23.9	14.2
Sunflower	75.0	30.1	28.0	10.9	1.9	29.1	10.9
Cassava	93.0	5.7	4.0	0.7	5.0	75.7	13.9

ME Was calculated using the formulae of Janssen and Carre (1989)

ME =

Maize = 17.74 - 0.014 CP + 0.489 CF - 0.668 Fat

Cassava = 16.96 - 0.182 ash - 0.143 CF

Sunflower = 16.73 - 0.791 ash - 0.245 CF + 0.24 Fat

Appendix 2: Weekly live weights (g) of broilers on different treatments

	Age (week)							
	starter period				finishing period			
% FWCM	1	2	3	4	5	6	7	8
0	80.8	162.2^a	408.2^a	642.5^a	926.8^a	1254.6^a	1678.5	2143.9
20	76.5	150.5^b	385.0^a	533.2^b	778.2^b	1194.4^a	1709.1	2075.2
40	73.9	158.4^b	415.2^a	639.3^c	938.1^a	1228.3^a	1754.3	1993.3
60	92.9	182.1^c	461.1^b	714.6^a	1024.0^a	1455.3^b	1675.7	2154.7
80	85.6	172.4^c	413.9^b	662.1^a	957.7^a	1377.4^a	1750.5	2094.5
100	79.1	167.1^a	416.9^b	623.7^c	904.2^a	1370.6^a	1688.0	1887.0

Values within the same column with similar superscripts are not statistically different ($p > 0.05$)

Appendix 3: Total live weight gains (g) of broilers on different treatments over the starter period

	Treatment					
	0%	20%	40%	60%	80%	100%
R1	601.4	492.2	597.8	674.7	621.0	582.4
R2	600.6	492.0	610.0	658.0	611.0	580.0
R3	621.0	480.0	586.0	690.7	632.0	596.0
Means	607.4	488.1	597.9	674.5	621.3	586.1

T1 - T6 Treatment one to six

R1 - R3 Replicates one to three

Appendix 4: Total live weight gains (g) of broilers on different treatments over the finisher period

	Treatment					
	0%	20%	40%	60%	80%	100%
R1	1504.8	1542.0	1354.1	1440.0	1432.5	1263.4
R2	1549.1	1563.2	1370.2	1492.0	1489.0	1321.7
R3	1442.1	1552.8	1407.6	1409.3	1363.3	1228.8
Means	1498.7	1552.7	1377.3	1447.1	1428.3	1271.3

T1 - T6 Treatment one to six

R1 - R3 Replicates one to three

Appendix 5: Total feed intake (g) of broilers on different treatments over the starter period

Treatment

	0%	20%	40%	60%	80%	100%
R1	1007.5	1069.7	1118.9	1083.7	1039.0	1121.4
R2	1039.5	1067.0	1099.9	1080.0	1035.0	1112.0
R3	1039.5	1060.0	1120.0	1130.0	1043.0	1108.0
Means	1028.8	1065.6	1112.9	1097.9	1039.0	1113.8

T1 - T6 Treatment one to six

R1 - R3 Replicates one to three

Appendix 6: Total feed intake (g) of broilers on different treatments over the finisher period

	Treatment					
	0%	20%	40%	60%	80%	100%
R1	2946.0	2905.3	2881.0	2929.3	2881.0	2992.6
R2	2940.5	2903.3	2900.1	2936.0	2885.0	2988.0
R3	2912.5	2910.0	2880.0	2926.0	2877.0	2992.6
Means	2933.0	2906.2	2887.0	2930.4	2881.0	2991.1

T1 - T6 Treatment one to six

R1 - R3 Replicates one to three