EVALUATION OF CASSAVA *(Manihot esculenta* Crantz*)* **ROOT PRODUCTS AS REPLACEMENT FOR MAIZE** *(Zea mays* Linn*)* **IN PULLET AND LAYER PRODUCTION**

BY

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ABSTRACT

Availability of dietary energy is a major problem in poultry in Nigeria. Maize, a conventional energy ingredient is expensive. Cassava, which could be a cheaper alternative energy source, has not been tried in Nigeria. The performance of pullets and layers fed various Cassava Root Products (CRP) was examined in this study.

The study was divided into two phases. In the first phase, 408 pullet chicks, 240 growing pullets and 240 layers were each allotted to eight diets. In diets 1, 2, 3, and 4, maize was replaced with 0%, 25%, 50% and 100% of Unpeeled Cassava Chips (UCC). Diet 5 contained 25% Peeled Cassava Chips (PCC), while diets 6, 7, and 8 had 25%, 50% and 100% replacement with Unpeeled Cassava Pellets (UCP). In phase two, UCC, UCP were compared with Unpeeled Cassava Grits (UCG) which replaced maize at 50% and 100% in the diets of 210 chicks, 210 growers and 315 layers. The Control Diet (CD) contained 100% maize. All experiments were in a completely randomized design with three replicates of 17, 10, 10, 10, 10 and 15 birds per replicate, respectively. Parameters measured for all the birds included Feed Intake (FI), Weight Gain (WG), Feed Conversion Ratio (FCR) and mortality. Age at First Egg (AFE) and Hen Day Production (HDP) were also recorded for growers and layers, respectively. Feacal and blood samples were collected for nutrient digestibility and serum thiocyanate determination. Data obtained were analysed using descriptive statistics and ANOVA (P=0.05).

Birds fed 25% CRP were not significantly different from those on CD for all the parameters. The WG of chicks fed 50% and 100% UCC and 100% UCP were significantly lower than those fed CD. Average FCR of 50% CRP was similar to those on CD. There were no significant difference between growers fed CRP and CD for WG (8.4

g/day - 10.0 g/day), FCR (8.0 – 9.4) and mortality (0.0-3.6%). Average FI, HDP and WG of layers fed 100% UCP were significantly lower than those on CD. Average FI, WG, and FCR of chicks fed 100% UCG (31.2 g/day, 10.7 g/day and 2.9 respectively) were similar to those on CD (30.9 g/day, 10.7 g/day and 2.9, respectively). Performances of growers fed UCG were not significantly different from that of CD, while AFE of growers fed 100% UCC (153 days), and 100% UCP (154 days) were higher than those on CD (146 days). Average HDP of layers fed 100% chips (57.8%), pellets (58.6%) and grits (58.3%) were significantly lower than those on CD (63.1%). Feed intake and WG for layers on 100% UCG were similar to those recorded for the CD. Nutrient digestibilities of growers were similar. Nitrogen retention of chicks and layers fed 100% CRP were lower than those on CD. Serum thiocyanate values of layers fed 50% CRP were higher than CD and lower than 100% UCC, UCP and UCG.

Complete replacement of dietary maize with cassava chips, pellets and grits resulted in optimum performance for growers while 50% replacement achieved same for chicks and layers.

Keywords: Cassava root products, Egg production, Feed intake, Pullets, Alternative poultry feed.

Word count: 499

CERTIFICATION

I certify that this work was carried out by M. A. Mosobalaje, in the Department of Animal Science, University of Ibadan, Ibadan, Nigeria.

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DEDICATION

This work is dedicated to Late Pa Tiamiyy Ayinla Mosobalaje and Late Madam Hosenat Awero Mosobalaje, may their souls rest in perfect peace.

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CHAPTER ONE

INTRODUCTION

1.1 Statement of fact

Africa is currently plagued with food crisis partly due to increase in human population and the drop in per capital food production particularly in the last decade. The food deficit situation is indeed more serious with protein deficiency when compared with the availability of calories. Shortage of protein is prevalent in all parts of West African countries where protein supply from livestock products (to include contributions from fish and wildlife) was estimated to be only 3.0 g/ caput/ day in 1993 and a projection of 5.2g/caput/day has been made for the year 2010 (Shaib *et al.*, 1997). These figures are still far cry from the 35g/day recommendation of FAO (1986). However, with the economy of many third world countries including Nigeria improving, there appears to be increased demand for animal products and especially meat and egg (Leeson and Summer, 1997). Poultry production is a good area to target in the livestock sub-sector for increased animal protein supply to meet the consumption needs of Nigerians. Poultry has a short generation interval and can be multiplied quickly. In fact, it has rapid turnover compared with other livestock species (Longe, 2006).

Energy supply for poultry feeding is a major problem facing poultry industry in Nigeria. The energy component of poultry feed constitutes the largest proportion of compound feed for efficient productivity (Tewe, 2004). The deplorable level of livestock production in the third world countries has been attributed to a number of factors which include the spiraling price of cereals due to competition for it by both human and animals. Shortage of cereals especially maize has recently been a serious issue in several regions of the world: in many of these the use of 1cereal products as livestock feeds is increasingly unjustified in economic terms. The current food crisis fuelled by the diversion of maize for bio-production fuel has further reduced the availability of this cereal for human and animal consumption. As a result of increasing use of maize for producing ethanol and bio-fuel, maize prices in the United States increased from $2.60 a bushel in 2006 to near $4 a bushel (35.24litres) in 2007 (Chanyuarong *et al*., 2009).

The astronomic increase in price of maize, which is the major energy source in African countries, constitutes a major problem in poultry production. Non-ruminants like poultry are markedly affected by such a trend. Therefore, there is need to exploit cheaper energy sources, to replace expensive cereals for livestock production to relieve the food/ feed competition in the nation.

1.1.1 Alternative energy sources

The Presidential task force on alternative formulations was constituted in Nigeria in 1989 in recognition of the need for alterative energy sources. Compilations from its various committees revealed the possibilities of formulations from a variety of alternative ingredients as energy sources among which are wheat, millet, sorghum, sweet potatoes and cassava. Cassava is very appropriate for this purpose. Cassava being a cheap energy source offers great potential as a viable alternative to scarce maize (Balagopalan *et al*., 1988). It is abundantly produced in Nigeria with about 50 million tonnes produced annually (FAO, 2008). Potential of cassava for livestock feed is further justified by the expanding bio-fuel market which has forced livestock production to the more available cassava as energy source.

1.1.2 Production of cassava in Nigeria

Nigeria is presently the largest producer of cassava in the world with 49.5 million tonnes annually (FAO, 2008). This is still very far from 150 million tonnes per year target by the Federal Government initiative on production and export of cassava (Philip *et al*., 2004). Cassava (*Manihot esculentum* Crantz), is a staple food widely grown in the tropical Africa, because of its efficient production of cheap energy, year-round availability, tolerance to extreme ecological stress conditions, and suitability to present farming and food system in Africa. Cassava is capable of providing high energy/ha, about 13 times more than maize and guinea corn (Oke, 1978). Cassava productivity in terms of calories per unit land area per unit of time is significantly higher than other staple food crops as cassava can produce 250 x 10^3 cal/ha/day compared to 176 x 10^3 cal/ha/day for sorghum (Balagopalan *et al*., 1988). Cost of production per metric tonnes is lower for cassava when compared with alterative food stables (Nweke and Ezumah, 1992).

1.1.3 Nutritive value of cassava

The cassava tuberous root is essentially a carbohydrate source. Its composition shows 60-65% moisture, 20-30% carbohydrate, 0.2-0.6% ether extract, 1-2% crude protein and a comparatively low content of vitamins and minerals. However, the roots are rich in calcium and vitamin C and contain a nutritionally significant quantity of thiamine, riboflavin and nicotinic acid. Of its carbohydrate, 64-72% is made of starch. The starch content increases with the growth of the tubers and reaches a maximum between 8^{th} and 12^{th} month after planting. Thereafter, the starch decreases and fibre content increases.

Cassava roots also contain sucrose, maltose, glucose and fructose in limited levels (Tewe, 2004).

1.1.4 Utilization of cassava in livestock feeding

Researchers in Africa have long recognized cassava as an appropriate animal feed and it has been recommended as an important and cheap feed in poultry feed. Tewe (1991) indicated that the development of cassava products, which meet minimum requirement for incorporation into commercial livestock production in cassava producing areas, would relieve the pressure on the demand for available cereal grains. However, these research findings have not been demonstrated in commercial livestock feed in Africa. Of a total production of 87 million tonnes annually produced in Africa, only 6% of this is used in livestock production mainly in traditional system (IFAD and FAO 2000). Expressing feed usage as a percentage of total production showed that maize used for livestock feed stood at 20% of total domestic production while cassava stood at 5% of total production in Nigeria in 2000 (Tewe, 2004). Inclusion of cassava in commercial livestock feed in Nigeria still stands at less than 10% even at period of scarcity of maize in the country (Tewe, 2004). Expanding cassava usage for food into commercial livestock raw materials is essential to eliminate cycle of glut that is related to large harvest of cassava.

The use of cassava flour in animal feed started at a commercial level in the 1970's when Thailand launched an aggressive programme to produce and export cassava chips to European Economic Countries (EEC). In 1970, about 1 million tonnes of cassava flour and pellets were exported from Thailand to the European Union (Buitrago *et al.*, 2002). By 1989, the volume increased to 9.0 million tonnes (Howeler, 2007).

In Columbia, the use of cassava for animal feeding has been practiced during the last 30 years. However, the volumes used did not match the tremendous market potential that the balanced feeds sector offers in Colombia and other Latin American countries. Latin American and Caribbean Consortium to Support Cassava Research and Development (CLAYUCA) was established to contribute to solve the problem of relatively low use of cassava products in animal feeding (Buitrago *et al*., 2002).

In Thailand, cassava is one of the most important economic crops. The country produces approximately 18-22 million tonnes of fresh roots annually of which approximately 8 million tonnes are used for starch production and the remaining 10-14 tonnes are processed into 4.5-6.0 tonnes of dried chips and pellets for animal feed. The chips are mainly utilized domestically while the pellets are exported to European Economic Countries (EEC) (Kanto and Juttopornpong, 2002). While in Vietnam, annual fresh cassava root production is about 2 million tonnes (GSO, 2001) most of which is used for animal feeding (Le Due Ngoan and Ly, 2002).

In African countries, total usage of cassava for feed varies from 0-10% (Tewe, 2004). While in Nigeria, annual cassava production is about 50 million tonnes (FAO, 2008) only about 5% is used in animal feed (Tewe, 2004).

Utilization of cassava in commercial livestock feed industry as animal feed ingredient is hampered by three major limitations. These limitations include excessive fine nature of cassava that leads to dustiness, low crude protein content and presence of antinutritional factor i.e cynogenic glucosides that liberate hydrogenic acid (HCN). To improve utilization of cassava in livestock feed, cassava based rations must be balanced for all the nutrients and in particular energy, sulphur containing amino acids, phosphorus, zinc, iodine and vitamin B_{12} (Khajarern and Khajarern, 1992). Palatability of cassava based ration is an important factor limiting feed intake of poultry. Physical properties such as dustiness and bulkiness are closely related to palatability and limit feed intake. Further processing of cassava based diets including pelleting and the addition of fat to eliminate dust improve texture of the diets. Fat supplementation supplies essential fatty acids and additional energy to cassava based rations (Balagopalan *et al*., 1988).

Many traditional processing methods have been developed in various parts of the world for preparing cassava for human consumption and feed. In Nigeria, these methods include sun-drying, fermentation, frying, cooking etc. Pelleting is a novel method of processing cassava into livestock feed, apart from reducing dustiness of cassava products, steam pelleting also assist in the volatization of free hydrogenic acid (HCN) (Leeson and Summer, 1997). However, due to high cost of importing cassava pelletizer, cassava pellets production in Nigeria has been limited to native pellets. These pellets are only the original mash enclosed in a hard capsule and have not benefited from the cooking process brought about by moisture and heat. Alternative to cassava pellets is cassava grits. Cassava grit is a gelatinized cassava product. It is produced like gari except that it is not peeled and sieved. The processing steps for preparing cassava grit include: detailing (cutting of stalk and tail), washing, grating, dewatering (squeezing out of the excess water) and frying. Processing cassava into grit will produce grit form that has thoroughly benefited from cooking process and will not result into original mash form when milled.

1.2 Objectives of the study

The main objective of the study was to evaluate performance of pullets and layers fed cassava root products

The specific objectives of this study are:

1. To determine the nutritive values of cassava chip, pellet and grit.
2. To evaluate the effect of substituting cassava root products for maize on performance and nutrient utilization of chicks, growers and layers.
3. To determine the effects of feeding cassava based diets on egg quality.
4. To study the toxic effects of cassava as determined by hydrocyanic acid and serum thiocyanate levels.
5. To determine the economic evaluation of cassava substitution in poultry diets .

1.3 Justification of the study

- The capacity and potential of cassava production in Nigeria demand for expanded utilization.
- The caloric density of cassava root products proves that it is a viable alternative to maize.
- The skyrocketing price of maize demands for alternative energy sources.
- Utilization of cassava products for poultry feeding in Nigeria will solve the problem of cassava glut and provide expanded market.
- Reduction of dustiness in cassava through pelleting and grit producton will encourage utilization of cassava for poultry feeding.
- Chemical composition of different cassava products is needed for effective utilization.
- Appropriate formulation of diets containing cassava products that will give efficient production and better economics gain is needed.

- Economic evaluation through partial budgeting will demonstrate the economic advantage of cassava utilization in pullet and layer production over maize.
- Sensitivity analysis will provide break even price of cassava.
- Economic evaluation of the project will enhance link between town and gown

1.4 Criteria for the evaluation of objectives

The under listed parameters will be used to evaluate the responses of experimental replacement pullets and laying chickens to the above-mentioned experimental investigations.

- Performance indices: Feed intake, efficiency of feed utilization, mortality, egg producing ability of the birds.
- Proximate composition
- Hematological and serum biochemical evaluation
- Egg quality analysis
- Economic analysis through cost of production, partial budgeting and sensitivity analysis.

CHAPTER TWO

LITERATURE REVIEW

2.1 Energy sources in poultry feed

The energy composition of livestock feed constitutes the largest proportion of compound ration for efficient productivity. The major ingredients used in poultry rations are energy and protein feedstuffs which are supplemented with vitamins and minerals (Longe, 2006).

Generally, cereals (grains) represent the major source of energy in poultry feeding (Austic and Nesheim 1990). Among grains, the energy level of corn is the best for poultry, making the corn a reference for feed formulation. Corn has become the major cereal in poultry diets, and because of its inclusion level, it is usually the major source of energy (Leeson and Summer, 1997). In poultry rations, maize constitutes about 50% of the diet. However, shortage of cereals has recently been a serious issue in several region of the world (Khajaren and Khajerren, 1992). Tewe (2002) added that the shortage has also reduced quality of maize due to large variation in the commodity for the industry. The poultry industry is thereby going through a terrible frightening and depressing phase due to scarcity of this major commodity. Other cereals used as energy sources in poultry feeding include sorghum, millet, barley and wheat. Other energy sources include sweet potatoes and cassava.

2.2 Cassava as a feed source for poultry

Cassava according to Tiemoko (1992) is an energy source that could take the place of maize or other cereal used for feeding poultry in tropical Africa. The incorporation of cassava feeds for production started with the experiment of Tabayoyang who extracted a product from cassava starch and fed this to chicken (Tabayoyang, 1935; Balagopalan *et al.*, 1988). Cassava roots contain energy value of more than 3000kca/metabolisable energy per kilogram (Stevenson and Jackson, 1983).

Onabowale (1992) reported that detoxified cassava tubers supplemented with other locally available ingredients and vitamins provided a complete feed formulation for growing and laying birds at rates varying from 40 to 50 percent of the concentrate mixture. His findings from animal feeding studies revealed that detoxified cassava based ration compared well with the maize based commercial feeds. Egg production efficiency of chicken fed cassava based diet was higher than chickens on maize based diet. He also found that feed conversion efficiency of cassava based grower feed was the same as that of the maize based feed.

Tewe and Bokanga (2001) reported that a cassava root and leaves mixture in the ratio of four to one completely replaced maize in poultry feed and reduced cost without a loss in weight gain or egg production. Stevenson and Jackson (1983) also reported that a rate of up to 50 percent cassava in the diet by no means impaired the growth performance of poultry. However, Willie and Kinabo (1980) observed a linear decrease in weight of poultry resulting from the increasing in the quantity of cassava inclusion in the ration.

Tiemoko (1992) reported that when rate of inclusion of cassava flour in poultry diet exceeded 10 percent, the feed consumption index increased, resulting in nutritional deficiency of the diet. Hamid and Jalaludin (1972) reported that replacement of up to 60 percent of corn diet with cassava did not affect feed efficiency and egg production. Higher levels of cassava (75%) increased feed intake but feed efficiency was less (Jalaludin and Leong, 1973). Ngoka *et al*. (1984) recommended substitution of up to 75 percent with appropriate processing to detoxify the root meal. Buitrago *et al.* (2002) suggested that inclusion of cassava should not exceed 25% in the diet. However, Khajarern and Khajarern (1986) and Saentaweesuk *et al*. (2000) found that laying hens on 100% cassava diet had similar production performances to those on 100% maize diet.

Phalaraksh *et al.* (1979) reported that under heat stress conditions, cassava fed pullets were more tolerant to stress and showed lower loss (42%) in terms of mortality than those fed corn or broken rice.

Ademosu and Eshitt (1980) found that varying levels of cassava up to 40% did not affect the feed conversion, egg production and egg weight from feeding trials conducted on starter and grower chicks. They concluded that pullet diets should not contain more than 15 and 30% cassava root meal respectively. In a study conducted by Rangilal *et al*. (1995), broiler birds were fed cassava based starter and finisher diets. It was concluded that up to 40% of maize in broiler starter diet could be replaced with cassava diet without adversely affecting live weight and feed intake. In finisher diets (weeks 6-8), 60% could be replaced with cassava meal. Ochetim (1992) also reported that cassava root and leaf meal (CRLM) in the proportion of 3:1 could replace 50% of maize in broiler diet. Buitrago and Luckett (1999) found that 20% inclusion of cassava gave a satisfactory performance for broiler.

Monitilla *et al.* (1969) found that the feed efficiency decreased as the percentage of inclusion of cassava increased, probably as a result of the powdery characteristic of cassava root meal. The excessive fine nature of cassava root meal could be reduced by pelletization which has been found to improve feed intake (Balagopalan *et al*. 1988).

In nutritionally balanced pelleted cassava feed, up to 58% replacement of maize was reported to give satisfactory performances in broiler (Chou and Muller, 1972). However, Tewe and Bokanga (2001) reported total replacement of maize with cassava pellets in layer diet.

Cassava containing diet could be improved by the addition of fish meal (Jalaludin and Leong, 1773) methionine (Balagopalan *et al.*, 1988) fat and oil (Hutagalung, 1972) and vitamin C (El-Boushy *et al.*, 1968). Buitrago and Luckett (1999) stated that the low concentration of essential nutrients present in cassava root flour can be compensated satisfactory by including soya beans in the balance feed and the resulted product compared favorably with maize as shown in Table 1.

Table 1: Nutritional composition of cassava flour (82%) mixture with integral soybean (18%) as compared to that of maize

Nutrient	Cassava flour 82% integral soybean 18%	Maize
Metabolizable energy, MEcal/g	3.25	3.34
Protein, %	9	8.5
Lysine,%	0.46	0.26
Methionine,%	0.12	0.18
Methionine+cystine,%	0.24	0.35
Threonine,%	0.28	0.29
Thryptophane, %	0.10	0.07
Arginine, %	0.51	0.40
Fat, %	3.5	3.6
Linoleic acid, %	1.7	2.1
Fiber, %	3.9	2.8
Ash, %	3.6	2.1
Calcium, %	0.29	0.04
Available phosphorus,%	0.09	0.08

Source: Buitrago and Luckett (1999)

2.3 Chemical composition of cassava root

Cassava roots are primarily a source of carbohydrate and are virtually known to be notoriously deficiency in protein (Tewe and Egbunike, 1992). Available reports on the detailed chemical composition of cassava vary widely depending on the age of the plant, variety, climatic conditions, cultural practices followed, etc (Balagopalan *et al*., 1988). Proximate composition of cassava and some of its products is presented in Table 2.

The cassava root has an average composition of 60-65% moisture, 30-35% carbohydrate, 0.2-0.6% ether extract and a comparable low content of vitamins and minerals (Omole, 1977) and a nutritional significant quantity of thiamine, riboflavin and nicotinic acid (Balagopalan *et al*. 1988). The carbohydrate fraction contains 3.2% to 4.5% crude fiber and 95% to 97% Nitrogen Free Extract (NFE). The NFE contain 80% starch and 20% sugars and amide (Balagopalan *et al*. 1988). According to Gomez *et al.* (2005), cassava starch contains 17% amylose and 83% amylopectin in contrast to corn starch which is about 28% amylose and 72% amylopectin. The amylase content of barley, rice and maize is higher than that of cassava starch (Chauynarong *et al.,* 2009). Cassava root has been reported to have about one third the amylolytic activity of corn and is highly digestible, yielding a digestible energy of 4000keal ME /kg of dry root meal for pigs as compared with 4,055kcal/kg of maize (Ketiku and Oyenuga, 1970). Khajarern and khajarern (1992) estimated metabolizable energy of cassava for poultry to vary between 2.87 -4.27kcalME/kg of dry cassava root and they added that cassava root meal contains very low levels of protein (2.5%). Starch is the main carbohydrate in cassava 64% - 72% (Tewe 2004), it also contain sucrose, maltose, glucose and fructose to limited levels

(Balagopalan *et al*. 1988). Streeramamurthy (1977) reported that the raw cassava starch has a digestibility of 48.3%, while cooked starch has a digestibility of 77.9%.

Cassava root is a poor source of protein making the economic utilization of roots in animal feeds highly dependent on the incorporation of other protein rich ingredients (Maini, 1973). However Tewe (2004) stated that the quality of cassava root protein is however, fairly good as far as the proportion of essential amino acid as a percentage of total nitrogen is concerned. Methionine, cystenine, and cystine are the limiting amino acids in the cassava roots. Only about 60% of the nitrogen is derived from amino acid and about 1% of it is in the form of nitrates, nitrites, and HCN (Balagopalan *et al*,. 1988). The remaining 38 – 40% of the total nitrogen remains unidentified. However, Maner (1973) reported that out of the total nitrogen; only 50% existed as true protein, while the remaining existed in the form of free aspartic and glutanic acids. In contrast of this, Oyenuga (1968) reported that 62% of the total nitrogen was true protein. The levels of lysine and tryptophan are high in the true protein fraction. Essential amino acid profile of cassava tuber and leaf is presented in Table 3.

The lipid fraction of cassava flour is 0.25% and it is 50% extractable with conventional solvents (Hudson and Ogunsua, 1974). Only about 1.46 percent of lipids in cassava are linoleic acid (Hilditch and Williams, 1974). This is very low compared to corn that contains about 4% fat with about 50% linoleic acid, (Austic and Neishem, 1990).

According to Austic and Neishem (1990), linoleic acid must be present in the diet of growing chick or they will grow poorly and layer fed diets severely deficient in linoleic acid will lay very small eggs that will not hatch well. Thus, maize is considered a good source of this essential fatty acid in poultry rations. The component fatty acids of cassava are relatively saturated compared with the structural lipids of the potato (Balagopalan *et al.*, 1988). The extractable lipids in cassava are mainly polar galactosyl diglycerides, and the fatty acids are mainly saturated (Hudson and Ogunsua, 1974). Balagopalan *et al*. (1988) stated that it is quite possible that linoleic acid deficiency may be created in cassava ration, it thus imperative to supplement cassava based diet with fat.

Cassava roots are relatively poor source of minerals and vitamins. However, there is a high content of calcium and phosphorus in the tubers (Balgopalan et al., 1988) unlike corn that is low in sodium, calcium and available phosphorus (Austic and Neishen 1990). The mineral content of the dry bark is higher than that of the cortex. Calcium values in the whole root range from 15 to 129mg/100g, while phosphorus value is approximately 100mg/100g. The content of iron in the central cylinder is 32mg/100g, while in the bark it is 77mg/100g. Vitamin C content of raw root ranged from 38.5 – 64.6mg. Drying reduces the vitamin C content apparently with values going down to 2.0 – 13.0mg/100g (Tewe, 2004).

The main anti nutritional component in cassava are cynogenic glycosides, linamarin and lotaustralin, which are hydrolysed to hydrogen cyanide (HCN) by endogenous enzymes, linamarase, when the cellular structure of the plant is crushed or damage (Conn, 1969). No other mycotoxin is detected in cassava (Scudanwee, 1997). All tissues of cassava contain cyanogenic glycosides, and an acyanogenic cassava cultivar has never been found (Bokanga *et al*., 1994).

Table 2: Proximate analysis of cassava and some of its products

Composition g/100g	Cassava tubers	Cassava flour	Cassava marcaroni	Gari	Fufu
Moisture	59.40	9.50	10.60	14.40	15.30
Protein	0.70	1.60	11.20	0.90	0.60
Fat	0.20	0.40	1.90	0.10	0.14
Crude fibre	0.60	0.80	0.70	0.40	0.20
Carbohydrates	38.10	84.90	73.90	81.80	75.80
Ash	1.00	1.80	1.80	1.40	0.50
Calcium	0.05	0.06	0.03	0.07	0.16
Phosphorus	0.04	0.08	0.14	0.04	0.02
Thiamine, mg/100g	0.05	0.08	0.22	-	-
Iron, mg/100g	0.90	3.50	2.90	2.20	6.20
Vitamin C,mg/100g	0.025	-	-	-	-
Calories kcal/100g	157.00	338	351	323	393

Source: Maini (1973)

Table 3: Essential amino acid profile of cassava tuber and leaf (% on dry weight basis)

	Free tuber	Amino acids leaf	Amino acids in tuber	Protein in leaf
Arginine	0.29	1.48	7.74	5.21
Histidine	0.27	0.66	1.50	2.47
Isoleucine	0.03	1.67	5.33	4.12
Leucine	0.31	2.72	5.56	10.00
Lysine	0.07	1.87	6.23	7.11
Methionine	0.03	0.36	0.60	7.45
Phenylalaine	0.03	0.92	3.45	3.87
Tryptophan	0.03	1.31	3.83	4.70
Valine	-	0.24	0.53	1.09

Source: Balagopalan *et al. (*1988)

2.4 Antinutritional factor in cassava

The first reference to toxic principle in cassava was made by Clusium (1605) and the association of toxicity with hydrocyanic acid was first made by Dunstan and Henry (1806). The two glycosides, linamarin and Lotausatralin were later identified as the toxic component of cassava tuber (Dunstan and Henry, 1906; Bulter *et al*, 1965 and Bisset *et al*., 1969). Today the presence of cyanide in cassava has caused a global scare as to safety of cassava and its products for human and animal consumption (Tewe, 2004).

The two glycosides, linamarin and lotaustralin are present in all parts of the cassava plant. The synthesis of the glycosides and the storage in various organs take place throughout the life cycle of the plant. The concentration of the glycosides varies considerably between varieties and also with climatic and cultural conditions.

Cardoso *et al*. (1999) reported that incidence of drought greatly increased the cyanide level in cassava. Bokanga *et al* .(1994) and Woodrow *et al*. (2001), also reported that cyanogenic plant like cassava responded to stress, including water stress producing increased amount of cyanogenic glycosides.

The normal range of cyanoglycoside content is from 15 to 400ppm calculated as mgHCN/kg fresh weight. Occasionally, varieties with very low HCN content 10mgHCN/kg or very high HCN content up to 2200mg HNC/kg have also been encountered (Balagopalan *et al.*, 1988).

Bediako *et al*. (1981) investigated the biosynthesis pathway of linamarin and lotaustralin in cassava. The precursor amino acids for linamarin and lotaustralin are L-valine and L-isoleucine respectively. Bediako *et al.* (1981) concluded that the petioles were the major synthetic site of linamarin in cassava followed by the leaves, upper stem and shoot apex. However, Koch *et al.* (1992) stated that cyanogenic glycosides are synthesized in the leaves and translocated to all parts where they are accumulated. Bediako *et al.* (1981) also showed the translocation of synthesized cyanogenic glycosides down the cassava plant from the leaves.

2.5 Chemistry and biochemistry of cyanide

2.5.1 Chemistry of Cyanide

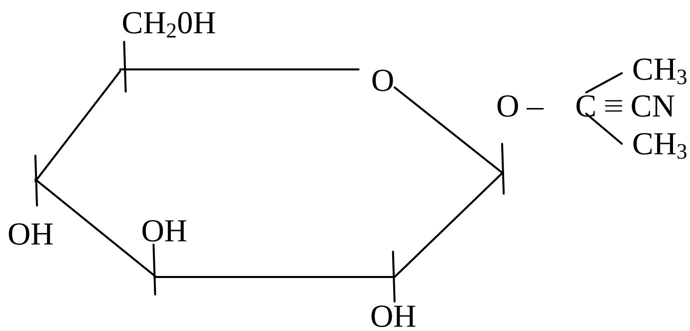
Cyanide (CN – CAS No 57 - 12.5) most commonly occurs as hydrogen cyanide (HCN.CAS NO, 74 - 90.8) and its salts sodium cyanide (NaCN, CAS NO, 143 – 33.9) and potassium cyanide (KCN CAS No 151 – 50.8). Cyanides are ubiquitous in nature, arising from both natural and anthropogenic sources. Cyanogenic glycosides, producing hydrogen cyanide upon hydrolysis, are found in a number of plant species including cassava. Source and levels of cyanide in some edible plants are presented in Table 4. Cyanides are also produced by certain bacterial, fungi and algae. Cyanide is released to the environment from numerous sources. Metal finishing and organic chemical industries as well as iron and steel production are major sources of cyanides released to the aquatic environment. More than 90% of emulsion to the air is attributed to releases in automobile exhaust (ATSDR, 1989). Other sources include flavourings and food ingredients with flavouring properties (EFSA, 2004). Chemical structures of linamarin and lotaustralin are presented in Figures 1 and 2.

Hydrogen cyanide is a colorless liquid with a characterized odour of butter almonds (Verschueren, 1983), has a molecular weight of 27.03 and a boiling point of 25.60^{0}C. It is miscible with water and alcohol and slightly soluble in ether (Budavari *et* *al.*, 1989). Hydrogen cyanide is a weak acid with a P_{ka} of 9.2 (US EPA, 1984). Hydrogenic acid is a colourless gas or liquid with characteristic odour (EFSA, 2004. On hydrolysis, one gram of linamarin liberates 109.3mg HCN (equivalent of 105.2mg CN). The release of HCN can occur as a result of enzymatic hydrolysis by β glucosidase. The hydrolysis also liberates glycosidic portions and acetone.

Table 4: Hydrocyanic acid concentrations in food products (mg/kg) and beverages (mg/L)

Types of product	Hydrocyanic acid concentrations (mg/kg or mg/L)
Cereal grains and their products	0.001-0.45
Soy protein products	0.07-0.3
Soybean hulls	1.24
Apricot pits	89-2,170
Fruit juice (Cheery. Apricot, Prune)	1.9-4.6
Cassava	300-2,360
Sorghum (immature)	2,400
Bamboo (immature shoot tip)	7,700
Lima beans	2,000-3,300

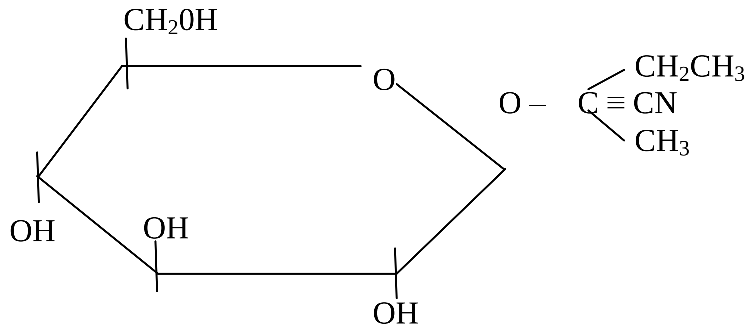
Source: EFSA (2007)



Molecular formula – $C_{20}H_{17}NO6$
Molecular mass – 247.2474
CAS Number – 554-35-8

Fig 2: Chemical structure of linamarin

Source – EFSA (2004)



Molecular Formular	–	$C_{11}H_{19}NO_6$
Molecular Mass	-	261.272
CAS – Number	-	554-67-8

Fig 2: Chemical Structure of Lotaustralin

Source: EFSA (2004)

2.5.2 Absorption and Distribution

Hydrogen cyanide is rapidly absorbed by the gastro-intestinal and respiratory tract. The liquid and possibly the concentrated vapour are also absorbed directly through the intact skin (Hartung, 1982; US EPA, 1984). Hydrogen cyanide is more rapidly absorbed from the gastro intestinal tract than cyanide salts (US EPA, 1984). Following absorption, cyanide is rapidly distributed throughout the body by the blood. Cyanide enters erythrocytes and is found at low concentrations in normal human blood and other organs. After no lethal exposure, plasma cyanide levels tend to return to normal levels within 4-8 hours. The estimated plasma half-life is 20 minutes to 1 hour (Hartung, 1982).

In cases of fatal oral poisoning, cyanide was detected in the brain, blood, kidney, stomach wall, liver and urine (Ansell and Lewis, 1970). Gettler and Baine (1938) reported brain and liver cyanide levels of 0.06 – 1.37mg/100g and 0.22 – 0.91mg/100g tissue, respectively, in four human subjects who ingested fatal doses of cyanide. Tissue levels in a human after inhalation of hydrogen cyanide were 0.75, 0.42, 0.41, 0.33 and 0.2mg hydrogen cyanide / 100g in the lung, heart, blood, kidney and brain respectively. Cyanogenic glycosides absorbed intact from the gut are not biotranformed to cyanides by mammalian enzymes. As a consequence, cyanogenic glycosides are relatively non toxic in germ free animal (Chauynarong *et al., 2009)*

2.5.3. Metabolism

The principal pathway of cyanide metabolism is conversion to thiocyanate catalyzed by either rhodanase (thiosulfate sulphur transferase) or by β mercaptopryustate sulphur transferase. Both enzymes are widely distributed in the body. Conversion of cyanide to the less toxic thiocyanate by rhodanase is enhanced when cyanide poisoning is treated with the intravenous administration of a sulfur donor such as sodium thiosulfate (ATSDR 1989, Westley 1980). The toxicity of thiocyanate is significantly less than that of cyanide, but chronically elevated levels of blood thiocyanate can inhibit the uptake of iodine by the thyroid gland, thereby reducing the formation of thyroxine (Hartung 1982). Other metabolic pathways include the conversion to z-aminothiazoline – 4-carboxylic acid, incorporation into a 1-carbon (formate) metabolic pool, combination with hydroxycobalamine to form cyanocobalamine (Vitamin B_{12}) and combination with cystine to form 2-aminothioazoline-4-carboxylic acid (ATSDR, 1989).

2.5.4. Excretion

In humans and animals, the major route of cyanide elimination from the body is via urinary excretion of thiocyanate. Small amounts of thiocyanate are also eliminated via lungs and feaces (US EPA, 1985). Some free hydrogen cyanide is excreted unchanged in breathe, saliva, sweat and urine (Hartung, 1982).

2.6 Health effects of oral exposures to cyanide

Primary target organs in oral exposure to cyanide toxicity are the central nervous system, thyroid, reproductive and development organ, and kidney.

2.6.1 Acute toxicity

Hydrogen cyanide and its simple salts are among the most rapidly acting poisons with the central nervous system (CNS) as the target organ resulting in instantaneous collapse and cessation of respiration. At much lower doses, the earliest symptoms are weakness, headache, mental confusion and occasionally nausea and vomiting. The most specific symptom in acute cyanide poisoning is the bright red colour of venous blood which is evidence of the inability of the tissues to use oxygen (Hartung, 1982).

Cyanide exerts its toxic effect by forming a complex with ferric ion (Fe^{+3}) of mitochondrial cytochrome oxidase, the enzyme that catalyses the terminal step in the electron transport chain, thereby preventing use of oxygen by cells. Inhibition of cytochrome oxidase leads to the disruption of cellular respiration producing cytotoxic hypoxia. Cyanide also combines with approximately 2% of metaheamoglobin normally present (ATSDR 1989, US EPA, 1985, Hardy and Boylen, 1983).

In animals, oral LD_{50} in rats are 8.5mg/kg for hydrogen cyanide (US EPA, 1989). Gettler and Baine (1938) reported that dogs treated orally with 20, 50 or 100mg/kg potassium cyanide died 155, 21 or 8 minutes, respectively after dosing.

2.6.2 Chronic toxicity

In tropic regions of Africa, a high incidence of ataxia neuropathy, goiter, amblyopia and other disorders has been associated with chronic ingestion of cassava (Westley 1980, EPA 1984). Philbride *et al*. (1979) reported decreased weight gain, primary myelin degeneration of the spinal cord and decreased plasma thyroxin levels when male rats were fed 0-1500mg potassium cyanide/kg diet for 11.5 months.

2.6.3 Development and reproductive toxicity

Congenital hypothyrodrism is present in 15% of newborns in certain area of Zaire where cassava is a staple food (Ermans, 1980). Litter size, weight of pups at birth, food consumption and growth rate of pups were not significantly different from control (Tewe and Maner, 1981a). However, feotuses of sows fed 277 or 521ml cyanide/kg diet throughout gestation and lactation exhibited decreased organ to body weight ratios for thyroid, heart and spleen when compared with those born to sows fed 3mg cyanide /kg diet for the same time period. Hyperplasia of the kidney glomeruli and morphologically changes in thyroid cells were seen at all three exposure levels (Tewe and Maner, 1981b).

2.7 Enzymatic degradation of cassava cyanogenic glycosides

It is well recognized that the plants containing a cyanogenic glycoside also contain enzyme capable of degrading it (Cooper-Driver and Swain, 1976). However, Balagopalan *et al.* (1988) stated that there exists an excellent compartmentation in the plant between the cyanogenic glycosides and the degrading enzymes. Thus, in the healthy plant, these two will not come together. Kojima *et al.* (1976) studies the degradative pathway of cyanogenic glycosides in other plants like *sorghum bicolar* and cassava is believed to follow the same catabolic pathway (Conn, 1989).

In cassava, the glycosidase hydrolyzing the cyanogenic glycoside is linamarase which according to Butler *et al.* (1965) is highly specific. When tissue is wounded, the glycosidase hydrolyzing enzymes "Linamarase" come into contact with the substrate "cyanogenic glycosides" causing autolytic hydrolysis of these glycosides, first to ∝ _ hydroxynitrite then dissociate to hydrocyanic acid and acetone.

2.8 Physiological and biochemical implications of cassava cyanogenic glycoside and cyanide

A comprehensive study on cyanogenic character of cassava and their implication in productivity of livestock has been reported (Tewe, 1997). The safety for cyanide in cassava feed according to Codex Standard for Edible Cassava Flour is 10mg/Kg dry weight (JECFA, 1993; WHO, 1993). However, Tewe (2004) reported a safe level of cyanide in cassava based ration to be 100ppm (100mgHCN/kg dried chips) and that satisfactory growth can be obtained in livestock production provided the feed is adequately supplemented with protein (especially methionine) and iodine.

Tewe (1983) reported that in growing pig fed cassava peel rations, there were pathological changes in colloid and secretary cell of the thyroid gland. There was also increase in amniotic fluid thiocyanate in gestating rat fed cassava (Tewe *et al.*1977). Consistently high serum thiocyanate and rhodanase activity occurred in growing rat fed fresh or dry cassava meal (Tewe and Maner, 1981a). Ayangbade *et al,* (1980) found increase levels of plasma and amniotic fluid throcyanate in cassava eating women.

Ingestion of cassava can trigger several toxic manifestations due to the release of HCN from cassava cyanogenic glycosides. Balagopalan *et al.* (1988) stated that the incidence of acute poisoning from consumption of cassava is relatively low and that chronic intake of cassava can lead to toxic condition.

The toxicity of cassava is due to the release of HCN in vivo which is a potent cytotoxin exerting a wide range of biological effects which include inhibition of tissue respiration (terminal oxidase of the mitochondrial respiratory) (Solomonson, 1981). It also inhibits a number of other enzymes like catalase, superoxide dismutase, nitrate reductase (Balagopalan *et al.*, 1988). Solomonson (1981) reported that cyanide inhibits the terminal cytochrome oxidase by combining with it and concluded that brain cytochrome oxidase may be the site of lethal action of cyanide.

Cyanide also inhibits metalloenzymes (e.g. alkalic phosphatase and cytosolic Cu/Zn superoxide dismutase). It forms a 1:1 inhibiting complex with carbonic anhydrase. It also inactivates glutathione peroxidase by the removal of selemium from it.

The cyanide ion is rapidly absorbed from the gastrointestinal tract. Acute and sub acute toxic affects of cyanide can vary from events like convulsions, screaming, vomiting, coma and death. Halstrom and Muller (1945) and Fassett (1963) reported that inhalation of HCN at concentrations of 110 to 135ppm produced fatality within a few hours.

Sublethal doses of cyanide cause increase in blood glucose and lactic acid. Isom *et al.* (1975) found that cyanide caused a 100% increase in the catabolism of glucose via the pentose phosphate pathway and a 50% decrease in its breakdown via the glycolytic pathway.

Human diseases linked with cassava cyanide include Leber's optical, Atrophy and tobacco amblojopia (Monekosso and Wilson 1966, Wilson *et al.* 1966, Wilson *et al.* 1971), tropical ataxia neuropathy (Lessel 1971; Osuntokun 1971), endemic goiter and cretinism (Ekpechi, 1967), tropid calcifying pancreatic (Osuntokun *et al.,* 1970; Puslipa 1980; Geevarghese 1983). Ernesto *et al* (2002) reported that an irreversible spastic paraparesis (paralysis of legs) known as konso occurred mainly in children and women of child bearing age due to HCN over – loaded from consumption of cassava.

However, cassava intake has reported to possess some prophylactic action. Oke (1969) reported that the metabolite formed from cassava cyanogenic glycosides are physiologically active and can exert some beneficial effects in the body. These prophylactic actions include requirement of hydrocyanic acid for the formation of cyanocobalamin (vitamin B_{12}), incidence of certain cases of hypertension resulting from low levels of serum thiocyanate and partial alleviation of the sickle cell disease (Oke, 1976). Oke (1976) also reported that schistosomiasis produce by infections of *schistomias hematobin* and *S – mansion* finds relief through treatment with the cyanoglycoside amygdalin. Minute amount of cyanide in the form of vitamin B_{12} (cyanocobalamine) are a necessary requirement in the human diet (ATSDR, 1989).

2.9 Detoxification of cyanogenic glycosides in cassava

2.9.1 *In vivo* detoxification of cassava cyanogenic glycoside

The body system has defense mechanisms to disarm harmful foreign bodies injected into the body, a process known as detoxification. The foreign compounds are chemically altered and excreted more or less efficiently. The ingestion of sub lethal doses of cyanide stimulates the defense mechanism of the body so as to ensure the detoxification to a less toxic product. Balagopalan *et al.* (1988) stated that the principle detoxification pathway for cyanide is controlled by rhodanase (E.C.2.8.1.1: thiousulfate –cyanide sulfur transferase) which catalyses the transfer of sulfur from thiosufate to cyanide forming thiocyanate. Lang (1933) was the first to report that injection of cyanide accelerated the excretion of thiocyanate and postulated the existence of an enzyme which he called rhodanase.

$$S_2O_3^{2} + CN \xrightarrow[\text{rhodanase}]{} SNC + SO_3^{2}$$

Sorbo (1953) found that rhodanase contained an active disulfide group which participated in the reactions. Auriga and Koj (1975) reported that rhodanase is widely distributed in the body with the highest concentration in the liver and kidney. Therefore the ability of animal to cope with cyanide depends on the concentrations of rhodanase in the liver which varies with animal. Hinwich and Saunders (1948) found that the highest levels were presents in rats, followed by Rhesus, monkeys and rabbits, while the lowest levels were found in dogs

Meister (1954) found that 3-mercaptopyruvic acid arising from the transamination or deamination of cystein can also act as a sulphur donor for cyanide detoxification. Another pathway for cyanide detoxification is conversion of cyanocobalamin to hydroxocobalamin in the presence of light, which further reacts with cyanide to form cyanocobalamin (Vitamin. B_{12}) (Kaczka *et al.*, 1950). Cystine and cysteine can also act as sulphur donor for cyanide detoxification through another pathway (Voegthin *et al.*, 1926, Blakeley and Coop, 1949). Detoxification of hydrogen cyanide to thiocyanate reduces toxicity in 200 fold. By this mechanism, the body is able to cope with small amount of cyanide (Balagopalan, *et al.*, 1988).

2.9.2. Detoxification of cassava cyanogenic content through processing techniques

Traditional detoxification processes adopted with the intention of reducing the hydrogen cyanide (HCN) content vary from country. These methods are drying, soaking, boiling, fermentation, or combination of two or more of these (Balagopalan *et al*., 1988).

2.9.2.1 Drying

Drying considerably reduces the hydrogen cyanide level in cassava. Tewe *et al*. (1980) demonstrated that sun drying was more effectives than oven drying in reducing cyanide in cassava during processing. The effect of oven drying of cassava chips at 60, 105 and 165^{0}C was investigated by Bourdoux *et al*. (1982). The hydrogen cyanide content was found to be reduced at temperature just above 60^{0}C. Gomez *et al*. (1984) studied the effect of chip thickness on oven drying at 60^{0}C and reported that the total and bound cyanide were found to be low in thick chips after oven drying compared with thin chips. They further explained that in thick chips, the linamarase activity might have continuing for longer time as dehydration was at a slower rate, while water, which is a substrate for the enzymes was lost at a faster rate from thin chips. Tewe and Maner (1980) found that 43 and 94 percent of cyanide was lost from sweet and bitter grated cassava by oven drying. Different heat treatments were found to retain different levels of cyanide (Nambisan and Sundaresan, 1985). Tewe and Egbunike (1992) reported that when cassava leaves were sun dried or dehydrated, all the hydrogen cyanide was liberated and no toxic effects were therefore found when leaves were consumed by animals.

2.9.2.2. Soaking and boiling

According to Fukuba *et al*. (1984), soaking 1cm diced samples for 24 hours followed by 10 minutes of boiling has been reported to eliminate up to 60 percent of the total cyanide, and removed the free cyanide completely. However, soaking alone was not effective in removing cyanide since only 14 percent reduction was observed. Their studies also revealed that the time of heating and sample size were two key factors determining the extent of cyanide elimination. Prolonged soaking of tuber up to 5 days could reduce the cyanide content to 3 percent of the initial level (Bourdoux *et al.*, 1982).

2.9.2.3 Fermentation

In fermented products like garri and fufu changes to cyanide loss were much higher. It was reported by Ernest *et al*. (2000) that the total cyanide content of cassava flour produced by sun drying of peeled, chopped cassava roots was twice that of peeled, chopped cassava which was heap fermented for a few days before sun – drying.

The detoxifying role of exogenously added linamarase during garri production was evaluated by Ikediobi and Onyike (1982). They reported that enzyme hydrolysis and not low pH was responsible for detoxification of cyanogenic glycoside during garri production.

2.10 Biochemical and haematological indices as affected by dietary intake

Blood parameters are important indices of body physiological, pathological and nutritional states of an organism. However, a number of factors, nutritional status and physiological changes can affect these blood parameters.

The ingestion of numerous dietary components has measurable effects on the blood constituents (Church *et al*., 1984). The heamatological parameters usually considered are Packed Cell Volume (PCV), White Blood Cell (WBC), Heamoglobin (Hb), Mean Cell Volume (MCV), Mean Cell Heamoglobin (MCH) and Mean Cell Heamoglobin Concentration (MCHC). Serum biochemical indices of importance in toxicity especially cassava based ration are serum thiocyanate, Alanine Amino Transferase (ALT) and Aspertate Amino Transferred (AST). Other serum metabolites are glucose, triglycerides, total protein, albumin and glubolin.

Heamoglobin (Hb) is involved in transporting oxygen and carbodioxide within the blood. Normal value for normal chickens as recorded by Maxwell *et al.* (1990) was 10.6g/100ml while value ranging from 7.0-18.6g/dl was reported by Mistruka and Rawnsley (1977) and Ross *et al.* (1978). Lindsay (1977) observed that it fall gradually in animals on a low protein intake, parasitological infections or liver damage. Values for PCV ranged between 23-55% (Mistruka and Rawnsley 1977; Ross *et al.*, 1978 and Maxwell *et al.*, 1990). A low value indicates anaemia while high values suggest dehydration. Normal values for White Blood Cell (WBC) ranged from 9.32 x 10^3/mm^3. However, it is affected by age, sex, temperature, nutritional status and degree of stress. Red blood Cell (RBC) is involved in gas exchange, (the transport and releases of O_2 and $C0_2$), in the buffer system of the blood and a role in the clothing mechanism. Values reported by Mistruka and Rawnsley (1977) vary from 1.25-4.00 million/ mm^3 in chickens. Values for MCV, MCH and MCHC are calculated from RBC, Hb and PCV (Mistruka and Rawnsley, 1977).

Serum enzymes (ALT and AST) are used for the estimation of liver function, they are very active in the liver and their activities could be detected in the blood where they are useful in monitoring blood serum of animals exposed to dangerous chemicals. Serum Aspartate Amino Transferase (AST) is used to measure hepatic function in liver disease and toxicity. It is liberated into blood when liver cell are damaged hence the increase in acute viral and toxic hepatitis, shock and progressive post necrotic cirrhosis. The normal range is 9.5-37.2 U/L (Mistuka and Rawnsley, 1977). The serum Alamine Amino Transferase (ALT) functions in the conversion of Aspartic acid to glutamic acid. Lohr (1975) associated an increased activity of ALT with hepatocelular damage in chickens. Reported values range from 88-208IU/L.

The ingestion of cyanide stimulates defense mechanism of the body to detoxify cyanide to thiocyanate. Detoxified cyanide (thiocyanate) is transported from cite of detoxification through blood. Thus, serum thiocyanate is useful in determining dietary cyanide.

2.11 Dietary effect of cassava inclusion in feed on egg quality

Egg quality can be divided into two: external and internal qualities. The internal quality includes egg size, shell colour, shell thickness, percentage shell, shell porosity, shell surface area, soft shelled eggs while the internal quality include yolk weight, yolk colour, yolk percentage, albumen height and weight, Haugh unit, yolk index, meat and blood spot percentage.

Egg quality is an economically important index of performance in commercial layers apart from egg production (Oluyemi and Robert, 2000). Many studies had been reported that showed the effects of dietary nutrients on the performance and egg quality of layers (Babatunde and Fetuga, 1976; Keshavarz and Kackson, 1992; Brakes and Peeble, 1992; Shafer *et al.*, 1992). Brakes and Peebles (1992) reported an increase in egg protein and quality when dietary intake of lysine was increased from 0.6% through 0.725 to 0.775% of the diet. Also, Shafer *et al.* (1992) reported that there were increase in egg weight, egg component yield, solids and percentage protein of the albumen as dietary methionine intake was increasing.

The average egg weight of the tropic birds is taken to be 58g with a range of 55-70g. This could be affected by age and strain of the birds (Oluyemi and Robert, 2000), dietary nutrients intake especially protein and fat (Schichai and Balnave, 1981, Keshavarz and Jackson, 1992; Cantor *et al.*, 1992) and environmental conditions (Neshiem *et al.*, 1979). Oluyemi and Roberts (2000) stated that the average shell thickness of the domestic fowl egg is about 0.34mm and the shell tends to be thinner in the tropic than in the temperature region. This trait could be influenced by mineral intake of the laying hen and oviposition time (Chinies *et al.*, 1992, Vandepopuliete and Lyons, 1992).

Albumen quality is another important parameter of egg quality. Albumen quality includes albumen height, albumen weight, Haugh Unit (HU). Oluyemi and Roberts (2000) stated that the general accepted measurement of quality is the Haugh Unit (HU). The height of albumen is the most accurate physical criterion of albumen quality because it is used to calculate Haugh Unit. Johnson and Merrift (1955) found that egg of higher producers tend to have lower albumen height towards the end of laying year.

Yolk colour is influenced by the bird diet and metabolism of carotenoids (Degroote, 1966), Xanthopyll source, inhibitor and dietary nutrients such as lipids, antioxidant, vitamins and minerals (Karunajeers *et al.,* 1984). Another parameter of determining yolk quality is the yolk index, which is the ratio of the length to the width of the yolk.

Other economically important qualities of egg include shape index, shell thickness, shell surface area, soft shelled percentage, and meat and blood spots percentage. All these factors influence the quality of egg and its acceptability (Jeffery, 1941).

2.12 Cassava products used in livestock feeding

Ugwu and Ay 1992 identified more than 80 cassava products in West Africa countries while about 15 were found in Nigeria. However, Khajarern *et al.* (1982) sated that root, chips, flour and pellets are the most common type used as livestock feed. Other cassava products used in livestock feed are whole tuber, cassava leaf, fermented or ensiled cassava meal, and dried cassava wastes including peels. These according to Khajarern and Khajaern (1992) were used to limited level due to high cost of processing. Cassava grit is a new product for livestock feeding, it is “feed grade” garri.

2.12.1 Cassava flour

Cassava flours are the most widely food product made from cassava in Africa and are processed in a variety of ways (Ugwu and Ay, 1992). There are two types of cassava flour, fermented and unfermented cassava flours. It is the conventional cassava products used in livestock feed in Africa. Usually, this product is too powdery and it accounts for attributed dustiness of cassava products.

2.12.2 Cassava chip

It is the shredded dried root. Chips are dried irregular slices of roots, which vary in size but should not exceed 5mm in length (Khajarern and Khajarern 1992). It is the most common form in which dried cassava roots are used in livestock feed. Chips are produced in various forms, sizes and shapes in different parts of the tropical world and known by different names, e.g. kokome, gaplek, bombo and cassettes (McFarlane 1982 and Lancaster *et al*., 1982).

2.12.3 Whole/broken root

It is similar to chips in appearance, but generally thicker and longer. They are often 12-15cm long. It is the best for large animals especially ruminants. It usually takes longer period to dry and could only be produced in areas with dry weather.

2.12.4 Cassava pellets

The pellets are obtained from dried broken root, flour and chips. These cassava products are milled and hardening into cylindrical shape with pelleting machine. Cassava pellet is a uniform cylindrical product of about 0.5 to 0.8cm diameter and 1.0 to 2.0cm long. The recent impetus to pelleting has come from the demand generated within the European Economic Countries (EEC) for cassava products as a source of energy in compound animal feed (Maust *et al*, 1974). According to Manurung (1974), temperature must reach 180^{0}F (82.22^{0}C) for proper pelletization. There are two types of pellets; brand and native pellets. Brand pellets are produced on imported machines while native pellets are made in locally manufactured pelletizers. Balagopalan *et al.* (1988) stated that native pellets are inferior due to variability, poor composition, excessive moisture content, high temperature of the product, presence of too much meal and softness.

2.12. 5 Cassava grits

This is a gelatinized cassava product. It is produced like garri for human consumption except that it is not peeled and sieved. During roasting cassava starch is cooked and gelatinized. Cooked cassava starch has a digestibility of 72% while raw starch has a digestibility of 48.3% (Tewe, 2004).

Gelatinization also removes dustiness and improves utilization for livestock. Production of cassava grits also removes the major bottleneck in the cassava processing which is peeling. Chemical composition and true metabolizable energy of cassava chips, pellet and grit is shown in table 5.

Table 5: Some chemical composition and hydrogen cyanide content of cassava root products

Composition %	PCC	UCC	UCP	UCG
Dry matter	86.78	88.65	91.65	92.10
Crude protein	1.54	4.06	4.62	3.22
Esther extract	0.90	1.45	1.16	1.34
Crude fibre	1.30	9.95	7.87	5.95
Ash	1.91	2.40	2.13	2.33
NFE	81.33	70.49	75.87	79.26
Phosphorous	0.05	0.09	0.05	0.06
Calcium	0.10	0.185	0.19	0.17
Cyanide (ppm)	19.24	51.08	35.34	39.36
ME (Kcal/g)	3.22	3.17	3.29	3.28

Source: Mosobalaje and Tewe (2009)

2.13 Economic evaluation of feed ingredients

The economic turnout from a given resource measured in profit at the farm can be at maximum only if each unit of commodity is produced with a minimum cost of resource outlay (Heady, 1964). In poultry production, feed account for at least 70% of total cost of production of poultry meat and eggs (Longe, 2006). The major ingredients used in poultry feeding are energy and protein. Thus, to maximize profit in meat and eggs production, energy and protein could be targeted (Longe, 2006).

The problem in resource substitution is one of the major factors in minimizing the cost of producing a given amount of product. It is important to estimate economic value of ingredient in order to use ingredient with a better value. Least-cost feed formulation has largely replaced the need to consider the economic value of individual ingredients. With most formulation programmes, the economic value of ingredients being used or rejected is usually available. However, for new ingredients some means of economic analysis is essential to know the economic worth of these ingredients. Some of economic evaluation methods of ingredients include

i) Economic comparison of new ingredients with protein, energy and price of maize and soya bean meal using simultaneous equation (Leeson and Summer, 1977).

ii) Evaluation of feedstuffs with different crude protein or energy concentration by calculating how much money would be saved (or spent) by using a similar feed with higher or lower nutrient concentration using Pearson's square formula (Church and Varela-Alvarez, 1991).

iii) Economic evaluation of feed on the basis of performance of birds fed the feed. Oluyemi and Robert (2000) stated that the most reliable assessment of the feed quality is on the basis of its effect on the performance of the birds. This gives economic evaluation of feedstuff based on cost per quantity of product produced.

However, agricultural research should demonstrate the economic advantage of proposed production input over the existing one(s). Alimi and Manyong (2000) stated that farmers adopt new production technology that is economically superior to the existing methods. Before changing from one production method to another, the farmer considers many factors, such as agro ecological requirement, availability of the required additional resources (labour, credit, skill etc) additional cost and additional income resulting from the change. Farmers also asked will the extra-income earned by changing to the new technological justify the extra costs.

One of the tools in economics used to compare the economic benefits of technologies is partial budget analysis. The tool aims at quantifying and comparing the effects of a proposed input on production to those of the alternative inputs. Kay (1981) stated that the results of partial budget analysis assist agricultural scientist in identifying weakness (high cost and /or low income) of technology being developed. It also aids researchers in deciding which technology to recommend to farmers.

iv) Partial budget. Budget is a formal quantitative expression of plans on production and output. Budgets indicate the type, quality and quantity of production resources or inputs needed, and the type, quality and quantity of output or product obtained (Lipsey 1975). Three types are used in agriculture (i) whole farm budget (ii) enterprise budget and partial budget.

Partial budget shows the effect of change(s) in farm operations. For example, farmers know that fertilizer application will likely increase maize yield and thus the gross income. The use of fertilizer also results in additional costs. To decide whether to use fertilizer for maize production or not requires a partial analysis. Alimi and Manyong (2000) mentioned the following as the concepts of sound partial budget analysis. These include: farm gate price, adjusted yield, farm gate benefit, net benefit, dominance analysis, marginal analysis, marginal rate of return, acceptable minimum rate of return.

Partial budget gives recommendation that does not hold if there is variability in either yields or relative prices of inputs and /or output. Sensitivity analysis addresses the problem of variability in prices (Alimi and Alofe, 1992).

v) Sensitivity analysis. Sensitivity analysis uses different prices or yields to determine what would happen to the net benefits and the choice of proposed technology, if it were to occur in different price or yield conditions to those expected. Sensitivity analysis is used to test a proposed technology or input for ability to withstand yield or price changes (Alimi and Mayong, 2000).

Sensitivity analysis gives break-even price of input and breakeven yield or production above which the recommendation will not hold again. Tewe (2004) stated that a price of between 60-75% for cassava products compared to maize is recommended for its competitiveness in feeds. Khajarern *et al.* (1979) reported a sensitivity analysis of 60% of cassava as a substitute for maize.

CHAPTER THREE

DETERMINATION OF NUTRITIVE VALUE OF CASSAVA ROOT PRODUCTS AS ENERGY SOURCES IN POULTRY PRODUCTION

3.1 Introduction

Cassava roots are primarily a source of carbohydrate and are virtually know to be deficient in protein. Available reports on the details chemical composition of cassava vary widely (Balagopalan *et al.*, 1988). Omole (1977) reported that the cassava root has an average composition of 60%-65% moisture, 30%-35% carbohydrate, 0.2%-0.6% ether extract and comparatively low content of vitamins and minerals. While, Smith (1992) reported 13.0%-43.0% dry matter, 1.5%-3.5% crude protein. 1.3%-7.7% crude fibre, 0.8%-3.2% ether extract, 85.0%-94.1% NFE and 1.6% ash.

Contrasting reports are also available on metabolizable energy of cassava root meal. Olson *et al.* (1969) reported caloric value of 3.44kcal/g of dry flour while Maust *et al.* (1972) reported value of 4.31kcal/g. Muller, *et al* (1974) found value of 3.65kcal/g while Hutagalung (1972) reported value of 3.23kcal/g. Kanto and Juttuporgong (2002) reported value of 3.53kcal/g. The variation in reported chemical composition and metabolizable energy of cassava is attributed to many factors including age of plant, variety and processing method (Balagopolan *et al.*, 1988).

The use of a feed ingredient presupposed that the nutritive value in terms of nutrient composition and metabolizable energy are known. It is either that average values already available and acceptable in literature due to series of analysis. Measurement of the metabolization energy value of individuals poultry feed ingredients are commonly used in overall estimate of their nutritional value (Austic and Neishem, 1990).

Cost of an ingredient is very important in least cost formulation. Muller *et al*, (1974) stated that economic considerations are of paramount importance, since cereals can be replaced by cassava only if the nutritional equivalent mixture of cassava with proteinous foodstuffs is cheaper than feed prepared with cereal. Tewe (2004) stated that cassava could only replace maize if cost of cassava is not more than 60-70% of the cost of maize. It is thus imperative to determine nutritive value and cost of cassava meal products in reference to described method of processing.

The study was aimed at determining proximate composition, hydrogen cyanide content, true metabolizable energy and the cost of four cassava root products.

3.2 Materials and methods

3.2.1 Processing of cassava root products

Cassava chips and pellets were prepared at International Institute of Tropical Agriculture (IITA) while cassava grit was prepared at McTee Farm, Awotan, Ibadan. Cassava tubers used were harvested, detailed (removal of stalk and tail) and washed. A sample was peeled, chipped, dried, bagged and labeled as Peeled Cassava Chips (PCC). Another sample was chipped without peeling, dried, bagged, and labeled as Unpeeled Cassava Chips (UCC). Dried UCC was fine-milled, pelleted, dried and bagged as Unpeeled Cassava Pellets (UCP). Another sample of unpeeled cassava tubers was grated, dewatered, fried, cooled and labeled as Unpeeled Cassava Grits (UCG). The processes are presented in Fig 3.

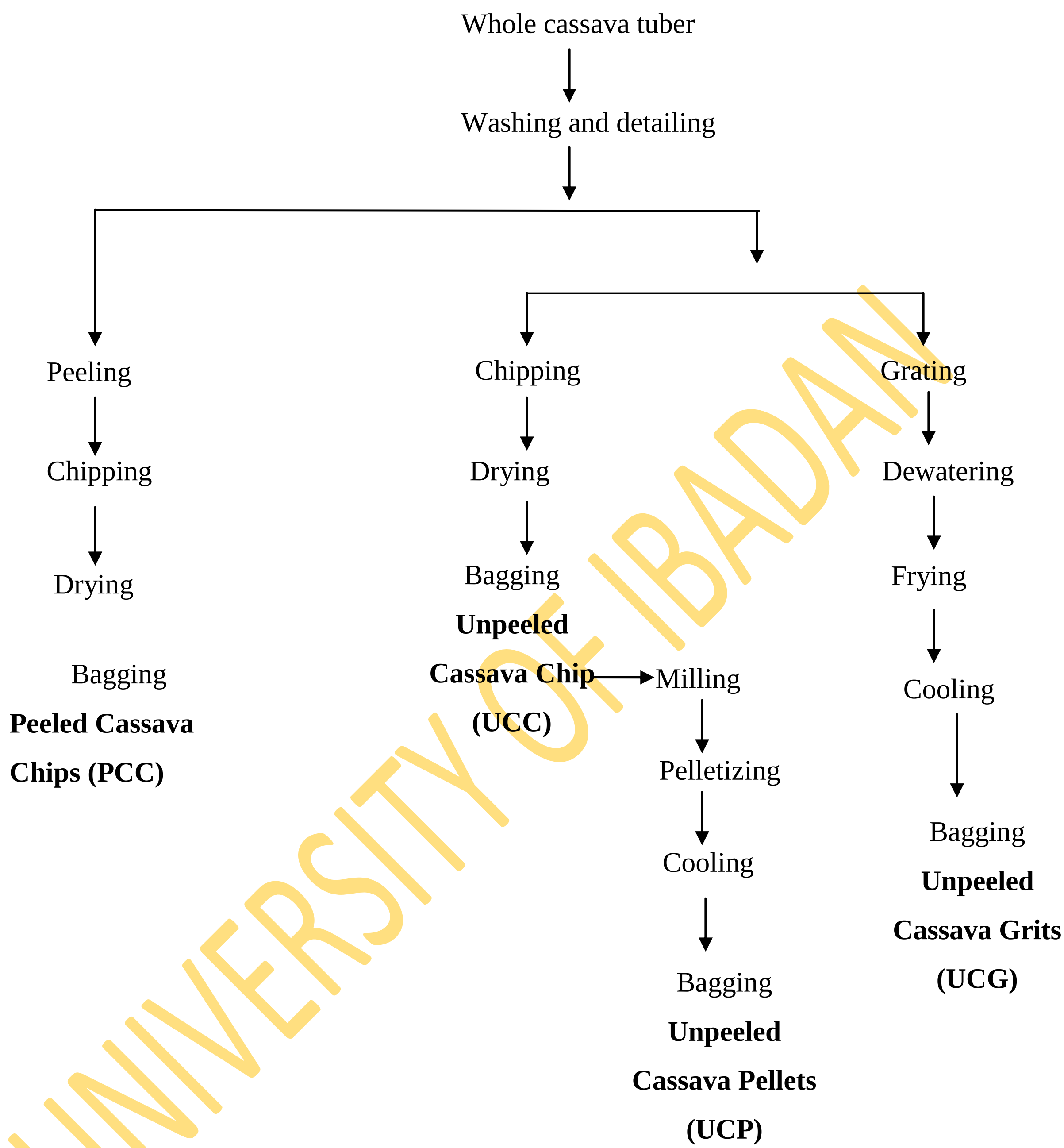


Figure 3: Diagrammatic illustration of the processing steps

3.2.2. Determination of proximate composition and cyanide content of cassava root products

Dry matter, crude protein, crude fibre, ether extract and ash of the four CRPs were determined according to the official method of AOAC (1990). Determination of hydrogen cyanide content involved hydrolysis of cyanoglycoside with endogenous linamarase and estimation of cyanide formed using alkaline picrate paper method described by Bradbury *et al.* (1990). The four cassava products were milled to powder form. Then, 100mg of each cassava product was carefully weighed with the spoon glued to the small potable balance of the kit. Round paper disc containing buffer at pH 6 and enzyme was placed in a flat bottomed plastic and 100mg of powdered cassava product was poured on top of it. 0.5ml of clean water was added with the aid of pipette. Immediately, yellow picrate paper was added and the bottle was closed with a screw capped lid. The bottle was allowed to stand for 20 hours at room temperature and, then the bottle was opened and the colour of the paper was matched against the colour charts to determine cyanide content.

3.2.3. Determination of True Metabolizable Energy (TME)

True metabolizable energy of the four cassava products was determined according to Sibbald (1976). Force feeding technique was adopted. Fifteen, 10 week old adult broilers were used for force feeding trials. The force feeding trial was carried out at McFee Farm, Ibadan. There were three birds each on PCC, UCC, UPC and UCG and the remaining three were fasted. The birds were randomly selected and housed with free access to water. All the birds were starved for 24 hours according to Sibbald (1978). Twenty five (25g) of each of cassava meal product was made into slurry by adding 100ml of clean water and forced fed to respective birds according to Ukachukwu (2005). The other three birds continued on starvation and were referred to as fasted members while the former is termed fed members. Both fed and fasted birds still had access to water. Exactly 24 hours after feeding, the excreta collecting trays were removed. The excreta was collected quantitatively, oven dried, weighed and stored for gross energy determination.

3.2.4 Gross energy determination

Gross energy was determined according to Oghae and Berhan (1997) and the equation below was used to calculate true metabolizable energy.

$$TME\ (Kcal/g) = \frac{(GE_{F}.\ W)-(Y_{a}-Y_{b-})}{W}$$

GE_f = Gross energy of the feedstuff (J/gDM)

Y_a = Gross energy voided as excreta of fed birds (J/gDM)

Y_b = Gross energy voided as excreta of fasted birds (J/gDM)

W = Weight of feedstuff fed (g)

Gross energy recorded as Joule per gram dry matter (J/gDM) was converted to kilocalories per gram dry matter (Kcal/KgDM) by dividing J/gDM by 4.184 according to Austic and Neshiem (1990).

3.2.5 Data analysis

The data obtained were analysed using descriptive statistic and ANOVA (SAS, 1999). Treatment means were separated using Duncan Multiple Range Test (Duncan, 1955).

3.3 Results

Table 6 shows the proximate composition and cyanide content of the four cassava samples. Dry matter content of cassava samples considered were similar (p>0.05). Crude protein content of unpeeled cassava products were significantly (P<0.05) higher than that of peeled cassava chips; 1.54%, 4.06%, 4.62% and 3.22% were the crude protein contents of PCC, UCC, UCP and UCC, respectively. Values recorded for ether extract were similar (p>0.05) and ranged between 0.90% and 1.45%. Crude fibre content of peeled cassava chip was significantly (p<0.05) lower than unpeeled samples. However, UCG (5.95%) had value that was significantly (p<0.05) lower than UCC (9.95) but not significantly (p>0.05) different from that of UCP (7.87%). Crude fibre contents of UCC and UCP were similar (p>0.05).

Ash content, phosphorus and calcium of all the four cassava samples were similar (p>0.05) and followed the same trend. The ranges were 1.91 - 2.40%, 0.05-0.09%, 0.10-0.19% respectively. Nitrogen Free Extract (NFE) of the four cassava samples were similar (p>0.05). PCC recorded the highest value (81.33%), UCC had the lowest value (70.49%) while UCP and UCG recorded 75.60% and 79.40% respectively.

Hydrogen cyanide contents of unpeeled cassava products (UCC, UCP and UCG) were significantly (p<0.05) higher than that of PCC, while values recorded for UCP and UCG were lower (p<0.05) than that of UCC. The values were 19.04ppm, 51.08ppm, 35.34ppm and 39.36ppm respectively for PCC, UCC, UCP and UCG.

Table 7 shows the true metabolizable energy of CRPs. The results showed that energy yield of all the four samples were similar (p>0.05) and metabolizable energy were also similar. UCP gave the highest value (3.2kcal/g) while UCC recorded the lowest value (3.17cal/g). Values of 3.22 and 3.28kcal/g were recorded for PCC and UCG respectively.

Table 8 shows the cost of production analysis of cassava samples. Dry matter yield of UCC was the highest (355kgDM/tonne fresh tubers) followed by UCG (350kgDM/tonne fresh tubers) and UCP (340kgDM/tonne fresh tubers). PCC recorded the lowest value (282kgDM/tonne fresh tubers).

However, cost per kilogram dry matter of UCC was the lowest (₦17,320.00/tonne) followed by UCG (₦19,130.00/tonne) and PCC (₦ 22,520.00/tonne). The highest was recorded for UCP (₦ 25,880.00/tonne).

Table 6: Chemical composition and hydrogen cyanide content of cassava root products

Composition %	PCC	UCC	UCP	UCG	±SEM
Dry matter	86.78	88.65	91.65	92.10	2.53
Crude protein	1.54[b]	4.06[a]	4.62[a]	3.22[a]	0.93
Esther extract	0.90	1.45	1.16	1.34	0.44
Crude fibre	1.30[c]	9.95[a]	7.87[ab]	5.95[b]	0.36
Ash	1.91	2.40	2.13	2.33	0.40
NFE	81.33	70.49	75.87	79.26	1.01
Phosphorous	0.05	0.09	0.05	0.06	0.03
Calcium	0.10	0.19	0.19	0.17	0.03
Cyanide (ppm)	19.24[c]	51.08[a]	35.34[b]	39.36 [b]	5.12

[a,b,c] means in the same row with different superscripts are significantly different ($p<0.05$)

PCC – Peeled Cassava Chips; UCP - Unpeeled Cassava Pellets; UCC – Unpeeled Cassava Chips; UCG - Unpeeled Cassava Grits

Table 7: Metabolizable energy values of cassava root products

Composition %	PCC	UCC	UCP	UCG	±SEM
Gross energy (input) KJ/g	454.94	440.92	454.35	454.89	
Gross energy (output), KJ/g	118.11	109.34	111.26	111.73	
Energy yield (%)	74.04	75.49	75.51	75.49	0.09
Metabolizable energy (Kcal/g)	3.22	3.17	3.29	3.28	0.04

Means in the same row with same superscript are not significantly different ($p>0.05$)

PCC – Peeled Cassava Chips; UCP - Unpeeled Cassava Pellets; PCC – Unpeeled Cassava Chips UCG - Unpeeled Cassava Grits

Table 8: Cost of production of cassava root products

Costs (₦/tonne)	PCC	UCC	UCP	UCG
Tubers	5000	5000	5000	5000
Peeling	500	-	-	-
Chipping	600	800	800	-
Grating	-	-	-	800
Dewatering	-	-	-	200
Drying	250	350	550	-
Frying	-	-	-	800
Milling	-	-	700	-
Pelleting	-	-	1750	-
Total cost	**6450**	**6150**	**8800**	**6800**
Yield (kg/tonne)	282	355	340	350
Cost of production	22,520	17,320	25,880	19,130

PCC – Peeled Cassava Chips; UCP - Unpeeled Cassava Pellets; UCC – Unpeeled Cassava Chips; UCG - Unpeeled Cassava Grits

3.4 Discussion

Unpeeled cassava products (UCC, UCP, UCG) had higher (P<0.05) crude protein, crude fibre and cyanide contents compared to the values obtained for PCC. This might be due to higher contents of these nutrients in the peels. Tewe *et al* (1976) and Aderemi (2000) reported that these nutrients are higher in the peels compared to pulp. However, effects of heat on cassava pellets and grits accounted for lower (p<0.05) crude fibre and cyanide contents of these products. Longe and Fagbenro-Byron (1990) reported that moist heating reduced the levels of fibres of these feedstuffs. Khajarern *et al*. (1979) had earlier stated that steam improved pelleting of cassava and further reduced the cyanide content. Leeson and summer (1997) also stated that steam pelleting can assist in volatization of free cyanide in cassava.

Higher values of ash, calcium and phosphorus contents were recorded for unpeeled cassava products though the differences were not significant, this confirmed report of Tewe (2004) that the mineral content of the dark bark is higher than that of the cortex. The NFE values were also similar (p>0.05) and the results revealed that the higher the crude fibre, the lower the NFE, Proximate composition values of cassava samples were similar to values reported by Smith (1992), but crude fibre content were higher than values reported by Kanto and Juttuporpong (2002).

Results obtained on true metabolizable energy revealed that calorie values of the four CRPs were similar (p>0.05). However, the result showed that the higher the crude fibre of cassava product, the lower the caloric value except for cassava grit. This might be due to loss of soluble carbohydrate through effluent (dewatering process). Phansurin *et al*. (2002) and Lokaewmanee *et al*. (2002) reported that increasing the levels of crude fibre significantly ($p<0.05$) decreased the ME content of the cassava chips, both in pigs and chickens. The ME values recorded were similar to value reported by Hatagalung (1972), which is 3.23kcal/g, the values were however lower than 3.5kcal/g reported by Kanto and Juttupornpong (2002).

Cost of unpeeled cassava chips was the lowest (₦17, 320/tonnes) while cassava pellets had the highest cost. Cost of pelleting increased cost of production of UCP while cost of peeling and removal of peels accounted for high cost of PCC. Cost of maize at the time of the study was ₦32,000/tonne, thus UCC and UCG were 54.12% and 59.78% cost of maize while PCC and UCP were 70.57% and 80.88%, respectively. Compared to cost of maize, UCC (54.12%) and UCG (59.78%) were lower than 60% recommended by Tewe (2004) and PCC (70.57%) and UCP (80.88%) were higher. Tewe (2004) stated that price of cassava meal should not more than 60% price of maize for economic reason.

3.5 Conclusion

Peeling significantly ($p<0.05$) reduced crude fibre, crude protein and cyanide contents but considerably increased cost of production. Cereals represent the major source of energy in poultry feeds and their metabolisable energy vary between 2.68 – 3.33kcal/g. Unpeeled cassava products (UCP, UCP and UCG) gave nutritive values comparable to many energy feedstuffs, hence are recommended for use in poultry feeding. However, Unpeeled Cassava Chips (UCC) and Unpeeled Cassava Grit (UCG) were favoured because of price and UCG is promising because of possible mechanization and all year round production.

CHAPTER FOUR

REPLACEMENT OF MAIZE BY CASSAVA CHIPS AND PELLET IN THE DIETS OF REPLACEMENT PULLET AND LAYER

4.1 Introduction

Energy supply for poultry feeding is a major problem facing livestock industry in Nigeria. The energy component of poultry feed constitutes the largest proportion of compound feed for efficient productivity (Tewe, 2004). The deplorable level of livestock production in the third world countries has been attributed to a number of factors which include the spiraling price of cereals due to competition for it by both man and animals (Khajarern and Khajarern, 1986).

The current food crisis fuelled by the conversion of maize to biofuel has further reduced the availability of this cereal for human and animal consumption. This has caused astronomic increase in price of maize, which is the major energy source in African countries. Therefore, there is need to exploit cheaper energy source, to replace expensive cereals for livestock production. Cassava as cheap energy source offers great potential as a viable alternative to scarce maize (Balagopalan *et al.*, 1988).

The total annual production of cassava in Nigeria is put at 49.5 million tonnes (FAO, 2008). Cassava *(Manihot esculentum* Crantz) is a staple food widely grown in the tropical Africa because of its efficient production of cheap energy, year-round availability, tolerance to extreme ecological stress condition and suitability to present farming and food system in Africa (Oke,1978). The cassava tuberous roots is essentially a carbohydrate source with 60-65% moisture, 20-30% carbohydrate, 0.2-0.6% ether extracts, 1-2% crude protein (Omole, 1977). Ademosu and Eshiett (1980) reported that chick diet should not contain more than 15% cassava root or else performance will be affected. While Rangilal *et al.* (1995) concluded that up to 40% of maize in broiler starter diet could be replaced with cassava, and Buitrago and Luckett (1999) found that 20% inclusion of cassava gave a satisfactory performance.

Three feeding trials were conducted in this study as follows.

Trial I – chick phase

Trial II – grower phase

Trial III – layer phase

4.2. Trial I: Chick phase

Trial 1 was the partial and complete replacement of maize by cassava chips and pellet in the diet of chick pullets.

4.2.1. Materials and methods

Peeled Cassava Chips (PCC), Unpeeled Cassava Chips (UCC) and Unpeeled Cassava Pellets were prepared as described in chapter three. The three products were used to formulate feed as described below.

4.2.1.1. Diet formulation and management of birds.

Four hundred and eight, day old Bovan strain of chicks, bought from a commercial hatchery in Ibadan were first fed for a week with commercial feed and then randomly allotted to eight experimental diets. Diet 1 was maize – based diet and served as Control Diet (CD). Maize was replaced by UCC and UCP at 25%, 50% and 100% while PCC was only used at 25% level. There were three replicates of seventeen birds each per treatment. The chicks were fed *ad libitum* for seven weeks. Parameters considered included, feed intake, body weight gain, Feed Conversion Ratio (FCR), mortality and economy of production. Gross composition of the experimental feed is shown in Table 9

4.2.1.2. Chemical analysis

Samples of diets were analyzed for proximate composition and hydrogen cyanide content using the procedures of AOAC (1990) and Bradbury *et al*. (1999), respectively.

4.2.1.4. Statistical analysis

All data were subjected to analysis of variance using SAS (1997)

4.2.2. Results

The proximate compositions of the experimental diets are presented in Table 10. The dry matter values ranged from 88.99% to 90.64%. Results of proximate composition of the experimental diets were similar. Values of chemically determined cyanide content were higher than those based on calculation.

Table 9: Gross compositions of the experimental chicks' diets

	TREATMENTS							
COMPOSITION %	**100% Maize**	**25% UCC**	**50% UCC**	**100% UCC**	**25% PCC**	**25% UCP**	**50% UCP**	**100% UCP**
Maize	40.50	33.00	22.50	-	33.00	33.00	22.50	-
UCC	-	11.00	22.50	44.50	-	-	-	-
PCC	-	-	-	-	11.00	-	-	-
UCP	-	-	-	-	-	11.00	22.50	44.50
Corn brain	17.00	9.50	9.00	7.00	9.50	9.00	9.00	7.00
Toasted Soya	20.00	20.50	21.00	28.00	20.00	21.00	21.50	28.00
Groundnut cake	6.00	10.00	10.00	10.80	10.00	10.00	10.00	10.80
Wheat offal	6.80	6.80	4.80	-	6.80	6.80	4.80	-
Fish meal (72%)	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Bone meal	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Oyster shell	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Premix*	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
DL Methionine	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
L- Lysine	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Total	100	100	100	100	100	100	100	100
Cal. Value	2822	2823	2829	2812	2823	2832	2835	2819
Cal. Protein	20.20	20.60	20.00	20.20	20.60	20.60	20.00	20.20

UCC = Unpeeled Cassava Chips,PCC = Peeled Cassava Chips, UCP = Unpeeled Cassava Pellets

* Premix Content per kg**:** Vitamin A 12,500,000.00I.U, Vitamin D_3 2,500,000.00I.U, Vitamin E 40,000.00mg, Vitamin K_3 2,000.00mg, Vitamin B_1 3,000.00mg, Vitamin B_2 5,500.00mg, Niacin 55,000.00mg, Calcium Pantothenate 11,500.00mg, Vitamin B_6 5,000.00mg, Vitamin B_{12} 25.00mg, Folic acid 1000.00mg, Biotin 80.00mg, C holine chloride 500,000.00mg, Manganese 120,000.00mg, Iron 100,000.00mg, Zinc 80,000.00mg, Copper 8,500.00mg, Iodine 1,500.00mg, Cobalt 300.00mg, Selenium 120.00mg, Anti-oxidant 120.000.00mg,

Table 10: Proximate Compositions and cyanide contents of experimental chick diets

	TREATMENTS							
Composition (%)	**100% Maize**	**25% UCC**	**50% UCC**	**100% UCC**	**25% PCC**	**25% UCP**	**50% UCP**	**100% UCP**
Dry Matter	90.64	89.88	89..32	89.27	88.99	90.01	88.99	90.13
Crude protein	20.61	21.74	21.52	21.89	20.33	21.30	20.33	21.30
Ether extract	6.03	6.13	5.93	5.72	5.66	6.01	5.89	5.99
Crude fibre	5.22	5.56	6.08	5.93	5.55	5.94	5.59	5.84
Ash	7.98	8.02	8.43	7.47	8.22	8.04	7.83	7.97
NFE	50.80	48.43	47.38	49.28	48.99	48.92	49.35	49.03
Cyanide (ppm)	0.05	10.43	15.83	30.65	5.85	3.09	10.58	20.75

UCC = Unpeeled Cassava Chip; PCC = Peeled Cassava Chip; UCP = Unpeeled Cassava Pellet

The performance characteristics of the chicks are shown in Table 11. Birds fed 25% cassava based diets gave values similar to the control diet. Mortality and feed intake values were similar for all the experimental diets. The respective values ranged from 0.05% to 2.00% and 26.71g/bird/day to 28.5g/bird/day. Final body weight, weight gain and FCR were significantly ($p<0.05$) affected by the experimental treatments. Final weight and feed conversion ratio of 100% UCC (460.12g/bird and 3.31) and UCP (452.50/bird and 3.33) were significantly ($p<0.05$) different from the control diet (576.00g/bird and 2.54 respectively). Weight gain of birds fed 50% UCC (19.32g/bird/day), 100% UCC (8.36g/bird/day) and 100% UCP (8.25g/bird/day) were lower ($p<0.05$) than that of the control diet (11.22g/bird/day).

Economy of production was calculated as cost of feed intake per kilogramme gain in weight. The result revealed that cost of feed decreased with increase in inclusion levels of cassava in the diets. Birds fed 100% UCC and UCP based diets (₦103.77/kg and ₦119.32/kg respectively) recorded higher ($p<0.05$) cost per kilogramme gain compared to 25% UCC (₦876/kg), however, similar to other experimental treatments.

Table 11: Performance characteristics of birds fed experimental chick diets

Parameters	TREATMENTS								
	100% Maize	**25% UCC**	**50% UCC**	**100% UCC**	**25% PCC**	**25% UCP**	**50% UCP**	**100% UCP**	**±SEM**
Initial Weight (g/bird)	105.01	109.03	109.02	109.6	111.10	108.14	106.17	106.15	0.50
Final Weight (g/bird)	576.11^{a}	560.50^{ab}	500.44^{ab}	460.1^{c}	540.2^{ab}	560.18^{ab}	505.00^{abc}	452.50^{c}	10.99
Weight gain (g/bird/day)	11.22^{a}	10.75^{ab}	9.32^{bc}	8.36^{c}	10.22^{ab}	10.29^{ab}	9.50^{abc}	8.25^{c}	0.51
Feed intake (g/bird/day)	28.52	27.24	27.43	27.63	27.00	27.10	27.55	26.71	0.62
FCR	2.54^{b}	2.54^{b}	2.94^{ab}	3.31^{a}	2.64^{b}	2.63^{b}	2.90^{ab}	3.33^{a}	0.14
Mortality (%)	2.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.18
Cost of feed (₦)	35.13	34.55	33.28	31.35	34.77	34.99	34.68	33.13	
Cost/Kg wt (₦ /kg)	89.23^{ab}	87.76^{b}	97.84^{ab}	103.70^{a}	91.79^{ab}	92.02^{ab}	100.57^{ab}	110.30^{a}	2.02

a,b,c: means in the same row with different superscripts are significantly different (p>0.05)

UCC = Unpeeled Cassava Chip; PCC = Peeled Cassava Chip; UCP = Unpeeled Cassava Pellet

4.2.3. Discussion

Proximate compositions of the experimental diets were similar since diets were formulated to balance for deficiencies in cassava. Buitrago and Luckett (1999) reported that mixture of 82 parts of cassava root meal with 18% part of full fat soybean resulted in a product with similar characteristics to those of maize. However, results obtained for cyanide from chemical analysis were higher than calculated values due to the fact that soybean also contains cyanide (EFSA, 2004).

The similar feed intake of the experimental chicks collaborated Tiemoko (1992) and Buitrago *et al.* (2002) who observed no significant differences in feed intake of broilers fed cassava based diets. Result of mortality revealed that cassava products used were not toxic to the chicks. Processes involved in the production of cassava chips and pellet greatly reduced cyanide content to levels that were not toxic to chicks. This confirmed Khajarern and Khajarern (1986) and Tewe (1991) that steam assisted pelleting and sun-drying will reduce cyanide content of pellets and chips respectively to a safe level.

Results of weight gain and feed conversion ratio showed that 50% replacement of maize with cassava chips and pellet did not adversely affect chick pullets, and that total replacement led to impaired growth rate and poor feed efficiency. Willie and Kinabo (1980) reported that body weight gain and FCR increased as cassava level in the rations rose from 17% to 34%, but at 41% and 51% levels, body weight gain declined and from 34% FCR was significantly ($p<0.05$) less than the control diet. Khajarern and Khajarern (1986) and Saentaweesuk *et al.* (2000) also reported slightly poorer weight gain and FCR of birds fed cassava based diet compared to maize. This study however, contradicted

Buitrago *et al.* (2002) that reported similar or superior weight gain and FCR for broilers fed cassava pellets.

4.3. Trial II: Grower phase

Two hundred and forty 10 weeks old growing Boval Black pullets were used in this study. The PCC, UCC and UCP were used to formulate experimental feed for the birds.

4.3.1. Materials and methods

4.3.1.1. Diets formulation and bird management

Diets were formulated to replace maize at 25% with PCC and 0%, 25%, 50% and 100% with UCC and UCP to form eight experimental diets. There were three replicates per treatment and 10 birds per replicate. The experimental design was completely randomized design. The birds were housed in battery cage system and provided with feed and water *ad libitum.* Parameters considered were feed intake, final weight, weight gain, feed conversion ratio, age at first egg, hen day production, egg production at 24th week, egg weight at 24th week and mortality. Gross composition of the experimental feed is shown in Table 12.

Table 12: Gross compositions of the experimental grower diets

COMPOSITION %	TREATMENTS							
	100% Maize	25% UCC	50% UCC	100% UCC	25% PCC	25% UCP	50% UCP	100% UCP
Maize	35.00	24.00	18.00	-	24.00	24.00	18.00	-
UCC	-	12.00	18.00	36.80	-	-	-	-
PCC	-	-	-	-	12.00	-	-	-
UCP	-	-	-	-	-	12.00	18.00	36.80
Wheat bran	22.50	20.00	17.30	12.00	20.00	20.00	17.30	12.00
Soya	10.00	13.50	15.20	20.70	13.50	13.50	15.20	20.70
Palm kernel cake	26.00	24.00	25.00	24.00	24.00	24.00	25.00	24.00
Fish meal (65%)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Oyster meal	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Bone meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Premix*	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Total	100	100	100	100	100	100	100	100
Cal. value	2466	2467	2466	2466	2467	2467	2466	2466
Crude protein	15.20	15.10	15.10	15.10	15.10	15.10	15.10	15.10

UCC = Unpeeled Cassava Chip; PCC = Peeled Cassava Chip; UCP = Unpeeled Cassava Pellet

* Premix composition per kg: Vitamin A 10,000,000.00I.U, Vitamin D_3 2,000,000.00I.U, Vitamin E 20,000.00mg, Vitamin K_3 2,000.00mg, Vitamin B_1 3,000.00mg, Vitamin B_2 5,000.00mg, Niacin 45,000.00mg, Calcium Pantothenate 10,000.00mg, Vitamin B_6 4,000.00mg, Vitamin B_{12} 20.00mg, Choline chloride 300,000.00mg, Folic acid 1,000.00mg, Biotin 50.00mg, Manganes 300,000.00mg, Iron 120,000.00mg, Zinc 80,000.00mg, Copper 8,500.00mg, Iodine 1,500.00mg, Cobalt 300.00mg, Selenium 120.00mg, Anti-oxidant 120.000.00mg

4.3.1.2. Chemical analysis

Samples of diets were analyzed for proximate composition and hydrogen cyanide content using the procedures of AOAC (1990) and Bradbury *et al*. (1999), respectively.

4.3.1.4. Statistical analysis

All data were subjected to analysis of various using SAS (1997)

4.3.2. Results

Proximate composition of the experimental diets is shown in Table 13. Control diet had the lowest value for crude protein. However, crude fibre content of diet containing 25% peeled cassava chip recorded the lowest value (6.30%) while diet containing 100% UCC had the highest value (7.83%). Cyanide content of the feed increased with increase levels of cassava products in the diets.

Results of performance of growers fed the experimental diets showed that feed intake, weight gain, age at first egg, egg weight at 24 weeks and mortality were not significantly ($p>0.05$) affected by dietary treatment (Table 14). Average feed intake of growers fed the control diet was the highest (81.72g/bird/day) while those fed 25% UCC had the lowest value (77.62g/bird/day). Weight gain ranged from 8.40 -10.06 g/bird/day. The first-egg was recorded form birds fed 25% UCC at 147th day while those on 100% UCC started last at 154day. Mortality record showed no significant ($p>0.05$) differences. Birds fed control diet, 100% UCC and 25% PCC recorded 3.5% each. Other dietary treatment recorded no mortality.

Final weight (weights at 20weeks), FCR and HDP at 24 weeks were significantly ($p<0.05$) affected by dietary treatment. Birds on 100% cassava based diets recorded lower ($p<0.05$) final weight compared to control diet, 25% UCC and PCC. Average final weight ranged from 1200g – 1300g. FCR of birds fed 25% PCC and UCC (7.95 and 7.99 respectively) were significantly ($p<0.05$) lower than those on 100% UCC (9.30), and UCP based diets (9.30, 9.22 and 9.22 for 25%, 50% and 100% respectively).

The hen day production at 24 weeks of birds fed 25% PCC (58.94%) was the highest and significantly ($p<0.05$) higher than values records for birds on cassava pellets based diet, but, similar ($p>0.05$) to values recorded for birds fed cassava chip based diets and the control. The values ranged from 28.10% - 58.94%.

Table 13: Chemical compositions of experimental grower diets

COMPOSITION (%)	TREATMENTS							
	100% Maize	25% UCC	50% UCC	100% UCC	25% PCC	25% UCP	50% UCP	100% UCP
Dry Matter	89.25	88.97	88.72	88.78	90.13	91.64	90.73	88.96
Crude Protein	13.30	14.98	15.54	14.70	14.84	15.10	13.86	14.84
Ether Extract	3.19	5.05	4.83	3.36	5.14	4.81	3.97	4.07
Crude Fibre	6.59	6.25	7.22	7.83	6.30	6.83	6.33	6.91
Ash	9.91	10.00	9.92	9.50	11.86	13.20	12.83	12.54
NFE	56.26	52.69	52.21	55.01	50.46	51.23	53.74	50.64
Phosphorus	0.47	0.42	0.46	0.47	0.56	0.56	0.58	0.58
Calcium	0.91	097	1.02	1.02	0.90	1.01	1.05	0.99
Cyanide (ppm)	0.03	8.33	11.44	25.72	5.22	6.62	12.11	20.64

UCC = Unpeeled Cassava Chip; PCC = Peeled Cassava Chip; UCP = Unpeeled Cassava Pellet

Table 14: Performance characteristics of bird fed experimental grower diets

Parameters	100% Maize	25% UCC	50% UCC	100% UCC	25% PCC	25% UCP	50% UCP	100% UCP	±SEM
	TREATMENTS								
Initial Weight (kg/bird)	0.63	0.61	0.62	0.61	0.60	0.61	0.61	0.61	0.05
Final Weight (kg/bird)	1.30	1.29	1.30	1.20	1.30	1.21	1.22	1.21	0.30
Weight gain (g/bird/day)	9.57	9.71	9.71	8.43	10.00	8.57	8.71	8.71	0.15
Feed intake (g/bird/day)	81.72	77.62	79.71	80.85	79.53	79.71	80.33	80.28	1.21
FCR	8.54^{ab}	7.99^{b}	8.21^{ab}	9.39^{a}	7.95^{b}	9.30^{a}	9.22^{a}	9.22^{a}	0.54
Mortality (%)	3.57	0.00	0.00	3.57	3.57	0.00	0.00	0.00	2.19
Age of birds at first egg (days)	149.00	147.00	149.00	154.00	151.00	149.00	152.00	153.00	2.42
Hen day production at 24th week (%)	46.68^{ab}	46.93^{ab}	49.59^{ab}	37.74^{ab}	58.94^{a}	32.74^{b}	32.74^{b}	28.10^{b}	6.58
Egg weight at 24 weeks(g)	55.47	56.03	55.69	53.69	56.82	54.47	52.28	57.14	1.86
Cost of feed (₦/kg)	23.98	22.72	22.13	20.99	22.96	23.20	23.85	22.46	

$^{a,b,c:}$ means in the same row with different superscripts are significantly different ($p<0.05$)

UCC = Unpeeled Cassava Chip; PCC = Peeled Cassava Chip; UCP = Unpeeled Cassava Pellet

4.3.3. Discussion

Results of this feeding trial revealed that inclusion of cassava meal products did not adversely affect feed intake, weight gain, age at first egg and mortality. Leeson and Summer (1981) suggested that energy intake of the growing pullet is the limiting factor to growth rate, since regardless or diet specification, pullets seem to consume similar quantities of energy. The reported observations were expected since the eight experimental diets were formulated to contain similar energy levels, the results were expected. These results however confirmed Stevenson and Jackson (1983) who reported no adverse effect on growth performances of poultry fed up to 50% cassava.

Average body weight at 20 weeks was adversely affected by dietary treatment. This agreed with Willies and Kinabo (1980) that observed a linear decreased in weight of poultry resulting from the increased in the quantity of cassava included in the ration. However, there was no significant ($p>0.05$) effect of the dietary treatment on age at first egg. This result supported the argument that body weight at eighteen weeks has no effect on maturity. Leeson and Summer (1997) stated that the argument that is often heard about the role of body weight at maturity, is not in fact, too important, because the pullet will show catch up growth prior to first egg and that small pullet does show some compensatory growth to the time of the first egg.

Egg weight at 24 weeks was not adversely ($p>0.05$) affected by dietary treatment but hen day production at 24 week was adversely ($p<0.05$) affected. Lower ($p<0.05$) weight at 20 weeks of 100% cassava based diet did not affect egg weight at 24 weeks. This result contradicted Leeson and Summer (1983) that concluded that body weight is the major factor controlling early egg size.

4.4 Trail III: Layer phase

4.4.1. Materials and methods

Unpeeled cassava chips and unpeeled cassava pellets were used to replace maize at 25%, 50% and 100% levels. The PCC was only used at 25% in the diet of 240 layers. There were eight experimental diets as shown in table 15 with three replicates of ten birds each.

4.4.1.1 Diet formulation and bird management

Thirty weeks old Bovan black hybrid layers that were previously fed commercial layer ration were randomly allotted to eight experimental diets (Table 15). There were three replicates of ten birds each per treatment. The birds were fed *ad libitum*. Water and veterinary care were provided adequately. The following parameters were considered: feed intake, weight gains FCR, mortality, egg weight and economy of production.

4.4.1.2 Chemical analysis

The proximate composition of the experiment diets were determined by the method of AOAC (1990) while hydrogen cyanide content of feed was determined using alkaline paper method as described by Bradbury *et al.* (1999).

4.4.1.3 Statistical analysis

All the data obtained in the study were subjected to descriptive analysis and differences were analyzed using Duncan Multiple Range Test (Duncan, 1955).

Table 15: Gross compositions of the experimental layer diets

COMPOSITION%	TREATMENTS							
	100% Maize	25% UCM	50% UCM	100% UCM	25% PCM	25% UCP	50% UCP	100% UCP
Maize	41.90	32.40	22.00	-	32.40	32.40	22.00	-
UCM	-	10.50	22.00	46.00	-	-	-	-
PCM	-	-	-	-	10.00	-	-	-
UCP	-	-	-	-	-	10.50	22.00	46.00
Wheat bran	7.50	4.50	4.00	-	5.00	4.50	4.00	-
Corn bran	13.00	12.00	8.00	5.40	12.00	12.00	8.00	5.40
Soya bean meal	14.00	15.00	17.00	19.00	15.00	15.00	17.00	19.00
Toasted soya	2.00	4.00	5.40	10.00	4.00	4.00	5.40	10.00
Palm kernel cake	10.00	10.00	10.00	8.00	10.00	10.00	10.00	8.00
Fish meal	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Oyster meal	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50
Bone meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Premix*	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
DL Methionine	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Total	100	100	100	100	100	100	100	100
Cal. value ME Kcal/Kg	2599	2600	2599	2599	2600	2600	2599	2599
Crude protein	16.70	16.70	16.70	16.70	16.70	16.70	16.70	16.70

UCC = Unpeeled Cassava Chip; PCC = Peeled Cassava Chip; UCP = Unpeeled Cassava Pellet

*Premix Content per Kg**:** Vitamin A 10,000,000.00I.U, Vitamin D_3 2,000,000.00I.U, Vitamin E 23,000.00mg, Vitamin K_3 2,000.00mg, Vitamin B_1 3,000.00mg, Vitamin B_2 6,000.00mg, Niacin 50,000.00mg, Calcium Pantothenate 10,000.00mg, Vitamin B_6 5,000.00mg, Vitamin B_{12} 25.00mg, Folic acid 1,000.00mg, Biotin 50.00mg, Choline chloride 400,000.00mg, Manganese 120,000.00mg, Iron 100,000.00mg, Zinc 80,000.00mg, Copper 8,500.00mg, Iodine 1,500.00mg, Cobalt 300.00mg, Selenium 20.00mg, Anti-oxidant 120.000.00mg,

4.4.2. Results

Chemical compositions of the experimental diets are shown in Table 16. The proximate composition of all the diets were similar (p>0.05). Performance of birds fed 25% cassava products were similar (p>0.05) to those on control diet as shown in Table 17. Feed intake of birds on the eight experimental diets were similar (p>0.05). The highest value was recorded for the control diet (115.9g/day) and the lowest value was recorded for birds fed 25% pellets (106.40g/day). Hen day production of birds fed 50% and 100% cassava pellets were significantly (p<0.05) lower than the control diet. However birds fed cassava chip and 25% cassava pellets recorded values that were similar (p>0.05) to the control diet. Hen day production ranged from 63.56% to 70.31%.

The FCR of bird fed cassava chip and pellets based diets were similar (p>0.05) to the control diet, but 50% cassava pellets (5.15) was significantly (p<0.05) higher than 25% cassava chip (4.70). Weight gain of layers fed 50% and 100% cassava pellets (0.47g/day/ and 0.26g/day/ bird respectively) were significantly (p<0.05) lower than the control diet and 25% unpeeled cassava chips that were 2.12g/day/bird and 2.34g/day/bird respectively.

Result obtained on mortality showed that all the experimental diets recorded similar (p>0.05) values. Birds fed 100% maize (control diet) and 100% cassava chips recorded the absolute highest value (10%). The values ranged from 0.0%-10%.

Result on economy of production calculated as cost per a tray of egg revealed that birds fed 50% cassava pellets recorded the highest value (₦150.79/tray) which was higher (p<0.05) than birds fed cassava chips based diets, but similar to the control diet (₦142.46/tray). Cost per a tray or eggs ranged from ₦128.89/tray to ₦150.79/tray

Table 16: Chemical compositions of experimental layer diets

COMPOSITION (%)	TREATMENTS							
	100% Maize	25% UCC	50% UCC	100% UCC	25% PCC	25% UCP	50% UCP	100% UCP
Dry Matter	90.62	91.03	90.23	90.10	89.84	90.60	89.76	89.17
Crude Fibre	5.85	5.65	4.94	5.99	3.68	5.01	4.65	4.13
Ether Extract	3.70	5.20	4.85	4.05	4.78	4.23	6.82	5.40
Crude Protein	17.92	16.94	17.50	16.38	17.22	16.80	17.50	17.64
Ash	9.64	8.87	9.83	7.90	12.24	11.20	8.37	8.57
NFE	55.51	54.37	53.11	55.68	51.92	53.36	52.42	53.43
Phosphorus	0.65	0.53	0.54	0.64	0.60	0.61	0.61	0.58
Calcium	3.92	3.90	3.77	3.82	3.95	3.72	3.86	3.70
Cyanide (ppm)	0.02	6.58	18.34	29.12	6.44	8.33	15.12	25.33

UCC = Unpeeled Cassava Chip; PCC = Peeled Cassava Chip UCP = Unpeeled Cassava Pellet

Table 17: Performance of Birds Fed Experimental Layer Diets

Parameters	TREATMENTS								
	100% Maize	**25% UCM**	**50% UCM**	**100% UCM**	**25% PCM**	**25% UCP**	**50% UCP**	**100% UCP**	**±SEM**
Av. Feed intake g/day/bird	115.90	108.78	108.00	108.70	109.81	106.0	109.52	108.00	8.79
Wt. Gain (g)	2.12 [a]	2.45 [a]	1.62 [a]	1.05 [a]	1.51 [a]	1.39[a]	0.17[b]	0.26[b]	0.44
FCR kg/tray	4.95[ab]	4.70[b]	4.87[ab]	4.84[ab]	5.01[ab]	4.98[ab]	5.15[ab]	5.10[ab]	0.16
Mortality (%)	10.00	4.50	0.00	10.00	3.50	0.00	7.00	0.00	3.01
HDP (%)	70.31[a]	68.63[ab]	66.55[abc]	67.39[abc]	65.87[bc]	66.42[abc]	63.73[c]	63.56[c]	1.40
Av. Egg Weight (g)	56.84	57.04	57.75	56.38	57.13	59.53	57.65	57.13	3.77
Cost/kg feed(₦/kg)	28.78	28.33	27.72	26.63	28.53	28.23	29.28	28.47	
Cost/tray of eggs (₦)	142.46[ab]	133.15[b]	135.00[b]	128.89[b]	142.94[ab]	143.08[ab]	150.79[a]	145.48[a]	5.33

[abc:] means in the same row with different superscripts are significantly different (p>0.05)

UCC = Unpeeled Cassava Chip; PCC = Peeled Cassava Chip; UCP = Unpeeled Cassava Pellet

Egg quality characteristics (Table 18) revealed that egg quality parameters were not significantly (p>0.05) affected by dietary treatments, except albumen weight that was significant (p<0.05) as shown in table 18. Albumen weight of 25% UCP was the highest and significantly (p<0.05) different from 50% UCC and 100% cassava based diets. Albumen weight tends to reduce with increase in inclusion level of cassava in the diet. Ranges of yolk weight, albumen weight and shell weight were 14.14g – 15.11; 34.68g - 40.80g and 6.24g - 6.67g.

Yolk colour was not dietary affected however, cassava based diets recorded values lower than that of control diet and progressively reduced with increase in inclusion level of cassava. Shell thickness was similar (p>0.05) for all the experimental treatments.

Table 18: Egg quality characteristics of birds fed experimental layer diets

Parameters	TREATMENTS								
	100% Maize	25% UCC	50% UCC	100% UCC	25% PCC	25% UCP	50% UCP	100% UCP	±SEM
Egg weight (g)	59.5	57.43	55.62	55.8	58.25	62.38	58.65	57.85	
Yolk wt. (g)	15.03	14.19	14.14	14.20	14.46	15.11	14.86	14.69	0.93
Yolk height (cm)	1.66	1.63	1.64	1.63	1.66	1.69	1.59	1.60	0.07
Yolk %	25.26	24.65	25.45	25.40	24.80	24.27	25.34	25.40	1.49
Albumen wt. (g)	37.96^{ab}	37.00^{b}	35.21^{b}	34.68^{b}	37.66^{ab}	40.80^{b}	37.33^{b}	36.49^{b}	2.23
Albumen %	63.73	64.48	64.31	62.23	63.93	65.33	63.63	63.09	2.52
Shell wt. (g)	6.51	6.24	6.27	6.92	6.63	6.47	6.46	6.67	0.75
Shell %	11.94	10.87	11.25	12.37	11.27	10.40	11.65	11.51	1.29
Shell Thickness (mm)	0.41	0.35	0.37	0.41	0.38	0.37	0.38	0.39	0.09
Yolk Colour	1.71	1.60	1.50	1.04	1.62	1.60	1.69	1.00	1.34
Shell Surface Area	71.98	72.15	72.76	71.59	72.23	74.30	72.67	72.23	2.93

$^{a,b:}$ means in the same row with different superscripts are significantly different ($p<0.05$)

UCC = Unpeeled Cassava Chips; PCC = Peeled Cassava Chips; UCP = Unpeeled Cassava Pellets

4.4.3 Discussion

Proximate composition of cassava based diets were similar ($p>0.05$) to the control diet. Fibre content of unpeeled cassava based diets were also similar ($p>0.05$) to 100% maize (control diet) due to reduction in other fiber sources in the diets.

Feed intakes of birds fed the experimental diets were similar since all the experimental diets were formulated to be isocaloric. Birds eat primarily to satisfy their energy requirement (Smith, 1992). However, this result revealed that pelletization did not improve feed intake of layers on cassava based diets contrary to Balagopalan *et al.* (1988) probably due to large size of cassava pellets used (Mosobalaje *et al*., 2007). Pellet size of 5mm used was bigger than sieve size recommended for layers by Portella *et al* (1988). An attempt to mill it to desire size produced powdery form because pellets produced were native pellets which according to Leeson and Summer (1997) were only the original mash enclosed in a hard capsule.

Hen day production and weight gains of birds fed 50% and 100% cassava chips were similar to the control diet and confirm Hamid and Jalaludin (1972) that replacement of up to 60% of a corn diet with cassava did not affect feed efficiency and egg production. Large pellet size might have affected egg production, weight gain and feed efficiency ratio. Leeson and Summer (1997) stated that birds fed fine or coarse-ground corn seem to exhibit lower digestibility value.

Mortality values of cassava based diets were similar to the control diet.This result revealed that well processed cassava might not be toxic to laying birds. Cyanide content of cassava used ranged between 35.34 and 57.08ppm and confirmed Tewe (2004) that cyanide levels less than 100ppm in cassava product is safe for the animals. Tewe (1986) and Ngoka *et al*. (1986) also reported little or no mortality when cassava was used to completely replace maize.

High cost of pelleting increased cost of cassava pellets based diets. This consequently affected economy of production of cassava pellet based diets. Price of cassava pellets used was higher than 60% cost of maize recommended by Khajarern *et al*., (1979). However, costs of cassava chip based diets were lower than the control diets.

Egg quality characteristic were not significantly ($p<0.05$) affected by dietary treatment. Higher ($p>0.05$) albumen weight of birds fed 25% UCP might be due to bigger egg size as albumen percentage was not significant ($p>0.05$). Austic and Nesheim (1990) stated that the weight of an egg equals the weight of the parts (albumen and yolk). The higher the weight of an egg the higher the weight of the parts especially egg yolk and albumen. The results of this study revealed that the higher the albumen percentage the lower the shell percentage.

CHAPTER FIVE

EVALUATION OF CASSAVA ROOT PRODUCTS (CRP) AS REPLACEMENTS FOR MAIZE IN CHICK, GROWER AND LAYER DIETS

5.1 Introduction

Cassava is being transformed from a famine security and subsistence crop to an industrial crop notably in livestock feeding in Asia and Latin American. Its industrial potential has not been exploited beyond increase marketing of processed cassava "gari" in urban and export market in Nigeria (Nweke *et al*, 2002). Cassava usage for livestock feeds stand at 5%, 2%, 5% and 1% of total production in Nigeria, Ghana, Cote d vore and Liberia respectively in year 2000 (Tewe, 2004). However in Vietnam, most of 2.0 million tonnes of cassava produced is used in animal feeding (Le Du Ngoan and Ly, 2002) and about 10 - 14 million tonnes of total 18 -22 million tonnes of fresh tuber produced in Thailand were processed into dried cassava chips and pellet for animal feed (Kanto and Juttuporpong, 2002).

Nigeria is the world's leading producer of cassava with about 49.5 million tonnes annually (FAO, 2008). In spite of this, there has been a shortage of this root crop even with its present status as a traditional staple in Nigeria. This is due to cyclic glut that is always experienced after large harvest (Tewe, 2002). During this glut, producers loss money (Nweke *et al*, 2002) and that discouraged further production that later cause scarcity. Development of cassava into industrial raw materials have been hampered by the shortages and high cost of cassava after its cycle of glut.

Usage of cassava in livestock production will take care of the cycle of glut that accompanies over- production of cassava over time. Expansion of cassava production and utilization will create job opportunities which will make significant impact in poverty alleviation. Cassava, as energy raw materials in livestock industry will address skyrocketing price of maize. (Tewe, 2002)

Excessive fine nature of cassava root meal and its cyanogenic content are the major limitations of cassava inclusion in livestock feed. However, processing into pellet and grit will eliminate dustiness and sun-dying will reduce cyanide content to levels that are non-toxic to animal.

Unavailability of pelleting machine and the consequent high cost of pelleting make the use of cassava pellet in livestock feed in Nigeria uneconomical (Mosobalaje *et al.*, 2007). Garri, a roasted or gelatinized granule, is widely processed in Nigeria. This method of Garri processing could be exploited in production of feed grade cassava "cassava grit". Cassava grit is produced like garri except that there were no peeling and fermentation.

This study was designed to investigate the effects of replacing maize with cassava root products in the diet of chicks, grower and layer. Three experimental trials were conducted as described below.

Trial I – chick phase

Trial II – grower phase

Trial III – layer phase

5.2 Trial I: Effects of replacement of maize with cassava root products in the diet of chick pullets

5.2.1. Materials and methods

5.2.1.1 Feeding trial

Seven experimental diets were formulated. Diet I was maize based and served as the Control Diet (CD). Replacement of maize with 50% UCC, UCP and UCG constitute diets 2, 3 and 4, while 100% replacement formed diets 5, 6 and 7 respectively. Diets were formulated to be balanced for all nutrients. Two hundred and ten Bovan brown from a commercial hatchery in Ibadan were used. Thirty birds were randomly allocated to each of the seven experimental diets and there were three replicates of ten birds per treatment. Birds were provided with experimental feed and water ad *libitum*. Parameters considered were, feed intake, final body weight, weight gain, feed conversion ratio, mortality and economy of production. Gross composition of the experimental diets is shown in Table 19.

Table 19: Gross composition of the experimental chick diets

Ingredients (%)	100% Maize Diet 1	50% substitution UCC Diet 2	UCP Diet 3	UCG Diet 4	100% Substitution UCC Diet 5	UCP Diet 6	UCG Diet 7
Maize	44.50	22.50	22.50	22.50	-	-	-
Cassava	-	22.50	22.50	22.50	47.00	47.00	47.00
Toasted soya	19.00	24.50	24.50	24.50	29.00	29.00	29.00
Palm kernel cake	7.20	4.7	4.7	4.7	-	-	-
Wheat offal	11.00	7.50	7.50	7.50	4.70	4.70	4.70
Groundnut cake	10.00	10.00	10.00	10.00	11.00	11.00	11.00
Fish meal (72%)	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Bone meal	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Oyster shell	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Premix*	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25
DL Methionine	0.20	0.20	0.20	0.20	0.20	0.20	0.20
L-Lysine	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Crude value (Kcal/kgME)	2875.36	2875.46	2875.37	2875.67	2875.47	2875.47	2875.47
Calculated Protein (%)	20.39	20.13	20.13	20.13	20.55	20.55	20.55

UCC = Unpeeled Cassava Chips; UCP = Unpeeled Cassava Pellets; UCG – Unpeeled Cassava Grits

* Premix Content per kg**:** Vitamin A 12,500,000.00I.U, Vitamin D_3 2,500,000.00I.U, Vitamin E 40,000.00mg, Vitamin K_3 2,000.00mg, Vitamin B_1 3,000.00mg, Vitamin B_2 5,500.00mg, Niacin 55,000.00mg, Calcium Pantothenate 11,500.00mg, Vitamin B_6 5,000.00mg, Vitamin B_{12} 25.00mg, Folic acid 1000.00mg, Biotin 80.00mg, C holine chloride 500,000.00mg, Manganese 120,000.00mg, Iron 100,000.00mg, Zinc 80,000.00mg, Copper 8,500.00mg, Iodine 1,500.00mg, Cobalt 300.00mg, Selenium 120.00mg, Anti-oxidant 120.000.00mg,

5.2.1.2 Blood analysis

At six week of age, three birds per replicate were randomly selected and blood was carefully collected through wing vein collected into labeled EDTA bottles for estimation of heamatological parameters. Blood collected for serum metabolites estimation was allowed to clot and serum decanted after centrifugation.

Packed Cell Volume (PCV), Hemoglobin Concentration (Hb), Red Blood Cell (RBC), White Blood Cell (WBC), Plasma Protein (PP), Mean Cell Volume (MCV), Means Cell Haemoglobin (MCH) and Mean Cell Hemoglobin Concentration (MCHC) were assayed using the procedure of Schalm (1971). Serum total protein (albumin and globulins) were determined according to the method of Doumas (1975). The glucose fraction was determined using the method of Bonder and Mead (1974). Aspartate Amino Transferace (AST) and Alanines Amino Transferase (ALT) were analyzed using a method described by Ackers (1970). Serum thiocyanate was determined according to Tewe (1975).

5.2.1.3 Metabolic trial

At the 7^{th} week, two chicks were randomly selected from each of the experimental treatments and housed in the metabolic cage for metabolic study to determine the apparent nutrient digestibility of the experimental birds. Equal quatity of feed (75g) was offered to the birds. Remnants were weighed and recorded and feed intake was calculated.

Flat trays covered with aluminum foil were placed under each cage compartment. The droppings voided were collected daily by total collection process and weighed before being transferred to the laboratory for oven dry and chemical analysis. Sample of feed supplied and droppings voided were analyzed for their dry matter, crude protein, ash, ether extracts and crude fibre.

5.2.1.4 Chemical analysis

The proximate composition of the experimental diet and dropping were carried out by the method of AOAC (1990).

5.2.1.5 Statistical analysis

All the data obtained in the study were analyzed according to the procedure of the Statistical Analysis System (SAS, 1997).

5.2.3 Results

Chemical compositions of the experimental diets are shown in Table 20. The proximate composition values were similar for all the experimental diets. Results of performance of birds fed the experimental diets are shown in Table 21. Weight gain and final body weight of birds fed UCC containing diets were significantly ($p>0.05$) different from those on other experimental diets. Birds fed cassava pellet and grit containing diets (50% and 100%) recorded values similar ($p>0.05$) to the control diet for feed intake, weight gain, FCR, and final body weight. Feed intake of birds fed 100% UCC was the lowest (30.35g/bird/ day) and significantly ($p<0.05$) different from other experimental diets except 50% UCC (30.95g/bird/day). The highest was recorded for birds fed 50% UCP (31. 61/bird/day).

Results of weight gain and final weight showed that UCC based diets (50% and 100%) were significantly ($p<0.05$) lower than the CD, UCG based diets and 50% UCP based diet. Dietary treatments significantly ($p<0.05$) affected feed conversion ratio. The FCR of birds fed 100% UCC was significantly ($p<0.05$) lower than the control diet and 50% UCP. Mortality was not significantly ($p<0.05$) affected by dietary treatments. No mortality was however recorded in all the dietary treatments.

Feed cost reduced with increasing inclusion levels of cassava in the diet. Result of economy of production revealed that cost of weight gain was not significantly ($p<0.05$) affected by inclusion of cassava in the diets of chicks. Birds fed 100% cassava grit recorded the absolute lowest value (₦122.64/kg weight gain) and the highest absolute value was recorded for the birds fed 100% UCC (₦129. 61/kg weight gain). Cost of weight gain of birds fed control diets was ₦128.08/kg weight gain.

Nitrogen retention was however significantly ($p<0.05$) affected by dietary treatment as shown in Table 22. Birds fed 100% cassava based diets had significantly ($p<0.05$) lower nitrogen retention value than the control diet and 50% cassava based diets except for birds fed cassava grits containing diets. The dry matter, crude fibre and ether extract digestibility were not significantly affected. The respective values ranged between 65.33 - 70.01%, 29.69 - 32.70% and 77. 20 - 80.50%.

Result on hematological indices and serum metabolites are shown in Table 23 and 24 respectively. All hematological parameters investigated were not adversely ($p< 0.05$) affected by dietary treatment. Birds fed CD had highest values for PCV, Hb and RBC and lowest values for MCH and MCHC. The respective values range from 18.50 to

24.50ml%, 11.30 to 12.75g/dl, 2.43 to 3.69 $10^6/mm^3$, 32.96 to 50.87µµg and 44.65 to 63.41%.

Serum thiocyanate of birds fed CRP based diets were significantly ($p<0.05$) higher than the control diets as shown in Table 24. Bird fed 50% and 100% CRP had similar values. Blood glucose values of birds fed 100% CRP based diets were higher ($p<0.05$) than the control diets. Birds fed 50% UCC and UCP were similar ($p<0.05$) to those on 100% CRP based diets.

Table 20: Chemical compositions of the experimental chick diets

Composition (%)	100% Maize Diet 1	50% substitution UCC Diet 2	UCP Diet 3	UCG Diet 4	100% Substitution UCC Diet 5	UCP Diet 6	UCG Diet 7
Dry matter	90.64	89.88	89.32	89.27	88.99	90.13	89.92
Crude protein	20.61	21.74	21.52	21.89	20.33	21.13	21.50
Ether extract	6.03	6.13	5.93	5.72	5.89	5.99	6.01
Crude fibre	5.22	5.56	6.08	5.93	5.59	5.84	5.94
Ash	7.89	8.02	8.43	8.04	7.83	7.97	8.04
Nitrogen free extract	50.89	48.43	47.38	49.28	49.35	49.03	48.92
Calcium	1.01	1.11	0.99	0.97	1.11	0.95	0.94
Phosphorus	0.45	0.43	0.45	0.39	0.42	0.48	0.49

UCC = Unpeeled Cassava Chips; UCP = Unpeeled Cassava Pellets; UCG – Unpeeled Cassava Grits

Table 21: Performance and economy of production of pullet chicks on the experimental diets

Parameters	100% Maize (Diet 1)	50% Substitution UCC (Diet 2)	50% Substitution UCP (Diet 3)	50% Substitution UCG (Diet 4)	100% Substitution UCC (Diet 5)	100% Substitution UCP (Diet 6)	100% Substitution UCG (Diet 7)	±SEM
Initial weight (g/bird)	101.81	101.54	100.52	106.01	105.64	103.32	105.44	0.54
Final weight (g/bird)	551.50[a]	510.00[b]	558.25[a]	552.32[a]	502.44[b]	529.89[a]	553.39[a]	10.14
Feed intake (g/bird/day)	30.85[ab]	30.90[ab]	31.61[a]	31.20[a]	30.35[b]	31.45[a]	31.15[a]	0.21
Weight gain (g/day)	10.72[a]	9.73[b]	10.91[a]	10.64[a]	9.44[b]	10.42[ab]	10.68[a]	0.24
Feed conversion ratio	2.90[b]	3.18[ab]	2.90[b]	2.94[ab]	3.22[a]	3.01[ab]	2.92[ab]	0.09
Mortality	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feed cost (₦/kg)	44.24	40.58	43.50	42.50	40.25	43.00	42.00	--
Cost of wt gain (₦/kg)	128.08	129.05	126.15	124.96	124.61	129.23	122.23	3.64

[a,b:] means in the same row with different superscripts are significantly different ($p<0.05$)

UCC = Unpeeled Cassava Chips; UCP = Unpeeled Cassava Pellets; UCG – Unpeeled Cassava Grits

Table 22: **Apparent nutrient digestibility of pullet chicks on the experimental diets**

Components	100% Maize Diet 1	50% Substitution UCC Diet 2	UCP Diet 3	UCG Diet 4	100% Substitution UCC Diet 5	UCP Diet 6	UCG Diet 7	±SEM
Dry matter	69.70	67.52	68.22	66.11	70.01	65.33	67.33	1.30
Crude fibre	30.18	31.77	31.97	31.10	32.70	31.53	29.69	2.40
Ether extract	80.50	79.02	77.20	78.78	79.59	81.21	78.11	2.45
Nitrogen retention	73.30[a]	72.40[a]	72.41[a]	71.78[ab]	65.50[c]	66.33[c]	68.05[bc]	0.95

[a,b,c:] means in the row with different superscripts are significantly different ($p<0.05$)

UCC = Unpeeled Cassava Chips; UCP = Unpeeled Cassava Pellets; UCG – Unpeeled Cassava Grits

Table 23: Haematological indices of chicks on experimental diets

Components (%)	100% Maize Diet 1	50% substitution UCC Diet 2	UCP Diet3	UCG Diet 4	100% substitution UCC Diet 5	UCP Diet 6	UCG Diet 7	±SEM
Packed cell volume %	24.50	18.50	19.50	20.50	20.50	18.50	21.50	1.31
Haemoglobin (g/dl)	12.15	11.45	11.30	12.65	12.80	11.65	11.95	0.40
Red blood cell ($x10^6/mm^3$)	3.69	2.57	3.93	3.50	2.93	2.43	2.84	0.34
Mean corpuscular Haemoglobin (µmg)	32.96	40.83	34.25	36.97	44.94	48.14	50.87	7.34
Mean corpuscular Haemoglobin concentration (%)	49.65	61.91	57.96	61.81	55.83	63.41	60.52	3.50
Total while blood cell ($x10^6/mm^3$)	6.40	7.65	8.10	5.70	4.75	3.70	6.50	1.02
Mean corpuscular volume (μ^3)	99.95	90.18	81.41	89.26	90.61	96.17	108.30	5.92

[a,b,c:] means in the same row with the same superscripts are not significantly different ($p>0.05$)

UCC = Unpeeled Cassava Chips; UCP = Unpeeled Cassava Pellets; UCG – Unpeeled Cassava Grits

Table 24: Serum metabolites of chick pullets on the experimental diets

Parameters	100%	50% substitution			100% substitution			
	Maize Diet 1	UCC Diet 2	UCP Diet3	UCG Diet 4	UCC Diet 5	UCP Diet 6	UCG Diet 7	±SEM
Glucose (mg/dl)	125.44[b]	164.24[ab]	153.32[ab]	163.81[ab]	181.52	179.64[a]	163.24[a]	8.33
Total protein (g/dl)	10.10	9.80	9.35	9.25	9.60	9.60	8.20	0.54
Albumin (%)	2.85	2.45	2.95	2.65	3.05	2.55	2.90	0.25
Globulin (%)	7.25	7.05	6.90	6.60	6.55	7.05	6.30	0.23
Albumin Globulin Ratio	0.39	0.35	0.39	0.4	0.47	0.36	0.45	0.03
Thiocyanate (mg/dl)	0.14[c]	2.33[ab]	2.25[ab]	2.19[b]	2.56[a]	2.47[a]	2.38[ab]	0.24

[a,b,c:] means in the same row with different superscripts are significantly different ($p<0.05$)

UCC = Unpeeled Cassava Chips; UCP = Unpeeled Cassava Pellets; UCG – Unpeeled Cassava Grits

5.2.4. Discussion

Lower feed intake recorded in birds fed 100% UCC was due to dustiness of cassava chips containing diets. Milling of cassava chips resulted into fine particles and thus caused dustiness in the feed. Buitrago *et al*. (2002) stated that the processing system is one of the external factors that influence the level of cassava that can be used in the diet, and that the maximum level of cassava flour inclusion in poultry diets was about 25% to 30%, unless the feed is palletized or crumbolized. Gellatinization of starch in cassava grits and pellets might have improved digestion of cassava pellets and grit containing diets and also reduce dustiness. Streeramamurthy (1977) reported that the raw cassava starch has a digestibility of 48.3% while cooked starch has a digestibility of 77.9%.

Average weight gain and feed conversion ratio of birds fed UCP and UCG containing diet were similar to the control diet. These results confirmed Khajarern and Khajarern (1986), and Saentaweesuk *et al*. (2000) that recorded no significant (p>0.05) difference for broilers fed cassava containing diet compared to maize, sorghum and broken rice. Lower weight gain and feed conversion ratio of birds fed cassava chips containing diets might be due to lower feed intake of the chicks on these diets. These results contradicted the report of Gil *et al* (2001) who reported similar or superior weight gain and FCR when broilers were fed 100% cassava flour based diets. Result of FCR recorded for cassava pellet was similar to value reported by Mosobalaje, *et al*. (2010). However, cassava grit gave a better result.

All the experimental treatments recorded no mortality. Kanto and Juttaporpong (2002) stated that no cassava sample were found to be contaminated with aflatoxins or other mycotoxins in a study on occurrence of mycotoxin in 339 samples of raw ingredients used for animal feeding. Hydrogen cyanide, the only anti-nutritional factor in cassava samples was reduced to levels that were non-toxic to animal after sun drying for 3-4 days (Khajererrn *et al.,* 1979). Heat involved in production of cassava grits and pellets was perhaps sufficient to eliminate any risk of cyanide toxicity in the animals. This confirmed Kanto and Juttupurpong (2002) and Leeson and Summer (1997) that heat greatly reduce cyanide content of cassava.

Feed cost per kilogramme decreased with increased levels of cassava. Cassava pellets containing diets recorded the highest value among the cassava samples. High cost of cassava pellets containing diet was due to high cost of pelleting (Mosobalaje *et al.*, 2007). The encouraging results recorded from the use of cassava meal products in poultry diets might be due to the balancing of nutrients to meet requirements (Khajarern and Khajarern, 1992; Akinfala *et al.*, 2002; Chauynarong *et al.*, 2009).

Apparent dry matter, ether extract and crude fibre digestibility were similar ($p>0.05$). Values recorded on dry matter and ether extract digestibility were similar to values reported by Reas (1986) for cassava and maize in the digestive tract of pigs, and Ladokun (2003) for sweet potato in chick pullet diets. Digestibility measures the ratio of the nutrient retained to intake expressed in percentage. Results of dry matter, crude fiber and ether extract digestibility showed that the anti nutritional factor in cassava (HCN) did not adversely affect uptake of the nutrients in the digestive track of chick pullets. Digestion coefficient of ether extract was uniformly high. Probably reflects the preferential digestion for this feed nutrient, as its metabolism has been reported to be associated with lower heat increment, and efficiently completed than carbohydrate (Freeman, 1983).

Lower nitrogen retention reported in chickens fed 100% cassava-based diet might be due to higher hydrogen cyanide content of cassava containing diet. Higher percentage of nitrogen excreted might have originated from hydrogen cyanide. Hernadiz *et al.* (1995); Carlsson *et al.* (1999) and Sreeja *et al.* (2003) reported that about 75% of ingested cyanide is excreted after 24 hours. Thus, this result might not necessary indicate lower crude protein digestion but rather proves detoxification of antinutritional factor in cassava.

Heamotological indices were not adversely affected by dietary treatment. Feed intake of chick reduced and hence dietary intake of cyanide from cassava was very small to cause any adverse effect in the pullet chicks. However, values obtained for Hb, WBC, MCV and globulins were higher than values reported by Aderemi (2001). White blood cell values were lower than values reported by Mistruka and Rawney (1977) for adult chicken. This might probably account for susceptibility of chicks to diseases compared to adult birds.

Higher blood glucose reported in the study was due to effects of cyanide on glucose metabolism. Solomonson (1981) studied effect of sub lethal doses of cyanide on the metabolism of glucose in mice. He found that cyanide caused an increase in blood glucose and lactic acid levels and decrease in the ATP/ADP ratio indicating a shift from aerobic to anaerobic metabolism. EFSA (2003) also stated that cyanides apparently activates glycogenolysis and shunts glucose to the pentose phosphate pathway decreasing the rate of glycolysis and inhibiting the tricarboxylic acid cycle.

5.3 Trial II: Effects of replacement of maize with cassava root products in the diet of growing pullets

5.3.1 Materials and methods

Seven diets were formulated in which each of the cassava root products (chips, pellets and grits) replaced maize at 0%, 50% and 100%, and 100% maize served as the control diets. Two hundred and ten, Bovan brown pullets aged ten weeks were randomly allocated to the seven experimental diets. There were three replicates per experimental treatment and each replicate had ten birds. Feed and water were provided *ad libitum*. Gross composition of the experimental diets is presented in Table 25. Parameters considered were feed intake, weight gain, feed conversion ratio, mortality, economy of production, weight at 20 weeks, age at first egg, hen day production at 24 weeks and weight of first-egg.

Table 25: Gross composition of the experimental grower diets

Ingredients (%)	100% Maize Diet 1	50% Substitution UCC Diet 2	UCP Diet 3	UCG Diet 4	100% Substitution UCC Diet 5	UCP Diet 6	UCG Diet 7
Maize	35.00	18.00	18.00	18.00	-	-	-
Cassava	-	18.00	18.00	18.00	36.80	36.80	36.80
Palm kernel cake	26.00	25.00	25.00	25.00	24.00	24.00	24.00
Wheat offal;	22.40	17.40	17.40	17.40	12.00	12.00	12.00
Soya bean meal	10.00	15.20	15.20	15.20	20.40	20.40	20.40
Fish meal (72%)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bone meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Oyster shell	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Premix*	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Table salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25
DL-Methionine	0.05	0.05	0.05	0.05	0.05	0.05	0.05
L-Lysine	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated value (Kcal/kg ME)	2466.00	2466.00	2466.00	2466.00	2466.00	2466.00	2466.00
Crude protein (%)	15.20	15.10	15.10	15.10	15.10	15.10	15.10

UCC = Unpeeled Cassava Chips; UCP = Unpeeled Cassava Pellets; UCG – Unpeeled Cassava Grits

* Premix composition per kg: Vitamin A 10,000,000.00I.U, Vitamin D_3 2,000,000.00I.U, Vitamin E 20,000.00mg, Vitamin K_3 2,000.00mg, Vitamin B_1 3,000.00mg, Vitamin B_2 5,000.00mg, Niacin 45,000.00mg, Calcium Pantothenate 10,000.00mg, Vitamin B_6 4,000.00mg, Vitamin B_{12} 20.00mg, Choline chloride 300,000.00mg, Folic acid 1,000.00mg, Biotin 50.00mg, Manganes 300,000.00mg, Iron 120,000.00mg, Zinc 80,000.00mg, Copper 8,500.00mg, Iodine 1,500.00mg, Cobalt 300.00mg, Selenium 120.00mg, Anti-oxidant 120.000.00mg

5.3.1.2 Metabolic trial

At 16th week in to the feeding trial, two birds were randomly selected from each of the treatments and housed in the metabolic cage. Birds were fed for five days to adjust to the new environmental conditions after then a known quantity of feed was offered to the birds. Remnants were weighed and feed intake was recorded.

Flat trays covered with aluminum foil sheets were placed under each cage compartment, and the droppings voided were collected daily by total collection method and weighed before being transferred to the laboratory for oven drying. Proximate compositions determined were dry matter, crude protein, crude fibre and ether extract.

5.3.1.3. Chemical analysis

The proximate composition of the experimental diets and droppings were estimated by the methods of AOAC (1990).

5.3.1.4 Statistical analysis

All the data obtained in the study were analyzed according to the procedure of the statistical analysis (SAS, 1997).

Results

Proximate compositions of the experimental diet are shown in Table 26 and performance characteristics of growers fed the experimental diets were shown in Table 27. Performance of growers were not significantly (p>0.05) affected by dietary treatment. All parameters considered had similar values to the control diet except age at first egg and weight of first eggs. Birds fed 100% UCC and UCP based diets started egg production late (150-156days) compared to control diet (146days). Expectedly, egg weight increased with increase in age at first egg. Birds fed CD that produced the first egg had the lowest value (50.07g) while those that started a week after produced bigger eggs 56.01g and 56.20g for 100% cassava chips and pellets that started 153 day and 154 day, respectively. Feed intake, weight gain and feed conversion ration were not significantly (p>0.05) affected by the dietary treatments and recorded values ranged form 70.99 – 85.86g/bird/day, 10.48 – 11.63g/bird/day; and 7.32 -7.92 respectively.

Cost of feed decreased with increase in cassava inclusion in the diet.100% maize based diet (control diet) recorded the highest value (₦30.62/kg) while the lowest was recorded for 100% UCC based diet (₦27.48/Kg). However, cost of weight gain was not significantly (p>0.05) affected by dietary treatment. The highest value was recorded for birds fed 100% cassava pellet based diets (₦224.95/kg weight gain) while birds fed 50% cassava grit had the lowest value (₦208.20/kg weight gain). Result of mortality revealed that experimental birds were not adversely affected by dietary intake. Birds fed 50% UCG and 100% UCG recorded 3.33% each while other treatments recorded no motality.

The results of nutrient digestibility are shown in Table 28. Dry matter, crude fibre and ether extract digestibility were not significant (p>0.05) affected by the dietary treatments and ranged from 66.11%-70.01%, 71.33%-73.33%, 29.69%-32.70%, and 77.20%-81.21% respectively. However, nitrogen retention of birds fed 100% CRP based diets was significantly ($p>0.05$) lower than the control diet and 50% UCC and UCP. Nitrogen retention of birds fed control diet was 68.10%, and 50% UCC, UCP and UCG were 67.61%, 62.69% and 68.97%, respectively and 100% UCC, UCG, and UCG were 63.41%, 66.54% and 64.22%, respectively.

Table 26: Chemical composition of the experimental grower diets

	100%	50% Substitution			100% Substitution		
Composition (%)	**Maize Diet 1**	**UCC Diet 2**	**UCP Diet 3**	**UCG Diet 4**	**UCC Diet 5**	**UCP Diet 6**	**UCG Diet 7**
Dry matter	89.25	88.97	88.72	90.73	88.78	88.96	90.13
Crude protein	13.30	14.98	15.54	13.86	14.70	13.86	14.84
Ether extract	3.19	5.05	4.83	3.97	3.36	3.97	5.14
Crude fibre	6.59	6.25	7.22	6.33	6.21	6.33	7.83
Ash	9.91	10.00	9.92	12.83	9.50	12.83	11.36
Nitrogen free extract	56.26	52.69	52.21	53.74	55.01	53.74	50.46
Calcium	0.91	097	1.02	1.05	0.90	1.05	1.01
Phosphorus	0.47	0.42	0.46	0.58	0.47	0.58	0.56

UCC = Unpeeled Cassava Chips; UCP = Unpeeled Cassava Pellets; UCG – Unpeeled Cassava Grits

Table 27: Performance and economy of production of growers on the experimental diets

Parameters (%)	100% Maize Diet 1	50% Substitution UCC Diet 2	50% Substitution UCP Diet 3	50% Substitution UCG Diet 4	100% Substitution UCC Diet 5	100% Substitution UCP Diet 6	100% Substitution UCG Diet 7	±SEM
Initial weight (Kg/bird)	0.82	0.82	0.83	0.83	0.83	0.82	0.83	
Final weight (kg/bird)	1.59	1.56	1.56	1.62	1.62	1.59	1.57	0.04
Feed intake (g/bird/day)	83.81	79.99	80.86	82.15	85.86	82.82	82.63	2.83
Weight gain (g/bird/day)	10.87	10.48	10.91	11.25	11.63	10.86	10.56	0.59
Feed conversion ratio	7.32	7.66	7.42	7.31	7.60	7.69	7.92	0.48
Mortality	0.00	3.33	0.00	3.33	0.00	3.33	0.00	0.43
Age at first egg (days)	146.00[c]	148.00[ab]	149.00[c]	150.00[bc]	153.00[ab]	154.00[a]	150.00[bc]	1.21
Hen day production at 24th week (%)	26.19	29.05	24.76	28.57	27.23	20.19	19.33	7.01
Egg weight of 1st egg	50.07[b]	53.00[ab]	52.32[b]	55.38[a]	*56.01[a]*	56.20[a]	54.50[ab]	1.90
Feed cost (₦/kg)	30.62	28.01	29.50	28.48	*27.48*	29.25	28.03	
Cost of wt gain (₦/kg)	224.14	214.56	218.26	208.20	208.87	224.95	222.02	13.27

[a,b,c:] means in the row with different superscripts are significantly different ($p<0.05$)

UCC = Unpeeled Cassava Chips; UCP = Unpeeled Cassava Pellets; UCG – Unpeeled Cassava Grits

Table 28: Apparent nutrient digestibility of growers fed the experimental diets

Components (%)	100% Maize Diet 1	50% substitution UCC Diet 2	UCP Diet3	UCG Diet 4	100% substitution UCC Diet 5	UCP Diet 6	UCG Diet 7	±SEM
Dry matter	64.15	62.59	64.66	64.99	62.51	65.77	63.16	0.14
Nitrogen Retention.	68.13[a]	67.61[a]	68.97[a]	66.54[ab]	62.69[c]	63.41[c]	64.22[bc]	0.11
Ether extract	80.65	80.75	81.96	81.03	84.66	81.18	83.18	0.12
Fibre	39.94	45.02	42.33	46.11	40.22	41.28	44.00	0.93

[abc:] means in the row with different superscripts are significantly different ($p<0.05$)

UCC = Unpeeled Cassava Chips; UCP = Unpeeled Cassava Pellets; UCG – Unpeeled Cassava Grits

5.2.3. Discussion

Result obtained on performance of growers fed the experimental diets revealed that grower could successfully tolerate higher percentage of cassava in their diet. A complete replacement of maize with cassava in the diet of grower is possible. Final weight, feed intake, weight gain and FCR were not adversely affected by dietary inclusion of cassava in the diets. The satisfactory performance of grower confirmed the report of Khajarern and Khajarern (1986) that total substitution of maize in diet of growing pullet is possible. However the results contradicted Job *et al*. (1980) that reported that maximum inclusion of cassava, in the diet of grower is 0-25% and Ademosun and Eshiett (1980) that concluded that starter and grower should not contain more than 15 and 30% cassava root meal, respectively.

Feed gain ratio of growing pullet was higher than values reported for chick pullets. Oluyemi and Robert (2000) stated that feed efficiency decrease with increase in age of birds and that there is continuous decrease in efficiency of feed utilization for grower with the age of the fowl. The values obtained are higher than values reported by Khajarern and Khajarern (1986) and Ladokun (2003) for replacement pullets fed cassava based diets and for growers fed sweet potato meal respectively, however, lower than value reported by Aderemi (2001). Average final weights of birds fed experimental diets were similar. However age at first egg was significantly affected by dietary treatment. Birds fed 100% CRP had delayed age at first egg. This however contradicted Leeson and Summer (1997) that showed direct correlation between weight at first egg and age at first egg because final weights were similar. First egg was progressively heavier with delayed maturity. The trend observed from this study aggress with finding of other workers and in fact is one of the merit of delaying maturity as egg weight is known to increase, the longer the birds stay before attaining maturity (Hockings, 1987).

Cost analysis revealed that cost per kilogramme of feed decreased with increasing level of cassava in the diet. Cost of cassava pellets based diets was higher than other cassava based diets due to high cost of pelleting cassava in Nigeria. However, cost of feed consume per kilogramme body weight gain, were not significantly ($p>0.05$) different though cassava based diet recorded lower values except those fed 100% cassava pellets. The values obtained were similar to value reported by Mosobalaje *et al*. 2009.

Apparent dry matter and crude protein digestibility of growers were similar ($p>0.05$), however, lower than values reported for chick pullets. This result agreed with Ogunmodede and Afolabi (1978), that protein digestibility generally declined with age in growing birds probably due to declining in requirement for this nutrient for growth. However, fibre was better utilized by growers compared to chick pullets because fibre digestibility improves with age of animals.

5.4.1. Trial III - Effects of substituting Cassava Root Products (CRP) for maize in the diet of layers

5.4.1. Materials and Methods

5.4.1.1. Diet formulation and bird management

Seven experimental diets were prepared in which UCC, UCP and UCG were used to replace maize in the diet of layer at 0%, 50% and 100% each. Control diet was 100% maize based as shown in Table 29. Three hundred and fifteen, 30 weeks old bovan black layers were randomly allocated to the seven experimental diets. There were three replicates of fifteen birds each. Birds were provided with feed and water *ad libitum*. Records of feed intake, weight gain, Feed Conversion Ration (FCR), Hen Day Production (HDP) and mortality were recorded.

Table 29: Gross compositions of the experimental layer diets

Ingredients (%)	100%	50% Substitution			100% Substitution		
	Maize Diet 1	UCC Diet 2	UCP Diet3	UCG Diet 4	UCC Diet 5	UCP Diet 6	UCG Diet 7
Maize	48.00	24.00	24.00	24.00	-	-	-
Cassava	-	24.00	24.00	24.00	48.00	48.00	48.00
Full-fat soya	2.50	5.00	5.00	5.00	9.00	9.00	9.00
Wheat offal	17.50	11.00	11.00	11.00	5.00	5.00	5.00
Soya bean meal	6.70	10.30	10.30	10.30	12.00	12.00	12.00
Palm kernel cake	5.30	5.70	5.70	5.70	6.00	6.00	6.00
Groundnut cake	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Fish meal (72%)	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Bone meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Oyster shell	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Premix*	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Methionine	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Lysine	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated value (Kcal/kgME)	2588.45	2588.30	2588.30	2588.30	2589.20	2589.20	2589.20
Crude Protein (%)	16.37	16.43	16.43	16.43	16.43	16.43	16.43

UCC = Unpeeled Cassava Chips; UCP = Unpeeled Cassava Pellets; UCG – Unpeeled Cassava Grits

*Premix Content per Kg**:** Vitamin A 10,000,000.00I.U, Vitamin D_3 2,000,000.00I.U, Vitamin E 23,000.00mg, Vitamin K_3 2,000.00mg, Vitamin B_1 3,000.00mg, Vitamin B_2 6,000.00mg, Niacin 50,000.00mg, Calcium Pantothenate 10,000.00mg, Vitamin B_6 5,000.00mg, Vitamin B_{12} 25.00mg, Folic acid 1,000.00mg, Biotin 50.00mg, Choline chloride 400,000.00mg, Manganese 120,000.00mg, Iron 100,000.00mg, Zinc 80,000.00mg, Copper 8,500.00mg, Iodine 1,500.00mg, Cobalt 300.00mg, Selenium 20.00mg, Anti-oxidant 120.000.00mg,

5.4.1.2. Blood analysis

At the end of 37th week, blood collection was done. Three birds per treatment were randomly selected. Blood was collected through the wing vein and the blood samples were analyzed as described for chicks study.

5.4.1.3. Metabolic trial

Two, 40 weeks old layers of similar weight per group were used for the metabolic investigation. This was done to determine the apparent nutrient digestibility of the test diets. The birds were separately housed in metabolic cages and offered equal quantity of 150gm/bird/day of their respective feed and served at 8.00am daily.

The droppings were separately collected on the last five days of the experiment with flat trays covered with aluminum foil daily. Dry matter of the droppings was determined and the dried samples were kept for chemical analysis.

5.4.1.4. Chemical analysis

Samples of diets and droppings were analysed for proximate composition using the procedure of AOAC (1990).

5.4.1.5. Egg quality analysis

Three eggs were randomly selected from each replicate per week. The weights were taken and the eggs were broken with the aid of a blunt edge knife into weighted albumen sieve. Weights of albumen and yolk were taken. Colour of the yolk was scored using Rock colour fan number 1-15 by five participant and mean values were recorded.

Shell weight was taken and shell thickness was measured at the broad, narrow and equatorial region with micrometer screw gauge. Egg length and width were measured with Vanier caliper. Other egg quality parameters considered were percentages of shell, albumen and yolk, egg shape index, shell surface area and yolk index.

5.3.1.5 Statistical analysis

All data were subjected to analyses of variance using statistical analysis system (SAS, 1997).

5.3.2 Results

Chemical composition of the diets is presented in Table 30. Performance characteristics of layers fed partial and total replacement of cassava is presented in Table 31. The results revealed that feed intake, weight gain, FCR and HDP were significantly ($p<0.05$) affected by the dietary treatments. Replacement of maize with 50% CRP in the diets of layers did not adversely ($p>0.05$) affect performance of layers. Feed intake of birds fed 100% UCC and UCP based diets were significantly ($p<0.05$) lower than the control diet and 50% CRP. However, birds fed 100% cassava grit based diet was similar ($p>0.05$) to the control diet and 50% CRP based diets.

Results of HDP showed that egg production of birds fed 100% CRP were significantly ($p<0.05$) lower than those on control diet. Bird fed 100% UCC had the lowest value (57.82%) while those fed control diet had the highest value (63.12%). Feed conversion ratio of layers fed 50% UCG was the lowest (5.66) and significantly ($p<0.05$)

lower than value recorded for birds fed 100% UCG that had the highest value (6.20). Other dietary treatments were similar (p>0.05) to the two.

Weight gain was significantly (p<0.05) affected by the dietary treatments. Bird fed 100% UCC and UCP based diets recorded values (0.99g/bird/day and 1.00g/bird/day respectively) that were significantly (p<0.05) lower than other dietary treatments. Control diet had the highest value (1.69/bird/day). The levels of mortality and egg weight were not significantly (p>0.05) affected by the dietary treatments and the values obtained ranged from 0% - 6.60% and 58.10g - 61.11g, respectively.

Table 30: Chemical compositions of the experimental layer diets

Components (%)	100%	50% Substitution			100% Substitution		
	Maize Diet 1	UCC Diet 2	UCP Diet3	UCG Diet 4	UCC Diet 5	UCP Diet 6	UCG Diet 7
Dry matter	90.62	90.32	89.76	91.03	90.10	89.17	90.60
Crude protein	1792	17.50	17.50	16.94	16.38	17.64	16.80
Ether extract	3.70	4.85	6.82	5.20	4.05	5.40	4.23
Crude fibre	5.85	4.94	4.65	5.65	5.99	4.13	5.01
Ash	9.64	9.83	8.37	8.87	7.90	8.57	11.20
Nitrogen free extract	53.51	53.20	52.42	54.37	55.78	53.43	53.36
Calcium	3.92	3.77	3.86	3.90	3.82	3.77	3.72
Phosphorus	0.65	0.54	0.61	0.53	0.64	0.58	0.61

UCC = Unpeeled Cassava Chips; UCP = Unpeeled Cassava Pellets; UCG – Unpeeled Cassava Grits

Table 31: Performance and economy of production of layer on experimental layer diets

Parameters (%)	100%	50% substitution			100% substitution			
	Maize Diet 1	UCC Diet 2	UCP Diet3	UCG Diet 4	UCC Diet 5	UCP Diet 6	UCG Diet 7	±SEM
Feed intake (g/bird/day)	123.11[a]	118.58 [ab]	120.34[ab]	118.28[ab]	112.34[c]	109.08[c]	120.32[ab]	2.21
Weight gain (g/bird/day)	1.69[a]	1.32[ab]	1.45[a]	1.51[a]	0.99[b]	1.00[b]	1.49[a]	0.14
Feed conversion ratio	5.85[ab]	5.88[ab]	5.78[ab]	5.66[b]	5.83[ab]	5.70[ab]	6.20[a]	0.17
Mortality (%)	2.20	6.60	4.40	2.20	2.20	0.00	6.60	0.21
Hen day production	63.12[a]	60.52[abc]	62.50[ab]	62.72 [ab]	57.82[c]	57.39[c]	58.38[bc]	1.64
Egg weight (g/)	59.10	58.10	60.40	58.50	58.30	59.50	61.11	0.35
Feed cost (₦/kg)	37.17	34.71	36.15	35.19	32.30	35.08	33.16	
Cost of egg (₦ /tray)	217.57[a]	204.95[ab]	209.07[ab]	201.52 [abc]	187.73[c]	199.60[bc]	205.61[ab]	6.29

[a,b,c:] means in the same row with different superscripts are significantly different ($p<0.05$)

UCC = Unpeeled Cassava Chips; UCP = Unpeeled Cassava Pellets; UCG – Unpeeled Cassava Grits

Egg quality charateristics of the experimental birds are shown in Table 32. All the parameters considered were not significantly (p>0.05) affected by dietery treatments. Yolk colour score was generally low in absolute terms but and similar (p>0.05).

Apparent nutrient digestibility of layers on the experimental diets is presented in Table 33. Dry matter, crude fibre digestibility and nitrogen retention were significantly (p<0.05) affected by the dietary treatments. Birds fed 100% CRP recorded lower values for these parameters. Nutrient digestibility of birds fed 50% CRP was similar (p>0.05) to the control diet. Results on ether extract and NFE digestibility were not significantly (p>0.05) affected by the dietary treatments.

Hematological indices of layers on experimental diets were presented in Table 34. Red Blood Cell, WBC, MCH and MCHC were not adversely affected (p>0.05) by the dietary treatments. However, PCV and Hb, were significantly (p<0.05) affected by treatments effects. PCV and Hb of 100% UCC were higher (p<0.05) than the control diet. PCV and Hb increased with increase levels of CRP in the diet i.e. values recorded for birds fed 100% CRP were higher than those recorded for birds fed 50% CRP.

Table 35 showed the serum metabolities of laying birds fed the experimental diets Glucose, thiocyanate, aspartate amino-transfarase and triglycerides were significantly (p>0.05) affected by the experimental treatments while total protein, albumin, globulin, albumin-globulin ratio and alanine amino transferred were not adversely affected.

Blood glucose increased with increase level of cassava in the diets. Glucose level of birds fed 100% CRP based diets were significantly (p<0.05) higher than those fed maize containing diet. Triglycerides content of blood of birds fed 100% CRP were significantly ($p<0.05$) higher than the control diet, though those fed 50% CRP were similar ($p<0.05$) to the control diet and 100% CRP.

Serum thiocyanate however increased with increased level of cassava in the diets. Control diet recorded the lowest value (0.25mg/dl) that was significant ($p<0.05$) lower than all the other dietary treatments. Thiocyanate level of blood of birds fed 50% CRP were lower ($p<0.05$) than those fed 100% CRP. Birds fed 100% UCC had the highest value (21.5mg/dl)

Aspartate Amino Trasferase (AST) was significantly ($p<0.05$) affected by the experimental treatments. Bird fed 100% replacement level were significantly ($p<0.05$) higher than the control diet while 50% replacement level were not significantly ($p>0.05$) different from the control diet.

Table 32: Egg quality characteristics of layers on experimental diets

Parameters (%)	100% Maize Diet 1	50% substitution UCC Diet 2	UCP Diet3	UCG Diet 4	100% substitution UCC Diet 5	UCP Diet 6	UCG Diet 7	±SEM
Egg weight (g)	59.32	57.99	60.15	58.52	58.33	59.50	60.99	0.35
Yolk weight (g)	15.03	14.14	14.86	14.46	14.20	14.69	14.46	0.93
Yolk height (cm)	1.66	1.64	1.59	1.69	1.63	1.59	1.66	0.07
Albumen weight (g)	37.96	35.21	37.33	40.80	34.683	6.49	37.66	2.23
Shell weight (g)	6.51	6.27	6.46	6.47	6.92	6.67	6.63	0.75
Shell thickness (cm)	0.32	0.37	0.36	0.35	0.36	0.34	0.33	0.09
Yolk colour	3.71	3.50	3.69	3.60	3.04	3.00	3.62	0.34
Shell surface area(cm^2)	71.98	72.76	72.67	74.30	71.59	72.23	72.23	2.93
Egg shape index	0.76	0.75	0.77	0.75	0.74	0.74	0.77	0.07

UCC = Unpeeled Cassava Chips; UCP = Unpeeled Cassava Pellets; UCG – Unpeeled Cassava Grits

Table 33: Apparent nutrient digestibility of laying birds on the experimental diets

Components (%)	100% Maize Diet 1	50% substitution UCC Diet 2	UCP Diet3	UCG Diet 4	100% substitution UCC Diet 5	UCP Diet 6	UCG Diet 7	±SEM
Dry matter	75.90[a]	68.33 [bc]	73.72[a]	74.24[a]	66.71[c]	66.27[c]	69.27[b]	0.95
Nitrogen retention.	59.70[a]	50.19[bc]	49.90 [bc]	52.71[ab]	43.78[c]	46.19 [bc]	45.14 [bc]	2.39
Ether extract	87.41	85.54	82.39	83.63	84.51	87.51	87.60	1.71
Crude fibre	44.67	43.25	46.72	42.03	43.25	42.35	45.34	1.81
NFE	88.41	89.15	90.13	87.25	89.85	89.42	90.29	1.32

[a,b,c:] means in the same row with different superscripts are significantly different ($p<0.05$)

UCC = Unpeeled Cassava Chips; UCP = Unpeeled Cassava Pellets; UCG – Unpeeled Cassava Grits

Table 34: Haematological indices of layers on experimental diets

Components	100%	50% substitution			100% substitution			
	Maize Diet 1	UCC Diet 2	UCP Diet3	UCG Diet 4	UCC Diet 5	UCP Diet 6	UCG Diet 7	±SEM
Packed cell volume (%)	21.67[b]	22.00[ab]	22.00[ab]	21.67[b]	25.33[a]	24.00[ab]	24.00[ab]	1.02
Haemoglobin (g/dl)	7.30[ab]	7.37[ab]	7.30[ab]	7.23[b]	8.50[a]	8.00[ab]	8.00[ab]	0.35
Red blood cell ($x10^6/mm^3$)	1.85	2.12	2.43	2.31	2.14	2.58	2.72	0.44
Mean corpuscular Haemoglobin (µmg)	40.51	35.99	31.00	34.93	39.96	31.24	31.27	4.5
Mean corpuscular Haemoglobin concentration (%)	33.69	33.11	33.14	33.38	33.42	33.34	33.34	0.28
Total while blood cell ($x10^6/mm^3$)	25.87	32.80	29.27	34.27	29.73	29.60	32.20	1.02
Mean corpuscular volume (µ)	120.36	107.56	94.16	94.70	119.63	93.68	90.62	12.98

[a,b:] means in the same row with different superscripts are significantly different ($p<0.05$)

UCC = Unpeeled Cassava Chips; UCP = Unpeeled Cassava Pellets; UCG – Unpeeled Cassava Grits

Table 35: Serum metabolites of laying birds on the experimental diets

Parameters	100%	50% substitution			100% substitution			
	Maize Diet 1	UCC Diet 2	UCP Diet3	UCG Diet 4	UCC Diet 5	UCP Diet 6	UCG Diet 7	±SEM
Glucose (mg/dl)	145.68^{b}	178.71^{ab}	169.75^{ab}	152.78^{b}	202.48^{a}	188.41^{ab}	181.71^{ab}	13.18
Triglycerides (mg/dl)	365.08^{b}	493.65^{ab}	484.13^{ab}	441.27^{ab}	774.67^{a}	711.11^{a}	799.51^{a}	50.76
Total protein (g/dl)	5.21	5.5	5.16	5.37	5.47	5.04	5.16	1.26
Albumin (%)	1.08	0.93	1.01	0.93	1.01	1.08	1.11	0.09
Globulin (%)	4.13	4.21	4.35	4.36	4.46	4.03	4.06	0.5
Albumin Globulin Ratio	0.26	0.23	0.25	0.22	0.24	0.27	0.28	0.04
Thiocyanate (mg/dl)	0.25^{d}	13.67^{d}	9.33^{c}	8.33^{c}	21.59^{a}	21.19^{a}	17.33^{b}	0.81
Aspartate amino-transferase (I.U./I)	146.67^{cd}	143.67^{d}	159.67^{bc}	156.64^{c}	182.50^{a}	170.00^{b}	168.00^{b}	19.12
Alanine amino-transferase (I.U./I)	9.00	9.67	10.00	9.00	11.17	11.67	11.77	1.92

$^{a,b,c...}$: means in the same row with different superscripts are significantly different ($p<0.05$)

UCC = Unpeeled Cassava Chips; UCP = Unpeeled Cassava Pellets; UCG – Unpeeled Cassava Grits

5.4.3 Discussion

Similar proximate composition of cassava based diet compared to maize based diets was due to inclusion of full fat soybean in the diets. The low concentration of some essential nutrients present in cassava root meal can be compensated satisfactory by including soybean in balanced diet. Buitrago and Luckett (1999) have shown that a mixture of 82 parts of cassava root meal and 18 parts of integral soybean becomes a product with similar characteristics to those of maize.

Lower feed intake of birds fed 100% UCC and UCP might be due to dustiness and|or large size of pellet based diets. Large size of pellets discouraged intake. Attempt to cruble it resulted into original fine flour. Leeson and Summer (1997) stated that native pellets are just the original flour encapsulated in heard cover. However the size of pellets produced (5mm) was bigger than the sieve recommended by Portella (1988). Buitrago *et al.* (2002) stated that the dusty nature and the high starch content of the cassava root flour make it difficult to manage balanced feed with more than 25% inclusion level. This result contradicted Jalaludin and Leong (1973) that reported that higher levels of cassava increased feed intake, and also Aina and Fanimo (1997) who reported that cassava did not affect feed intake.

Lower weight gain and egg production of bird fed 100% cassava chips and pellets based diets might be due to the reduced feed intake of birds fed the diets. Leeson and Summer (1997), directly related feed intake to egg production. When there is a reduced feed intake, there is a reduced energy intake. These results however agreed with Stevenson and Jackson (1983) and Buitrago *et al.* (2000) that recommended 50% replacement of cereal by cassava root flour but contradicted Khajarern and Khajarern

(1986) and Seantaweesuk *et al* (2000) that recommended total replacement of maize by cassava in layer ration.

Result of mortality showed that cyanide levels of cassava products used were safe for birds in all dietary treatments animal consumption. Tattawa *et al* (2002) found that broilers fed with cassava diets always had about half the mortality rate than those fed with maize diets. The result also confirmed that of Khajarern and Khajarern (1986), Tiemeko (1992) and Saetaweesuk *et al* (2000) that found that mortality were not adversely affected when cassava flour was fed to layers.

Egg quality characteristics were not significantly ($p>0.05$) affected by the dietary treatment however, albumen and yolk percentage were higher than values reported by Austic and Neishem (1990) and Leeson and Summer (1997). Yolk colour scores were similar and generally low. Khajarern and Khajarern (1986) reported similar yolk colour score when cassava was used as sole source of energy feed ingredient in diet of layer when compared to maize, broken rice and sorghum. However, Saentaweesuk *et al* (2001) suggested that when maize is totally replaced with cassava, the diet should be supplemented with 0.2% marigold meal to provide adequate yolk pigmentation.

Dry matter digestibility and nitrogen retention were adversely affected by dietary treatment. Diets containing 100% CRP recorded values that were significantly ($p>0.05$) lower than the control diet. The lower dry matter digestibility might be due to attempt by the birds to eject the ingested anti-nutritional factors. Nitrogen determined in feed and droppings of birds fed cassava based diet came from crude protein, non protein nitrogen and cyanide. It was reported that after cassava was eaten, about 25% linamarin were excreted in the urine within 24 hours in metabolished form and about 50% as the less toxic thiocyanate (Barret *et al*, 1977). This will increase feacal nitrogen and reduce nitrogen retention. Another reason for poor nitrogen retention might be due to deamination and transmination of sulphur containing amino acid for cyanide detoxification (Meister, 1954)

Result of fibre digestibility was not significant affected by dietary treatment. Though fibre contents of unpeeled cassava root products were higher than that of maize but diets were formulated to contain similar fibre content as other fibre sources were reduced in the cassava containing diets.

Blood is an important index of physiological, pathological and nutritional status of the organism. Higher glucose level of birds fed cassava based diets was due to effect of cyanide on glucose catabolism. Isom *et al.* (1975) studied the effect of sub-lethal doses of cyanide on glucose catabolism. They found that cyanide caused 100% increase in the catabolism of glucose in the pentose phosphate pathway and 50% decrease in its break down via the glycolytic pathway. Increased glucose level of birds fed cassava based diet might also be due to linamarin competing with glucose for binding to a glucose transporter (GLUT) and then transported into cytoplasm in the brain (Sreeja *et al.*, 2003). Glucose is taken up from blood across the brain-brain barrier via GLUT (Gerhart *et al.*, 1989, Maher *et al.*, 1991, Vannucci *et al.*, 1997; Choi *et al.*, 2001; Simpson *et al.*, 2001). The displaced glucose will remain in the blood and thus increase blood glucose. Injested linamarin is hydrolysed to glucose and cyanohydrin in the intestinal tract (Winkler, 1958). Glucose is actively absorbed from the lumen of the small intestine (Chessworth *et al.*, 1998) and thus resulted in high blood glucose. However, the results of this study fell within the values given by Mistruka and Rawney (1977).

Birds fed 100% CRP recorded higher ($p<0.05$) blood triglycerides levels. Higher triglycerides levels could be attributed to higher blood glucose levels of the birds fed CRP. Chesworth *et al.* (1998) stated that the main source of the acctyl Co-A required for fatty acid synthesis is glucose in non ruminant. In addition, lipid synthesis is regulated in several ways. One of these depends on the availability of the glucose for the synthesis of fatty acids and the glycerol- 3-phosphate needed for triacylglycerol formation (Chessworth *et al.*, 1998). Availability of glucose increased synthesis of fatty acid and hence increased blood triglycerides.

Results of serum protein showed that treatment effects were not significant ($p>0.05$), though, Hoffenberg *et al.* (1966) had reported that serum protein was directly affected by the quality of dietary protein. Cassava is notoriously deficient in protein (Tewe and Egbunike, 1992) however, inclusion of soyabean meal in cassava containing diets adequately compensated qualitatively and quantitatively for the protein deficiency of cassava. This confirmed Buitrago and Luckett (1999).

Extents of biochemical, nutritional and toxicological effects of feed are frequently monitored in the blood. The following heamatological parameters WBC, RBC, MCH MCG and MCHC were not significantly affected by dietary treatments. Results on WBC and RBC revealed that cyanide in cassava did not cause death of blood cells. Values obtained for the above parameters were within the ranges given by Mistruka and Rawney (1977).

Results on heamoglobin was significantly ($p<0.05$) effected by dietary treatments. Binding of cyanide to metheamoglobin affected heamoglobin concentration of birds fed CRP based diets. About 99% of the absorbed HCN binds to methaemoglobin in erythrocyte; it is later converted in the liver to less toxic metabolites (Frankenbery and Sorbo, 1975). EFSA (2004) stated that at normal physiological levels the total body methaemoglohin of an adult human can bind approximately 10 mg of HCN to form cyanmetheamoglobin. Cyanmetheamoglobin method is the most commonly used and accepted method for determining Hb concentration (Mistruka and Rawney, 1977). Cyanide in cassava binds with metheamoglobin and increase optical density or transmittance.

PCV gives the ratio of total erythrocytes mass to total blood volume. About 55% of every red blood cell is heamoglobin (Mistruka and Rawney, 1977). Reaction of cyanide to metheamoglobin might cause increase in erythrocyte mass and thus accounted for increased PCV values recorded for birds fed cassava based diets.

The principal pathway of cyanide metabolism is its conversion to thiocyanate in the liver (Balagopalan *et al* 1988). This was the reason for the higher serum thiocyanate reported for birds fed CRP containing diets. Serum alanine amino-transferase is used to measure hepatic function in liver disease and in toxicity (Chesworth *et al*, 1998). ALT is expected to be higher in birds fed cassava containing diets due to cyanide detoxification process. However, the result obtained from this study might be due to the fact that maize also contains anti-nutritional factors e.g. mycotoxin (Leeson and Summer, 1997).

Detoxification of cyanide involves deamination and transmination of sulphur containing amino acids e.g methionine (Meister, 1950) and cystine and cystenine (Blakelay and Coop, 1926). Aspartate Amino Transferase (AST) functions in the conversion of aspartic acid to glutaric in the complete oxidative deamination of glutamate. Higher levels of this enzyme detected in blood serum of birds fed CRP containing diets might be due to activity of this enzyme in deamination of sulphur donor amino acids for cyanide detoxification.

CHAPTER SIX

ECONOMIC EVALUATION OF PERFORMANCE OF PULLETS AND LAYERS FED CASSAVA ROOT PRODUCTS (CRP) AS REPLACEMENT FOR MAIZE

6.1 Introduction

Researchers should demonstrate the economic advantage of a proposed production input over the existing one. Partial budget is one of the economic tools used to compare the economic benefit of technologies (Alimi and Mayong 2000). Farmers will adopt new production technique that is economically superior to the existing methods (Alimi and Mayong 2000).

Feed accounts for about 60 - 80% of total cost of production (Longe, 2006), and maize, which is the major conventional source of energy accounts for about 50-55% in a balanced poultry ration (Olayemi, 1989). Due to astronomical increase in price of maize, there has been increase in the number of alternative ingredients as energy source. However, economic considerations are of paramount importance in ingredient replacement. Muller *et al.* (1974) stated that cereals can be replaced by cassava only if the nutritional equivalent of cassava with proteineous feedstuffs is cheaper than feed prepared with maize. Methods used in evaluating replacement value of a new ingredient include simultaneous equation (Church and Verela Alvarez, 1991), Pearson's square method (Leeson and Summer, 1997), Performance characteristics of fed animals (Oluyemi and Robert, 2000) and Partial budget (Alimi and Mayong, 2000).

A partial budget is a simple, time saving tools that can help in evaluating changes in operation that will affect only a portion of business. It helps researchers to demonstrate the economic advantage of proposed production input over the existing ones (Teegerstron *et al* 1999). However, there is usually the problem of variability in prices of input and also performance of the experimental animals. An economic tool appropriate to address the problem of variability in yield is sensitivity analysis. Sensitivity analysis gives break – even price and yield. Break – even price is the price at which the proposed price is as good as the current practice, above which the proposed practise is not economically superior (Alimi and Mayong, 2000).

This study is aimed at assessing economic viability of replacing cassava root product as replacement for maize in the diet of layers.

6.2. Materials and methods

6.2.1. Partial budget

The following concepts of partial budget were adopted according to Alimi and Mayong (2000)

- Farm Gate Price – This is the price of an input/ output at the farm gate.
- Adjusted Yield – This is the experimental yield adjusted to approximate the yield that farmer can obtain on their farms.
- Gross Farm Gate Benefit (GFGB) – This is the product of the farm gate price of the output and the adjusted yield.
- Total Variable Input Cost (TVIC) – Is the sum of all variable input cost (cost of feed, drugs, labour and miscellaneous).

- Net Benefit (NB) – The net benefit is the difference between the gross farm gate benefit and the total variable input cost.
- Dominance Analysis – The process of eliminating dominated treatments from further analysis is called dominance analysis. A dominated treatment is the treatment with the same or lower net benefit than other treatment of a lower total variable input cost.
- Acceptable Minimum Rate of Return (AMRR) - This is minimum return which farmers expect to earn from an enterprise. This is the addition of cost of capital and interest rate acceptable in the area.
- Farmer Acceptable Minimum Return – (FAMR) – This is the product of the AMRR and the total variable cost of each treatment.
- Residue Analysis – This is the difference between the net benefit and the acceptable minimum return of each treatment.
- Recommendation – This decision criterion is that the treatment with the highest residual is selected and recommended.

6.2.2. Break-even analysis

The formula given by Alimi and Mayong (2000) was used to calculate break-even price of cassava as shown below.

$$Px = \frac{\frac{\Delta NB}{AMRR} - VIC_X^{1}}{\Delta X}$$

ΔNB = Change in net benefit

AMRR = Acceptable Minimum Rate of Return

$\Delta VIC_X{}^1$ = Variable cost other than cassava

X = Cassava input

ΔX = Change in quantity of cassava used

X^1 = Other variable input (excluding cassava)

Px = Break even price of cassava

6.3. Results

Tables 36, 37 and 38 showed the partial budget for performance of chicks, growers and layers fed different cassava products, respectively. Residual analysis values favoured 100% UCC and UCG for chicks and growers, respectively. Adjusted yield of layers fed 100% maize was the highest while the lowest values were recorded for birds fed 100% UCP for both egg and live weight (Table 38). Gross farm gate benefits of layers fed CD was the highest (₦5675.00) while those fed 100% UCP had the lowest value (₦5,135.00). Total variable input cost of CD was the highest and the lowest was recorded for birds fed 100% UCP.

However, net benefit of layers fed 50% UCG was the highest (₦3688.55) while the lowest was recorded for birds fed 100% UCP (₦3321.10). From values of total variable input cost and net benefit, CD and 50% UCP were dominated by treatment containing 50% UCG. While, 100% UCC dominated treatments containing 100% UCP and UCG.

Residual analysis values of CD, 50% (UCC, UCP,UCG) and 100% (UCC, UCP and UCG) were ₦1040.84, ₦1138.64, ₦1118.72, ₦1328.08, ₦1308.54, ₦1108.40 and

₦1115.83 respectively. Birds fed 50% UCG had the highest value and thus recommended.

Equation 1 showed break-even price of 50% unpeeled cassava grit in the diet of layers. The sensitivity equation shows that the break even price of UCG was ₦25.75\Kg, above which the recommendation is no more valid.

$$\frac{\frac{₦3689.19}{1.22} - ₦3587 - (₦2087.43 - ₦1737.62)}{-10.36}$$

$$= \frac{₦83.05 - ₦349.81}{-10.36} \qquad = N25.75$$

Equation 1: Breaks even price of cassava.

Percentage of this value (₦25,750.00\tonne) to price of maize (₦40,000:00\tonne) was 64.37%.

Table 36: Partial budget analysis for performance of chicks fed experimental diets

Parameters	100% Maize Diet 1	50% substitution UCC Diet 2	UCP Diet 3	UCG Diet 4	100% Substitution UCC Diet 5	UCP Diet 6	UCG Diet 7
Adjusted yield (live-bird, g)	551.50	510.00	558.25	552.32	502.44	529.89	553.39
Gross Farm gate benefit (₦)	450	450	450	450	450	450	450
Variable inputs							
Cost of feed (₦)	76.43	70.22	77.02	74.26	68.41	75.73	73.27
Cost of chips (₦)	50.00	50.00	50.00	50.00	50.00	50.00	50.00
Cost of Labour (₦)	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Miscellaneous (₦)	45.00	45.00	45.00	45.00	45.00	45.00	45.00
Total variable input cost (₦)	191.43	185.22	192.02	189.26	183.41	190.73	188.27
Net benefit (₦)	285.57	264.78	257.98	260.74	266.59	259.27	261.73
Dominance analysis	5*	5*	5*	5*	5	5*	5*
AMRR	1.22	1.22	1.22	1.22	1.22	1.22	1.22
FAMR (₦)	233.54	225.97	234.26	230.90	223.76	232.69	229.69
Residual(₦)	25.04	38.81	23.72	29.84	42.82	26.88	32.04
Recommendation					**42.82**		

* Dominated by

UCC = Unpeeled Cassava Chips; UCP = Unpeeled Cassava Pellets; UCG – Unpeeled Cassava Grits;
AMRR – Acceptable Minimum Rate of Return; FAMR = Farmer' Acceptable Minimum Return
Price of bird (live weight, ₦) = ₦450.00
Price of 1kg of maize (₦) = ₦40.00
Price of 1kg of UCC (₦) = ₦17.32
Price of UCP (₦) = ₦25. 88
Price of UCG (₦) = ₦19.13

Table 37: Partial budget analysis for performance of growers fed experimental diets

Parameters	100%	50% substitution			100% Substitution		
	Maize Diet 1	UCC Diet 2	UCP Diet 3	UCG Diet 4	UCC Diet 5	UCP Diet 6	UCG Diet 7
Adjusted yield (live-bird, Kg)	1.59	1.56	1.56	1.62	1.62	1.59	1.57
Gross Farm gate benefit (₦)	800	773.36	800	773.36	800	773.36	800
Variable inputs							
Cost of feed (₦)	195.04	174.56	188.44	187.17	195.83	203.39	185.74
Cost of Drugs (₦)	50.00	50.00	50.00	50.00	50.00	50.00	50.00
Cost of Labour (₦)	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Miscellaneous (₦)	22.00	22.00	22.00	22.00	22.00	22.00	22.00
Total variable input cost (₦)	287.04	266.56	280.44	279.17	287.83	295.49	277.74
Net benefit (₦)	512.46	506.80	519.56	494.19	512.17	477.87	522.26
Dominance analysis	7*	2	7*	7*	7*	7*	7*
AMRR	1.22	1.22	1.22	1.22	1.22	1.22	1.22
FAMR (₦)	350.19	325.20	342.14	340.59	351.15	360.50	338.84
Residual(₦)	162.27	181.60	177.42	153.60	161.02	117.37	183.42
Recommendation							**183.42**

* Dominated by

UCC = Unpeeled Cassava Chips; UCP = Unpeeled Cassava Pellets; UCG – Unpeeled Cassava Grits;
AMRR – Acceptable Minimum Rate of Return; FAMR = Farmer' Acceptable Minimum Return

Price of bird (live weight, ₦) = ₦800.00
Price of 1kg of maize (₦) = ₦40.00
Price of 1kg of UCC (₦) = ₦17.32
Price of UCP (₦) = ₦25. 88
Price of UCG (₦) = ₦19.13

Table 38: Partial budget analysis for performance of layers fed experimental diets

Parameters	100% Maize Diet 1	50% substitution UCC Diet 2	50% substitution UCP Diet 3	50% substitution UCG Diet 4	100% Substitution UCC Diet 5	100% Substitution UCP Diet 6	100% Substitution UCG Diet 7
Adjusted yield (eggs, trays)	9.14	8.76	9.05	9.08	8.37	8.31	8.44
Adjusted yield (live-bird, Kg)	2.21	2.04	2.09	2.17	1.98	1.96	2.11
Farm gate benefit (egg, ₦)	1105	1020	1045	1085	990	980	1055
Farm gate benefit (live-bird, ₦)	4570	4380	4525	4540	4185	4155	4220
Gross farm gate benefit (₦)	5675	5400	5570	5625	5175	5135	5275
Variable inputs							
Cost of feed (₦)	1670.24	1502.31	1587.86	1519.23	1324.43	1396.68	1456.28
Drugs (₦)	157.22	157.22	157.22	157.22	157.22	157.22	157.22
Labour (₦)	90.00	90.00	90.00	90.00	90.00	90.00	90.00
Miscellaneous (₦)	170.00	170.00	170.00	170.00	170.00	170.00	170.00
Total variable input cost (₦)	2087.46	1919.53	2005.08	1936.45	1741.65	1813.90	1873.50
Net benefit (₦)	3587.54	3480.47	3564.92	3688.55	3433.35	3321.10	3401.50
Dominance analysis	4*	2	4*	4	5	5*	5*
AMRR	1.22	1.22	1.22	1.22	1.22	1.22	1.22
FAMR (₦)	2546.70	2341.83	2446.20	2362.47	2124.81	2212.96	2285.67
Residual(₦)	1040.84	1138.64	1118.72	1326.08	1308.54	1108.14	1115.83
Recommendation				**1326.08**			

* Dominated by

UCC = Unpeeled Cassava Chips; UCP = Unpeeled Cassava Pellets; UCG – Unpeeled Cassava Grits;
AMRR – Acceptable Minimum Rate of Return; FAMR = Farmer' Acceptable Minimum Return

Price of a tray of eggs (₦) = ₦500.00
Price of 1 kg live weight (₦) = ₦500.00
Price of 1kg of maize (₦) = ₦40.00
Price of 1kg of UCC (₦) = ₦17.32
Price of UCP (₦) = ₦25. 88
Price of UCG (₦) = ₦19.13

6.2 Discussion

Analysis of partial budget recommended 100% UCC for chicks (Table 36), while 100% UCG was recommended for growers (Table 37). However, 50% UCG was recommended as the best diets for layers compared to other experimental treatments. Partial budget considered egg production, weight gain and prices of input and output. Dalsted and Gutierrez (1992) stated that partial budget is based on the principle that a change in farm operation will results in reduced cost and/or return or increased cost and/or return. Results obtained from partial budget revealed that inclusion of cassava in the diet of layers caused reduced cost and return. Birds fed cassava based diets had lower total variable input cost (reduced cost) and lower farm gate benefit (reduced return). However, net benefit of 50% UCG was higher than that of CD.

Dominance analysis revealed that 50% UCG dominated CD, 50% UCC and 50% UCP while 100% UCP and UCG were dominated by 100% UCC. Alimi and Mayong (2000) stated that dominated treatment has the same or lower net benefit than other treatments of a lower total variable input cost. Birds fed 50% UCG had the highest residual value and thus recommended as Alimi and Mayong (2000) stated that a treatment with the highest residual value is chosen and recommended.

Result of break-evenanalysis gave ₦25.75 which was 64.37% price of maize as the break even price above which the chosen treatment (50% UCG) will not be economically superior. This value (64.37%) confirmed Khajarern *et al* (1979) that gave sensitivity value of cassava to maize as 60%. The result also confirmed Tewe (2002) that stated that price of cassava should be 60-70% price of maize.

6.3 Conclusion

Partial budget assess economic viability of a new production input. This study proved economic superiority of 50% inclusion of cassava grit in the diet of layer and also presented the price of cassava above which this recommendation will be uneconomical. Inclusion 50% unpeeled cassava grit gave a better performance and superior economic gain compared to 100% maize in the diet of layer. This conclusion will hold provided that price of cassava is not more than 64.37% price of maize on kilogramme basis.

CHAPTER SEVEN

SUMMARY, CONCLUSION AND RECOMMENDATION

7.1 Summary

A preliminary study was carried out to reveal the nutritive value, cyanide content and the metabolic energy of Cassava Root Products (CPRs). This study involved force feeding of fifteen, 10 weeks old adult broilers to determine TME of four cassava products (UCC, UCP and UPG and PCC). There were three birds each on the four CRPs and the remaining three were fasted. Chemical analysis was carried out on the CRPs and feacal output of the fed birds. Six experimental trials were carried out. The six experimental trials reported were divided into two phases. In phase one, maize was compared with cassava chips and pellet in the diets of chicks, growers and layers. Phase two involved the comparism of cassava grit with cassava chips, pellets and maize in the diets of chicks, growers and layers.

In trial 1 compared cassava chips and pellet were compared with maize in diets of chicks. Maize was replaced at 25%, 50% and 100% with each of UCC and UCP. The PCC was replaced at 25%, while the control diet had 100% maize whithout the inclusion of any of the cassava products. Four hundred and eight chicks were divided into eight experimental diets with three replicates each, Trial II and III were grower and layer stages involving 240 growers and 240 layers, respectively. The experimental diets were the same with chick trial.

Trial IV was a chick trial involving replacement of maize at 50% and 100% with UCC, UCP and UCG constituting seven experimental diets. There were thirty birds on each diet with three replicates each. Trial V was the grower trial, using the same dietary treatments described for chick's trial. There were two hundred and ten birds divided into the seven experimental diets with three replicates of fifteen birds each. Trial VI involved three hundred and fifteen thirty weeks old laying birds allotted to seven experimental diets as described for chicks. Parameters considered were feed intake, weight gain, FCR, HDP, mortality, economy of production, digestibility, partial budget and sensitivity analysis.

7.2 Results

Crude protein, crude fibre and cyanide contents of unpeeled cassava products were higher than those of unpeeled cassava chip.

Ash and NFE results were similar for all the CRP.

True metabolize energy values were similar.

Birds fed 25% cassava root products recorded values that were not significantly different form the control diet.

Weight gain of chicks fed 50% and 100% unpeeled cassava chip and 100% cassava pellet were significantly lower than those fed CD.

Average FCR of birds fed 50% cassava chip and pellet were similar to CD

Growers fed cassava chips and pellet recorded values of weight gain and mortality that were not significantly different from CD.

Average feed intake, weight gain and hen day production of layers fed 100% cassava pellet were significantly lower than those on CD.

Performances of layers fed 50% UCC and UCP were similar to the CD.

Average feed intake, weight gain and FCR of chicks fed 100% cassava grit were similar to those fed control diets.

Performances of growers fed cassava grit were not significantly different from those on CD.

Age at first egg of growers on 100% UCP and UCC were higher than those on CD.

Hen day productions of layers fed 50% CRP were similar to CD.

Average HDP of 100% CRP was significantly lower than those on CD.

Nutrient digestibility of growers were similar

Nitrogen retention of chicks and layers fed 100% CRP were lower than those on CD.

Blood glucose and triglycerides of layers fed CRP were higher.

7.3 Conclusions

The following conclusions were drawn from all the studies:

Crude protein, crude fibre and cyanide contents of unpeeled cassava products were higher than peeled product

TME of CRPs were similar

Cost of peeling increased cost of PCC by 30%.

Cost of pelleting increased cost of UCP by 49%.

Cost of frying increased cost of UCG by10%

Inclusion of 25% CRPs in the diet of laying chicken did not affect performance and nutrient utilization.

Mortality was not adversely affected by the inclusion of CRPs

Partial replacement (50%) of maize with UCC and UCG gave satisfactory performance in chicks.

Complete replacement of maize with cassava grits is possible in the diet of chicks.

Complete replacement of maize with CRPs is possible with growers.

Partial replacement (50%) of maize with CRPs gave performance values comparable to 100% maize based diet in layers production.

Cost of pelleting affected economy of production of birds fed pellets containing diets.

100% replacement of cassava grit in diet of layers gave value of feed intake, weight gain and economy of production similar to those fed with maize based diets.

Nitrogen retention of laying chicken was affected by dietary inclusion of CRP.

Serum thiocyanate increased with increase level of CRPs in the diets.

Blood glucose increased with increase in inclusion levels of cassava.

Blood triglyceride increased with increase in inclusion levels of cassava.

Results of AST revealed anti nutritional factor in CPRs based diet.

Partial budget analysis for performance of layer fed CPRs recommended 50% UCG.

Break - even price of UCG was N25.75.

Break-even analysis revealed that cassava will be suitable provided it is at least 64.38% price of maize

7.4 Recommendations

- Studies should be carried out on Non Starch Polysaccharides (NSP) component of cassava products to identify specific cell wall material for enzyme supplementation.
- Possible improvement by appropriate enzymes to boost energy content of cassava products.
- There is need to increase scale of production of cassava grit in order to reduce cost and enhance availability.

REFERENCES

Ackers, G.K. 1970. Analytical gel chromatography of protein. *Advanced Protein Chemistry.* 324-343.

Ademosu, A. A and Eshiett, N. 1980. Feeding cassava root meal to starter, grower and laying chickens. *Tropical Agric* 57:277

Aderemi, F.A. 2000. Enzymic supplementation of cassava root sieviate and its utilization by layer. Ph.D Thesis. University of Ibadan. Nigeria. IX+229pp.

Aina, A.B.J. and Faniwo, A. O. 1997. Substitution of maize with cassava and direct potato meal as the energy source in the rations of layers birds. *Pertanical Journal of Tropical Agricultural Science.* 20:163-167.

Akinfala, E. P., Aderibigbe A.O. and Matamin, O. 2002. Evaluation of nutritive value of whole cassava plant as replacement for maize in the starter diets for broiler chicken. *Livestock Research for Rural Development*. 14: 1-6

Alimi, T. and Mayong V.M. 2000. Partial budget analysis for on-farm research. IITA Research Guide 45:53pp.

Alimi, T. and Alofe C.O. 1992. Profitability response of improved open pollinated maize varieties to nitrogen fertilizer levels. *Journal of Agricultural and Rural Development.* 5(1):42-47.

Ansell, M. and Lewis, F.A.S. 1970. A review of cyanide concentration fond in human organs-A survey of literature concerning metabolism, “normal,’’ nonfatal and fatal body cyanide levels. *J. Forensic Med.* 17:148-155.

AOAC. 1990. Official methods of analysis. 13th edition. Association of Official Analytical Chemist. Washington D.C.

ATSDR {Agency for Toxic Substances and Disease Registry}.1989.Toxicological profile for cyanide. ATSDR\Tp-88\12; prepared by Syracuse Research Corporation for ATSDR, U.S. Public Health Service, under Contract no 68-C8-0004.

Auriga, M. and Koj, A. 1975. Protective effects of rhodanase on the respiration of isolated mitochondria intoxicated with cyanide. *Bull. Acad. Pol. Sci. (Biology)* 5: 305.

Austic, R.E and M.C. Nesheim. 1990. *Poultry Production.* Lea and Febiger, Philadelphia. London. 173pp.

Ayanbade, S.O., Oyebola, O.O. and Oke, O.C. 1982. Aminotic and serum thiosulphase levels in cassava eating women. *Nutria. Rep Int*. 26: 73.

Babatunde, G.M and Fetuga, B.L. 1976. Effect of protein levels in the diet of layers on the egg production rate and the calcium composition of poultry egg in the tropics. *J. Sci. Food Agric.* 27: 452-462.

Balagopalan, C., Padamaja, I.G., Nanda, S.K. and Moorthy, S. N. 1988. *Cassava in food, feed and industry.* C. R. C Press, Inc. Boca Raton, Florida. 205pp.

Barret, M.D., Hill, D.C., Alexander, J.C. and Zitnak, Z. 1977. Fate of orally dosed linamarin in the rat. *Con J. Physical Pharmacol*. 55:134-136.

Bediako, M.K.B., Tapper, B.A. and Pritchard, G.D. 1981. Metabolism, synthesis and translocation of cyanogenic glycosides in cassava. In proc. Trennical Symp. International Soc. Trop. Root Crop. Terry, E.R., Odure. K.A and Caveness Eds-IDRC, Ohawa IDRC-163E143.

Bisset, F.H., Chapp, R.C, Coburn, R.A, Ethinger, M.G. and Long, L, 1969. Cyanogenesis in manioc concerning lotaustralin, *Phytochemistry*, 8: 2235.

Blakeley, R.L., and Coop, I.E. 1926. The metabolism and toxicity of cyanides and glycosides in sheep. II Detoxification of hydrocyanide acid *N.Z Journal Science Technol*. 31: 1

Bokanga, M., Ekanayake, I.J., Dixon, A.G.O. and Ports, M.C.M. 1994. Genotype O environment interactions for cyanogenic potential in cassava. *Acta Hort*. 375: 131-139.

Bonder R.J.L. and Mead, D.C. 1974. Evaluation of Glucose 6 phosphate dehydrogenase from lecuonostoc mebteteriodies in the hexokinanase method for determining glucose in serum. *Chinical Chemistry*. 568-580.

Bourdoux, P., Seghers P., Mafuta, P., Vanderpas, M. I., Vanderpas Rivera, M., Delange F and Eminaus A.M. 1982. Cassava products, HCN content and detoxification process. In nutritional factors involved in the goitrogenic action of cassava. Delange, F., Heke F.B., and Ammans, A.M Eds IDRC. Ottawa, IDRC- 184e51.

Bradbury. M. G., Egan B. V. and Bradbury, J. H. 1999. Picrate paper kit for determination of total cyanogens in cassava roots and all forms of cyanogens in cassava product. *Journal of Science, Food And Agriculture*. 76:593-601.

Brake, J.D. and Peebles, T. D. 1992. Laying hen performance as affected by diet and caging density. *Poultry Science*. 71 (Suppl.l) 945-950.

Brimer, L. and Rosling, H. 1993. A microdiffusion method with solid state detection of cyanogenic glycosides in cassava in human urine. *Food Chem. Toxicol.* 31: 599-603.

Budavari, S., O ‘Neil, M.J. and Smith, A. 1989. The Merck Index. Merck & Co., inc., Rahway, NJ, P.4722

Buitrago J. A., Osipina, B., Gill, J. L. and Aspanicio, H. 2002. Cassava root and leaf meal as the main ingredients in poultry feeding: some experience in columbia: *In Exploring New Opportunities For An Ancient Crop*. Howeler (eds). 7th Refinal workshop held in Bangkok. Thailand. Oct.28-Nov.2002. pp523.

Buitrago, J. A. and Luckett, A. 1999. Potential of industrial cassava production for animal feed. Publications of the American Soybean Association. Demonstrative Report of Workers, Cali, Colombia 27pp.

Bulter, G.W. 1965. The distribution of the cyanoglycosides: linamarin and lotaustration in higher plants. *Phytochemistry*. 4: 127.

Butler, G.W., Bailey, R.W, and Kennedy, L.D. 1965. Studies on the glucosidase "Limanarase" *Phytochemistry* 4: 369

Cantor, A. H., Pascatore, A.J., Johnson T.H and Straw, M.L. 1992. Effect of dietary methionine level on egg production parameters of brown shell laying hens. *Poultry Science*. 71 (suppl. 1) 39: (abstract).

Cardoso, A.R., Ernesto, M., Chiff, J. and Bradbury, M. 1999. High levels of total cyanogens in cassava flour related to drought in Mozambique, *Root* 6: 4-6.

Carlsson, L. Milingi Juman A., Ronguist G. and Rosling H. 1999. Metabolic fates in human of linamarin in cassava flour ingested as stify porridge food. *Chem.. Toxicol* 37: 307-312.

Carlsson, L. Ronguist, G. and Rosling, H. 1995. A specific and sensitive method for the determination of linamarin in urine. *Nat Toxins.* 3: 378-382.

Chau, K. C., and Muller, Z. 1972. Complete substitution of maize by tapioca in broiler rations. *In proc. Aust. Poultry Science Convention. World Poultry Science Association.* Auckland, New Zealand. 149pp.

Chauynarong, C., Elangovan A.V and Iji P.A. 2009. The potential of cassava products in diets for poultry. *World Poultry Journal.* 65: 23-35.

Chesworth, J.M., Stuchbury, T.. and Scaife, J.R. 1998. *Agricultural biochemistry*. Chapman an Hall, 206 Boundary Raw, London SEI 8HN U.K. pp490.

Chinies, M., Parks D. and Leeson, S. 1992. Calcium and Phosphorus metabolism and egg shell formation of hen fed different amount of calcium. *Poultry Science.* 71: 482-489

Choi, I.Y., Lee S.P., Kim, S.G and Gruetter, R. 2001. *In vivo* measurements of brain glucose transport using the reversible Michaelis-menten model and simultaneous measurements of cerebral blood flow changes during hypoglycemia *J.Cereb Blood Flow Metab* 21: 653-663.

Church, J.P., Jud, J.T., Young, C.W., Kelay, J.L an Kim, W.W. 1984. Relationship among dietary constituents and specific serum clinical compounds of subjects eating self selected diet. *Am. J. Clinical Nutr.* 40: 1338-1344.

Church D.C. and Verela-Alvarez H. 1991. Ration formulation. *In: Livestock feed and feeding*. Ed. D.C. Church. Prentice Hill, Eagel Wood Cliff. New Jersey 218-243.

Clusium, C. 1605. Exoticorium: Labridecem .

Conn, E.E. 1969. Cyanogenic glycosides. *Agric. Food chemical* 517-519.

Cooper-driver, G.A. and Swain, T. 1976. Cynogenic polymorphism in bracken in relation to herbivore predation nature (London) 260: 604.

Dalsted, H.L. and Gutierez, P.H. 1992. Partial budgeting. Farm and Ranch Series. Economies Colorado State University Cooperative Extension Services. Fot Collins Co. No. 3 760. 9/1992.

Degroote, G.E. 1966. The effect of pigment sources on yolk pigmentation. *World Poultry Science Journal.* 20(4): 271-273.

Douman, B.T. 1975. Standard for total protein assays. A collaborative study. *Clinical Chemist Hist.* 21: 1159-1166.

Duncan, G.B. 1955. Duncan multiple range test. *Biometric.* 11:1-42.

Dunstan, W.R. and Henry, T.A. 1906. Cyanogenesis plants V. The occurrence of phase pollination in cassava (*Manihot aipi* and *Manihot utilissina*). Proc. R. Soc. London ser. B 78, pp 152.

EFSA. 2004. Opinion of the scientific panel on food additives, flavourings, processing Aids and Materials in Contact with Food (AFC). In hydrocyanide acid in flavourings and other food ingredients with flavoring properties. *The EFSA Journal*. 105: 1-28.

EFSA. 2007. European Food Security Agency. *The EFSA Journal 551:1-44*

Ekpechi, O. L. 1967. Pathogenesis of endemic goiter in eastern Nigeria. *British Journal of Nutrition.* 21: 537.

El-boushy, A R., Simons, P.C.M. and Wiertz G. 1968. Structure and utrastructure of the hen's egg shell as influenced by environmental temperature, humidity and vitamin C. addition. *Poultry Sci*. 47: 456.

Ermans, A.M. 1980. General Conclusions" *In: Role of cassava in the etiology of endemic goitre and cretinism,* A.M. Ermans, N. M. Mbulamoko, F. Delange and R.

Ahlvertartia, eds. Report on international Development Research centre, Ottawa, Canada; pp147-152.

Ernest, M., Cardoso, A.P., Clitt, J. and Bradbury, M. 2000. Cyanogens in cassava flour and roots and urinary thiocyanate concentrate in Mozambique. *J. Food Comp and Anal*. 13: 1-12.

Ernesto, M., Cardoso P., Nicala D., Marione E., Massaz, F., Eliff, J., Haque, M. R and Bradbury, M. 2002. Strategy for the elimination of kanzo in Mozambique. *Root* 8(1): 8-11.

FAO .2008. Food outlook. Food and Agriculture Organization of the United Nations FAO Rome. Italy.

FAO. 1986. African Agriculture, the next 25 years. Food and Agriculture Organization of the United Nations FAO Rome, Italy.

Fassett, D.W. 1963. In industrial hygiene and toxicology Vol 2 2nd ed. Fassett D.W and Irish D.D eds. John wiley & sons. New York pp191.

Fetuga B.L. 1994. Techniques in feed formulation. A paper presented at the feed mill management training workshop, Department of Agric Economic, University of Ibadan. April 10- May 2, 1984.

Frankenberg, L. and Surbo, B. 1975. Effect of cyanide antidotes on the metabolic conversion of cyanide to thiocyanate. *Arch. Toxicology* 24:417-420.

Freeman, C. P. 1983. Fat supplementation in animal production: monogastic animal production. *Proc. Nutria. Soc*. 42: 351-352.

Fukuba, H., Igarashi, O., Briones, C.M, and Menoza, E.M. 1984. Cyanogenic glucosides in cassava and cassava products. Determination and detoxification. *In: tropical* *root crops post harvest physiology and processing*. Uritani,I. and Reye, E.D. eds. Japan Scientific Society Press Tokyo pg255.

Geevarghese, P.J. 1983. Cassava diet, tropical calcifying pancreatitis and pancreatic diabetes in cassava toxicity and thyroid: Research and public health issues. Proc. Workshop Delange, F and Ahluwalia, R. eds IDRC, Ottawa. pp177.

Gerhart, D.Z., Levasseur, R.J., Broderious, M.A and Drewes, L.R. 1989. Glucose transporter localization in brain *Res* 22:464-472.

Gettler, A.O. and Baine, J.O. 1938. The toxicology of cyanide. *Am. J. Med. Sci.* 195:182-198

Gil, J. Gescobar, L. and Buitrago, J.A. 2001. Technical and economic evaluation of four diets based in cassava flour and a commercial diet for feeding broilers. Technical report, CLAYUCA. 14pp.

Gomez, E. Souza, S.R, Grandi, R.P. and Silva, R.D. 2005. Production of thermo stable glucoamylase by newly isolated *Aspegillus flavus* Al.A and *Thermomyces lanuginosus* A13.37. *Brazilian Journal of Microbiology*. 36:82-95.

Gomez, G.I., Valdivieso, M., Dela Cuesta, D. and Salcedo, T.S. 1984. Effect of variety and plant age on the cyanide content of root cassava chips and its reduction by sun drying . *Animal Feed Science and Technology*. 11:57-65.

GSO (General Statistic Office). 2001. Statistical Publishing house. Hanoi, Vietnam.

Halalaung, R.I. 1977. Additives other than methionine in cassava diets. In cassava as animal feed. Proc. Workshop, (Nestel, B and Graham, M, eds) University of Guelph, Ontario IDRC 095C 18.

Halstron, F. and Muller, K.D. 1945. Content of cyanide in human organs from cases of poisoning with cyanide taken by mouth, with contribution to toxicology of cyanides. *Acta Pharmacol. Toxicol.* 1: 18.

Hamid K, and Jalaludin, S. 1972. The utilization of tapioca in rations for laying poultry Malaysian Agricultural Research 48-53.

Hardly, H.L. and Boylen Jr. G.W. 1983. Cyanogen, hydrocyanic acid and cyanides. In: Encyclopaedia of occupational health and safety, 3rd ed, Vol. 1, L.Parmeggiani, ed. International Labour office, Geneva, pp574-577.

Hartung, R. 1982. Cyanides and nitriles. In: Patty's industrial Hygiene and Toxicoloy. Vol. 2c, G.D. Clayton and E. Clayton, eds. John Wiley & son's New York, NY, 4845-4900.

Heady, E.O 1964. *Economic: Agricultural production and resource use*. Prentice hall inc. Englewood cliffs N.J 167-200.

Hefferberg, R., Black, E and Block, J.F. 1966. Serum metabolites. *J. Clinical Investment: 45*:143-150.

Henry, O. And Boutron – Charland L. 1936. Recherches sur le principle veneneux du manioc amer, mem: *Acad. Med.* Paris 5: 212.

Hermandiz, T., Lundquist, P., Lourdes, O., Perez Cristi, R., Rodriguez. E. and Rosling, H. 1995. Fate in humans of dietary intake cyanogenic glycosides from root of sweet cassava consumed in Cuba. *Nat Toxins* 2:114-117.

Hiditch. T.P. and Williams P.N. 1974. The chemical constitution of natural rats 14th ed Champman and Hall ltd London.

Hinwich, W.A and Saunders, J.P. 1948. Enzymatic conversion of cyanide to thiocyanate *Am Journal of Physiol*. 153: 348.

Hockings, D.M. 1987. Nutritional interactions and reproduction in bird. *Proc. of the Nutrition Society*. 46: 217-225.

Howeler, R.H 2007. Production and use of cassava based diets in smallholder livestock systems in Asia. Workshop on exploring opportunities of developing the use of cassava based diets to mitigate feed scarcity in West and Southern Africa. Held at IITA, Ibadan. Nigeria 08-10 August 2007 pp 16.

Hudson, B.J.F. and Ogunsua A.O. 1974. Lipids of cassava tubers (*Mainhot esculenta* Crantz). *Journal of Science and Food Agricultural*. 25: 1503

Hutagalung, R.I. 1972. Nutritive value of leaf meal, topiaco root meal, normal maize and opagu-2 maize and pineapple bran for pig and poultry. 17th Annual Conference, Malaya, Kanla Lunpur Malaysia.

IFAD and FAO. 2000. International Fund for Agricultural Development (IFAD) and Food and Agricultural Organisation of the United Nations FAO. The World Cassava Economy Facts and Outlook. Rome Italy.

Ikediobi, C.O. and Onyike, E. 1982. Linamarase activity and detoxification of cassava (*Manihot esculenta*) during fermentation for gen production. *Agric. Boil. Chem.* 46: 1662.

Isom, G.E., Liu, D.A.W. and Way J. I. 1975. Effects of sublethal doses of cyanide on glucose metabolism. *Biochem. Phammacology* 24: 81.

Jaffery, F.P. 1941. Changes in pullet year albumen index as affected by age of birds. *Poultry Science* 20: 298-301.

Jalaludin,S. and Leong, S.K. 1973. Response of laying hens to low and high levels of tapioca. *Malaysian Agricultural Research.* 2:47.

JECFA. 1993. Toxicological evaluation of certain food additions and naturally occurring toxicants WHO food additives series 30:299-339.

Job. T.A., Oluyemi, J.A., Awopeju, A.F. and Odeyemi, T.O. 1980. Optimal level of cassava (*Manihot esculenta* Crantz) flour in the diet of the growing chick. *Zentralblatt Verterinary Medicine* 27: 669-674.

Johnson, A.S., and Merrift, E.S. 1955. Heritability of albumen height and specific gravity of egg from white leghorns and barred rocks and the correlation of these traits with egg production. *Poultry Science* 34: 578-587.

Kaczka, E.A., Denkewalter, R. G. and Folker, A. 1950. Vitamin B_{12}. XIII additional data on vitamin B_{12}. *Journal of American Chem. Society* 73: 35.

Kanto U., and Juttopornpong, S. 2002. Clean cassava chips for animal feeding in Thailand: In exploring new opportunities for an ancient crop. Howeler (ed) 7th regional workshops held in Bangkok. Thailand Oct. 28- November 1 2002, pp 542.

Kanto, U and Khajarern. S. and Bunsiddhi, D. 1979. The substitution equation in replacing cassava meal for maize in broiler ration. Cassava/Nutritional Project, Annual Report. Khonkean, Tailand, pp543.

Karunajeers, H.R., Huges, J., McDonald, M.W., Schenstone, S. 1984. A review of factors influencing pigmentation of egg yolk. *World Poultry Science* 40(5):52-65.

Kay, R.D. 1981. Enterprise and partial budgeting, whole farm planning and budgeting. *In farm management planning and control and implementation*. McGraw Hill book company, USA. pp 60-100.

Keshavarz, K. and Jackson, M.E. 1992. Performance of growing pullets and laying hen fed low protein amino acid supplemented diet. *Poultry Science* 71: 905-918.

Ketiku, A.O. and Oyenuga, V.A. 1970. Prelamadra Report on the carbohydrate constituents of cassava root and yam tuber. *Nigeria Journal of Science.* 4-25.

Khajarern J., Khajarern, S. and Bunsiddhi, D. 1979. The substitution equation in replacing cassava meal for maize in broiler ration. Cassava/nutrition project annual report. Khoukaen 1979. pp57.

Khajarern J., Khajarern, S., Sirapraphagon, A and. Nandhapipat, U. 1982. A survey on the changes in chemical composition of cassava root product in Khon Kaen region in 1980. In KKU –IDRC Cassava /Nutrition Project 1976. Annual report. Khon Kaen University, Khon Kaen,. Tailand pp13-32.

Khajarern S. and Kajarern, J.M. 1992. Use of cassava products in poultry feeding. Proc. FAO expert consultative committee on ultization of roots, tubers, plantain and banana in feeding. Held in CIAT, Cali, Colombia. 21-25 Jan 1991. David M. and Solveig N eds. pp 79-90.

Khajarern, S, and Khajarern, J. 1986. Utilization of cassava for animal feed. *In Proc. 24th Kasetsert University Conference* Kasetsert. University, Bangkok, Thailand pp 66-72.

Koch, B., Nielsen, V.S., Halkier, B. A., Olsen, C.E and Moller B.L. 1992. The biosynthesis of cyanogenic glycosides in seedlings of cassava. *Achieves of Biochemistry and Biophysics* 292: 141-150.

Kojima, M., Poulton, J.E., Thayer, S.S. and Conn, E.E. 1976. Tissue distributions of dhurrin and enzymes involved in its metabolism in leaves of sorghum bicolor. *Plant physiology*. 63: 102.

Ladokun, O.A. 2003. Nutritional evaluation of sweet potato plant for chicks, pullets and layers. Ph.d Thesis. University of Ibadan, Nigeria. pp IX+176

Lancaster, P.A., Ingram, J.S., Lim M.Y and Loursey, D.G 1982. Traditional cassava based foods : A survey of processing technique. *Econ: Bot* 36: 12.

Lang, S 1933. Dre rhodanbildnny in terkorper, *Biochem*. 2: 259: 262.

Le Du Ngoan, and Nguyen Thittoa Ly. 2002. The use of cassava roots and leaves for feeding pigs in Vetnam. In exploring new opportunities for an ancient crop. Howeler (eds) 7th regional workshop held in Bangkok. Thailand oct. 28th 2002 pp518.

Lessel, S. 1971. Experimental cyanide optic neuropathy. *Arch Opthalmol.* 84. 194.

Leeson S. and Summer, J.D. 1981. Effect of rearing diet on performance of early maturing pullet. *Can. J.Animal Sci.* 61:743-749.

Leeson S. and Summer, J.D. 1983. Performance of laying hens allowed self selection of various nutrients. *Nutr. Rep Int.* 27: 837-844.

Leeson, S. and Summer, J. D. 1997. *Commercial poultry nutrition.* 2nd Edition, University Books, Ontario Canada.

Lindsay, D.B. 1977. The effect of feeding pattern and sampling on blood parameters. Lister D. eds Occa. Publi. No. 1. Br. Soc. Anim. Prod. pp 99-120.

Lipsey, R.G. 1975. The theory of costs. *In an introduction to positive economics*. English language book society and Weidenfeld and Nicolson 4th edition page 211-242.

Lohr, J.E. 1975. Fatty liver and kidney syndrome in New Zealand chicken. *NZ Vet.* 23:167-169

Lokaewmanee, S., Kanto, U. and Juttuporpong, S. 2002. A study of metabolizable energy (ME) of chips in broiler diet. *In: Proceeding 40th Kasetsert University conference*, Kasetsert University. Bangkok. Thailand.

Longe O.G. 2006. Poultry: Treasure in a chest. An inaugural lecture delivered on behalf of the Faculty of Agric. and Forestry. University of Ibadan, Ibadan 24th August, 2006.

Longe, O.G. and Fagbero-Byron, J. O. 1990. Composition and physical characteristics of some fibrous waste and by-products for pig feeds in Nigeria. *Bietri. Tropical Landwirtsch Veterinary Medicine.* 28: 199-205.

Maini, S.B. 1973. Quality aspects of cassava: *In cassava production technology*. Hrishi B and Nair, R.G eds. Centra Tuber Crops Research Institutes Trivandrum India pp 49.

Maner, J.H 1973. Cassava in swine feeding in Centro International de Agriculture Tropical. Cal Colombia bulletin.

Manurung, F. 1974. Technology of cassava chips and pellets in Indonesia, Malaysia and Thailand. In proc. Interdisciplinary workshop on cassava processing and storage Araullo.E.V., Nostel, B. and Lampbell M. eds Pataya, Thailand. pp 89.

Maher, F, Vannucci, S.J. and Simpson, I.A. 1991. Glucose transporter protein in brain. *FASEB J* .8: 1003-1011.

Maust, L. E., Scott, M. L. and Pond, W. G. 1972. Metabolize energy of rice bran, cassava flour and black eye cowpea for growing pig diets. *Poultry Science.* 51: 1397.

Maxwell, M.H., Pobertson. G.W., Spences S. and McCorquedule, C.C. 1990. Composition of heamotological values in restricted and *libitum* fed domestic fowls; red blood characteristics *Br. Poultry Science*. 31: 407-413.

Mayong, V.M. and Oyewole, B. 1996. Data collection guideline for farm level economic analysis. Training workshop on measuring the benefits of legumes in crop-livestock based system. Mineo IITA, Ibadan, Nigeria 13pp.

McFarlane, J.A. 1982. Cassava storage II. Storage of died cassava products. *Trop. Sci.* 24: 205.

Meister, A. 1954. Preparation and enzymatic reactions of the ketdanalozines of asparagine and glutamic. *Fed. proc*. 12: 245.

Mitruska, B.M and Rawnsley, H.M. 1977. In: Clinical, biochemical and haematological reference value in normal experimental animal. Masson publishing, U.S.A Inc.

Monekasso, G.L. and Wilson J. 1966. Plasma thiocyanate and vit B_{12} in Nigerian patients with degenerative neurological disease, *Lancet*, 1: 1062.

Monitilla, J.J. 1977. Cassava in the nutrition of broilers and animal feed. In cassava as livestock feed in Africa. Eds. Hahn, S.K Reynolds, R and Egbunike E. Proc. of the IITA/ ILRA/ University of Ibadan workshop on the potential utilization of cassava as livestock feed in Africa, Nigeria pp 43-50.

Mosobalaje, M. A. and Tewe, O.O. 2009. Studies on nutritive value of cassava root products as energy sources in poultry production. *Journal of Applied Agricultural Research* 1:47-52.

Mosobalaje, M.A, Adedoyin A.A and Tewe O.O 2009 Effect of feeding cassava pellets and chips as replacement for maize in the diet of growing pullets. Pro. 3rd national conference school of voc. and tech education. Emmanuel Alayande College of Education Oyo State. June 16-18 2009, pp1-3.

Mosobalaje, M.A., Tewe, O.O., Adebayo, B.F., Adedoyin, A.A. and Lawal, T.E. 2007. Performance and economy of production of layers fed whole cassava mash and pellets as replacement for maize. *Tropical Journals of Animal Science.* 10(1-2): 99-104.

Mosobalaje, M.A., Adedoyin, A. A., Kehinde, A.S., Amuda A.J and Tewe, O.O 2010.Effects of replacing maize with cassava chips and pellets in the diet of pullets chicks on performance and economy of product. *Journal of Agric. Research and policies* 5(1): 51-53.

Muller, D.K., S. Chou and K.C. Nah. 1974. Cassava as total substitute for Cereal in Livestock and poultry ration. *World Animal Review*, 12: 19.

Nesheim, M.C., Austic, R.E and Card, L.E. 1979. *Poultry Production*. Philadelphia. Lea and Febiger pp221-243.

Ngoka, D. A., Ene, L. S.O., Okpokiri, A.O. and Odurukwe ,1984. The use of cassava root meal as energy substitute for maize in poultry diets. Research bulletin no. 2 of the NRCRI, Umudike, Nigeria.

Nweke, F. and Ezumah, H.C. 1992. Cassava in African farming and food Systems: Implication for use in livestock feeds: In cassava as livestock feed in Africa. Eds. Hahn, S.K Reynolds, R and Egbunike E. Proc. of the IITA/ ILRA/ University of Ibadan workshop on the potential utilization of cassava as livestock feed in Africa, Nigeria pp 7-15.

Nweke, S.I. Spencer D.S.C. Lynam, J.K. 2002. *The cassava transformation. African best kept secret*. Michigan, State University press. East Lausing U.S.A

Ochetims, O. 1992. The substitutability of maize with cassava and leaf meal mixture in broiler diets. *Journal of South Pacific Agriculture*. 1: 29-33.

Ogbea, M. and Berhan, T.S. 1997. Analytical method for feeds, animal excrements and animal tissues and nutrient. Laboratory Manual, ILRI Ethiopia.

Ogunmodede, B.K. and Afolabi S.O. 1978. Replacement of groundnut cake by dried poultry manure in the diet of laying hens. *Br. Poultry Science*. 19: 43-47.

Oke, 1978. Problems in the use of cassava as animal feed. *Animal Feed Science Tech*. 3:345-380.

Oke, O. L. 1973. The mode of cyanide detoxification in chronic cyanide toxicity. Proc. Interdisciplinary workshop Nestle B. and Mac. Intyre R. eds, London, IDRC Ottawa. IDRC – 100e 97.

Oke, O.L., 1976. The prophylactic action of cassava. In proc. Fourth symposium international of society of tropical root crop. Cock J., Mac Intyre R., and Graham M., Eds IDRC – 080R Ottawa. pp232.

Oke, O.L., 1969. The role of hydrocyanide acid in nutrition. *World Review Nutr. Diet* 11: 170.

Olayemi, J.K. 1989. Factors determining the growth of the feed mill industry. In: feed mill management in Nigeria. O. Oguntowora, J.K. Olayemi and M.F Mabawonku eds. Ibadan University Press pp 29-24.

Olson, D.W., Sunade, M. L. and Bird H.R. 1969. The metabolizable energy content and feeding value of mandioca meal in diets for chicks. *Poultry Science*. 48: 1445.

Oluyemi, J. A. and Robert, F.A. 2000. *Poultry Production in Warm Wet Climate.* Macmillian publishers, London and Basingstoke 197 pp.

Omole. T. A. 1977. Cassava in the nutrition of layers. In: Cassava as animal feed, Proc. Cassava as Animal Feed Conf. eds. B. Nestel and M. Graham, University of Guelph 18-20 April 1977, Canada IDRC – 095e Ottawa. 51-55.

Onabowale, S.O. 1992. Constraints and projection for processing and utilization of cassava. Eds. Hahn, S.K Reynolds, R and Egbunike E. Proc. of the IITA/ ILRA/ University of Ibadan workshop on the potential utilization of cassava as livestock feed in Africa, Nigeria pp 112-118.

Osuntokun, B.O. 1971. Epidemiology of tropical nutritional neuropathy in Nigerian. *Trans. R. Soc Trop. Med. Hyg* 65: 454.

Oyenuga, V.A 1967. *Nigeria's Foods and feeding stuffs.* University of Ibadan press, Ibadan Nigerian pp. 97.

Phalaraksh, K., Khajarern S and Bunsiddhi D. 1999. An evaluation of the replacing value of cassava root meal for maize, broken rice or sorghum in layers diets. Cassava/nutrition project annual report, khonkaea. Thailand

Phasurin, K., Kanto, U and Juttupornpong, S. 2002. A study on metabolizable energy (ME) of cassava chips in growing finishing pig diets. In Proc.40th kasetsert University Conference. Kasetsant University Bangkok, Thailand (in thai).

Philbrick, D.J., Hopkins, J.B. and Hill, D.C.. 1979. ‘‘Effects of prolonged cyanide and thiocynate feeding in rats. ‘‘*J. Toxicol. Environ. Health* 5:579-592.

Philips, T. P., Taylor, D.S., Sanii, L. and Akoroda M.O. 2004. A cassava industrial revolution in Nigeria. The potential for a new industrial crop. The global cassava development strategy. International Fund for Agricultural Development (IFAD) and the Food and Agriculture Organization (FAO), Rome. 49pp.

Portella, F. J., Caston, L.J. and Leeson, S. 1988. Apparent feed particle size preference by laying hens. *Can j. Animal Science*. 68:915-922.

Rangilal, S.S., Dinokar, C.V. and Kaikon, A.S. 1995. Studies on the replacement of maize by tapioca meal in broiler ration. *Poultry Adviser:* 21: 49-52.

Reas, B.R. 1986. A study on the comparative digestibility of cassava, maize, sorghum and barley in growing pigs. Master of veterinary study thesis. University of Queens, Land, Australia.

Ross, J.G., Christie, G., Halliday, W.G. and Jones, R.M. 1978. Hematological and blood chemistry comparison value for clinical pathology in poultry. *Vet. Record*. 102:29-31.

Saentaweesuk, K., Kanto, U., Juttupornpong, S. and Harinsut P. 2000. Substitution of cassava meal for corn in broiler diets. In; Proc. 35th Kasetsert University conference. Kaetsent University, Bangkok, Thailand.

SAS. 1997. Statistical Analysis System. User guide SAS/STAT. 6th Edition SAS Institute Inc. carry, NC USA.

Schalm, O.W. 1971. *Veterinary heamatology.* 2nd edition. Lea and Febriger. Philadepia.

Schesinger, P and Westley J. 1974. An expanded mechanism for rhodanase. *Journal of Biol. Chem.* 249: 780.

Schichai and Balnave, D. 1981. Egg weight response to dietary supplementary with sun flower oil and rice polland. *Poultry Science*. 60: 1102-1112.

Scudanwe, K. A., Hetmanski, M.I., Chan, H.K. and Collins, S. 1997. Occurrence of mycotoxins in raw ingredients used for animal feedstuffs in the United Kingdom in 1992. *Food Additives and Contaminants.* 14:167-173.

Shafer, D.J, Carey, J.B. and Sams, A.R. 1992. The effect of Methionine intake on liquid egg components. *Poultry Science.* 71 (supp 1) 107.

Shaib, B., Aliyu, A. and Bakshi, J.S. 1997. Nigerian National Agricultural Research Strategy plan: 1996-2010. Fed. Ministry of Agric and Natural Resources, Abuja, Nigeria.

Sibbald, I. R. 1976. A Bioassay for true metabolizable energy in feeding stuffs. *Poultry Science*, 55:303-308.

Sibbald, I.R. 1978. The effect of the duration of the time interval between assays on true metabolizable energy value of feedstuff. *Poultry Science*, 57:455-460.

Simpson, I.A., Vannucci, S.I., DeJoseph, M.R. and Hawkins, R.A. 2001. Glucose transporter asymmetreis in the bovine blood-brain barrier. *J Biol Chem.* 276: 12725-12729.

Smith, A. B. A. 1992. A review of ruminant responses to cassava based diet. In cassava as livestock feed in Africa. Eds S.K. Hahn, L. Reynolds and G.N. Egbunike. Proc. of the IITA/ ILRA/ University of Ibadan workshop on the potential utilization of cassava as livestock feed in Africa, Nigeria..pp 39-63.

Solomonson L.P. 1981. Cyanide as metabolic inhibition. In cyanide in biology, Vennesland B., Conn, E.E., Knowles, C.I., Westley J., Wissing F. eds. Academic press, New York pp 11.

Sorbo, B.H. 1953. Studies on rhodanase. *Acta Chem.. Scand.* 7: 238.

Stevenson, M.H. and Jackson, 1983, The nutritional value of dried cassava root meal in broiler diets. *Journal of the Science of Food and Agriculture* 34: 1361-1367.

Streeja, V.G., Nagahara N., Li, Q. and Minami, M. 2003. New aspects in pathogenesis of konso: neural cell danama directly caused by linamarin contained in cassava (*Manihot esculenta* Crantz). *British Journal of Nutrition.* 90:467-472.

Streeramamurthy, V.V. 1945. Investigation on the nutritive value of tapioca. *India Journal of Medical Resources*. 33, 229.

Tabayoyang. T.T. 1935. The value of cassava refuse meal in the rations for growing chicks. *Philipp. Agric*. 24: 509.

Tattawa, S., Moonchaisuk, S., Tanasrisutarat, N., Kanto, U and Juttapornpong, S. 2002. A comparative study of corn and cassava diet both supplemented and unsupplemented with antibiotic on performance and mortality rate of broiler. Proc. of 40^{th} Kasetsart University Conference Kasetsart University Thailand.

Teegerstrom, T. 1997-98. Arizonal farm machinery costs. Arizonal Cooperation Extension bulletin February, 1998.

Teegerstrom, T., Clerk, L. and Walser, R. 1999-2000. Arizonal field crop budget. Gam Country. Arizonal Cooperative Extension, March 1999.

Tewe, O.O. 1975. Implications of the cyanogenic glycoside fraction of cassava in the growth and reproduction of rats and pigs. Ph.D thesis Department of Animal Science. University of Ibadan.

Tewe O.O. 1983. Thyroid cassava toxicity in animals. In cassava toxicity and thyroid. Research and public health issues. Proc. Workshop. Delange, F and Ahlumalia, eds, IDRC Ottawa IDRC 207 pp 114.

Tewe, O.O. 1991. Detoxification of cassava products and effect of residual toxins on consuming animals. Invited paper presented at the FAO Expert Consultative Committee on utilization of roots, tubers, plantains and banana in feeding, CAT, Cali, Colombia, South America. David, M.. and Solveig, N. eds 21-25 Jan. 1991. pp 34-38.

Tewe, O. O. 1997. Sustainability and development: Paradigms from Nigeria livestock industry. Inaugural lecture delivered on behalf of Faculty of Agriculture and Forestry, University of Ibadan, Ibadan. 41pp

Tewe O.O. 2002. Cassava for livestock feed in sub-Sahara Africa: Strategies for Industrialization. Commissioned paper presented at the International workshop on cassava competitiveness. Nov. 18-22, 2002. IITA, Ibadan.

Tewe, O. O. 2004. Cassava for livestock feed in sub-Sahara Africa. A commissioned paper for Food and Agriculture Organization (FAO) Rome Italy 75pp.

Tewe O.O. and Bokanga, M. 2001. Cost effective cassava plant based rations for poultry and pig. Proceedings of the ISTRC, Africa branch 11-10 November 2001.

Tewe O. O. and J.H. Maner. 1981a. Long- term and carry-over effect of dietary inorganic cyanide {KCN] in the life cycle performance and metabolism of rats. *Toxicol. Appl. Pharmacol*. 58:1-7

Tewe, O. O. and J.H. Maner. 1981b. Performance and pathophysiological changes in pregnant pigs fed cassava diet containing different levels of cyanide. *Res. Vet. Sci*. 30: 147-151.

Tewe O.O. and Egbunike G.N. 1992. Utilization of cassava in non ruminant livestock feeds. In: *cassava as livestock feed in Africa*. Eds. Hahn, S.K Reynolds, R and Egbunike E. Proc. of the IITA/ ILRA/ University of Ibadan workshop on the potential utilization of cassava as livestock feed in Africa, Nigeria. pp. 28-38.

Tewe, O.O. and Maner J. H 1980. Cyanide, protein and iodine interactions in the performance metabolism and pathology of pigs. *Research in Veterinary Science*, 29: 271-276.

Tewe, O.O. Maner, J.H. and Gomez, G. 1977. Influence of cassava diets on placenta thiocyanate transfer, tissue rhodanase activity and performance of rat during gestation. *Journal of the Science Food and Agriculture*. 28: 750.

Tewe, O.O., Gomez, G. and Maner, J.H. 1980. Effect of extraneous linamarase on the hydrocynanic acid content of some tropical cassava varieties. *Nigerian Journal of Sciences* 1: 27: 32.

Tewe, O.O., Job, T.A. Loosli, J.K. and V.A. Oyenuga. 1976. Composition of two local cassava varieties and the effect of processing on their hydrocyanic content and nutrient utilization by the rat. *Nigerian Journal of Animal Production.* 3(2): 60-66.

Tiemoko, Y. O. 1992. The use of cassava in broiler diets in Cote D'ivore: Effects on growth performance and feed costs. In: Cassava as livestock feed in African. Eds: S.K Hahn, I. Reynolds, and G.N. Egunike, IITA Ibadan Nig. pp112-118.

U.S EPA.1985. Drinking water criteria document for cyanide (final Draft). Prepared by the Environmental criteria and Assessment office of the office of drinking water, Cincinnati, OH. ECAO-CIN-422, PB866-117793.

U.S. EPA.1984. Health Assessment for Cyanide. Prepared by the environmental criteria and assessment office, Cincinnati, OH for the Emergency and Remedial Response office, Washington, DC. EPA/540/1-86-011.

Ugwu, B.O. and Ay, P. 1992 Seasonality of cassava processing in Africa and test of hypothesis. In: Product development for root and tuber crops Vol. III Africa. Proc. Workshop on processing, marketing and utilization of roof and tuber crop in Africa. Eds. Gregory J, Scott, C., Jose E. held October 26-Nov. 1991 at IITA Ibadan. 193-214.

Ukachuckwu, S.N. 2005. Studies on the nutrient value of composite cassava pellets for poultry: chemical composition and metabolizable energy. *Livestock Research for Rural Development.* 17:11.

Van Poppel, F. 2001. Analyse vitslagen KB grounds-toffen. Hoof veevoeding en Kwaliteif, antond inc. Avicultures Jun. 2001 FENAVI-FONAV.

Vandepopuliete, J.M. and Lyons, J.J. 1992. Effect of inorganic phosphate source and dietary phosphorus level on laying hen performance and egg shell quality. *Poultry Science* 71: 1022-1037

Vannucci, S.J., Gibbs, E.M and Simpson, I.A. 1997. Glucose utilization and glucose transporter proteins GLUT3 in brains of diabetic (db/db) mice. *Am J Physics*. 272 E267-E274.

Verschueren, K. 1983. Handbook of Environmental data on organic chemicals. Van Nostrand, New York, pp741-743.

Voegthin, O., Johnson, J.M. and Dyer, H.A. 1926. Glutathione content of turnover animals. *Journal of Pharmacological Exp. Ther*. 27: 467.

Wesley, J. 1980. Rhodanase and the sulfane pool. In Enzymatic basic of detoxification, Vol. ll. Academic press, New York, pp. 245-262.

WHO. 1993. Toxicological evaluation of certain food additives and natural occurring toxicants. Report of the 39th meeting of the joint FAO/WHO experts committee on food additives (TECFA) Food additives series. World Health Organization Geneva. 30:299-337

Willie, D. and Kinabo, A. 1980. Cassava or maize meal for broiler and the effect of supplementation with methionine and sulphate in cassava based diets. *Tropical Animals Productions* 5: 182-190.

Wilson, J., Linnell, J.C and Mathecous D. 1971. Plasmacobalamines in neuro-opthalmological diseases, *Lancet*, 1. 259.

Winkler. W.O. 1958. Report on method for glucosidal HCN in lima beans. *J. Assoc Agric Chem* 41: 282-287.

Woodrow, I.E., Slocum, D.J. and Gleadow, 2001. Influence of water stress on cyanogenic capacity of eucalyptus chadocalyx. *Austi Journal of Plant Physiology.* 22: 113-125.