ASSESSING THE GROWTH PERFORMANCE AND ECONOMICS OF FEEDING A MAIZE SUBSTITUTE (MAIZE REPLACER) USING NON-CONVENTIONAL FEEDSTUFFS FOR BROILER DIETS

BY

KANTANKA GOODMAN SARFO

(BSC AGRICULTURE TECHNOLOGY, ANIMAL SCIENCE)

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DECLARATION

I, SARFO KANTANKA GOODMAN, author of this thesis titled “formulating a maize substitute (maize replacer) using agro-industrial by-product(s) and non-conventional feedstuffs for broiler diets”, do hereby declare that apart from the references of other people’s work which have been duly acknowledged, the research work presented in this thesis was done entirely by me in the Department of Animal Science, Kwame Nkrumah University of Science and Technology. This work has never been presented in whole or in part for any other degree in this university or elsewhere.

Kantanka Goodman Sarfo STUDENT (PG8832805)	….…………………………… Signature	………………. Date

Certified by:

Dr. O.S. Olympio SUPERVISOR	……………………………… Signature	……………….. Date
Dr. (Mrs). Victoria Attoh-Kotoku Head of Department	..…………………………… Signature	………………. Date

DEDICATION

This work is dedicated to my Supervisor, family and friends, my father Mr. Okyere A. A. Darko, mother Mad. Margaret Manu and especially to my 6 months old daughter Leilani Bernadette Abena Sarfo. God bless you.

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ABSTRACT

Two feeding trials involving 360 Cobb broilers were conducted to evaluate a maize substitute (Maize Replacer) formulated and compounded using non-conventional feedstuffs in both Experiment One and Two. The Maize Replacer which contained maize bran, rice bran, palm kernel cake, cassava flour, tuna waste, maize and palm oil was formulated to have 17% crude protein and 11.2 MJ/kg of metabolisable energy. With the incorporation of the Maize Replacer as an ingredient, the experimental diets were formulated to be iso-nitrogenous and iso-caloric. The diets contained an average of 21% crude protein and 12.0 MJ/kg of metabolisable energy. A Completely Randomized Design was used and each diet was replicated three times. Each treatment group had 90 birds for both experiments. Parameters measured were feed intake, live weight, feed conversion efficiency, mortality, feed cost and carcass characteristics. T_1 denotes the control diet, which contained 60.80% of maize, T_2 had 40% of maize, $T_{3,}$ 35% and $T_{4,}$ 33%.

In Experiment One, birds fed the four diets (T_1, T_2, T_3 and T_4) were significantly different ($P<0.05$) from each other in mean feed intake and weight gain. With final body weight (FBW) and average daily gain (ADG), as the level of Maize Replacer increased, body weight and body weight gain decreased. In terms of FCE, birds on the control treatment were the most efficient in converting feed into muscle. Feed efficiency deteriorated with increasing levels of Maize Replacer. The treatments did not have any significant effect ($P>0.05$) on the carcass parameters measured, bled weight, empty gizzard, eviscerated weight, full gizzard, kidney weight , liver weight and de-feathered weight. Dietary treatments had no effect on mortality as post mortem results did not attribute the cause of the three deaths from T_1, T_2 and T_3 to the feed. In Experiment Two, a similar trend was observed, with regard to final body weight (FBW) and average daily gain (ADG), the level of Maize Replacer increased, body weight and body weight gain decreased . However, T_1 was

not significantly different ($P>0.05$) from T_2. T_2 was significantly different ($P<0.05$) from T_3 and T4. T_3 and T_4 were also not significantly different ($P>0.05$) from each other. In terms of FCE there was no significant difference ($P>0.05$) between T_1 and all the other treatments. Total feed intake recorded in T_1 was significantly different ($P> 0.05$) from T_2, T_3 and T_4. T_2 was also significantly different ($P> 0.05$) from T_3 and T_4. T_3 also differed from ($P<0.05$) T_4. Dietary treatments had no effect on mortality as post mortem results did not attribute the cause of the two deaths from T_1 and T_3 to the feed. Maize Replacer could replace maize in Experimental One and Two up to 40% without any effects on all the parameters measured. On benefit-cost ratio, it may be concluded that investment in broiler farming using Maize Replacer is financially viable on all treatments. Benefit-cost ratio (BCR), investment in broiler production for Treatment One was found to be most profitable, followed by Treatment Two and Treatment Four. This was due to the fact that the benefits per bird were highest for Treatment One, followed by Treatment Two and Treatment Four. In contrast, the benefits per bird were lowest for Treatment Three.

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LIST OF ABBREVIATIONS

Non-Conventional Feed Resources (NCFRS)

Palm Kernel Cake (PKC)

Anti- Nutritional Factors (ANFS)

Cocoa Pod Husk (CPH)

Wheat Bran (WB)

United States Department of Agriculture (USDA)

Hydrogen Cyanide (HCN)

Parts per Million (PPM)

Maize Replacer (MR)

CHAPTER ONE

1.0 INTRODUCTION

Broilers are the meat type chickens that have been specially bred for marketing at an early age. They are usually sold when they weigh approximately 1.4 kg. Many countries including Ghana have adopted intensive poultry production as means of bridging the protein deficiency gap (Smith, 1990). The rearing of broilers in Ghana has been on the small scale but in recent times, the role of poultry production in enhancing life has increased the need for production on a large scale (Tachie-Menson, 1990).

Broiler meat is among the highest quality human foods and it is acceptable to all religions (Jordan and Pattinson, 1996). It serves as an important source of animal protein in those areas of the world that have protein insufficiency (Daghir, 1995).

Many are the constraints facing and hindering the progress and expansion of the animal industry in Ghana and most developing countries. The most important issue for the poultry sub-sector to consider is in relation to feed; its demand, availability and price. It becomes more of a problem when man competes with farm animals for feed ingredients such as maize and fish (Anchovy).

As the demand increases for these ingredients, prices also increase resulting in higher prices of feed inputs. Feed inputs contribute 70%-80% of the total cost of poultry (Okai and Aboagye, 1990). Careful attention should be given to ensuring adequate feed resources, which represent 60-80% of the economic inputs in the commercial poultry production sector (Aini, 1990).

Since conventional feed inputs have been identified as the major cost area and because they are often scarce during certain periods of the year, it will be economically expedient to explore the use of non-conventional feed resources. These are feed ingredients, which are not commonly used in the formulation of diets for poultry and livestock (Devendra, 1992). Examples of non-conventional feed resources useful for poultry production include cassava tuber, cassava peel, and cassava chips (Oluyemi and Roberts, 1979), discarded biscuits, bakery waste, rice bran, blood meal, corncob, maize bran, and copra cake. Others are cocoa pod husk, coffee pulp, oil palm slurry, groundnut skin, pito-mash, sorghum marsh, brewers spent grain, bone meal, molasses, sugar beet pulp, citrus pulp, yeast, whey, wheat bran, cocoa and distillers soluble.

Feed cost and the competition between animals and humans for the same foodstuff suggest strongly that alternative energy sources such as agricultural by-products be used partially or totally to replace maize and fish in poultry diets to reduce costs in meat production and to make the food items competed for more available for human consumption (Ngou and Mafeni, 1983).

1.1 Objectives

The objectives of this study are to:

1. Formulate a Maize Replacer with a combination of various non-conventional feedstuffs.
2. Examine the effects of the different levels of the Maize Replacer in the diets on the growth parameters of broilers.
3. Assess the economics of incorporating the Maize Replacer in the diet of broilers.

CHAPTER TWO

2.0 LITRATURE REVIEW

2.1 NON-CONVENTIONAL FEED RESOURCES (NCFRS) USED IN ANIMAL INDUSTRY

Non-Conventional Feed Resources are those feeds that have not been traditionally used in animal feeding and commercially produced rations for animals (Devendra, 1992). A large number of agro-industrial by-products, forest wastes, aquatic herbages and animal organic wastes which have been identified, processed and used for feeding of farm animals are designated as unconventional or non-conventional feeds (Pathak, 1997). Examples include discarded biscuits, bakery waste, rice bran, blood meal, corncob, maize bran, cassava tuber, cassava peel, cassava chips and copra cake. Others are cocoa pod husk, coffee pulp, oil palm slurry, groundnut skin, pito marsh, sorghum marsh, brewers spent grain, bone meal, molasses, sugar beet pulp, citrus pulp, yeast, wheat bran, cocoa meal and distillers soluble (Pathak, 1997).

Feed cost and animal competition with human beings for maize and fish (Anchovy) suggest strongly that alternative energy sources such as agricultural by-products be used partially or totally to replace maize and fish in poultry diets to reduce cost in meat production and to make available the major crops for human consumption (Ngou and Mafeni, 1983).

Careful attention should be given to ensuring adequate feed resources, which represent 60-80% of the economic inputs in the commercial poultry production sector (Aini, 1990).

2.1.1. PALM KERNEL CAKE (PKC)

Palm kernel meal is the by-product obtained after the extraction of oil from the palm-nut. It is abundant in the tropical areas of the world and attempts have been made to feed it to livestock (Hutagalung, 1981; Abu *et al*., 1984). McDonald *et al*. (1995) and Hutagalung (198) have indicated that palm kernel meal has been found to have limited use in pig feeding because of its high fibre content, low palatability and low availability of amino acids and energy. Okai (1998) was of the opinion that the processing technique for locally produced palm kernel meal is not only insufficient but also produces a product of doubtful quality because of the extreme heat applied and that the product is quite moist (25% moisture) and easily goes mouldy.

2.1.1.1 Utilization of Palm Kernel Cake (PKC) in Poultry

Owing to its high fibre content, the use of PKC in poultry rations is very limited (Wan Zahari and Alimon, 2004). There exist wide variations on the optimum inclusion level of PKC in poultry rations. The main reasons are due to the origin and variations in the oil and shell content of the PKC used (Wan Zahari and Alimon, 2004). Broilers can tolerate up to 20% PKC in their diets without affecting their growth performance and feed efficiency **(**Yeong, 1983). In layer rations, PKC can be included up to 25% without any deleterious effects on egg production and quality (Radim *et al*., 1999). Inclusion of PKC at levels greater than 20% was reported to reduce egg production and egg quality (Yeong *et al*., 1981). But in another study, reduced egg production was observed only at level greater than 40% (Onwudike, 1988).

2.1.1.2 Chemical Composition of Palm Kernel Cake (PKC)

The proximate analyses of PKC (Table 1) showed that it can be classified as an energy feed. This is because, its protein content is only 16%-18%, which would exclude it as a protein feed (Wan Zahari and Alimon, 2004).

Table 1: Proximate Analysis (%) of Palm Kernel Cake

Nutrient	% Composition
Dry matter	88.0-94.5
Crude protein	14.5-19.6
Crude fibre	13.0-20.0
Ether extract	5.0-8.0
Ash	3.0-12.0
Nitrogen-free extract	46.7-58.8
Neutral detergent fibre	66.8-78.9
Metabolisable energy ($MJKg^{-1}$)	
Ruminants	10.5-11.5
Poultry	6.5-7.5
Swine	10.0-10.5

Source: (Wan Zahari and Alimon, 2004).

2.1.1.3 Protein and Amino Acid Content of Palm Kernel Cake

Palm Kernel Cake is invaluable in supplying protein to ruminants. Nevertheless, poultry and pigs are also able to utilize its protein and other nutrients. The amino acid profile of PKC is shown in Table 2.

Table 2: Amino Acid Contents of Palm Kernel Cake (g/16g N)

Amino Acids	% Composition
Alanine	3.83
Arginine	11.56
Aspartic acid	3.63
Cystine	1.13
Glycine	4.17
Glutamic acid	16.80
Histidine	1.91
Isoleucine	3.22
Leucine	6.07
Lysine	2.68
Methionine	1.75
Phenylalanine	3.96
Praline	3.31
Serine	4.11
Threonine	2.75
Tyrosine	2.60
Valine	5.05

Source: (Wan Zahari and Alimon, 2004).

2.1.1.4 Mineral Contents of Palm Kernel Cake (PKC)

The ratio of calcium to phosphorus as shown in Table 3, is low and diets based on PKC need to be supplemented with calcium to meet the requirements of most animals (Wan Zahari and Alimon, 2004).

Table 3: Mineral Contents of Palm Kernel Cake

Mineral	% Composition
Calcium (%)	0.21-0.34
Phosphorus (%)	0.48-0.71
Magnesium (%)	0.16-0.33
Potassium (%)	0.76-0.93
Sulphur (%)	0.19-0.23
Copper (ppm)	20.5-28.9
Zinc (ppm)	40.5-50.0
Iron (ppm)	835-6130
Manganese (ppm)	132-340
Molybdenum (ppm)	0.70-0.79
Selenium (ppm)	0.23-0.30

Source: (Wan Zahari and Alimon, 2004).

2.1.2 COCONUT MEAL (COPRA CAKE)

This is the by-product obtained from the production of oil from the dried “meats” of coconuts (Banerjee, 1988). Coconut meal is available in many parts of the Western region of Ghana.

Even though the meal contains only moderate levels of crude protein, it is an economically important source of protein in areas which other sources are not readily available or are expensive (Pond and Maner, 1974). Coconut meal contains up to 26% crude protein, about 6% of ether extract when expeller processed and about 10% of crude fibre (McDonald *et al.*, 1995). In the expeller- extracted coconut meal, the digestibility as given by Creswell and Brooks (1971) is as follows.

Dry matter	83.7%
Ether extract	100%
Nitrogen free extract	94.1%
Energy	85.4%

Say (1987) reported that copra cake has nitro-compound contents ranging from 19 to 23%; the cellulose content is high, that is between 9% and 24%. However, according to (Banerjee, 1988) it is poor in lysine and histidine and thus should be restricted in swine and poultry rations. It was, however, suggested that if it should be fed to monogastrics then it has to be supplemented with lysine and methionine. Furthermore, the lipid component of copra meal is very low in unsaturated fatty acids; hence the feeding of copra cake meal produces firm or hard body fat in swine.

Say (1987) indicated that copra cake meal might be freely used in the diet of layers. At an inclusion level of 20% of the diet, performances remained comparable with those obtained with standard rations.

2.1.3 BLOOD MEAL

According to McDonald *et al.* (1987) blood meal is obtained by drying the blood of slaughtered animals and poultry, and this product has a dark-chocolate colour with a characteristic smell. Blood meal contains about 800 g/kg protein, small amount of fats and oil, and about 100 g/kg water. It is important nutritionally as a source of lysine, a rich source of arginine, methionine, cysteine and leucine but it is very poor in isoleucine and contains less glycine than fishmeal, meat and bone meal (MacDonald *et al*., 1987). Pond *et al*. (1995) also observed that blood meal is a high protein source with 80-85% crude protein but it is quite deficient in isoleucine and is best used as a partial supplementation of protein source. Evans (1960) as cited by Pond *et al*. (1995) and MacDonald *et al.* (1987) reported that blood proteins are rich in lysine but deficient in certain amino acids, notably methionine. Meals made or prepared commercially provide particularly useful raw materials because of their lysine content. Meals made locally are of variable qualities. If drying has been done in rainy weather they appear as incompletely dried masses, foul smelling and a site for bacterial fermentation making their use more or less dangerous (Say, 1987).

2.1.4 RICE BRAN

Rice bran is the most important rice milling by-product and it is readily available in Ghana. It is used as a substitute for wheat bran and as a partial replacement for maize or the cereal component of the diet (Okai, 1998). Rice bran is a valuable feedstuff because it is rich in B vitamins, fat and protein and compares favourably with other cereal grains in amino acid composition (Warren and Farrell, 1991). The bran fraction contains 14- 18% oil. The oil has a marked softening effect on body fat and on the butter fat in milk (Gohl, 1981).

Rice bran includes the pericarp and aleuron layers, germ and some endoplasm. The proportion of these fractions determines its composition but generally it contains 13% crude fibre and an equal amount of crude protein and ether extract (McDonald *et al.*, 1995). Pond *et al*., (1991) reported that rice bran is of highly variable quality depending on the quantity of hulls included with the bran. However, since many rice mills do not separate bran and polishing, and the characteristic of each are so poorly defined that they are difficult to distinguish, what is therefore termed bran is a mixture of bran, polishing and hulls. They further stated that satisfactory gains and efficiency of feed utilization can be obtained when moderate levels of rice bran (30-45%) are used in growing finishing pig diets. However, reduced pig performance can be expected when higher levels are incorporated into the diet. Tuah and Boateng (1982) had earlier reported reduced growth rate when rice bran levels of 40%, 50% and 60% were fed to finishing pigs. For young, growing pigs (5-15 kg), not more than 15-20% should be included in the diet (Pond *et al*., 1991). Okai (1998) agrees with the above inclusion level for young pigs. He reported that for younger pigs, levels more than 20% rice bran should not be exceeded. Gohl (1981) is also of the opinion that for pigs, rice bran should not exceed 30-40% of the total ration to avoid soft pork. In the final weeks of fattening, lower levels must be used. Up to 25% can be included in poultry rations, but double that amount has been used successfully in other experiments.

According to Crampton and Harris (1968) and Morrison (1961), rice bran has a high fibre content while the protein content is fairly low, thus high levels of inclusion may increase the rate of passage of the feed through the alimentary tract and thereby reduce the digestibility of the nutrients (Andah, 1973). Boa-Amponsem (1973) observed lower performance when rice bran was used as the only cereal bran. In spite of this, rice bran can be used in finisher diets to reduce the fatness of the carcass. Say (1987) reported that rice bran cannot be used in poultry feeding but in case of necessity, it may be incorporated in the ration at the end of the growing period and for pullets and layers, in proportions lower than 10%. However, rice bran tends to become rancid rapidly because of its relatively high content of unsaturated fats. Nevertheless, defatted rice bran is available for use in some other countries (Banerjee, 1988; McDonald *et al*., 1995). Table 4 shows proximate analysis of rice bran from 10 mills as presented by Okai *et al*. (2003).

Table 4: Analysed Proximate Composition of Rice Bran from 10 Mills (%, as-Fed basis)

Mill	Rice Mill Type	DM	CP	EE	ASH	CF	NFE
A	Imported	94.96^{b}	7.98^{b}	7.93^{bc}	11.25^{bc}	15.18^{f}	52.62^{bc}
B	Imported	95.57^{a}	7.82^{b}	8.27^{b}	9.80^{g}	18.73^{d}	50.95^{d}
C	Locally-made	94.91^{b}	5.50^{f}	5.81^{e}	17.77^{a}	20.87^{b}	44.96^{g}
D	Imported	95.54^{a}	7.91^{f}	10.20	12.64	14.38	50.40
E	Locally-made	94.85	5.97	5.94	12.97	20.81	49.17
F	Imported	93.97	7.33	7.44	9.66	16.41	53.10
G	Locally-made	94.81	5.23^{g}	5.84	13.39	21.83	48.52
H	Imported	94.49	9.74	7.69	9.16	14.06	53.84
I	Locally-made	94.10	6.39	4.78	11.84	18.82	52.27
J	Locally-made	0.1263	0.1105	0.1979	0.1660	0.1547	0.3417

Source: Okai *et al*. (2003).

a, b, c, d, e, f, g, h: Values in the same column with different superscripts are significantly different ($p<0.05$).

2.1.5 MAIZE BRAN

Maize bran is a by-product of dry milling maize, which consists of the bran coating and the maize germ. It is palatable to all classes of farm animals and approaches maize grain in feeding value though it contains more fibre because of the hulls, which are included.

Maize bran consists of the outer coating of the kernels, including the hull and tip cap, with little or none of the starchy part of the germ (Morrison, 1961). Pond *et al*. (1991) defined maize bran as a by-product obtained from the milling of maize, which is the removal of the hull. They added that the hull contains about 15 % crude fibre. Okai (1998) reported that maize bran is very much sought after by small and medium scale pig and poultry farmers. It is a very good partial replacement for maize for these species partly because milling machines used in the milling process are not very efficient and the by-product contains most of the germ, bran and some proportions of the endosperm. It is therefore a high-energy source, but unfortunately during the manufacturing process, water is added to the maize and thus the maize bran may be wet. If not dried immediately, it can easily become mouldy and may also become rancid. Wherever there are large concentrations of poultry and pigs, the demand is high, and therefore it can be scarce leading to high costs.

2.1.6 GROUNDNUT CAKE

Groundnuts are treated in one of two ways: namely, continuous pressure, which produces expeller cake and solvent treatment which gives extraction cake. Groundnut cake has moderate cellulose content of 5-7%. Residue oil contents are variable, according to the technique of preparation from 4-8% for the expellers and 1% for the solvent extracted cakes. Nitro-compound contents are fairly high, that is, 45% on the average for expellers and 50% for solvent extracted cakes. However, the latter are poor in methionine and lysine (Say, 1987). It was added that moulds contaminate groundnut cakes amongst which *Aspergillus flavus* is the best known and most common. It secretes a toxin called aflatoxin, which is dangerous for animals that consume these cakes. However, if it is aflatoxin- free, it can be used extensively up to 30% in feed intended for pullets and broilers. Fortunately, recent techniques, used particularly in Senegal, enable detoxification of groundnut cake contaminated with aflatoxin by ammonia treatment (Say, 1987).

Okai (1998) reported that limited amounts of groundnut cake are produced in Ghana for the feed industry but the bulk of the nation's requirement is imported from neighbouring countries. Furthermore, groundnut cake can help to reduce the demand for the major protein source, fishmeal, and thus reduce the cost of feeding pigs and poultry.

2.1.7 COCOA POD HUSK (CPH)

It is quite likely that more than 100,000 metric tones of CPH is generated in Ghana annually and the bulk of this is usually left to rot on the farms (Okai, 1998). He mentioned that the Ghanaian CPH has about 8% crude protein but its fiber content is quite high (64.4% neutral detergent fibre on dry matter basis). Okai *et al*. (1994) reported that dried CPH contains 8.1% crude protein, 34.8% crude fiber and 3.3% ether extract, 7.6% ash and 33.6% nitrogen free extract. They also observed that the high crude fiber content could limit its use in non-ruminant diet. Several experiments have been conducted with CPH using both ruminants and non-ruminants in Ghana.

In one such experiment, Okai *et al*. (1984) found that finishing pigs could be fed diets containing up to 25% CPH, where the CPH levels studied were replacing similar levels of maize, without any adverse effect on pig performance and carcass characteristics. CPH diets were generally cheaper. Gohl (1981) added that cocoa pod meal has been fed without toxic effect to cattle up to 7 kg per day and to pigs in quantities up to 2kg per day. For dairy cows, cocoa pod meal seems to be comparable in value to corn-on-cob meal. However, rations containing cocoa pod meals have a somewhat lower feed efficiency for beef cattle, but this could be compensated for by the larger intake. For pigs, cocoa pod meals can replace some of the maize and can constitute up to 35% of the ration without decreasing weight gains (Gohl, 1981). Various studies (Atuahene *et al.*, 1984; Donkoh *et al*., 1991) indicated that cocoa pod husk can be included in broiler chicken diets up to 10% without any deleterious effect on performance

2.1.8 BREWER'S DRIED YEAST

Brewer's dried yeast is a by-product obtained from the brewery industries. Dried yeast is rich in protein containing about 120g – 240g crude protein per kg dry matter. The dried yeast is storable for long periods and can be used as a protein substitute in animal feeds (MacDonald *et al*., 1995)

Brewer's dried yeast is highly digestible and may be used for all classes of farm animals. The protein is of fairly high nutritive value and is specially favoured for feeding pigs and poultry. It is a valuable source of many of the B-vitamins and is relatively rich in phosphorus but has low calcium content (MacDonald *et al.*, 1995). It is also believed that it contains unidentified but important growth factors useful for efficient poultry production. When irradiated with ultraviolet light it also provides vitamin D (Gohl, 1981). It is usually included at levels of 2-5% in rations for pigs and poultry but if the price of dried brewer's yeast is low it can replace up to 80% of the animal protein in pig and poultry diets provided that additional calcium and vitamin B $_{12}$ are added as well. Brewer's dried yeast has constituents which make the feed unpalatable if included in large amounts. The bitter taste can be removed by mixing the slurry with a solution of NaOH and sodium sulphate (at pH 10) and heating to 45 ^{o}C, after which the mixture concerntrate, is washed and dried (Gohl, 1981).

2.1.9 CASSAVA FLOUR

Cassava has a high production potential and can adapt to different types of soils. It is an energy source which could take the place of maize or other cereals used for feeding poultry in tropical Africa. Cassava roots can be used to make flour with an energy value of more than 3000 kcal of metabolizable energy per kg (Müller and Chou, 1974; Stevenson and Jackson, 1983; Kirchgessner, 1985). Cassava's tuberous roots have not always been properly used because of their high linamarin content. Linamarin is a cyanogenic glucoside which releases highly toxic cyanide (HCN) during hydrolysis at the time of digestion (Scott *et al*., 1976; Stevenson and Jackson, 1983; Preston, 1987).

Cyanide is believed to be responsible for many of the poor results obtained when using cassava to feed livestock although only little accurate information on the effective incidence of the HCN rate on the performance of animals is available (Gomez, 1985). Experiments conducted using Cassava flour have given somewhat contradictory results. Müller and Chou (1974) and Stevenson and Jackson (1983) reported that a rate of up to 50 percent of cassava in the diet by no means impaired the growth performance of poultry, whereas Longe and Oluyemi (1977) as well as Willie and Kinabo (1980) observed a linear decrease in the weight of poultry resulting from the increase in the quantity of cassava included in the ration. Gomez (1985) showed that diets including more than 10 to 20 percent of cassava varieties with low or high HCN contents gave similar results.

2.2 CONSTRAINTS IN THE USE OF NON-CONVENTIONAL FEESTUFFS (ANTI-NUTRITIONAL FACTORS IN FEEDS)

Anti-nutritional factors may be defined as the chemical constituents of feedstuffs which interfere in the normal digestion, absorption and metabolism of the feed and some of these factors may have deleterious effects on the animal systems (Nityanand, 1997).

Anti-nutritional factors are present in many conventional feeds in lower quantities but they occur in larger quantities in most of the non-conventional feeds. It is necessary to know their nature, their harmful effects on animal performance and health, optimum tolerance limits and also the methods of treatment for their removal or neutralization in the feeds. A few of the antinutrional factors are referred to as toxic factors due to their harmful and even fatal effects when consumed in large quantities beyond the tolerance levels (Nityanand, 1997).

2.2.1 FACTORS INTERFERING WITH DIGESTION AND UTILIZATION OF DIETARY PROTEINS AND CARBOHYDRATES

2.2.1.1 TANNINS

These are polyphenolic compounds of high molecular weight and contain a large number of reactive phenolic hydroxyl groups. The tannins form complexes with proteins and starch and interfere with their optimum utilization in the digestive tract and systems. When Sal seed meal was fed to chicks containing 1.5% tannin on dry matter basis, the chicks showed symptoms like, decrease in haemoglobin concentration, and white and red blood cells. Also, there is was the swelling and hydropic degeneration of hepatic cells. No method has been found for the complete detannification of feeds, but some methods such as soaking and washing with water removes substantial amounts of tannins, but these methods are associated with dry matter loss.

Washing also causes pollution when the used water is poured away after washing. Washing followed by cooking further improves nutrient digestion (Nityanand, 1997).

2.2.1.2 SAPONINS

Saponins are glycosides. They are widely distributed in more than 500 plants species belonging to 80 different families (Banerjee, 1988).

Greater biological activity of saponins is thought to be due to the following characteristic properties:

1. Saponins are bitter in taste which reduces palatability.
2. Saponins combine with cholesterol reducing its activities.
3. Saponins have haemolytic properties, making them fatal when injected into the blood system.
4. Saponins tend to alter the permeability of the cell wall and therefore produce toxic effects on organized tissues when they come into contact with them.

Soyabean among other cultivated conventional fodder is a rich source of saponins (Nityanand, 1997).

A 20% Lecerne meal in a poultry diet (equivalent to 0.3% saponins) produces a significant growth depression attributable solely to the saponins whereas the same level is harmless to pigs (Banerjee, 1988).

2.2.2 PROTEASE INHIBITORS OR TRYPSIN INHIBITORS

These are feed constitutes which interfere with the normal activities of proteolytic enzymes. They are also called trypsin inhibitors because of their specific action on trypsin in chickens (Nityanand, 1997).

Leguminous seeds are the richest source of protease inhibitors. In raw soyabean, two main groups of protease inhibitors have been identified. They are (a) Kunitz inhibitors which contain few disulphide bonds and have specific inhibitory effects on trypsin. (b) Bowman- Brik inhibitors contain a greater number of disulphide bonds and have inhibitory effects on both trypsin and chymotrypsin. Feeding raw soyabean to chicks has resulted in reduced growth rate, pancreatic hyperplasia and low production (Banerjee, 1988).

All the above mentioned inhibitors are heat labile and easily inactivated by suitable heat-treatment, like roasting, toasting, popping and cooking. Pelleting by hot method only partially inactivates the protease inhibitors and may not be considered a satisfactory treatment (Nityanand, 1997).

Haemagglutinins are protein in nature and resistant to the action of pancreatic juice (Banerjee, 1988). They are present in many plants and seeds, and those that are likely to affect animals are rich in ricin, present in castor bean, phaseolotoxin A, present in *Phaseolus vulgaris* (Kidney bean). Haemagglutinins in soyabean and field bean are important in animal feeding. These antinutritional factors produce inflammatory reactions causing edema and clotting of blood in capillaries.

Autoclaving or moist cooking in 2% NaOH solution inactivates most of these Haemagglutinins (Nityanand, 1997).

2.2.3 FACTORS INTERFERING IN THE AVAILABILITY OF MINERALS

2.2.3.1 PHYTATES OR PHYTIC ACID

Phytates are the salts of phytic acid. They are found in almost all feeds of plant origin. Phytates are present in association with protein and generally high protein feeds also contain high levels of phytates, namely groundnut cake, soybean cake, sesame cake, cotton seed cake and wheat bran (Banerjee, 1988).

Phytic acids have a high chelating ability and in the plant it is found as phytates which are mostly not available to monogastric animals as they lack phytase enzyme. Phosphorus is the main constituent of phytic acid complex and zinc, manganese, iron, calcium, magnesium and potassium are also found chelated. The phytase enzymes have been found to increase the availability of phytic phosphorus in simple stomached animals and poultry (Nityanand, 1997).

2.2.3.2 OXALATES OR OXALIC ACID

Oxalic acid is found in free form but mostly as salts (oxalates). Oxalic acid forms insoluble salts with magnesium, and calcium which imparts antinutritional action (Banerjee, 1988).

2.2.3.3 GLUCOSINOLATES AND OTHER GOITROGENS

Glucosinolates are also known as thioglucosides. They impart pungent flavour and reduce palatability. The glucosinalates in feeds are found with the enzyme thioglucosidase which hydrolyses these compounds in the body into glucose, acid sulphate and either thiocynates, isothiocynates or nitriles. Some isothiocynates are subsequently cyclised to Oxazoolidine -2-thriones (OZT). Progoitrin and epigoitrin are the glucosinolate precursors of the anti-thyroid compound goitrin (5-vinyl-OZT) as well as precursors of nitriles and epithionitriles (Ranjhan, 1997). It has been noted that 0.15% 5-vinyl-OZT in the diet of young chickens causes depression of growth rate, hyperplasia and hypertrophy of the thyroid. In growing pigs, 10 - 20% rapeseed meal in the diet produces growth depression, hyperplasia of the thyroid and enlargement of the liver and kidneys.

Protein bound iodine present in the blood serum is reduced and difficulty in conception of gilts can occur. Furthermore, litter size and weight of the pig at weaning are reduced. The compound reduces the incorporation of iodine into the precursor of thyroxine resulting in iodine deficiency and development of goiter (Banerjee, 1988). Prolonged water soaking resulting in partial fermentation or cooking of seed with goitrogenic substances significantly inactivates the effect of goitrogens (Nityanand, 1997).

2.2.3.4 GOSSYPOL

This is a toxic phenolic compound of the cottonseed. It is present as pigments in the gland of cottonseed. About 15 types of pigments have been identified as present either in free form or as a complex form (gossypol-protein complex) according to Nityanand (1997).

Ferrous salts form a complex with the free gossypol and reduce its harmful effects while increasing its iron content. High levels of calcium, magnesium, sodium and protein are also helpful in reducing the adverse effects of gossypol. Heat treatment has been found to considerably destroy gossypol but the availability of lysine is greatly reduced warranting the need for supplementation in diets of simple stomached animals (Nityanand, 1997). Table 5 shows the utilization of cottonseed meal Gossypol pigments.

Table 5: Utilization of Cottonseed Meal Gossypol pigments

Species	**Maximum level in diet**
Broilers	60ppm free form
	300ppm with 600ppm ferrous sulphate
Laying Hen	400ppm with 160ppm ferrous sulphate
Breeding Hen	120ppm free form

Source: (Nityanand, 1997).

2.2.3.5 PHYTOESTROGENS

High concentrations of these chemical compounds produce harmful effects on health and productivity. Clovers, soya beans and other legumes contain high levels of them. Phosphorus deficiency and some climatic conditions favour the synthesis of phytoestrogens in these plants. Many reproductive problems develop as a result of extensive feeding on such feeds (Nityanand, 1997).

2.2.3.6 ANTI -VITAMINS

Anti-vitamin activities against vitamin A and D have been observed in soybean, against Vitamin E in kidney bean (*Phaseolus vulgaris*), against vitamin K in sweet clover and against pyridoxine in linseed cake (Banerjee, 1988).

2.2.3.7 CYANOGENS

These compounds are present in the form of glucosides in many fodders particularly sorghum, maize and cassava root. The glucosides are not toxic, but when plants are damaged, the hydrolytic enzymes released from the tissues of the plant hydrolyse the glucoside and as a result hydrocyanic acid (HCN) is produced. The hydrocyanic acid so produced is rapidly absorbed in the body of animals and in excess causes anoxia of the CNS resulting in death within a few seconds (Ranjhan, 1997). Also, based on the intensity, animals show nervousness, abnormal breathing, trembling or jerking of muscles, blue colouration of the lining of the mouth, spasms or convulsions and respiratory failure. Boiling is found to be satisfactory for its removal or destruction from linseed meal (Banerjee, 1988).

2.2.3.8 LATHYROGENS

Lathyrogens are protein in nature and are neurotoxins. Prolonged cooking or roasting of lathyrus seeds in hot sand has been found to destroy most of the lathyrogens (Nityanand, 1997).

2.2.3.9 NITRATES AND NITRITES

Nitrates and nitrites are the nitrogenous compounds accumulated in fodder plants under unfavourable climatic conditions. The toxic compounds which are present in forages are mainly nitrates which are converted to nitrites during the storage of high moisture fodders (Ranjhan, 1997).

Nitrates have caustic action on the mucosa and cause gastroenteritis (Nityanand, 1997).

Absorption of nitrates into the blood circulation system results in the formation of methaemoglobinaemia. The methaemoglobin is unable to transport oxygen due to change of iron from ferrous (Fe^{++}) to ferric (Fe^{+++}) (Banerjee, 1988). High nitrate containing fodders should not be fed to animals.

Table 6 gives a summary of list of some common anti-nutritional factors and their effects in the monogastric farm animal.

Table 6: Major Effects of Anti-Nutritional Factors in Monogastric Farm Animals

Anti-Nutritional Factors	Major In Vivo effect
Trypsin inhibitors	• Reduction of (chymo) trypsin • Pancreas hypertrophy • Increased secretion of pancreatic enzymes
Tannins	• Formation of protein-carbohydrate complexes • Interference with protein and carbohydrate digestibility
Phytic acid	• Form complexes with minerals and protein • Depresses absorption of minerals
L-Dopa	• Causes fever • vomiting • Toxic to the brain
HCN	• Causes vomiting • Collapsing and sometimes death
Amylase inhibitor	• Interference with starch digestion

Source: (Huisman and Tolman, 1992)

2.3 TECHNIQUES FOR PREPARATION OF BY-PRODUCTS FOR FEEDING PURPOSES

2.3.1 Application of Heat

Heating is known to cause denaturing of proteinaceous inhibitors. It is a good method of decreasing the activity of lectins and also that of trypsin and chymotrypsin inhibitors (Araba and Dalo, 1990). Heat treatment has been achieved by roasting, dry heating, autoclaving and boiling.

2.3.2 Roasting

Roasting is the act of cooking by exposure to dry heat, often with addition of fat and especially in an oven (Cambridge International Dictionary, 1996**)**. Roasting can reduce the negative effects of protease and alpha-amylase inhibitors on digestion by 96% (Siddhuraju *et al*., 1996). Siddhuraju *et al*. (1996) also reported a reduction in L-Dopa level due to its racemisation under roasting. Amino acid residues in protein and in synthetic peptides can racemise under roasting conditions (Hayase *et al.*, 1975).

2.3.3 Autoclaving

Autoclaving is the act of using a strong steel container that can be made air tight and filled with pressurised steam in order to sterilize equipment (Cambridge International Dictionary, 1996). Autoclaving reduces phytate content by 47% in Mucuna seed. Autovlaving at 130^0C for 1 hour removed 15% of the Beherenic acid and 96% of trypsin inhibitors in *Mucuna* (Siddhuraju *et al.*, 1996). Autoclaving under pressure at 115^0C - 140^0C followed by drying and removal of fat by pressing or extraction is also used to obtain various kinds of animal protein meals such as meat and bone, fish, feathers and other meals produced from dead and condemned animals (Karzimerz, 2000).

2.3.4 Boiling

This involves cooking in water (liquid) in such a way that the liquid turns to vapour upon reaching a boiling point, often with the formation of copious bubbles of vapour within the liquid. The boiling point of water is 100^0C. Heat treatment through boiling has been found to be most effective in reducing anti-nutrients in Mucuna beans. Cooking velvet beans removes the negative effects of trypsin inhibitors by 100% (Siddhuraju *et al*., 1996). In human nutrition, cooking has been the most common method of velvet been preparation. According to Dossa *et al.* (1998) however, grilling was better than boiling in-terms of nutrient preservation. This contradicts the findings of an earlier study where boiling was reported to be better than roasting velvet beans (Laurena *et al*., 1994). Heat treatments by thorough roasting or cooking can successfully reduce HCN levels by as much as 68%. There is no danger of cyanide poisoning from thoroughly heat-treated velvet beans (Liener, 1983; Siddhuraju *et al*., 1996). Boiling whole beans or grits without soaking in water reduced L-Dopa by 44.75% (Nyirenda *et al*., 2002).

2.3.5 Hydrothermal, Acid and Alkali Hydrolysis

These are used for processing wastes rich in keratin e.g. feathers, hooves, animal hair, tannery, waste or some plant products containing glycosides such as rape seed meal (Karzimerz, 2000).

2.3.6 Microbiological and Chemical Souring

These techniques are used to prepare the by-products and are effective methods of reducing harmful substances e.g. isothiocyanates from rape, souring of skim milk and whey, preserving by-products of animal origin: blood, rumen content and animal and poultry excrements which are now used as fodder ingredients (Karzimerz, 2000).

2.3.7 Dehulling

Dehulling is the physical removal of the seed coat or testa or hull. This method of removing ANFs is useful where they are confined to a specific part of a feedstuff, such as in the hull portion of legume seeds or in the testa layer just under the seed coat of legumes. Physical removal of the hull reduces the tannin as reported for faba beans (Van der Poel *et al*., 1991) and sorghum (Eggum *et al*., 1983). Tannins have been shown to form protein-carbohydrate complexes, which interfered with protein digestibility (Huisman and Tolman, 1992). There is also a reduction of fibre content associated with removal of the testa. Longstaff and Macnab (1991) also reported that dehullling could reduce ANFs such as lectins and trypsin inhibitors, which are concentrated in the cotyledons.

2.3.8 Soaking

Soaking is the act of leaving or making a substance stand in liquid for some time. Soaking grits of Mucuna for 24 hours reduced L-dopa by 30% while in the whole beans only by 6% (Nyirenda *et al.*, 2002). Soaking prior to cooking may improve the extraction efficiency of protease inhibitors (Moneam, 1990). Soaking has been achieved either by using water or calcium hydroxide. Bressani (2002) proposed that alkaline solution such as calcium hydroxide might be useful in reducing the L-Dopa content of Mucuna

2.4 EFFECT OF PROCESSING BY-PRODUCTS ON CHICKEN PERFORMANCE

2.4.1 Effect of Feeding Processesed Rice Bran on Poultry Performance

The high fat content of rice bran (13-15%) makes it fairly good for poultry feed (North, 1984). The inclusion level of rice bran in the diets for non-ruminants may be critical as it has high fibre content (Warren and Farrell, 1991). Daghir (1995) reported that rice bran could be used in poultry rations at fairly high levels if it is low in rice hulls and if the high oil level in it can be stabilized by an antioxidant as much of the energy value will be lost through oxidative degradation. Gohl (1981) suggested that up to 25% of rice bran can be included in poultry rations, but double that amount has been used successfully in other experiments.

2.4.2 Effect of Processing Cocoa Pod Husk on Chicken Performance

A ten-month feeding trial was conducted by Osei *et al.* (1991) to investigate the nutritive value of cocoa pod husk (CPH) meal for 37-week old laying chickens. Diets containing 0, 25, 50, and 75% levels of CPH meal per kg were used for the study. Results from the study indicated that, with the exception of Haugh unit score, which showed a significant positive response ($P<0.05$) to dietary treatments, the addition of CPH did not significantly affect any of the haematological variables studied.

Another study was conducted by Osei *et al.* (1995) using graded levels of CPH meal to determine the response of 192 ready to lay pullets (20 weeks old) in an 8-month long experiment. Four dietary treatments 0, 50, 100, 150g of CPH meal/kg were fed to the birds in a Completely Randomized Design. Results obtained indicated that, while feed consumption significantly increased as dietary CPH levels increased, the efficiency of feed conversion, final body weight and weight gain declined (P<0.05).

Olubamiwa *et al.* (2002) investigated the effects of the utilization of urea treated cocoa husk meal (UCHM) on growing pullets. Four percent urea solution was mixed thoroughly with cocoa husk meal (CHM) and the material was stored in polythene bags for two weeks under a shade. One hundred and eighty ten week old Nera pullets were used for the feeding trial which lasted for 16 weeks. The pullets were reared to twenty weeks of age on 0, 10, 15 and 20% UCHM diets. Results of the study indicated that, up to the 20th week, weight gains were similar (P>0.05) for birds reared on the control, 10% and 15% UCHM diets. However, there was a reduction in weight (P<0.05) in the 20% UCHM birds.

Atuahene *et al*. (1984) conducted a nine-week feeding trial in Ghana with 300 Babcock broiler chickens to determine the performance and carcass characteristics of birds fed various levels of cocoa pod husk (CPH). The birds were fed five diets containing 0, 25, 50, 70 and 100g of CPH per kg during the starter period (5 weeks). All the birds were fed a common finisher diet during the four – week finisher period. Results of the study indicated that there were significant increases in feed consumption and body weight gain (P<0.05) as the dietary levels of CPH were increased during the starter phase. In their discussion, the significant increase in feed consumption was attributed to the increase in palatability of the feed with CPH inclusion due to the presence of volatile and non-volatile compounds.

An experiment was carried out by Boa –Amposem *et al*. (1984) to determine the amount of cocoa pod husk (CPH) that may be incorporated into starter diets without any deleterious effect on the growth and slaughter characteristics of broilers. Five diets were prepared in which CPH replaced 0, 25, 50, 75 and 100g of maize per kg. Results showed that the differences observed in feed intake and feed to gain ratio were not statistically significant ($P<0.05$).

In another study, Donkoh *et al*. (1991) conducted an experiment on the chemical composition of cocoa pod husk (CPH) and its effect on growth and food efficiency in broiler chicks. The study assessed the extent to which CPH can further reduce the quantity of maize included in broiler diets. In a seven-week trial, five diets containing 0, 50, 100, 150 and 200 g kg^{-1} CPH with maize and fishmeal as major ingredients were given *ad libitum* to 450 one week old AF Bosbek broiler chicks. The addition of graded levels of CPH to broiler diets increased feed intake by 60% for the highest level of inclusion.

Teguia *et al*. (2004) undertook a study in Cameroon on broiler performance upon dietary substitution of cocoa pod husk (CPH) for maize. The study aimed to determine the effect of replacement of maize by CPH in a growing –finisher ration. Two hundred Amak broiler chickens at 7 weeks of age were given rations containing 0, 10, 30% CPH for 8 weeks. The results indicated a significant increase in the growth rate for those birds fed the diet with the 10% substitution level compared to the control birds. However, there was no significant difference between the birds fed the diet with 20% substitution level and the control.

2.4.3 Effect of Wheat Bran on Chicken Performance

Dzineku (1996) investigated the effect of including high amounts of wheat bran (WB) in finisher diets on growth performance and economy of gain of broiler chickens. The chemical composition of the wheat bran used in the study is as shown in Table 7. In the feeding trial, four finisher diets containing maize, fishmeal, micro-ingredients and either 150, 250, 350 or 450g of WB kg^{-1} diet and designated as dietary treatments WB 150, WB 250, and WB 450, respectively, were fed *ad libitum* to 480 3-week old commercial broiler chickens for 35 days. The results indicated a significant (P<0.01) increase in feed intake per bird. There were significant differences (P<0.01) in body weight gain and feed conversion efficiency during the period. Birds on dietary treatment WB 150 registered the highest weight gains and were more efficient in feed use utilisation compared with other treatments; treatments WB 450 was the least efficient. There was no health – related problems attributed to the level of WB in the diet. Also, mortality did not show any consistent trend. There was also a decrease in the cost per kg feed and feed cost kg^{-1} live weight gain with increasing levels of dietary WB.

Table 7: Chemical Composition of Wheat Bran on Fresh Basis

Chemical Composition	%DM
Dry matter	89.43
Crude protein	19.35
Ether extract	6.21
Crude fibre	9.71
Ash	4.95
Neutral detergent fibre	50.38
Acid detergent fibre	16.72
Hemicelluloses	33.66
Lignin	2.93
Starch	19.70
Metabolisable energy (MJ/Kg	6.72

Source: Dzineku (1996)

Say (1987) reported that wheat bran may be included in broiler feed at less than 25% and for layers and growing pullets he suggested, as acceptable, a maximum rate of 40% wheat bran.

2.5 MAIZE

2.5.1 Overview

Maize (*Zea mays* L.), or corn, is the most important cereal crop in sub-Saharan Africa and, with rice and wheat, one of the three most important cereal crops in the world. Maize is high yielding, easy to process, readily digested, and cheaper than other cereals. It is also a versatile crop; growing across a range of agroecological zones. Every part of the maize plant has economic value: the grain, leaves, stalk, tassel, and cob can all be used to produce a large variety of food and non-food products.

In industrialized countries, maize is largely used as livestock feed and as a raw material for industrial products, while in developing countries, it is mainly used for human consumption (Table 11). In sub-Saharan Africa, maize is a staple food for an estimated 50% of the population. It is an important source of carbohydrate, protein, iron, vitamin B, and minerals (Table 9). Africans consume maize as a starchy base in a wide variety of porridges, pastes, grits, and beer (Table 11). Green maize (fresh on the cob) is eaten parched, baked, roasted or boiled; playing an important role in filling the hunger gap after the dry season.

2.5.2 Maize in Poultry Diet

Maize is palatable and suitable for all classes of livestock. The digestibility and palatability of maize can however be increased by processing, using methods like roasting, dry rolling, flaking etc. Flaking is the most widely used method. In this method, the grains are steam-cooked and then passed between rollers while still hot and soft (Gohl, 1981). It has been found that, flaked maize passes through the alimentary tract about 25% more rapidly and has 5% higher digestibility and more palatable than cracked maize. Flaked maize should not be stored for a long period before feeding (Gohl, 1981).

The colour pigment in yellow maize, cryptozanthine, is valuable in poultry diets. It gives the meat and egg yolk a desirable yellow colour. The pigment is partly transformed into vitamin A in the animal (Gohl, 1981). A list of top ten producers of maize in the year 2007 is found in Table 8.

Table 8: Top Ten Maize Producers in 2007

Country	Quantity
US	332,092,180
China	151,970,000
Brazil	51,589,721
Mexico	22,500,000[F]
Argentina	21,755,364
India	16,780,000
France	13,107,000
Indonesia	12,381,561
Canada	10,554,500
Italy	9,891,362
World	**784,786,580 [A]**

No symbol = official figure, F = FAO estimate, A = Aggregate (may include official, semi-official or estimates);

Source: Food and Agricultural Organization (2007).

Sweet corn also called sugar corn and pole corn is a variety of maize with a high sugar content, although is a major energy source. Protein are also found in appreciable quantities. The edible part of the corn has nutritional values and weights as given in the Table 9.

Table 9: Sweetcorn, Yellow, Raw (Seeds Only) Nutritional Value per 100 g (3.5 oz)

Nutrient	Content **(Nutritional value per 100 g (3.5 oz))**
Energy	360 kJ (86 kcal)
Carbohydrate	19.02 g
Sugars	3.22 g
Dietary fiber	2.7 g
Fat	1.18 g
Protein	3.22 g
Trytophan	0.023 g
Threonine	0.129 g
Isoleucine	0.129 g
Leucine	0.348 g
Lysine	0.137 g
Methionine	0.067 g
Cystine	0.026 g
Phenylalanine	0.150 g
Tyrosine	0.123 g
Valine	0.185 g
Arginine	0.131 g
Histidine	0.089 g
Alanine	0.295 g
Glutamic acid	0.636 g

One ear of medium size (6-3/4" to 7-1/2'' long) maize has 90 grams of seeds percentages are relative to US recommendation for adults.

Source: Debra (2003).

2.5.3 Maize Consumption

Maize consumption is concentrated in the southern regions, particularly in Greater Accra, where it is a traditional staple. This tends to magnify its perceived significance as a food security crop. According to some estimates, maize and other cereals account for about 60% and 50% of the calorie supply of rural and urban households respectively. However, as shown in Table 10, roots and tubers (especially cassava) constitute a far more important source of calorie supply, providing about 65% starchy staple consumption in Ghanaian households compared to 12% from maize.

Table 10: Estimated Share of Maize in Direct Human Consumption of Starchy Staple Crops

Crop	1	2	3	4	5	6	7
Maize	1,056	740	54	686	348	238,728	12%
Rice	233	255		255	363	92565	5
Cassava	7831	5461		5461	148	806253	42
Plantain	2169	1844		1844	119	219436	11
Cocoyam	1832	1465		1465	98	143570	7
Sorghum	372	260		260	332	86320	4
Millet	160	112		112	327	36624	2
Yam	3360	2688		2688	114	306432	16
Total Staples						1,929,828	100%
Total root crops						1,256,155	65%

Key

1. Production (Ktonnes)
2. Edible Production

3. Estimated feed use*(Ktonnes)
4. Production net of poultry use(Ktonnes)
5. Calory weight
6. Calory weighted production net of feed use
7. Calory -weighted production as % of total staples

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1 Location and Duration of Experiment

Two experiments were carried out at the Poultry Section of the Department of Animal Science, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, Kumasi. Experiment 1 lasted for seven weeks and Experiment 2 also lasted for eight weeks covering the periods June 26^{th} to August 15^{th}, 2007 and October 9th to December 4^{th}, 2007 for Experiment 1 and 2 respectively. The study area is located within the semi-deciduous humid forest zone of Ghana characterized by bimodal rainfall pattern with average annual rainfall of 1300 mm. Daily temperatures range from 20^{o}C to 35^{o}C with an average of 26^{o}C. The relative humidity varies from 97 percent during the mornings in the wet season to as low as 20 percent during the late afternoons in the dry season. (Meteorological report, Unpublished).

3.2 Ingredients Used

Ten ingredients comprising, conventional, non – conventional feedstuffs and agro-industrial by – products were used in the study. They were:

1. Wheat bran
2. Tuna Waste (Tuna Fish)
3. Maize
4. Russian Fishmeal
5. Palm Kernel Cake

6. Rice bran
7. Maize Bran
8. Oyster shell
9. Palm oil
10. Cassava flour
11. Salt
12. Vitamins
13. Dicalcium phosphate

3.3 Source of Dietary Ingredients

Wheat bran was purchased from commercial suppliers in Kumasi; Rice bran was sourced from the Beef and Dairy Cattle Production Station-Boadi; palm kernel cake from the Golden Web Company Limited – Atonsu Agogo; cassava flour, maize bran and maize were sourced from selected millers around Atonsu in the Kumasi Metropolis; tuna waste, Russian fishmeal and oyster shells were purchased from Akate Farms and Trading Company Limited. The palm oil was also sourced from the Atonsu new market.

3.4 Composition of the Maize Substitute

The study aimed at formulating a special maize substitute. The nutrient components considered were the crude protein percent, metabolisable energy (MJ/kg), crude fibre percent and three of the essential amino acids, lysine, methionine and cystine. Maize has a crude protein level ranging from 8.9% to 9.8%, metabolisable energy of 14.28 MJ/kg, crude fibre level ranging from

2.0% - 2.4%, methionine and cystine levels of 0.18% each. The maize substitute however, was formulated to have a higher level of crude protein than maize (Table 11). For the metabolisable energy (ME), maize happens to contain a level higher than what is required in the diets of the birds therefore the maize replacer was formulated to a ME level less than that of maize.

Table 11: Percentage Composition of Maize Replacer

Soybean Meal	15
Palm Kernel Cake	3.8
Palm oil	4.2
Rice Bran	10
Cassava flour	20
Maize bran	17
Tuna Waste	10
Maize	20
Calculated Analysis	
Crude Protein %	17
ME (MJ/kg)	11.2
Crude fibre	6.2
Lysine	1.04
Cystine	0.22
Methionine	0.69

3.5 METHOD OF FORMULATION

This study employed the Microsoft Excel Solver as a tool, in formulating the maize substitute.

3.6 Formulation of Experimental Diets

The composition of the experimental diets is shown in Table 12. T_1 denotes the control diet, which contained 60.85 % of maize, T_2 had 40% of maize, T_3 35% and T_4 denotes 33%. The diets were formulated to be iso-nitrogenous (21% CP) and iso-caloric (12.0 MJ/kg) for both experiments.

Table 12: Percentage Composition of Experimental Diets (%)

	Treatments			
Ingredients	T_1	T_2	T_3	T_4
Maize	60.85	40	35	33
Fishmeal	8	9.7	8.0	8
Wheat bran	5	0	0	0
Soybean	23.3	12.1	13.5	13
(Maize Replacer)	0	36.5	43	45
Oyster shell	2	1.2	0	0.5
Dicalphos	0.35	0	0	0
Vitamin Premix	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25
Calculated Nutrient Analysis				
Crude protein (%)	21.7	21.4	21.6	21.6
Metabolisable Energy(MJ/Kg)	12.0	12	12	12
Crude fibre	3.2	3.9	4.3	4.3
Lysine	1.2	1.3	1.3	1.3
Cystine	0.4	0.3	0.3	0.3
Methionine	0.4	0.6	0.6	0.6

Vitamin mineral premix per 100kg diet: Vitamin A, 2 million IU; E 3000 IU; K, 200 IU; B_1, 200mg; B_2, 900mg; B_{12}, 2400mg; niacin, 5000mg; and minerals: Fe, 9000mg; Cu, 500mg; Mn 12000; Co, 100mg; Zn, 10000mg; 1,400mg; Se, 40mg.

3.8 EXPERIMENTAL BIRDS AND EXPERIMENTAL DESIGN

Four-hundred day-old Cobb broilers were obtained from Darko Farms, Akropong. They were weighed and allotted to each of the four dietary treatments in a Completely Randomized Design for a four-week brooding period (starter phase). At the end of the fourth week, ninety (90) unsexed (straight-run) birds were maintained in each treatment. Each dietary treatment had three replicates. Each replicate group consisted of thirty birds totalling ninety (90) birds for each treatment. Each group was maintained in a deep litter pen with floor space of $0.21m^2$ per bird from five to seven and five to eight weeks of age for Experiment One and Two, respectively.

3.9 MANAGEMENT OF EXPERIMENTAL BIRDS

The broilers were given feed in mash form and water was given *ad-libitum*.

3.10 SCHEDULE OF VACCINATION

First Gumboro and first Newcastle disease vaccinations were administered through drinking water on the seventh (7^{th}) and fourteenth (14^{th}) days, respectively. Gumboro vaccination was repeated on the 21^{st} day of age. On the 35th day, the 2^{nd} Newcastle disease vaccination was administered.

Administration of coccidiostat, and antibiotics were the same for each treatment group. The vaccination schedule was as recommended by the Kumasi Metropolitan Veterinary Office.

The schedule for the prophylactic treatment and vaccination is shown in Appendix (9).

3.11 PARAMETERS MEASURED

The parameters measured were initial weight, four week body weight, average daily gain, weight gain, feed consumption (feed intake), feed conversion efficiency, mortality, carcass characteristics, feed cost and feed cost per weight gain.

3.11.1 FEED CONSUMPTION

Weekly average feed consumed per bird per replicate was calculated by subtracting feed left in the feeding trough at the end of the week from the total feed provided for the week. This was divided by the number of birds in a replicate and number of days to obtain feed intake per bird per day.

3.11.2 LIVE WEIGHT AND LIVE WEIGHT GAIN

The birds in each pen were weighed at the beginning of the trial and subsequently at the end of every week. Birds were batch weighed and the weight divided by the number of birds in each batch to obtain the mean live weight per bird. The initial average live weight per bird was subtracted from the weekly average live weight to obtain the live weight gain per week.

3.11.3 FEED CONVERSION RATIO (FCR)

Feed conversion efficiency was computed as feed/gain ratio. Mean weekly feed conversion was calculated by dividing the feed consumed by the live weight gain during the same period.

3.12 CARCASS PARAMETERS

At the end of the 49th and 56th day for experiment one and two, respectively, two birds (one female and one male) from each replicate per treatment were selected randomly for carcass evaluation. The birds were starved for about 13 hours to empty the crops. The following measurements were taken for the carcass analysis: live weight, weight after defeathering, weight after eviscerating, dressed weight, weight of gizzard, weight of intestine, weight of head and weight of legs (shanks). The legs and gizzard were calculated as a ratio of these to live weight of the bird. Dressing percentage was also calculated.

Dressing (%) = $\frac{Eviscerated\ Carcass\ weight}{Live\ weight} \times 100$

3.13 Mortality

Mortality was recorded as it occurred throughout the experimental periods. Dead birds were sent for post-mortem examination.

3.14 ECONOMICS OF PRODUCTION

3.14.1 Economics of Gain

Economics of production were calculated based on the feed cost per kg diet and feed cost per kg live weight gain. Feed costs per kg for each of the experimental diets were calculated based on the prevailing prices of the ingredients at the time of the experiment. Feed cost per kg live weight gain was calculated for individual dietary treatments as a product of the feed cost and the feed conversion ratio. The profit margin was computed by subtracting the cost of producing a kg carcass from the cost of carcass per kg.

3.14.2 Benefit Cost Analysis of the Maize Replacer

The differences in costs are as a result of the inclusion and exclusion of some ingredients, as well as the quantity used.

The benefit cost ratio for T_1, T_2, T_3 and T_4 were computed as;

$Benefit - Cost\ Ratio = \frac{Benefit}{Cost}$; Therefore,

3.16 Statistical Analysis

Means and associated standard errors for measured parameters were computed. One way analysis of variance (ANOVA) was carried out using GenStat statistical software and differences between means were detected using the Least Significance difference (LSD) test and Duncan Multiple Range Test in Experiment 1 and Experiment 2, respectively.

CHAPTER FOUR

4.0 RESULTS

4.1 EXPERIMENT ONE

4.2 Effect of Different Levels of the Maize Replacer During the Seven Week Experimental Period

A summary of the growth performance of the experimental birds is presented in Table 13.

Table 13: Effect of Maize Replacer on the Growth Performance of Broilers (Day Old – 7 Weeks**)**

Parameter	Treatment 1	Treatment 2	Treatment 3	Treatment 4	SEM	% CV
Initial weight (g/bird)	43.43±1.65^a	43.43±1.15^a	43.43±1.45^a	43.43±0.75^a	1.058	3.0
Final body weight (g/bird)	2423.3±22.0^a	2299.8±13.0^b	2273.3±15.0^b	2190.7±18.0^c	9.86	0.7
ADG (g/bird)	48.57±0.42^a	46.05±0.28^b	45.51±0.27^b	43.82±0.34^c	0.192	0.7
WG (g/bird/week)	339.98±2.9^a	322.34±2.0^b	318.56±1.9^c	306.75±2.4^d	1.343	0.7
TWG (g/bird)	2379.9±20.0^a	2256.4±14.0^b	2229.9±13.0^b	2147.2±17.0^c	9.40	0.7
Total Feed intake (g/bird)	4900.0±58.0^a	4784.0±29.0^b	4702.0±36.0^c	4628.0±11.0^d	21.5	0.8
Feed intake (g/bird/week)	700.0±8.4^a	683.4±4.2^b	671.7±5.1^c	661.2±1.6^d	3.07	0.8
Feed intake (g/bird/day)	100.0±1.17^a	97.62±0.59^b	95.95±0.73^c	94.45±0.23^d	0.439	0.8
FCR	2.06±0.12^a	2.12±0.002^b	2.11±0.004^b	2.16±0.02^c	0.006	0.5

$^{a-d}$ *Means in the same row bearing different superscript are significantly different ($p<0.05$)*

Means ± Standard Deviations (SD); Standard Errors of Means (SEM); Least Significant Difference (LSD); Coefficient of Variation (CV)

ADG – Average Daily Gain; WG – Weight Gain; TWG – Total Weight Gain; FCE – Feed Conversion Efficiency

4.2.1 Final Body Weight

From Table 13, T_1 was significantly different ($P<0.05$) from T_2, T_3 and T_4. However, T_2 was not significantly different ($P>0.05$) from T_3 but significantly different ($P<0.05$) from T_4. T_3 and T_4 were also significantly different ($P<0.05$) from each other. As the level of MR increased, body weight and body weight gain decreased.

4.2.2 Total Feed Intake

T_1 was significantly different ($P<0.05$) from T_2, T_3 and T_4. T_2 was also significantly different ($P<0.05$) from T_3 and T_4, T_3 also differed ($P<0.05$) from T_4 (Table 14). Feed intake decreased with increasing levels of Maize Replacer.

4.2.3 Feed Conversion Ratio

There were significant differences ($P<0.05$) between T_1 and all the other treatments. T_2 and T_3 were not significantly different ($P>0.05$) but T_2 was significantly different from T_4 (Table 13). Birds on the control treatment (T_1) were the most efficient in converting feed to gain. Feed efficiency deteriorated with increasing levels of Maize Raplacer.

4.2.4 Mortality

T_1, T_2 and T_3 all recorded 0.9% of mortality each. The post mortem result did not attribute the cause of death to the feed. No mortality occurred among birds on the dietary treatment T_4.

4.2.5 Carcass Results

The results for the carcass characteristics of birds on the different dietary treatments are presented in Table 14.

Table 14: Effect of Different Levels of the Maize Replacer on the Carcass Characteristics of Broilers.

	Experimental Diets				
Carcass Characteristics	**T1**	**T2**	**T3**	**T4**	**SEM**
Bled weight	$2363.^{a}$	$2230.^{ab}$	$2074.^{b}$	$2038.^{b}$	62.4
De-feathered weight	2270^{a}	2102^{ab}	1985^{b}	1914^{b}	60.2
Eviscerated weight	$1985.^{a}$	$1870.^{ab}$	$1736.^{b}$	$1698.^{b}$	58.0
Full Gizzard	78.50^{a}	68.25^{b}	69.50^{b}	66.50^{b}	1.68
Empty Gizzard	54.8^{a}	53.0^{a}	52.0^{a}	48.0^{a}	2.29
Kidney weight	2.60^{a}	2.40^{a}	2.45^{a}	3.00^{a}	0.23
Liver weight	43.0^{a}	42.2^{a}	42.0^{a}	39.5^{a}	2.20

[abc] Means in the same row bearing different superscript are significantly different (p<0.05)
Standard Errors of Means (SEM)

4.2.6 Bled Weight and Defeathered Weight

Dietary treatment T_1 was not significantly different ($P>0.05$) from T_2, but was significantly different ($P<0.05$) from T_3 and T_4 (Table 15). However, T_2 was not significantly different ($P>0.05$) from T_3, and T_4.

4.2.7 Eviscerated Weight

From Table 14, T_1 was not significantly different ($P>0.05$) from T_2, but significantly different ($P<0.05$) from T_3 and T_4. However, T_2 was not significantly different ($P>0.05$) from T_3, and T_4.

4.2.8 Full Gizzard

Dietary treatment T_1 was not significantly different ($P>0.05$) from T_2, but was significantly different ($P<0.05$) from T_3 and T_4. However, T_2 was not significantly different ($P>0.05$) from T_3, and T_4 (Table 14).

4.2.9 Liver Weight, Kidney Weight and Empty Gizzard

T_1 was not significantly different ($P>0.05$) from T_2, T_3 and T_4 with respect to liver weight, kidney weight and empty gizzard (Table 14).

4.3 Economics of Production

4.3.1 Benefit Cost Analysis of the Maize Replacer

The differences in costs are as a result of the inclusion and exclusion of some ingredients, as well as the quantity used. The benefit-cost ratios for all the treatments (T_1, T_2, T_3 and T_4) were more than one. The ratios recorded for T_1, T_2, T_3 and T_4 were 1.46, 1.42, 1.28 and 1.33 respectively. Compared to T_1 the feeds containing the Maize Replacer (T_2, T_3 and T_4) were also profitable.

4.3.2 The Economics of Gain

Table 15: Economics of Production of the Broiler Chicks Fed on the Experimental Diets

Parameter	**T_1**	**T_2**	**T_3**	**T_4**
Total feed intake (g/b) *fc*	4900	4784	4702	4628
Unit cost of feed *cf* (GH¢)	0.39	0.39	0.38	0.38
Feed consumed × Cost of feed	1911	1865.76	1786.76	1758.64
Weight gain of bird *(wg (g)*	2379.9	2256.4	2229.9	2147.2
Economics of gain (Gh¢/kg gain)	0.80	0.83	0.80	0.82

4.4 EXPERIMENT TWO

4.4.1 Effect of Different Levels of the Maize Replacer During The Eight Week Experimental Period

A summary of the growth performance of broiler chickens fed different levels of the Maize Replacer for Experiment two is presented in Table 16

Table 16: Effect of Maize Replacer on the Performance of Broilers (Day Old – 8 Weeks)

Parameter	Treatment 1	Treatment 2	Treatment 3	Treatment 4	SEM	%CV
Initial weight (g/bird)	44.40±0.56^{a}	44.37±0.55^{a}	44.40±0.70^{a}	44.37±0.64^{a}	0.4	1.4
Final body weight (g/bird)	2690. ±29^{a}	2637. ±38^{a}	2551. ±59^{b}	2524. ±18^{b}	22.3	1.5
ADG (g/bird)	47.25±0.51^{a}	46.30±0.68 ^{a}	44.77±1.05 ^{b}	44.27±0.32^{b}	0.4	1.5
WG (g/bird/week)	330.7±3.6^{a}	324.1±4.7^{a}	313.4±7.3^{b}	309.9±2.3^{b}	2.8	1.5
TWG (g/bird)	2646.±29^{a}	2593.±38^{a}	2507.±59^{b}	2479.±18^{b}	22.4	1.5
Total Feed intake (g/bird)	5141. ±34^{a}	5074. ±31^{b}	4922. ±44^{c}	4842. ± 30^{d}	20.4	0.7
Feed intake (g/bird/week)	642.6±4.3^{a}	634.2± 3.9 ^{b}	615.2±5.5^{c}	605.2±3.7^{d}	2.6	0.7
Feed intake (g/bird/day)	91.80± 0.61^{a}	90.60±0.56^{b}	87.89± 0.79^{c}	86.46±0.53^{d}	0.4	0.7
FCR	1.94±0.34^{a}	1.96±0.02^{a}	1.96±0.04^{a}	1.95±0.01^{a}	0.1	1.4

$^{a-d}$ Means in the same row bearing different superscript are significantly different ($p<0.05$)
Means ± Standard Deviations (SD); Standard Errors of Means (SEM); Coefficient of Variation (CV)
ADG – Average Daily Gain; WG – Weight Gain; TWG – Total Weight Gain; FCE – Feed Conversion Efficiency

4.4.2 Final Body Weight

T_1 was significantly different ($P<0.05$) from T_3 and T_4 (Table 18). However, T_1 was not significantly different ($P>0.05$) from T_2.T_2 was significantly different ($P<0.05$) from T_3 and T_4. T_3 and T_4 were also not significantly different ($P>0.05$) from each other. The performance of birds on the control treatment was similar to that of those on the 36.5% Maize Replacer, and thus was higher than those of birds on the other two treatments.

4.4.2 Total Feed Intake

T_1 was significantly different ($P<0.05$) from T_2, T_3 and T_4. T_2 was also significantly different ($P<0.05$) from T_3 and T_4, T_3 also differed from ($P<0.05$) T_4. Feed intake decreased with increasing levels of Maize Replacer.

4.4.3 Feed Conversion Ratio

There were no significant differences ($P<0.05$) among and all the treatments. The Feed Conversion Ratio of birds on all treatment diet were similar

4.4.4 Mortality

T_1 and T_3 recorded mortality levels of 2.2 and 0.9% respectively. The post mortem result did not attribute the cause of death to the feed. T_2 and T_4 recorded zero mortality.

4.5 Economics of Production

Table 17: Economics of Production of the Broiler Chicks Fed on the Experimental Diets

Parameter	**T1**	**T2**	**T3**	**T4**
Total feed intake (g/b) *fc*	5141	5074	4922	4842
Unit cost of feed *cf* (GH¢)	0.39	0.39	0.38	0.38
Feed consumed ×cost of feed	2005	1979	1870.4	1840.0
Weight gain of bird *(wg(g)*	2646	2593	2507	2479
Economics of gain (Gh¢/kg gain)	0.76	0.76	0.75	0.74

CHAPTER FIVE

5.0 DISCUSSION

5.1 FORMULATION OF THE 'MAIZE REPLACER'

The Maize Replacer contained non-conventional feed resources and agro-industrial by-products. The formulated product was used to replace maize partially. This concept is different from the single ingredient substitutes because, the single ingredient substitutes do not replace maize in-terms of composition. Moreover, this concept gives an opportunity for the new product (Maize Replacer) to be better in one way or the other than maize. With the single ingredient substitutes one can only replace some quantity of maize but cannot change the composition of the product. Therefore, the philosophy is to formulate a product which will be as good as maize or similar to maize or better than maize.

It can be observed from the formulated maize replacer (Table 11) that the cassava flour was used at a high level in the formulation. It must be noted that a maximum of 45% of the Maize Replacer was used in the formulation of the ration for the birds in treatments 4. This implies that the total quantities of Cassava Flour in the diets for the birds were 7.3 %, 8.6 % and 9 % respectively, for treatments 2, 3 and 4 on percentage basis.

Fat from PKC constituted four percent (4%) of the Maize Replacer thus the levels of fat in the diets were 1.53%, 1.81% and 1.89% for treatments 2, 3, and 4 respectively. These levels are below the recommended level of 2.4% for broiler rations. Though the inclusion levels are still high, farmers can comfortably use them provided the fat is well stabilized since stabilized fats do not go rancid easily. If a farmer should use stabilized fat at these levels, he stands to gain because fat in the ration. According to Rahman *et al*. (2010), fat aids the absorption of vitamins A, D, E and K from the digestive system and serves to cushion and protect vital organs in the body. It was stated further that addition of small amounts of fat to feed tends to reduce dustiness, increase the palatability of the diet, and improve the texture of the feed.

Wheat bran also formed 17% of the Maize Replacer. It forms 6.2%, 7.3%, and 7.7 % of treatments 2, 3 and 4, respectively. These levels fall within those suggested by Say (1995) for broilers, layers and 8-20 weeks old pullets meaning that the farmers can comfortably use it provided they have access to that quantity.

Soybean meal constituted 15% of the formulated diet, which is less than the recommendation of Ralf (1987) which is 30% for growing poultry and 20% for layers. This also contributes to the improvement in the levels of lysine, methionine and cysteine in the Maize Replacer.

Palm Kernel Cake inclusion level in the formulated Maize Replacer was low (3.8%) amounting to 1.39%, 1.63% and 1.71% inclusions in Treatments 2, 3 and 4, respectively. These do not pose danger in the diet because Ralf (1987) stated that, it was advisable not to exceed 15% in layers and that some farms have been able to use them without inconvenience up to 30%.

The energy level was boosted by the 20% addition of maize. Tada *et al*. (2004) stated that maize will continue to constitute a major proportion of broiler diets. With reference to the control diet (T_1), which had 60.85% maize, it can be deduced that, 13.55%, 17.25%, and 18.85% less maize were used in Treatments 2, 3 and 4, respectively.

It is envisaged that the Maize Replacer will reduce the cost of meat production and the competition between animals and humans for maize as there continues to exist serious deficit in the face of increasing numbers of humans and animals. This will make maize more available for human consumption. This agrees with the observations of Ngou and Mafeni (1983) that agricultural by-products used partially or totally to replace maize and fish in poultry diets reduce costs in meat production and make food items competed for more available for human consumption.

Secondly, agricultural and agro-industrial by-products, such as rice bran and PKC, which are not commonly used in the formulation of diets for poultry would be utilised through the use of the Maize Replacer.

Thirdly, as the demand increases for maize, prices also increase resulting in higher prices of feed inputs. Feed inputs contribute 70% - 80% of the total cost of poultry production (Okai and Aboagye, 1990).

5.2 Effect of the Maize Replacer on Final Body Weight, Feed Intake and Feed Conversion Ratio of Broiler Chickens in Experiments One and Two

The decrease in the final body weight of the birds on diets containing the Maize Replacer may be attributed to many factors including the effect of the hydrogen cyanide (HCN) in the cassava meal. Oke (1973) reported that when chickens consume cassava meal, the HCN is transformed in the liver by the enzyme rhodanese to thiocyanate, which is excreted in the urine. This process uses sulphur from methionine thereby increasing the requirement of the amino acid. This means that the birds might have been using the amino acids in detoxifying the cassava meal leading to inefficient protein utilization. Reduction of body weight could also be caused by the high PKC levels in the Maize Replacer diets as a result of the lower nutrient digestibility of PKC. Sundu and Dingle (2003) reported that during processing PKC may undergo Maillard reaction (the reaction of mannose with amino groups leading to the formation of a brown complex) due to the heat applied in the process before and during oil extraction and this adversely affects its digestibility.

Tewe and Egbunike (1988) reported that the dustiness of ground cassava can reduce intake in poultry and thereby adversely affect productivity. Khempaka *et al.* (2009) reported that, the depression in feed intake during the 14- to 35-d period by inclusion of 12 and 16% Dried Cassava Pulp could be due to the increased bulkiness of the diet and the limited digestive tract capacity of broilers. The increase in bulk has also been reported to reduce palatability (Weiss and Scott. 1979) and thus may limit the feed intake of broilers. The low intake could be attributed to the high fibre content, low palatability and low availability of amino acid (Hutagalung, 1982). The high fibre in the rice bran (12%) could also cause the decreasing weight recorded in both experiments as the Maize Replacer increased. Crampton and Harris (1968) and Morrison (1961) reported the high fibre in rice bran could lead to a rapid passage rate thereby leading to a decrease in digestion rate.

The physical characteristics of such high-fibre diets might also account for the observed changes and need further study. For example, high-fiber diets are known to increase the rate of feed passage through the gastrointestinal tract (Connell, 1981) and thus may result in a lowering of the actual ME values of the diets (Perez *et al*., 2000).

Also, high dietary fibre can provoke increased sloughing of intestinal epithelial cells, causing an increase in secretion of the mucosa into the intestine, which leads to losses of endogenous amino acids (Parsons *et al.*, 1983).

5.3 EFFECT OF THE MAIZE REPLACER ON CARCASS PARAMETERS

Liver, gizzard and kidney weights were not affected by feeding the Maize Replacer (Table 14).

5.4 Economics of Production

The economics of production in this study will be discussed under benefit-cost ratio, sensitivity analysis and the economics of gain.

5.4.1 Benefit-Cost Ratio of Using the Maize Replacer

The results of the benefit cost ratio indicated that, T_1 which was the control, was more profitable than all the dietary treatments. T_2 compared well in terms of profit to T_1. This means that T_2 is the best level to replace maize with the Maize Replacer. Therefore, the use of the Maize Replacer in broiler diets can reduce the demand for maize and the cost of broiler production. The use of non-conventional feedstuffs often leads to reduction in feed cost of broilers (Pido *et al.*, 1979).

5.4.2 The Economics of Gain

The data on economic performance indicated that as the maize was substituted by the Maize Replacer, the cost of formulating a kilogram of feed decreased with increased Maize Replacer in dietary T_3 and T_4 respectively. During the experiment, the cost of a kilogram of maize was GH¢0.35 while a kilogram of Maize Replacer was estimated at GH¢0.32. Even though the use of the Maize Replacer did not reduce feed cost significantly, it did reduce feed cost per kilogramme gain by 3.73% over T_1 and T_3 and 1.2% over T_4.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the conclusion of the study as well as the recommendations. Also, limitation and suggestions for future research are outlined.

6.1 CONCLUSIONS

The findings of the studies carried out indicate that the compounding of a maize substitute (Maize Replacer) with a combination of various Agro-industrial by-products and non-conventional feedstuff(s) was feasible with the help of an optimization software Microsoft Excel.

1. The Maize Replacer had a better composition than maize for calculated crude protein and its calculated amino acids contents.
2. It can be deduced that, 13.55%, 17.75 %, and 18.85% less maize would be used by the adoption of T_2, T_3 and T_4 respectively.
3. The Maize Replacer had no health related problems in all the diets for both Experiment One and Two.
4. The Maize Replacer could replace maize in Experiment One and Two up to 40% without any effects on all the parameters measured.
5. From the sensitivity results obtained, using Maize Replacer in broiler diets is viable.

6.2 RECOMMENDATIONS

1. Subsequent feed trials should consider the inclusion of enzymes to improve digestibility when the Maize Replacer is replacing maize completely in the ration.
2. In the extreme cases, some of the non-conventional ingredients can be processed to reduce the levels of anti-nutritional factors.
3. Further feeding trials need to be done in this area to determine the best formula for the Maize Replacer.
4. A chemical analysis needs to be carried out in subsequent research to determine the actual nutrient composition of the Maize Replacer.

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Appendix 1 Anova Table Overall Brooder Stage for Experiment One

Variate: Average Daily Gain/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	21.4784	7.1595	29.74	<.001
Residual	8	1.9256	0.2407		
Total	11	23.4040			

Variate: Feed Conversion Efficiency/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.000879	0.000293	0.20	0.896
Residual	8	0.011973	0.001497		
Total	11	0.012853			

Variate: Feed Iintake/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	61.742	20.581	13.94	0.002
Residual	8	11.814	1.477		
Total	11	73.556			

Variate: Initial Weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.000	0.000	0.00	1.000
Residual	8	13.427	1.678		
Total	11	13.427			

Variate: Total Feed Intake/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	48406.	16135.	13.94	0.002
Residual	8	9262.	1158.		
Total	11	57668.			

Variate: Total Body Weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	16839.1	5613.0	31.06	<.001
Residual	8	1445.6	180.7		
Total	11	18284.6			

Variate: Weekly Feed Intake bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	3025.35	1008.45	13.94	0.002
Residual	8	578.89	72.36		
Total	11	3604.24			

Variate: Weight Gain/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	16839.1	5613.0	29.74	<.001
Residual	8	1509.7	188.7		
Total	11	18348.8			

Variate: Weekly Weight Gain/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	1052.44	350.81	29.74	<.001
Residual	8	94.36	11.79		
Total	11	1146.80			

Appendix 2 Anova Table Overall Grower Stage for Experiment One

Variate: Average Daily Gain/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	60.051	20.017	17.61	<.001
Residual	8	9.093	1.137		
Total	11	69.144			

Variate: Feed Conversion Efficiency/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.0303952	0.0101317	13.69	0.002
Residual	8	0.0059222	0.0007403		
Total	11	0.0363173			

Variate: Feed Intake/bird/d

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	44.5820	14.8607	15.68	0.001
Residual	8	7.5828	0.9478		
Total	11	52.1648			

Variate: Initial Weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	16839.1	5613.0	31.06	<.001
Residual	8	1445.6	180.7		
Total	11	18284.6			

Variate: Total Feed Intake/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	19660.7	6553.6	15.68	0.001
Residual	8	3344.0	418.0		
Total	11	23004.7			

Variate: Total Body Weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
reatment	3	83479.3	27826.4	95.46	<.001
Residual	8	2332.0	291.5		
Total	11	85811.3			

Variate: Weekly Feed Intake/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	2184.52	728.17	15.68	0.001
Residual	8	371.56	46.44		
Total	11	2556.07			

Variate: Weekly Weight Gain/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	2942.51	980.84	17.61	<.001
Residual	8	445.54	55.69		
Total	11	3388.05			

Variate: Weight Gain/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	26482.6	8827.5	17.61	<.001
Residual	8	4009.8	501.2		
Total	11	30492.5			

Appendix 3 Final Anova Table for Experiment One

Variate: Average Daily Gain/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	34.7685	11.5895	104.93	<.001
Residual	8	0.8836	0.1104		
Total	11	35.6521			

Variate: Feed Conversion Efficiency/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3 0.	01432990	0.00477663	48.27	<.001
Residual	8 0.000	79169	0.00009896		
Total	11 0.	01512159			

Variate: Feed Intake/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	50.9757	16.9919	29.41	<.001
Residual	8	4.6226	0.5778		
Total	11	55.5983			

Variate: Initial Weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.000	0.000	0.00	1.000
Residual	8	13.427	1.678		
Total	11	13.427			

Variate: Total Feed Intake/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	122393.	40798.	29.41	<.001
Residual	8	11099.	1387.		
Total	11	133492.			

Variate: Total Body Weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	83479.3	27826.4	95.46	<.001
Residual	8	2332.0	291.5		
Total	11	85811.3			

Variate: Weekly Feed Intake/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	2497.81	832.60	29.41	<.001
Residual	8	226.51	28.31		
Total	11	2724.32			

Variate: Weight Gain/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	83479.3	27826.4	104.93	<.001
Residual	8	2121.5	265.2		
Total	11	85600.7			

Variate: Weekly Weight Gain/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	1703.658	567.886	104.93	<.001
Residual	8	43.296	5.412		
Total	11	1746.954			

Appendix 4 Anova Table on Carcass Parameters for Experiment One

Variate: Percentage Empty Gizzard (%EGIZZ)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREAMTENT	3	0.02464	0.00821	0.59	0.653
Residual	4	0.05556	0.01389		
Total	7	0.08020			

Variate: Percentage Heart Weight (%HRT_W)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREAMTENT	3	0.0212561	0.0070854	37.48	0.002
Residual	4	0.0007562	0.0001891		
Total	7	0.0220124			

Variate: Percentage Kidney Weight (%KID_w)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREAMTENT	3	0.0018195	0.0006065	3.01	0.158
Residual	4	0.0008067	0.0002017		
Total	7	0.0026262			

Variate: Percentage Liver weight (%LIV_W)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREAMTENT	3	0.02947	0.00982	0.66	0.619
Residual	4	0.05966	0.01492		
Total	7	0.08913			

Variate: Bled Weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREAMTENT	3	134835.	44945.	5.77	0.062
Residual	4	31157.	7789.		
Total	7	165992.			

Variate: Defeathered Weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREAMTENT	3	144794.	48265.	6.65	0.049
Residual	4	29015.	7254.		
Total	7	173810.			

Variate: Empty Gizzard Weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREAMTENT	3	49.09	16.36	1.55	0.332
Residual	4	42.12	10.53		
Total	7	91.22			

Variate: Full Gizzard Weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREAMTENT	3	171.844	57.281	10.13	0.024
Residual	4	22.625	5.656		
Total	7	194.469			

Variate: Full Intestine Weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREAMTENT	3	786.75	262.25	3.46	0.131
Residual	4	303.25	75.81		
Total	7	1090.00			

Variate: Kidney Weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREAMTENT	3	0.44375	0.14792	1.71	0.301
Residual	4	0.34500	0.08625		
Total	7	0.78875			

Variate: Liver Weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREAMTENT	3	13.844	4.615	0.48	0.715
Residual	4	38.625	9.656		
Total	7	52.469			

Variate: Live Weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREAMTENT	3	125700.	41900.	6.97	0.046
Residual	4	24052.	6013.		
Total	7	149753.			

Appendix 6 Anova Table Overall Brooder Stage for Experiment Two

Variate: Average Daily Gain/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	9.3943	3.1314	9.78	0.005
Residual	8	2.5602	0.3200		
Total	11	11.9545			

Variate: Feed Conversion Efficiency/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.006964	0.002321	1.23	0.361
Residual	8	0.015111	0.001889		
Total	11	0.022075			

Variate: Feed Intake/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	57.5925	19.1975	33.35	<.001
Residual	8	4.6052	0.5757		
Total	11	62.1977			

Variate: Initial Weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.0033	0.0011	0.00	1.000
Residual	8	3.0333	0.3792		
Total	11	3.0367			

Variate: Total Feed Intake/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	45152.5	15050.8	33.35	<.001
Residual	8	3610.5	451.3		
Total	11	48763.0			

Variate: Total Body Weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	7367.5	2455.8	9.83	0.005
Residual	8	1998.1	249.8		
Total	11	9365.6			

Variate: Weight Gain/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	7365.1	2455.0	9.78	0.005
Residual	8	2007.2	250.9		
Total	11	9372.3			

Variate: Weekly Weight Gain/b

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	460.32	153.44	9.78	0.005
Residual	8	125.45	15.68		
Total	11	585.77			

Appendix 7 Anova Table on Grower Stage for Experiment Two

Variate: Average Daily Gain/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	3.858	1.286	0.49	0.698
Residual	8	20.921	2.615		
Total	11	24.779			

Variate: Feed Conversion Efficiency/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.005904	0.001968	0.57	0.651
Residual	8	0.027651	0.003456		
Total	11	0.033555			

Variate: Feed Intake/bird/day

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	50.9447	16.9816	40.53	<.001
Residual	8	3.3520	0.4190		
Total	11	54.2968			

Variate: Initial Weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	34362.2	11454.1	96.19	<.001
Residual	8	952.7	119.1		
Total	11	35314.9			

Variate: Total Feed Intake/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	39940.7	13313.6	40.53	<.001
Residual	8	2628.0	328.5		
Total	11	42568.7			

Variate: Total Body Weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	53242.	17747.	11.95	0.003
Residual	8	11883.	1485.		
Total	11	65125.			

Variate: WFI_b

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	2496.29	832.10	40.53	<.001
Residual	8	164.25	20.53		
Total	11	2660.54			

Variate: Weekly Weight Gain/b

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	189.1	63.0	0.49	0.698
Residual	8	1025.1	128.1		
Total	11	1214.2			

Variate: Weight Gain/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	3025.	1008.	0.49	0.698
Residual	8	16402.	2050.		
Total	11	19427.			

Appendix 8 Anova Table on Overall Experimental Period for Experiment Two

Variate: Average Daily Gain/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	16.9751	5.6584	11.82	0.003
Residual	8	3.8289	0.4786		
Total	11	20.8040			

Variate: Feed Conversion Efficiency/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.0006656	0.0002219	0.29	0.834
Residual	8	0.0061913	0.0007739		
Total	11	0.0068569			

Variate: Initial Weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.0033	0.0011	0.00	1.000
Residual	8	3.0333	0.3792		
Total	11	3.0367			

Variate: Total Weight Gain/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	53234.	17745.	11.82	0.003
Residual	8	12007.	1501.		
Total	11	65241.			

Variate: Total Feed Intake/bird

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	169113.	56371.	45.25	<.001
Residual	8	9965.	1246.		
Total	11	179078.			

Variate: Weekly Feed Intake/b

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	2642.38	880.79	45.25	<.001
Residual	8	155.71	19.46		
Total	11	2798.09			

Variate: Weekly Weight Gain/b

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	831.78	277.26	11.82	0.003
Residual	8	187.61	23.45		
Total	11	1019.39			

Variate: Final Body Weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	53242.	17747.	11.95	0.003
Residual	8	11883.	1485.		
Total	11	65125.			

Appendix 9 Vaccination and Medication Programme

Days	**Programme**
1	Glucose solution
2	vitamin and Antibiotic
3	Vitamin and Antibiotic
4	Vitamin and Antibiotic
5	Plain water
6	Plain water
7	1st Gumboro vaccination
8	Plain water
9	Vitamin + Antibiotic+ Coccidiostat
10	Vitamin + Antibiotic+ Coccidiostat
11	Vitamin + Antibiotic+ Coccidiostat
12	Plain water
13	Plain water
14	1st Newcastle
15	Plain water
16	Vitamin + Antibiotic+ Coccidiostat
17	Vitamin + Antibiotic+ Coccidiostat
18	Vitamin + Antibiotic+ Coccidiostat
19	Plain water
20	Plain water
21	2nd Gumboro vaccination
22	Plain water
23-25	Vitamin + Antibiotic + Coccidiostat
26-27	Plain water
28-30	Vitamin + Antibiotic + Coccidiostat
35	2nd NCD Vaccination