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THE EFFECT OF STARTER-GROWER PIGS FED DIETS CONTAINING VARYING LEVELS OF DRIED CASHEW (*Anarcadium occidentale* L.) PULP (DCP)

BY

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A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY KUMASI, GHANA, IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE, MASTER OF SCIENCE IN ANIMAL NUTRITION

BY

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CERTIFICATION

I hereby certify that the work herein submitted as a thesis for the Master of Science (Animal Nutrition) Degree is entirely my own conducted research and has neither been presented nor is being presented concurrently for any other degree elsewhere. However, works of other researchers and authors which served as sources of information were duly acknowledged.

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ABSTRACT

Dried Cashew Pulp (DCP) was investigated for its nutritional quality. The DCP was obtained from Cocoa Research Institute of Ghana (CRIG), Bole and was prepared from fresh ripe cashew apples by slicing the pulp into flakes after the juice has been extracted followed by sun drying to a moisture content of about 10 %. The crude protein, fat, ash, crude fibre in g kg^{-1} DM and digestible energy contents were 86.0, 99.6, 38.0, 116.0 and 14.38 MJ, respectively. In a subsequent feeding trial, twelve Large White starter pigs with an average initial weight of 13.3 kg were randomly allotted into four groups in a completely randomized design and fed diets containing 0, 50, 100 and 150 g DCP kg^{-1} to determine growth performance and carcass characteristics. Water and feed were provided *ad-libitum*. The level of DCP had no significant ($P > 0.05$) effect on feed intake but had a significant ($P < 0.05$) effect on weight gain. Final live weights were 58.67, 53.0, 59.67 and 48.67 kg for pigs diets containing 0, 50, 100 and 150 DCP g kg^{-1} respectively. Furthermore the dietary treatments did not have significant ($P > 0.05$) impact on the various carcass traits, except ham weight. In this study, there were no health-related problems nor deaths that could be attributed to the inclusion of DCP in the diet. Feed cost per diet decreased with increasing DCP levels. The cost of feed to produce a kg weight gain was lowest for the diet containing the 100 g DCP kg^{-1}. It was concluded that up to 100 g DCP kg^{-1} diet had a positive effect on pig growth performance and that partial replacement of energy sources such as maize and wheat bran with DCP is possible.

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CHAPTER ONE

1.0 INTRODUCTION

Ghana has a human population of about 20 million and poultry and livestock population of little over 34 million. Unfortunately, the rate of growth of the animal population has not kept pace with that of humans. Ghana is therefore not only a net importer of animals and meat products but imports as much as 70 % of its animal protein requirements (Okai *et al.*, 2005).

The average Ghanaian diet is low in animal proteins, which contain all the essential amino acids in their balanced form, as a result of the high cost of these products. The importance of the pig production in helping to increase the animal protein intake of Ghanaians cannot be overemphasized. The pig historically, has been considered an unclean animal, wallowing in filth, an object of distaste and a hazard to human health. This is half truth. The pig although frequently maligned by some social and religious groups in Ghana has several good attributes including high prolificacy, high fecundity, short generation interval, early maturity, high feed conversion efficiency and a modest requirement with respect to building and equipment. (Okai *et al.*, 2005).

Unfortunately, efforts to assist the industry to expand has not yielded the expected results because of lapses in feeding the pigs. The high cost of meat and meat products in the country is due to the high cost of feed inputs. Reddy (1996) reported that feed accounts for 65-70% of the total cost in the intensive system of animal production. Pond *et al.* (1995) stated a similar figure of 50-80%. The situation is the result of competition between man and livestock for some feed and food ingredients, particularly energy sources. This competition is more rigorous in developing countries. This causes the developing countries to import cereals and other feed sources to meet the needs of both humans and animals (FAO, 1982).

Animal nutritionists are therefore in the search for alternative energy sources for use in livestock feed compounding. Feed cost and animal competition with humans for feed items suggest strongly that alternative energy sources such as residues of crop harvests be used partially or totally to replace maize in livestock diets, to reduce cost and enhance cheaper meat production and therefore make available the major food items for human consumption (Ngou and Mafeni, 1983).

More recently, the growth of the animal feed industry has allowed considerable use to be made of agricultural by-products and wastes, some of which although containing potentially toxic components, can be safely included in compounded feeds in relatively low proportions. Various agro-industrial by-products (AIBPs) and other non-conventional feedstuffs have been evaluated in Ghana as potential feed ingredients for the non-ruminant farm animals. Studies have been conducted on brewers spent grains, cocoa pod husk, dried coffee pulp, mango kernel meal, oil palm slurry, among others (Okai, 1995).

In many developing countries, there exists a largely untapped potential for utilizing non-conventional feedstuffs for feeding pigs. Among these is dried cashew pulp (DCP), a by-product obtained from the processing of the cashew fruit. Cashew pulp is currently under - exploited in terms of its use as a feed ingredient. While a large number of farmers nationwide have gone into the cultivation of the crop, the common practice has been to discharge this material (pulp) into near-by streams or heap them on farmlands resulting in the pollution of the environment. Its utilization as an animal feed will minimize the pollution problem as well as serve as a cheap source of nutrients for the livestock and poultry industries (Fanimo *et al.*, 2004).

Cashew has been widely used as an internal and external antiseptic against bacterial infections, heal stomach ulcers of all kinds, for ear and eye infections, to stop bleeding, and heal wounds. It is also rich in minerals and vitamins. The pulp that forms about 90 % of the fruit is of high economic value, has a pleasant flavour and aroma and can be processed into a variety of suitable products such as alcoholic and non-alcoholic drinks (Kankam-Boadu, 2000).

The present study was therefore aimed at determining the effects of including graded levels of DCP in diets on the growth performance and carcass characteristics of starter-grower pigs. It also aims to assess the profitability of partially substituting maize with DCP in the rations of the starter-grower pigs.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 THE PIG: ORIGIN AND EVOLUTION

It is probable that the pig is mainly derived from the European wild boar (*Sus scrofa*). Originally pigs colonized the forests and swamps and were designed to live in a moist, shady environment. Their short legs and powerful streamlined body were built for moving through dense undergrowth, and the strong head and tusk, with a cartilaginous disc in the snout, for digging and rooting.

Biblical writings have it that pigs were first domesticated as early as 2000 BC. As man has developed it as a meat animal, major changes in conformation have occurred from the typical, 'unimproved' type. The relatively large, narrow head, heavy forequarters, tapering light hind quarters and compact body have been replaced by a smaller head, lighter forequarters, a longer and wider body with bigger capacity and well developed, meaty hindquarters (Holness, 1995).

2.2 WORLD PIG POPULATION

The estimated world pig population of 826 million means that there is approximately one pig for every six people in the world. Although pigs are numerically fewer than some other domestic species, more pig meat is produced than any other meat. This reflects the greater productivity of the pig when compared with other domestic species as shown in Table 1.

Table 1: A comparison of the main livestock species in the world in terms of numbers and meat production.

	Number (million head)	Meat output (000 metric tones per year)
Cattle	1,253	50,098
Buffalo	137	
Sheep	1,174	80,801
Goats	521	
Poultry	10,050	11,495
Pigs	826	63,917

Source: Holness (1995)

2.2.1 DISTRIBUTION AND CONSUMPTION

The distribution of pigs throughout the world is not uniform. Nearly half the world's pig population is in Asia, with a further 30% in Europe and the former USSR. In contrast, the population in large parts of the tropical and sub-tropical developing regions is relatively small. It is noteworthy, that the majority of pigs in the developing world are located in one Asian country namely China (Holness, 1995).

In tropical Asia and parts of China, pork is the predominant component of the diet. On the other hand, in areas where the Islamic religion prevails, e.g. the Middle East, Pakistan and parts of Africa, Muslims are forbidden to eat pork. Similarly, believers in the Jewish faith are instructed not to eat pork meat. In some Pacific Islands, such as Tonga and Papua New Guinea, pigs are highly regarded as a source of wealth and associated with marriage customs. On the other hand, in Africa, people have traditionally obtained their meat supplies mainly from ruminants, particularly cattle, sheep and goats and this preference still exists as depicted in Figure 1.

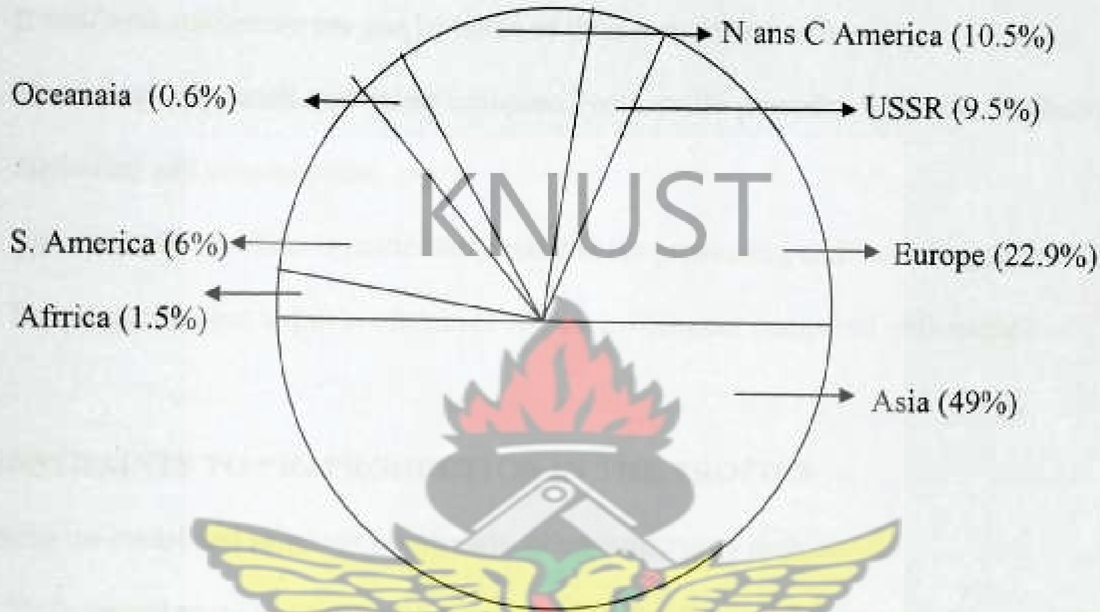

Fig 1: Regional distribution of the world pig population (Holness, 1995)

2.3 THE POTENTIALS OF PIG PRODUCTION IN DEVELOPING COUNTRIES.

When compared with cattle, and other ruminants, pigs have some major potential advantages, namely:

a) They produce meat without contributing to the deterioration of the natural grazing lands. This is of paramount importance in relation to the current steady rate of desertification, soil erosion and loss of productive land in tropical and sub-tropical parts of the world.

b) They convert concentrated food to meat twice as efficiently as ruminants.

c) They possess the potential to be highly productive because they are capable of producing large litters after a relatively short gestation period, and have a short generation interval and grow rapidly, their output in terms of yield of meat per tonne of live weight of breeding females per year is in the region of six times that of cattle.
d) If confined, maximum use can be made of their manure and effluent.
e) Their relatively small size when compared with cattle provides for more flexibility in marketing and consumption.
f) The meat pigs produce is particularly suitable for processing and has a longer shelf life.
g) Pig production has a quicker turnover rate on investment compared with cattle.

2.4 CONSTRAINTS TO PIG PRODUCTION IN THE TROPICS

Apart from the social and religious constraints, other constraints include:

a) They cannot provide a source of drought power for farming operations.
b) Since they tend to be raised close to human habitation, their effluent may cause a pollution problem
c) Because pigs and man are co-hosts to a number of parasites, they can cause health problems if they are not confined.
d) As simple stomached animals, they compete directly with humans for food, especially the staple grains and oil seeds. This can be partly overcomed by making use of crop by-products, waste feeds and grains unsuitable for human consumption (Holness, 1995).

2.5.0 NON-CONVENTIONAL FEED RESOURCES (NCFR'S) USED IN THE ANIMAL INDUSTRY

Non-conventional feed resources are those feeds that have not been traditionally used in animal feeding and/or are not normally used in commercially produced rations for animals (Devendra, 1992). A large number of agro-industrial by-products, forest waste, aquatic herbages and animal wastes which have been identified, processed and used for feeding of farm animals are designated as a group of unconventional or non-conventional feeds. Examples include discarded biscuits, bakery waste, rice bran, blood meal, corn cob, maize bran, cassava peel, cassava chips and copra cake. Others are cocoa pod husk, coffee pulp, oil palm slurry, groundnut skins, pito-mash, brewer's spent grains, bone meal, molasses, sugar beet pulp, citrus pulp, yeast, wheat bran and distillers solubles.

Shrub leaves (Leaucaena *spp*, Caltiandra *spp*, Sesbinia *spp*, etc), aquatic plants, fruits (palm oil fruit, papaya, guava, etc) and small animals (snails, earthworms), etc can also be used in poultry feed formulations (Sonaiya, 1990).

Feed costs and animal competition with humans for feed items suggests strongly that alternative energy sources such as residues of crop harvest should be used partially or wholly to replace maize in livestock diet to reduce cost of meat production and to make available the major crops for human consumption (Ngou and Mafeni, 1983).

Some non-conventional feedstuffs used for feeding poultry and their nutrient composition are presented in Table 2.

Table 2: composition of some non-conventional feedstuffs

Feedstuff	C.P %	E.E %	C.F %	Calculated Metabolizable Energy (Kcal/kg dry matter)
Neem leaves	17.5	4.2	12.3	752
Amarath seeds	16.0	0.2	5.5	922
Soybean testa	16.6	4.0	25.4	2096
Cowpea testa	17.0	2.6	20.3	1005
Melon pulp	8.6	43	31.1	1148
POS	4.1	0.6	0.1	1004
EPOS	4.3	53.2	7.5	5680
Cassava meal sieving	0.8	1.5	9.0	1787
Cassava fermented chaff	1.4	1.1	10.2	3436
Cassava peal meal	2.2	1.1	4.3	2460
Yam meal sieving	3.5	1.0	5.0	2115
Yam peel meal	6.4	5.0	7.3	136
Blood meal mixture	86.0	1.2	1.0	--
Rice bran and bloodmeal	25.6	-	21.3	-
Maize cob and bloodmeal	28.9	-	19.5	-
PKC and bloodmeal	38.5	5.0	-	-
Fish by-products	44.3	29.1	0.0	5055*
Plantain pulp	4.1	0.6	0.1	1004

Source: Sonaiya (1990). * The energy value for the fish products is gross energy.
CP = Crude Protein
EE = Ether Extract
CF = Crude Fibre

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

Food Deficit Countries (LIDCs), surplus of cereals is generally not available. It is therefore not advisable to develop a wholly grain-based feeding system. The recommended policy is to identify and use locally available feed resources to formulate diets that are as balanced as possible. Research capacities must be strengthened to develop strategies to optimize the use of locally available feed ingredients (FAO, 1982).

2.6.0 GROUPS OF NON-CONVENTIONAL FEED RESOURCES (NCFR'S) FOR FEEDING LIVESTOCK

These categories are particularly important in relation to the least-cost ration formulation where different ingredients are evaluated as sources of energy, protein, minerals, vitamins, in relation to their cost and level of inclusion subject to constraints in relation to specific nutrients or anti-nutritive properties (Ørskov, 1988).

2.6.1 BY-PRODUCTS OF LOW DIGESTIBILITY AND LOW CONTENT OF NITROGEN

These include straws, husks, pods, and haulms. The content of nitrogen in these by-products is so low that supplementary degradable nitrogen (e.g. urea) is required to speed up both rate and extent of digestion in the rumen of ruminant animals. Consequently, levels of voluntary intake are low. The products of this type are usually of little feed value unless they are supplemented with nitrogen (Ørskov, 1988).

2.6.2 BY-PRODUCTS OF LOW DIGESTIBILITY BUT RELATIVELY HIGH IN NITROGEN

Coffee residues, grape pulp, animal excreta and cocoa meal are included here. By-products in this category are therefore well suited to being used in a mixture with the latter category. They are also suited with other feedstuffs of high energy content and low in nitrogen, such as cereal grains (Ørskov, 1988).

2.6.3 BY-PRODUCTS OF HIGH ENERGY VALUE BUT LOW IN NITROGEN

The by-products of the sugar industry (molasses, sugar beet pulp) and products such as stock-feed potatoes are in this category. Fats and oils are the best examples here. Animal fat can be included in the diet of pigs and poultry but at levels, which are usually less than 5% of the diet (Ørskov, 1988).

2.6.4 BY-PRODUCTS HIGH IN ENERGY AND NITROGEN

These include abattoir products such as blood meal and poultry offal meal, fish meal, extracted oilseed meals and waste vegetables such as carrots (Ørskov, 1988).

2.7.0 AGRICULTURAL BY-PRODUCTS AND WASTES USED IN MONOGASTRIC DIET

Agricultural by-products and wastes available for feeding monogastric animals can be divided into three main groups based on their sources: These are those of animal, plant and industrial origins.

2.7.1 ANIMAL BY-PRODUCTS

These originate from the slaughter houses for large animals and poultry and fish processing factories. It includes such products as: meat and bone, offals, blood, bone, intestines, poultry heads and feet, fat, feathers, horns, hooves, animal hair, stomach, rumen content and the carcasses of animals disqualified by the Veterinary Services. Dairy by-products not utilized for food production (whey, casein, butter milk) as well as tannery by-products are included in this group. Animal and poultry manure, which are currently used as feed ingredients, can also be included in this group (Kazimerz, 2003).

2.7.2 BY-PRODUCTS OF PLANT ORIGIN

I. Milling industry by-products: examples include bran, waste flour, wastes resulting from grain cleaning processes, corn and rye germs, hulls of some seeds for example peas.

II. By-products of the oil industry: examples include solvent-extracted cake from soybean and oil yielding rape, sunflower, flax and products formed during refining of plant oils, lecithin and fatty acids.

III. By-products of the sugar industry: examples are beet pulp, molasses, defaco-saturation-residue

IV. By-products of the fruit and vegetable industry: examples include product resulting from peeling fruits and vegetables, pomace, stones of fruit e.g. tomatoes.

V. By-products of the starch industry: examples include beet pulp, potato cell juice and others, when corn or wheat are processed, residues after starch extraction and gluten germs (Kazimerz, 2003).

2.7.3 BY-PRODUCTS OF THE FERMENTATION INDUSTRY

This group includes grains, molasses, brewers yeast, bacteria and fungi biomass as a waste from production of lactic and citric acids and other organic acids as well as spent grains and malt sprouts in breweries. Activated sludge from treatments in the food industry also falls into this category (Kazimerz, 2003).

2.8.0 FEED INGREDIENTS AVAILABLE FOR PIGS IN GHANA

Feed ingredients available in Ghana for feeding pigs can be classified into four main groups. Despite the fact that the list below appears in four main classes, most of these will also provide other nutrients

(a) Energy Sources: this include maize, cassava, guinea corn, maize bran, rice bran, pito mash, yam, cassava and plantain peelings, garbage, molasses, oil palm slurry, dried bakery waste products, dried fruit pulp and peelings, corn cob, cocoa pod husk and coffee pulp.

(b) Protein Sources: examples in this group include fishmeal, groundnut cake, copra cake, cotton seed cake, soybean meal, dried spent yeast, blood meal, meat meal, hatchery waste, discarded skimmed milk powder, feather meal, palm kernel meal, cassava leaf meal, cassava foliage meal

(c) Mineral Sources: This group includes common salt, bone meal, dicalcium phosphate, oyster shell. calcium carbonate and commercial trace mineral supplements.

(d) Vitamin Sources: examples are fishmeal, green forages, yeast, yellow maize and commercial vitamin supplements (Okai and Bonsi, 1994).

2.8.3 OIL PALM SLURRY

Oil palm slurry (OPS) is the effluent or sludge left after extracting the red mesocarp of the palm fruit from the crude mixture with water. For every one tonne of finished oil, 2 to 3 tonnes of aqueous effluent is produced (Davis, 1978) including the tremendous quantities of oil palm slurry available in palm oil producing countries. On dry matter basis, it contains 5% crude protein, 4.7% ash, and 66.1% ether extract. Oil palm slurry-containing diets may have to be compounded at frequent (3 days) intervals in view of the high moisture and ether extract levels, in order to avoid problems with rancidity and mould growth (Okai *et al.*, 1984).

Okai *et al.* (1984) also reported that oil palm slurry can constitute 30% of the diets of growing-finishing pigs and replace 45% of the maize in the diet without any adverse effects on carcass characteristics and growth performance.

2.8.2 PROTEIN-RICH BY-PRODUCTS

2.8.2.1 BLOOD MEAL

Blood meal is quantitatively one of the richest protein sources of animal origin; with a crude protein content of about 86% (Patgiri *et al.*, 1978). It has low digestibility and poor balance of amino acids, being low in isoleucine and methionine but high in lysine. It is poor in calcium and phosphorus. Blood meal can be fed to both ruminants and non-ruminant animals. Blood meal was found to be superior to feather meal in diets for laying chickens (Vogt *et al.*, 1975). Feed intake and egg weight were progressively depressed as the level of feather or blood meal rose in the diets, although feed conversion efficiency was improved through the inclusion of these by-products.

2.8.2.2 MEAT SCRAPS

This is a by-product made from animal flesh and tissues. It contains about 50-55% protein. It is high in lysine but low in methionine, trytophan and cystine. It is used in moderate amounts in poultry and pig rations. Up to 10% may be included in pig diets (Aletor, 1986).

2.8.2.3 GROUNDNUT CAKE

Whole groundnuts, including the shells, have an average protein content of 25%. It is high in fibre and have very high metabolizable energy content because of its high oil content of 36%. Smith (1990) observed that, groundnut meal is very palatable and the quality of the protein is good, ranking it close to that of soya bean meal. Complete feed for poultry (except chicks) could contain less than 10% of groundnut cake (McDonald *et al.*, 1992). The groundnut cake may be decorticated or not. In the decorticated groundnut cake, fibre content is very high. It is the undecorticated product that is normally fed to monogastric animals. This product has a low fibre content of 6-10% and a protein level of 40-48%. Groundnut cake is deficient in lysine and methionine (Ranjhan, 1999).

However, when groundnut cake is used in high cereal diets, adequate supplementation with animal protein is necessary since its crude protein has sub-optimal amounts of cystine and methionine, although the limiting amino acid is lysine (McDonald *et al.*, 1992). Such supplementations also ensures that the requirement of vitamins B_{12} and calcium are met especially for fast growing animals such as poultry and pigs. In poorly-stored groundnut, a toxic factor (aflatoxin) known to be a metabolite of the fungus, *Aspergillus flavus,* may develop and consequently contaminate groundnut meal. The toxin causes liver damage.

2.8.2.4 SOYA BEAN MEAL (SBM)

This is one of the best and most widely-used protein supplements in animal feeding but it is highly priced in most tropical and sub-tropical countries, probably only slightly cheaper than groundnut cake among the oil-seed protein supplements. Soya bean protein contains all the essential amino acids but the amounts of cystine and methionine are sub-optimal and a number of toxic stimulatory and inhibitory substances including allergic, goitrogenic and anticoagulant factors may also be found (McDonald *et al.*, 1992).

Toasting inactivates the inhibitors, especially for simple stomached animals. It is however, a poor source of B vitamins which must therefore be provided if soya bean meal is used consistently as a major protein supplement for monogastric animals. Soya bean meal contains 48% crude protein, 2% fat and 3.5% cellulose. The cellulose content of this cake is partly digested by monogastric animals. Soya bean meal is adequate in magnesium, is a good source of potassium and supplies a fair amount of trace elements (Ralph, 1987).

2.8.2.5 PALM KERNEL MEAL (PKM)

Palm Kernel Meal (PKM) is the by-product obtained after the extraction of oil from the palm kernel. It is abundant in the tropical areas of the world and attempts have been made to feed it to poultry and pigs (Abu *et al.*, 1984). Although PKM is often used as a vegetable protein supplement in animal rations, it is not as popular as groundnut cake or cotton seed cake.

Fetuga *et al.* (1977), in detailed studies including chemical assays, described PKM as being a good source of methionine and cystine but marginal in lysine. Analysis at the Nutrition

Laboratory of KNUST indicated that such dried PKM contains 91.04% dry matter, 19.02% crude protein, 23.3% fat and 5.68% ash. This shows that it could be a good source of protein and energy for poultry. Okai *et al*. (1994) observed that fresh PKM could easily go mouldy and rancid if it is not fed within a short time (about a week) because of its high moisture content.

2.8.2.6 COPRA CAKE

The main by-product from coconut which can be used in poultry and pig feed is copra cake or meal obtained after the coconut oil has been extracted. Its nitrogen content varies from 19-23%. Their use for growing poultry and pig is limited by their low energy value. However, they may be freely used with layers. Copra cake is a vegetable protein supplement of mediocre quality and it is consequently less popular than other vegetable protein supplements. One of the disadvantages in its utilization is its susceptibility to rancidity, a low level of lysine and histidine and a high crude fibre content, all of which limit its use by simple-stomached animals (McDonald *et al*., 1992). Its incorporation in diets for simple stomached animals therefore requires further supplementations with animal proteins. Also, increasing the energy content of the diet by addition of maize oil improves efficiency of food utilization, feed intake and growth rate (Panigrahi, 1991). Coconut meal has the valuable property of absorbing up to half its own weight of moisture, and as a result is popular in feed compounding (McDonald *et al*., 1992).

2.8.2.7 RUBBER SEED CAKE

Rubber seed consists of approximately 40% shell and 60% kernel. The oil content of the kernel, on dry matter basis, is 50%. It contains 18.6% digestible crude protein and 54% total digestible nutrients and can be used at 20% level in concentrate mixture for growing calves and milking cows without adverse effects on their growth and milk yield. It contains HCN but it has been shown that it can be fed to poultry and pigs, however it should not be fed to breeding hens as it affects hatchability (Rajaguru, 1973).

2.8.2.8 COTTON SEED CAKE

The main by-product of interest in animal feeding obtained from the cotton plant is cotton seed cake. Relative to groundnut cake, it is cheaper as a standard protein supplement. However, it has low content of cystine, methionine and lysine (McDonald *et al.*, 1992). Consequently, it should be supplemented with animal protein supplement for optimum performance if incorporated in diets for monogastric animals. McDonald *et al.* (1988) suggested that, because of its gossypol content (about 0.03 to 0.2 %) which has a toxic effect on monogastric animals, this by-product should not form more than 10% of monogastric diets.

2.8.3 MINERAL-RICH BY-PRODUCTS

2.8.3.1 BONEMEAL

Bone meal has remained the most regular source of calcium and phosphorus to various kinds of animals in the developing countries (Aletor, 1986). It is important in diets for young animals or laying birds, which require large amounts of calcium and phosphorus for bone development and egg-shell formation respectively. Oyster shells also fall into this category.

2.8.4 MISCELLANEOUS BY-PRODUCTS

2.8.4.1 BREWERS BY-PRODUCT (GRAINS)

Brewers yeast, brewers spent grains and distillery wastes after fermentation of substrates are available as by-products of breweries and distilleries. They are intermediate sources of protein and energy. They are bulky in the wet form; high in crude fibre (about 21%) and moderate in protein (about 22%). They are 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 poultry and pigs. Various replacement levels of brewers' grains for cereals as the main energy source have been utilized in poultry diets and pig diets (Lamptey, 1978).

Lamptey (1978) reported an inclusion level of 50% without any deleterious effect on grower pigs. There was, however, a depression in daily feed intake and carcass dressing percentage when 100% of the breweries by-product was fed.

2.8.4.2 DRIED COCOA POD HUSK

This can be obtained by either sun drying or artificial dryers. Research works have indicated that sun drying reduced the percentage of protein, nitrogen free extract and fat content of the husk. It is therefore recommended that, fresh pods should be chopped into smaller pieces to guarantee quick drying. It contains about 60% protein, 31% crude fibre, 12% ash, and 16% fat. The high fibre content could limit the extent of its use in the diets of monogastric animals such as poultry and pigs (Okai *et al*., 1994).

Several studies conducted in different countries have shown that the product can be used as one of the ingredients in poultry, pig and ruminant diets. It can be used up to 10-15% in the diets of ruminants. In comparison with maize, it contains less metabolizable energy and crude protein and less of all the amino acids except lysine (Tuah *et al.*, 2003).

It contains traces of the alkaloid theobromine which, however, does not produce any deleterious effect on the animals due to its presence in insignificant amounts. One of the problems in the utilization of cocoa pod husk is its quick fermentation thereby increasing the theobromine levels. This can be prevented by proper sun-drying. Laud-Anderson and Okai (1980) and Donkoh (1992) incorporated up to 20% and 25% CPH respectively in the diet of growing pigs without any deleterious effect on performance.

2.8.4.3 SHEANUT CAKE

This is a by-product obtained after the extraction of oil from the nut. Okai *et al.* (1994) suggested that, sheanut cake could be useful energy/protein sources in the diets of poultry and pigs. Chemical analysis of batches of locally produced sheanut cake at the Nutrition Laboratory in KNUST, revealed that it contains 20% crude protein, 12% ether extract, 4.8% ash, 0.9% crude fibre and 54.5% carbohydrates. It contains saponins and tannins and these can irritate the digestive tract of animals.

2.9.0 THE CASHEW PLANT

2.9.1 ORIGIN AND BOTANY OF CASHEW

Cashew belongs to the family *Anacardiaceae*. It is a native of the American tropics from Mexico to Brazil and to the West Indies, but it has since become naturalized in many lowland tropical areas. The Portuguese, as a means of controlling coastal erosion, introduced it to Mozambique and then to India in the sixteenth century. It spread within these countries with the aid of elephants that ate the bright cashew fruit along with the attached nut. The nut was too hard to digest and was later expelled with the droppings. It was not until the nineteenth century that plantations were developed and the tree then spread to a number of other countries in Africa, Asia and Latin America (Ohler, 1998).

It is grown locally in many other lowland tropics and elevations of up to 1000 m. Since the crop must be harvested by hand, production is dependent on inexpensive labour for harvesting. The overall requirement for growing the crop, however, are low and plants will grow in relatively dry, infertile soils. The tree is a spreading, fast growing evergreen and up to 12 m in height. Leaves are leathery and ovate with prominent veins. Flowers are borne on terminal inflorescence, which consists of a mixture of male and hermaphrodite flowers (Ohler, 1998). The cashew tree bears a false fruit known as the cashew apple from which the nut protrudes. The cashew apple is between 6-9 cm long and has a smooth, shiny skin that turns from green to bright red, orange or yellow in colour as it matures. It has a pulpy, juicy structure with a pleasant but strong astringent flavour.

2.9.1 ENVIRONMENTAL AND ECOLOGICAL FACTORS FOR CASHEW DEVELOPMENT

The best soils for cashew are deep friable, well-drained, loamy soils and sandy loams without hardpan with water table of 5 to 10 meters. Cashew also thrives on pure sandy soils as well as lateritic soils poor in fertility, though productivity may register a decline. Cashew trees have low tolerance to salinity, however, differences of tolerance exist between trees. Under very poor soils, cashew responds well to fertilizers if the ecological conditions are adequate. High yields are obtained if fertilizers are applied when cashew trees are more than 5 years old. Fertilizers such as muriate of potash, rock phosphate and urea may be applied (Ohler, 1979). Land is a very important factor for a viable cashew industry in Ghana and the Brong-Ahafo region has the largest land area under cashew production; this has been estimated to be about 4000 ha in 2003 (Lawrence, 1999).

Cashew can grow within a wider range of temperatures. It is assumed that optimum monthly average temperature may be near 27°C. Cashew is very sensitive to frost when young. The plant can withstand temperatures approaching 0°C for short periods but one could hardly expect to grow cashew economically in areas with the mean temperature not higher than 20°C. Gibbon and Pain (1985) also stated that cashew can withstand harsh environmental conditions. In most important cashew growing areas, mean daily minimum temperatures are between 15°C - 25°C and mean daily maximum temperatures are between 25°C to 35°C. The absolute minimum and maximum are about 5°C and 45°C, respectively.

Cashew does well in a rainfall range from 800mm to 2000 mm per annum and a dry season of about 6 months. A shorter dry season induces the flowering and fruiting period, whereas a longer dry season may create a drought stress (Ohler, 1979). Figures 2 and 3 show pictures of the cashew fruit and tree, respecively.

Fig. 2 A picture of the cashew fruit
Source: Bicalho (2001).

Fig 3 A picture of the cashew tree
Source: Bicalho (2001).

2.9.2 GLOBAL CASHEW PRODUCTION

In the early 1970s, the majority of global cashew production took place in African countries, in particular, Mozambique and Tanzania. Over the following thirty years, production trends shifted, with Asian countries emerging as the world leaders in cashew production. Today. India commands about 40% of the international market in cashew production. Other Asian countries, particularly Vietnam and Indonesia, are beginning to expand their production capacities. Currently, the four main cashew producing regions are India, Brazil, Nigeria and Tanzania (Morton, 1995).

2.9.3 CASHEW PRODUCTION IN AFRICA

Overall cashew production in Africa steadily increased during the 1950s and 1960s. Until the mid-1970s when the continent was the prime producer of cashew nuts. The year 1975 was the start of fifteen-year period of decline in production throughout the continent due to a combination of biological, agronomic, and socio-political factors.

Table 3: Cashew production in African countries from 1961 to 2000 (tonnes)

Country	Year / Production									
	2000	**1998**	**1995**	**1990**	**1985**	**1980**	**1975**	**1970**	**1965**	**1961**
Angola	800	1200	900	1200	1200	1200	1400	1300	1000	1000
Benin	10000	10000	10000	3000	1200	1086	345	627	50	50
Burkina Faso	1000	1000	1000	1074	645	200	-	-	-	-
Cote D'voire	28000	28000	20000	7000	3500	600	450	300	400	400
Ghana	7500	7500	1000	500	-	-	-	-	-	-
GiuneaBissau	38000	38000	37000	30000	13000	3500	2500	2500	2000	2000
Kenya	8000	9000	5000	7000	8500	15000	21600	22200	9000	3000
Madagascar	7000	6500	6000	5300	4000	3400	2900	2400	1900	1600
Mozambique	35000	51716	33423	22524	25000	71100	188000	184000	136000	10700
Nigeria	176000	152000	95000	30000	25000	25000	25000	25000	22000	7000
Senegal	15000	7000	1500	500	-	-	-	-	-	-
Tanzania	106500	93200	63400	17060	32750	41416	115840	107445	76000	50000
Togo	155	155	748	587	-	-	-	-	-	-
Total Africa	**432,955**	**405271**	**274971**	**125747**	**114795**	**162502**	**358035**	**345772**	**248350**	**196100**

Source: FAO. 2000.

– implies that no production was made in those years

A decline in prices at the end of the 1970s, combined with lower levels of production, dissuaded many farmers from improving cultivation techniques and replanting their cashew plantations.

Since the early 1990s, production has recovered and has continued to increase steadily over the last decade. Today, Africa accounts for about 36 percent of the world cashew production. Historically, Mozambique and Tanzania were the main cashew producing countries in Africa, with smaller amounts produced in a number of other countries. During the last five to ten years Nigeria has emerged as a leading producer of cashew nuts in West Africa (Yidana, 2000).

2.9.4 CASHEW PRODUCTION IN GHANA

The July 12th, 2006 edition of the Daily Graphic reported that, " Cashew farmers at Kranka, a farming community in the Nkoranza District of the Brong Ahafo Region, have called on the government to establish a company which would deal with the production and marketing of the cashew crop in the country.

This is because a large number of farmers nationwide have gone into the cultivation of the crop. Currently over 100 farmers in the area were engaged in cashew farming because the areas' lands favoured the cultivation of the crop. It is the "Cocoa" of the grassland and the youth were proud to cultivate the crop in order to improve on their economic activities".

Cashew production in Ghana dates back to the 1960s when the government, under its Savannah Afforestation Programme established cashew plantations in Greater Accra, Eastern, Volta and Brong Ahafo Regions. Owing to lack of directions and enthusiasm for its development in subsequent regimes, the farms were neglected and left to deteriorate. As a result, no cashew plantation existed in Ghana until the mid 1990s as indicated in Table 3 (Majeed, 1990).

The Ghana Export Promotion Council (GEPC), in its non-traditional export commodity promotional drive in the 1989, moved in to further develop cashew production under its Export Production Village Programme which was funded by the UNDP and Ghana Government. Cashew seedlings were bred and supplied to farmers to rehabilitate existing farms or establish new ones.

Cashew cultivation, however, started in Ghana on a large scale in 1991. The area under cashew increased during the period from 1995 to 1998 when TechnoServe in collaboration with the Ministry of Food and Agriculture (MoFA) imported 18,989 kg of cashew seed in a joint effort with the GEPC (GEPC, 1995).

Area under cultivation and production are both increasing steadily. Total area under cultivation is estimated at 18,000ha nationwide whiles annual production is estimated at 5000 metric tonnes (MT) for 1997 (Yidana, 2000).

The cashew development units further stated that there were around 6500 small-holder farms in cashew production primarily engaged in traditional mixed cropping practices in 1997. The cultivation of cashew is largely concentrated along the savannah zone in Brong Ahafo region. Addaquay and Nyamekye-Boamah (1996), in their report on cashew industry study, documented that Ghana has about four million hectares of total land suitable for cashew production whilst Northern and Brong Ahafo regions alone have over two million hectares of suitable land for cashew cultivation. They further stated that with continued supply of quality seed and the demand for raw nuts, the country could produce over 67,000 MT annually by the end of 2004.

Yidana (2000) reported that vegetative propagation is the fastest method of producing high yielding plants and should be used for mass multiplication for farmers' fields whenever possible. Also, for most of the mature trees in the country, in terms of flowering and fruiting, there are two main types; those that flower at least once a year and those that flower twice or continuously. The continuously fruiting varieties tend to produce higher yields than those that fruit once a year.

2.9.5 CASHEW APPLE

The pseudo-fruit, the large pulpy and juicy part, has a fine sweet flavor and is commonly referred to as the "cashew fruit" or the "cashew apple". Fresh or frozen cashew fruit concentrate is as common a juice product in South American food stores as orange juice is in the United States. However, it is very perishable and therefore, no fresh cashew fruit is exported into the United States or Europe from South America.

In addition to being delicious, the cashew fruit is a rich source of vitamins, minerals, and other essential nutrients (Table 4). It has up to five times more vitamin C than oranges and contains a high amount of mineral salts. Volatile compounds present in the fruit include esters, terpenes, and carboxylic acids (Bicalho, 2001)

Table 4: Food Value (Per 100 g) of fresh cashew apple

Moisture	84.4-88.7 g
Protein	0.101-0.162 g
Fat	0.05-0.50 g
Carbohydrates	9.08-9.75 g
Fiber	0.4-1.0 g
Ash	0.19-0.34 g
Calcium	0.9-5.4 mg
Phosphorus	6.1-21.4 mg
Iron	0.19-0.71 mg
Carotene	0.03-0.742 mg
Thiamine	0.023-0.03 mg
Riboflavin	0.13-0.4 mg
Niacin	0.13-0.539 mg
Ascorbic Acid	146.6-372.0 mg

Source: Bicalho (2001).

The main chemicals found in the cashew fruit are alanine, alpha-catechin, alpha-linolenic acid, anacardic acids, anacardol, antimony, arabinose, caprylic acid, cardanol, cardol, europium, folacin, gadoleic acid, gallic acid, gingkol, glucuronic acid, glutamic acid, hafnium, hexanal, histidine, hydroxybenzoic acid, isoleucine, kaempferols, L-epicatechin, lauric acid, leucine, leucocyanidin, leucopelargonidine, limonene, linoleic acid, methylglucuronic acid, myristic acid, naringenin, oleic acid, oxalic acid, palmitic acid, palmitoleic acid, phenylalanine, phytosterols, proline, quercetin-glycoside, salicylic acid, samarium, scandium, serine, squalene, stearic acid, tannin, and trans-hex-2-enal tryptophan (Franca, 1996).

The apple and nut fall together when both are ripe and, in commercial nut plantations, it is most practical to twist off the nut and leave the apple on the ground for later grazing by cattle or pigs. But, where labor costs are very low, the apples may be gathered up and taken to markets or processing plants. In Goa, India, the apples are still trampled by foot to extract the juice for the locally famous distilled liquor, *feni*. In Brazil, fruit vendors display great heaps, and the juice is used as a fresh beverage and for wine (Mota, 1985).

In the field, the fruits are picked up and chewed for refreshment, the juice swallowed, and the fibrous residue discarded. In the home and, in a limited way for commercial purposes, the cashew apples are preserved in syrup in glass jars. Fresh apples are highly perishable. Various species of yeast and fungi cause spoilage after the first day at room temperature. Food technologists in India have found that good condition can be maintained for 5 weeks at 32° to 35° F (0°-1.67° C) and relative humidity of 85% to 90%.

In as much as the juice is astringent and somewhat acrid due to 35% tannin content (in the red: less in the yellow) and 3% of an oily substance, the fruit is pressure-steamed for 5 to 15 minutes before candying or making into jam or chutney or extracting the juice for carbonated beverages, syrup or wine. Efforts are made to retain as much as possible of the ascorbic acid. Food technologists in Costa Rica recently worked out an improved process for producing the locally popular candied, sun-dried cashew apples. Failure to remove the tannin from the juice may account for a nutritional deficiency in heavy imbibers of cashew apple wine, for tannin prevents the body's full assimilation of the body's full assimilation of dietary protein (Morton, 1995).

However, cashew apple juice, without removal of tannin, is prescribed as a remedy for sore throat and chronic dysentery in Cuba and Brazil. Fresh or distilled, it is a potent diuretic and is said to possess sudorific properties. The brandy is applied as a liniment to relieve the pain of rheumatism and neuralgia (Franca, 1996).

2.9.7 FEEDING VALUE OF THE CASHEW APPLE

Fanimo *et al.* (2004) studied the growth performance, nutrient digestibility and carcass characteristics of growing rabbits fed cashew apple waste (CAW) and found that rabbits fed diets with 20 and 30% CAW gained weight ($P < 0.05$) faster than those fed the control diet. Feed efficiency increased with increasing levels of CAW in the diets with rabbits on 30% CAW being most efficient. Crude protein digestibility decreased ($P < 0.05$) with increased level of CAW. There were no significant differences ($P < 0.05$) in the blood metabolites except cholesterol level which increased ($P < 0.05$) with CAW inclusion in the diets. Inclusion of CAW also increased ($P < 0.05$) the relative weights of kidney, liver and carcass characteristics. It was inferred that dried CAW can be included in growing rabbit diets at levels up to 30% of the dry matter.

In examining the chemical composition of cashew apple and cashew apple waste ensiled with poultry litter, La *et al.* (1997) found that cashew apple fruit and cashew apple waste (after juice extraction) can be preserved for a long term use by anaerobic ensiling and that there appeared to be little advantage in mixing them with poultry litter before ensiling. The conversion of the soluble sugars into organic acids and alcohol may have negative effects on nutritive value. They, however, concluded that several feeding trials are necessary to substantiate their findings.

2.10. CONSTRAINTS IN THE USE OF NON-CONVENTIONAL FEEDSTUFFS

The slow growth rate of livestock when fed by-products has been attributed to poor feed intake and digestibility. Several processing methods have been suggested. However, chemicals for the processing are expensive and are all harmful. Thus, the technology of processing must be carefully costed and programmed to fit within the income and competence limits of the poor farmer.

Feed analysis is becoming very expensive in terms of reagents and equipment repair. In this regard, simple, cheap basic analytical procedures must be sought to give the needed research data. Although there are large quantities of by-products available, the collection and transportation of these from production sites is tedious and time consuming. There is also great variability in these products from different sources as the planting and harvesting of crops is not synchronized. There is also variability in the soil nutrient composition which varies the nutrient content of these by-products.

2.10.1 FACTORS AFFECTING INCLUSION RATE OF ALTERNATIVE FEED INGREDIENTS FOR SWINE

Table 5 contains a summary of various feedstuffs and the constraints in using them as feed ingredients.

Table 5: Factors affecting inclusion rates of alternative feed ingredients

FEED INGRDIENT	FACTORS AFFECTING INCLUSION RATE
*Palm kernel meal	Could go rancid or mouldy
*Oil palm slurry	Could go mouldy or rancid. High moisture content
*Cocoa pod husk	Contains theobromine. High fibre content
*Groundnut skin meal	Could go rancid. Presence of aflatoxins could result in poor growth
*Sheanut cake	Contains tannins and saponins
Dried beet pulp	High fibre content; low digestibility; acts as a laxative
Dried brewer's grains,	High fibre content; low energy; low lysine; source of B vitamins
Corn gluten feed	Low lysine; high fibre; low energy; variable nutrient content; unpalatable; bulky
Soybean meal	With (44%) or without (48%) hulls; good amino acid balance in combination with corn; palatable
Soybeans, roasted	Higher energy and lower protein than soybean meal; can cause undesirable after-taste in pork at high inclusion

Source: Waldroup (1997)
*Okai and Bonsi (1994)

2.10.2 ANTI- NUTRITIONAL FACTORS

One major constraint in the use of non-conventional feedstuffs is the anti-nutritional factors contained in them. Anti-nutritional factors may be defined as the chemical constituent of a feedstuff, which interferes in the normal digestion, absorption and metabolism of feeds, some of which may have deleterious effects on the animal's digestive system. Some inherent chemical constituents present in different kinds of feedstuffs interfere in the optimum utilization of nutrients and some are also toxic in high concentrations. Although anti-nutritional factors are present in many conventional feeds, these are more common in most of the non-conventional feeds (Pathak, 1997). These anti-nutritional factors need to be removed or inactivated by various procedures before the use of the ingredients in the diet (Korte *et al.*, 1972).

Many seeds, which were once used in traditional human and animal diets, have now fallen into disuse as agricultural and nutritional needs are re-assessed (Huisman *et al.*, 1989). Seeds often contain factors such as lectins, which are deleterious or toxic to animal or man (Liener, 1989). Seed lectins present major problems as they are resistant to heat treatment and some seeds such as kidney bean, have to be heated for several hours at temperatures above 80 °C or boiled for 10-20 minutes to ensure the elimination of their lectin activity. Great caution should therefore be taken in the use of these seeds as dietary materials. This is particularly important since recent studies suggest that long-term exposure to relatively low levels of some anti-nutritional or toxic factors may have deleterious effects on body metabolism (Grant, 1989).

2.10.3 CLASSIFICATION OF ANTI-NUTRITIONAL FACTORS

The various anti-nutritional factors in feedstuffs may be classified (by different ways) on the basis of the chemical nature into acids, enzymes, nitrogenous compounds, saponins, tannins, glucosinolates and phenolic compounds (Pathak, 1997). Others are classified as follows:

1. Tannins
2. Saponins
3. Trypsin or protease inhibitors
4. Haemagglutinins

2.10.3.1 FACTORS INTERFERING WITH THE DIGESTION AND UTILIZATION OF DIETARY PROTEINS AND CARBOHYDRATES

2.10.3.1.1 TANNINS

These are polyphenolic compounds of higher molecular weight (500-3000 dalton) and contain large numbers of reactive phenolic hydroxyl groups. They are broadly classified into hydrolysable and condensed tannins. The tannins form complexes with protein, cellulose, hemicellulose, lignins and starch and interfere with their optimum utilization in the digestive tract and systems (Pathak, 1997). A number of chemical treatments have been found to remove considerable amounts but none has been commercially utilized due to laborious processing techniques and the cost of chemicals (Ranjhan, 1997).

2.10.3.1.2 SAPONINS

On the basis of the chemical nature, saponnins may be divided into two groups namely, steroids and phenoids. They are bitter and this reduces palatability. They also cause bloat in cattle. Saponins combine with cholesterol and reduce its activity. They are haemolytic and are fatal when injected into the blood (Pathak, 1997). They are widely distributed in plants like lucerne, white clover, red clover, soybean and mahuna seed cake. Saponins are water soluble and soaking of feed ingredients in water removes them (Ranjhan, 1997).

2.10.3.1.3 TRYPSIN OR PROTEASE INHIBITORS

The feed constituents interfering with the proteolytic enzymes are known as protease inhibitors and in poultry, trypsin inhibitor is due to specific activity on trypsin amino acid. Raw soybean cakes are rich in trypsin inhibitors (Ranjhan, 1997). These inhibitors are easily inactivated by suitable heat treatment. Roasting, toasting, popping and cooking are effective treatments for the inactivation of protease inhibiting properties in feeds (Pathak, 1997).

2.10.3.1.4 HAEMAGGLUTININS

The common agglutinins likely to affect animals are *ricin* in castor bean, phaseolotoxin in *Phaseolus vulgaris* and haemagglutinins in soybean (Ranjhan, 1997). These are protein in nature and resistant to the action of pancreatic juice. They produce anti-nutritional factors, which produce inflammatory reactions causing oedema and clotting of blood in capillaries. Most of them are inactivated by moist cooking in two percent sodium hydroxide solution or by autoclaving (Pathak, 1997).

2.10.3.2 FACTORS INTERFERING WITH THE AVAILABILITY OF MINERALS

2.10.3.2.1 PHYTATES

Phytates are the salts of phytic acid and are found in almost all feeds of plant origin. The phytates are present in association with protein and generally high protein feeds contain high levels of phytates, for example groundnut cake, mustard cake, soyabean cake, sesame cake, cotton seed cake and wheat bran. Phytic acid possesses high chelating ability and in plants it is found as phytates of many minerals which are mostly not available to monogastric animals as they lack the phytase enzyme. The use of the enzyme, phytase as a feed additive has been made feasible in some countries due to its cheaper commercial production with the application of biotechnological processes (Pathak, 1997).

2.10.3.2.2 OXALIC ACID

Oxalic acid is an organic dicarboxylic acid that readily forms insoluble salts with calcium and magnesium. Oxalic acid and its soluble salts are both corrosive and poisonous. Their anti-nutritive effect is mainly through complexing with calcium. The acid precipitates calcium and renders it less available for absorption. In pigs and poultry diets containing oxalic acid, there is depression in growth and a reduction in calcium retention (Banerjee, 1988). Oxalic acid is found in free form but mostly as salts (oxalates). Oxalic acid forms insoluble salts with calcium and magnesium and imparts anti-nutritional action. Paddy straw and wild paddy are the richest sources of oxalates (Pathak, 1997).

2.10.3.2.3 GLUCOSINOLATES

Plants, seeds and oil cakes of different mustard and rape varieties are rich sources of glucosinolates. These compounds reduce the incorporation of iodine into the precursor of thyroxine resulting in iodine deficiency and development of goiter. Prolong water soaking or cooking of feeds inactivates the effects of goitcrogens (Ranjhan, 1997). Glucosinolates are responsible for the pungent flavours found in some cultivated plants belonging to the *Cruciferae*, which includes rapeseed and mustard seed. Their main biological effect is to depress the synthesis of the thyroid hormones, thus producing goiter in animals fed on seed meals containing them (Banerjee, 1988).

Apart from restrictions on use imposed by compositional factors such as toxins or physical factors that might be associated with rapid deterioration, it is important to assess the feed value of by-products in relation to the type of animal and the system of production in which the material is to be used.

2.10.3.2.4 GOSSYPOL

Gossypol is a toxic phenolic compound found in cottonseed. Ferrous salts can form a complex with free gossypol and reduce its harmful effects. High levels of calcium, magnesium, sodium and protein are also helpful in reducing the adverse effect of gossypol. Heat treatment considerably destroys gossypol but availability of lysine is greatly reduced and needs supplementation (Pathak, 1997).

2.10.3.3 PHYTOESTROGENS

Some chemical compounds with oestrogenic activities are integral constituents of many plants and in some legumes their concentration is high enough to produce harmful effects on health and productivity.. Phosphorus deficiency and some climatic conditions favour the synthesis of phytoestrogens. Many reproductive problems develop on the extensive feeding of feeds containing phytoestrogens (Pathak, 1997).

2.10.3.4 ANTI-VITAMINS

Anti-vitamin activities against vitamin A and D have been observed in soyabean, against vitamin B in kidney bean, against vitamin K in sweet clover and against pyridoxine in linseed cake (Pathak, 1997).

2.10.3.5 CYNOGENS

Cynogenic compounds are present in sorghum, grass, maize, etc. These glucosides are non-toxic but during droughts they produce hydrogen cynide (HCN) which is toxic and results in the death of the animals (Ranjhan, 1997). So far no method of removal of cynogens from herbages has been developed but boiling has been found to be satisfactory for removing or destroying these from linseed meal (Pathak, 1997).

2.10.3.6 LATHYROGENS

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

2.10.3.7 NITRATES AND NITRITES

The nitrates are found in plants and these nitrates can be converted to nitrites during storage and when this is fed, it is toxic to the animals (Ranjhan, 1997).

2.11.0 TECHNIQUES FOR PROCESSING OF BY-PRODUCTS FOF FEEDING PURPOSES.

2.11.1 AUTOCLAVING UNDER PRESSURE AT 115°-140° C

Autoclaving under pressure at 115°-140° C followed by drying and removal of fat by pressing or extraction is carried out in this process. This is used to obtain various kinds of animal protein meals such as meat and bone, poultry, fish, feathers and other meals produced from dead and condemned animals or carcases (Karzimerz *et al.*, 2003).

2.11.2 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 rapeseed meal (Karzimerz *et al.*, 2003).

2.11.3 MECHANICAL OR THERMAL CONDENSATION AND DRYING

Centrifugation, pressing, or condensation in a vacuum evaporator is followed by spray, roller, flash or drum drying is carried out in this process. These techniques are used for yeasts, grains, potatoes, molasses, brewery waste, oil seedmeals and also blood of slaughtered animals. (Karzimerz *et al.*, 2003)

2.11.4 MICROBIOLOGICAL AND CHEMICAL SOURING

These techniques are used to prepare the by-products and are effective methods of removing harmful substances, for example , isothiocyanates from rape, souring of skim milk and whey, preserving by-products of animal origin: blood, rumen content, animal and poultry excrements which are now used as feed ingredients (Karzimerz *et al.*, 2003).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 LOCATION OF STUDY AREA AND PERIOD OF EXPERIMENT

The experiment was conducted at the Livestock Section of the Department of Animal Science, KNUST, Kumasi, in the Ashanti Region of Ghana. Kumasi is located in the south-central part of the country and lies between longitude 06^0 and Latitude 06^0 – 43'N 36'W. It is in the semi deciduous zone. The climate is hot and humid with mean temperatures varying from 24.5^0C in August to 28.0^0C in February with an annual mean of 26.3^0C. The mean minimum monthly temperature (20 –28^0C) is recorded in December while the maximum monthly temperature (34.0^0C) occurs in February.

Rainfall is bimodal with major rains occuring between March and July with the peak in June. A dry spell occurs in August followed by a short rainy season from September to October. The main dry season lasts from November to February. The mean annual rainfall amounts to about 1300 mm. About 55% of the rains occur between March and July.

The mean monthly minimum relative humidity may be as low as 36% in January and as high as 95% in May. The daily relative humidity varies from 36% in January to 83% in August with an annual mean of 75%. The experiment was conducted from 21st September, 2006 to 19th January, 2007.

3.2 SOURCES OF DRIED CASHEW PULP (DCP) AND PROCESSING METHOD

The DCP used in this study was obtained from the Cocoa Research Institute's Bole Station located in the Northern Region of Ghana. The processing involves sun-drying, during which the sliced pulps are constantly turned over. They are dried to a moisture content of about 15%, then ground in a hammer mill to produce the meal which was then stored in polythene sacks until used. The contents of all sacks were thoroughly mixed and about 1 kg of the bulked sample was then taken and stored in an air-tight bottle for chemical analysis.

3.3 CHEMICAL ANALYSES

Proximate analyses of DCP and experimental diets were carried out using the standard procedures of the Association of Official Analytical Chemists (1990). Acid detergent fibre (ADF), neutral detergent fibre (NDF) and hemicellulose (Goering and Van Soest, 1970) were also estimated on the DCP samples. Mineral analysis followed the procedure of Fick *et al.* (1979). The digestible energy of the samples of DCP was calculated from its chemical composition using the equation of Noblet and Perez (1993):

$$DE\ (MJ/kg) = (4.151 - 12.2 \times Ash) + (2.3 \times CP) + (3.8 \times EE - 6.4 \times EE)$$

The DE values of the experimental diets were however calculated from values for the ingredients given by NRC (1994) and the calculated DE content of DCP.

3.4 EXPERIMENTAL ANIMALS, HOUSING, DIETARY TRATMENT AND MANGEMENT

Twelve (12) entire male large white starter pigs with a mean initial liveweight of 13.3 kg were used in the study. All animals were dewormed with Levamiosol prior to the start of the experiment and at monthly intervals thereafter. The pigs were divided into four groups and individually housed in a 65cm × 150cm × 97cm wooden cages constructed on a concrete floor. Each group of 3 pigs were randomly allocated to one of four dietary treatments (Table 6) based on maize but in which DCP replaced equivalent amounts of maize (0, 50, 100, 150 gkg^{-1}). The diets were formulated to be isoproteic and isocaloric. Animals in the treatments were balanced for litter origin and weights.

Pigs were kept individually in a cage to facilitate feeding, collection of left-over feed and observation. Pigs were fed at 5% of body weight daily throughout the trial period. All the diets were offered to the animals in weighed quantities once daily at 08:00 hours throughout the trial period. Animals had free access to water. Left-over feed was collected and the weight recorded. Pigs were weighed every week and the level of feeding was adjusted accordingly

Table 6: Composition of experimental diets

Ingredients, (g kg^{-1})	Treatments			
	(0 g kg^{-1} DCP)	(50 g kg^{-1} DCP)	(100g kg^{-1} DCP)	(150 g kg^{-1} DCP)
Maize	590	560	500	450
Dried cashew pulp	0	50	100	150
Fishmeal	100	100	100	100
Wheat bran	160	140	150	150
Palm kernel cake	50	50	50	50
Soybean meal	80	80	80	80
Groundnut skins	10	10	10	10
Oyster shell	5	5	5	5
Common salt	2.5	2.5	2.5	2.5
Vitamin/trace-mineral premix	2.5	2.5	2.5	2.5
Calculated Chemical analysis (gkg^{-1}DM)				
Crude Protein	188.5	186.3	186.9	185.5
Crude Fibre	51.7	56.0	60..4	64.7
Ether Extract	38.1	41.4	44.7	48.0
Calcium	6.4	6.5	6.6	6.7
Phosphorus	6.7	6.7	6.6	6.5
DE (MJ kg^{-1})	14.0	14.2	14.3	14.4

3.5 PARAMETERS MEASURED

The performance of the animals was monitored in terms of feed consumption, weight gain and feed: gain ratio throughout the 116-day trial period. Economics of production was also computed.

3.5.1 AVERAGE DAILY FEED INTAKE

This was calculated as $\sum$ (FS - FL)/TDN kg where FS is the amount of feed served daily to pigs in each cage, FL is the feed left over after feeding each day, TDN is the total period under review in days and $\sum$ is a summation.

3.5.2 AVERAGE DAILY GAIN (ADG)

This was calculated as $\sum$ (FW - IW)/TDN kg where FW is the final body weight of each pig for a given period, IW is the initial weight of each pig at the start of each period and TDN is the total period under review in days.

3.5.3 FEED CONVERSION RATIO

This was calculated as the amount of feed consumed by each pig to gain 1kg of body weight.

3.5.4 ECONOMICS OF PRODUCTION

Economics of production was estimated based on the feed cost per kg diet and feed cost per kg weight gain. Feed cost per kg for each of the experimental diets was estimated based on the prices of the ingredients at the time of the trial. Feed cost per kg live weight gain was also calculated for the four dietary treatments as a product of the feed cost and the feed conversion efficiency.

3.5.5 CARCASS CHARACTERISTICS

At the end of the 116-day feeding period, the pigs were slaughtered to evaluate and measure carcass traits. Prior to slaughtering, the pigs were fasted overnight but had access to water. After slaughter, carcasses were eviscerated, weighed and chilled in cold room (4 °C) for about 24 hours. Each carcass was halved and measurements taken from the left half as recommended by Eusubio (1980). The following carcass data were determined:

3.5.5.1 DRESSING PERCENTAGE

The dressing percentage was obtained from the dressed weight expressed as a percentage of the weight at slaughter.

3.5.5.2 CARCASS LENGTH

After splitting the carcass into two, the distance between the first rib and the anterior edge of the pubis symphysis was used to determine the carcass length.

3.5.5.3 BACK-FAT THICKNESS

The average of the thickness of the back-fat from three areas viz, the first rib, the last rib and the rump gave the measurement of the back-fat thickness.

3.5.5.4 LOIN EYE MUSCLE AREA

This was obtained from tracing of a cross-sectional area of the loin eye muscle area (Longissimus dorsi) taken on the muscle between the 12^{th} and 13^{th} rib. The area was described on a tracing paper and was later measured with a planimeter.

3.5.5.5 WEIGHT OF GASTRO-INTESTINAL TRACT (GIT) – (FULL AND EMPTY)

The absolute weight of the GIT was determined when full and after the contents had been removed (empty). These were then expressed as a percentage of the dressed weights.

3.5.5.6 WEIGHT OF HAM, SHOULDER, THIGH AND BELLY

The weight of the ham, shoulder, thigh and belly were also expressed as a percentage of the dressed weight.

3.6.0 STATISTICAL ANALYSES

Data collected were subjected to analysis of variance using the Genstat Linear Model procedure of Statistical Analysis Systems (1996). Differences among means were determined by the least significant diference (LSD) method (Steel *et al.*, 1997) and considered significant if $p < 0.05$. Analysis of variance tables from the statistical analysis are shown in pages 64-67.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 CHEMICAL COMPOSITION OF DRIED CASHEW PULP

The chemical composition of DCP is shown in Table 7 along with data on maize which it replaced in the experimental diets, for comparison.

Table 7: Chemical composition of DCP and maize (g kg^{-1} DM)

Component	DCP[1]	Maize	DCP : Maize
Proximate composition			
Dry matter	810	887.5*	0.91
Crude Protein	86.0	89.2*	0.96
Ether extract	99.6	44.8*	2.22
Crude fibre	38.0	19.3*	2.00
Ash	38.0	19.0*	2.00
Nitrogen-free extractives	660.4	715.2*	0.92
Fibre Component			
Acid detergent fibre	121.7	32.3#	3.77
Neutral detergent fibre	206.8	108.4#	1.90
Hemicellulose	85.1	62.5#	1.36
Mineral elements			
Calcium	7.2	0.3	24.0
Phosphorus	6.0	2.8	2.14
Potassium	16.5	3.3	5.00
Sodium	5.6	0.1	56.00
Digestible energy (MJ kg^{-1} DM)[2]	14.0	13.7	1.02

[1] The values are the means of three samples
[2] Estimated using the formula of Noblet and Perez (1993)
Bressani (1990)
* Holness (1995)

The protein concentration of dried cashew pulp is slightly lower but the crude fibre, ether extract and ash contents as well as the digestible energy values are higher than maize. Even though the DCP contains higher amount of fibre (38.0 g kg^{-1} DM) compared to maize (19.3 g kg^{-1} DM), it had the higher energy content of 14.0 MJ/kg^{-1}.

The ADF fraction consists of lignin and cellulose, while the NDF fraction corresponds mainly to the sum of cellulose, hemicellulose and lignin values. Fibre level has been found to be inversely related to energy content (Mertens, 1985). This accrues at least in part from the low digestibility of the fibre component of the ingredients. The energy content of DCP, with its higher fibre content, was therefore expected to be the lower instead of being the higher when compared to that of maize. This could be explained by the fact that in addition to fibre, other chemical compounds can have a large effect on energy value. For example, the ether extract (fats and oils) which was higher for DCP, contains 2.25 times the energy of proteins and carbohydrates while ash contributes no energy. This might have influenced the energy content of DCP.

4.2.0 PERFORMANCE CHARACTERISTICS

4.2.1 HEALTH

The pigs readily consumed their allowances of the experimental diets and remained in apparent good health throughout the duration of the study. Table 8 shows the general growth performance of the experimental population.

Table 8: Effects of varying DCP on pig performance and carcass characteristics

Response criteria	Level of DCP (g kg^{-1})				SEM	r values and level of significance	
	0	50	100	150			
Growth performance							
Av. initial weights (kg)	13.34	13.3	13.67	13.17	0.385		
Av. final weights (kg)	58.67^{a}	53.0^{a}	59.67^{a}	48.67^{b}	2.10		
Av. daily feed intake (kg)	1.38	1.33	1.50	1.35	0.008	0.14	
Av. daily weight gain (kg)	0.39^{a}	0.36^{a}	0.39^{a}	0.30^{b}	0.02	-0.73	*
Feed : gain	3.58	3.69	3.76	4.36	0.21	0.88	
Economics of production							
Cost/ kg feed (GH¢)	0.1857	0.1777	0.1697	0.1617			
Cost of feed/ kg weight gain(GH¢)	0.6648	0.6557	0.6380	0.7050			
Carcass characteristics							
Warm dressing %	59.8	67.4	64.8	64.3	2.03	0.45	
Chilled dressing %	57.3	62.2	63.2	61.2	2.33	0.43	
Carcass length (cm)	76.0	71.7	75.2	72.3	1.06	-0.46	
Back fat thickness (cm)	1.82	1.89	2.20	2.00	0.185	0.66	
Loin eye muscle area (cm^{2})	27.7^{a}	27.9^{a}	27.4^{a}	25.9^{b}	1.33	0.84	
Ham (kg)	2.0^{a}	1.8^{b}	2.1^{a}	1.6^{c}	0.08	-0.52	*
Shoulder (kg)	3.5	3.6	3.4	3.0	0.13	-0.83	
Thigh (kg)	5.4	4.9	5.6	4.7	0.23	-0.43	
Belly (kg)	3.8	3.4	3.4	2.7	0.25	-0.67	
Loin (kg)	4.7	4.3	4.8	3.7	0.28	-0.65	

SEM – standard error of means

r - Correlation coeffient

a, b, c means on the same line with different superscripts are significantly different ($P < 0.05$)

* - Significant at 5 % level of probability

4.2.2 AVERAGE DALY FEED INTAKE

The different dietary treatments containing different amounts of DCP did not exert any significant ($p>0.05$) influence on the daily feed intake per pig suggesting that pigs will readily consume diets containing up to 150 g DCP kg^{-1}. The average daily feed ranged from 1.33 to 1.5 kg. Regression of feed intake against level of DCP in diets yielded the following equation: Y (feed intake) = $1.38 + 0.0002x$ ($r = 0.14$; $p>0.05$) where x is the level of DCP in the diet. Table 6 indicates that the energy contents of the experimental diets wee similar. Pigs, like other monogastric animals, generally eat to satisfy an inner metabolic need for energy and will therefore eat similar amounts of diets containing similar levels of energy.

4.3.2 AVERAGE LIVEWEIGHT GAIN

Although the pigs on the different dietary treatments consumed similar amounts of feed, liveweight gains of pigs fed the 0, 50 and 100 g kg^{-1} DCP diets were significantly ($p<0.05$) better than those fed the diets containing the highest amount of DCP (150 g DCP kg^{-1}). The following correlation between the level of DCP in the diet and the weight gain was found: Y (weight gain) = $0.39 - 0.0005x$ ($r = 0.73$; $p>0.05$). It was expected that consumption of similar amount of feed by the pigs would have yielded corresponding similar liveweight gains. The inferior liveweight gain of pigs fed the 150 g kg^{-1} DCP diet may be due to the high crude fibre level of the ration (Table 6). Several investigators (Graham *et al.*, 1986 ; Fernandez and Jorgensen, 1986 ; Graham and Aman, 1987a,b ; Fanimo *et al.*, 2003) have reported that addition of fibre to the diet can lead to a lower apparent digestibility of starch, fat, crude protein and peptides and withhold them from absorption (Bergner *et al.*, 1975 ; Sauer *et al.*, 1991). Moreover, the water-binding capacity of fibre has been reported to reduce diffusion of the products of digestion towards mucosal surface (Dierrick *et al.*, 1989). Thus the lower growth rate observed for pigs on the diet containing the highest concentration of DCP might be caused by a reduced amount of protein and other nutrients available for growth, particularly when true growth is considered as deposition of protein.

4.3.3 FEED CONVERSION RATIO

Feed conversion ratio value obtained for pigs fed the control diet was superior to those obtained for the other group of pigs on the DCP diets. Regression of feed conversion ratio against the level of DCP yielded the linear regression equation: Y (feed: gain) = 3.45 + 0.0005x ($r = 0.88$; $p<0.05$). This was expected as the DCP diets had higher crude fibre levels. It is clear that even though the pigs readily consumed the DCP-based diets, they were not capable of converting them efficiently into body constituents. The reduced ability to efficiently utilize DCP-based diets for growth was mainly caused by the negative effect of DCP as indicated by the high index of correlation for feed conversion efficiency ($r = 0.88$).

4.3.4 FEED COST AND THE ECONOMY OF GAIN

The costs per kilogram of feed for the four diets are shown in Table 8. Although the DCP was obtained free of charge from the Cocoa Research Institute's Station at Bole, it was assigned a value of GHp 2.00 being the cost of drying and transportation. The inverse relationship of feed cost observed as the level of DCP increased in the diet was due to the relatively cheaper price of DCP compared to maize (GH¢0.1600). The cost per kilogram of the control diet was GHp 240 more than the cost per kilogram of the 150 g DCP diet. However, the cost of feed to produce 1 kg of pork was lowest for pigs on the 100 g DCP kg^{-1} diet. Although pigs on the

150 g DCP kg^{-1} diet had a relatively lower cost of feed per kg diet, the effect was cancelled by the lowered efficiency of feed utilization.

4.3.5 CARCASS CHARACTERISTICS

Carcass measurements are presented in Table 8. The results of most of these measurements showed no significant differences between diets. The level of DCP in the diet gave correlation coefficients of 0.45, 0.43 and -0.46 when linearly regressed against warm dressing percentage, chilled dressing percentage and carcass length, respectively. There was, however, a trend towards increased back fat deposition as the level of DCP increased in the diets ($r = 0.66$). Similarly, the estimated loin eye muscle was not significantly affected by the level of dietary DCP but the trend showed a decrease due to the use of the 150g DCP kg^{-1} diet.

Data obtained for the other carcass measurements (weight of thigh, shoulder, belly and loin except for the ham) did not show significant differences between diets. The trend for most parts indicated decreased yield. This is particularly true for pigs fed on the 150 g kg^{-1} DCP diet. The results showed that the use of DCP beyond the 100 g/kg level could decrease the weight of ham, shoulder, belly and loin. The significantly lower weight of the mentioned carcass traits were mainly a reflection of the lower performance recorded by pigs on diets containing the highest concentration of DCP. Fanimo *et al.* (2004) indicated that weights of major cuts are indices of growth rates. Richmond *et al.* (1997) also observed a positive correlation between live weights at slaughter and the weights of the belly, ham and thigh.

The weights of some of the organs (heart, kidney, liver and spleen) were, however, not statistically significant (p>0.05) across treatments (Table 9). On the other hand, studies conducted by Fanimo *et al.* (2003) to determine the growth performance and carcass characteristics of growing rabbits fed cashew apple waste indicated that the kidney and liver weights increased as the level of cashew apple waste in the diets increased.

Table 9: Measurements of internal organs of pigs fed diets containing varying levels of DCP.

Item	Treatments				SEM	Significance
	(0 g kg^{-1} DCP)	(50 g kg^{-1} DCP)	(100 g kg^{-1} DCP)	(150 g kg^{-1} DCP)		
Heart, kg	0.23	0.17	0.2	0.18	0.0215	NS
Kidney, kg	0.12	0.14	0.15	0.17	0.1282	NS
Liver, kg	1.30	1.00	1.10	1.32	0.1362	NS
Spleen, kg	0.12	0.08	0.10	0.83	0.1576	NS

NS – No significant difference observed
SEM – Standard Error of Means

CHAPTER FIVE

5.0 SUMMARY AND CONCLUSIONS

The study was undertaken to evaluate the effect of partial substitution of maize with DCP and its effects on pig growth performance, carcass characteristics and economics of production. The following were observed at the end of the study:

1. Inclusion of DCP in the diet beyond 100 g kg^{-1} (at 150 g/kg) resulted in significant decreases in the rate of gain.
2. Inclusion of DCP in the diet up to 100 g kg^{-1} led to better carcass characteristics.
3. DCP up to 150 g/kg did not pose any health or mortality problems.
4. Apart from ham weight, DCP inclusion in the diet did not significantly affect weights of the major cuts (belly, shoulder, thigh and loin)
5. DCP inclusion in the diet at 100 g/kg resulted in the best feed cost per kilogram weight gain even though the 150 g kg^{-1} DCP inclusion recorded the lowest feed cost.

Analysis of the productive parameters studied indicated that dietary DCP up to 100 g kg^{-1} had a positive effect on growth performance and carcass characteristics of starter-grower pigs and that partial replacement of maize with DCP was possible.

5.1 RECOMMENDATIONS

1. To substantiate the results of this experiment, it would be worthwhile to repeat the experiment with a greater number of pigs.

2. Ghana abounds in agro-industrial by-products (AIBPs). The animal industry will therefore have to invest in harnessing their potential to reduce feed cost. For example, a combination of DCP and dried blood meal could be advantageous since that would have the capacity of partially replacing fishmeal which is the most expensive component of pig diets.

3. In areas where cashew waste abounds, pig farming should be encouraged.

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APPENDICES

Table 1: ANOVA FOR AVERAGE DAILY FEED INTAKE

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	2	0.04085	0.02042	1.08	0.489
treatment	3	0.05202	0.01734	0.91	
Residual	6	0.11395	0.01899		
Total	11	0.20683			

Table 2: ANOVA FOR AVERAGE DAILY GAIN

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication	2	0.0040500	0.0020250	2.30	0.037
treatment	3	0.0144917	0.0048306	5.49	
Residual	6	0.0052833	0.0008806		
Total	11	0.0238250			

Table 3: ANOVA FOR BACK FAT THICKNESS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication	2	0.0154	0.0077	0.08	0.238
treatment	3	0.5700	0.1900	1.86	
Residual	6	0.6141	0.1024		
Total	11	1.1996			

Table 4: ANOVA FOR WEIGHT OF BELL

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication	2	0.3654	0.1827	0.95	0.059
treatment	3	2.5200	0.8400	4.36	
Residual	6	1.1562	0.1927		
Total	11	4.0417			

Table 5: ANOVA FOR CARCASS LENGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication	2	10.282	5.141	1.51	0.070
treatment	3	40.789	13.596	4.00	
Residual	6	20.378	3.396		
Total	11	71.449			

Table 6: ANOVA FOR FEED CONVERSION RATIO

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	2	0.2447	0.1224	0.65	0.261
Treatment	3	0.9794	0.3265	1.72	
Residual	6	1.1361	0.1893		
Total	11	2.3602			

Table 7: ANOVA FOR WEIGHT OF HAM

Source of variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Replication	2	0.00500	0.00250	0.14	0.018
Treatment	3	0.40917	0.13639	7.55	
Residual	6	0.10833	0.01806		
Total	11	0.52250			

Table 8: ANOVA FOR HEART WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	2	0.001667	0.000833	0.60	0.256
Treatment	3	0.007292	0.002431	1.75	
Residual	6	0.008333	0.001389		
Total	11	0.017292			

Table 9: ANOVA FOR INSIDE FAT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication	2	0.01625	0.00812	0.32	0.383
Treatment	3	0.09229	0.03076	1.21	
Residual	6	0.15208	0.02535		
Total	11	0.26063			

Table 10: ANOVA FOR KIDNEY WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	2	0.19009	0.09505	1.93	0.291
Treatment	3	0.23289	0.07763	1.58	
Residual	6	0.29573	0.04929		
Total	11	0.71871			

Table 11: ANOVA FOR LOIN EYE AREA

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	2	4.215	2.108	0.40	0.685
Treatment	3	8.188	2.729	0.52	
Residual	6	31.648	5.275		
Total	11	44.052			

Table 12: ANOVA FOR WEIGHT OF LOIN

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication	2	0.7117	0.3558	1.52	0.119
Treatment	3	2.0867	0.6956	2.96	
Residual	6	1.4083	0.2347		
Total	11	4.2067			

Table 13: ANOVA FOR WEIGHT OF LIVER

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	2	0.06792	0.03396	0.61	0.360
Treatment	3	0.21562	0.07187	1.29	
Residual	6	0.33375	0.05562		
Total	11	0.61729			

Table 14: ANOVA FOR SHOULDER WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	2	0.10167	0.05083	1.02	0.058
treatment	3	0.65667	0.21889	4.40	
Residual	6	0.29833	0.04972		
Total	11	1.05667			

Table 15: ANOVA FOR WEIGHT OF SPLEEN

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	2	0.0004167	0.0002083	0.27	0.455
Treatment	3	0.0022917	0.0007639	1.00	
Residual	6	0.0045833	0.0007639		

Table 16: ANOVA FOR THIGH WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	2	0.4650	0.2325	1.48	0.103
Treatment	3	1.5233	0.5078	3.24	
Residual	6	0.9417	0.1569		
Total	11	2.9300			

Table 17: ANOVA FOR FINAL WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Replication	2	46.50	23.25	1.75	0.031
Treatment	3	238.00	79.33	5.99	

Residual	6	79.50	13.25		
Total	11	364.00			

Table 18: ANOVA FOR WEIGHT GAIN

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	2	24.932	12.466	1.60	
Treatment	3	187.110	62.370	8.01	0.016
Residual	6	46.695	7.782		
Total	11	258.737			

Table 19: ANOVA FOR CHILLED DRESSING PERCENTAGE

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	2	70.02	35.01	2.15	
Treatment	3	60.13	20.04	1.2	0.377
Residual	6	97.57	16.26		
Total	11	227.72			

Table 20: ANOVA FOR WARM DRESSING PERCENTAGE

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	2	74.77	37.38	3.01	
Treatment	3	89.25	29.75	2.40	0.167
Residual	6	74.49	12.41		
Total	11	238.51			

Table 21: ANOVA FOR FEED INTAKE

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	2	547.3	273.7	1.04	
Treatment	3	703.2	234.4	0.89	0.498
Residual	6	1579.3	263.2		
Total	11	2829.9			

Table 22: ANOVA FOR INITIAL WEIGTH

Source of variation	d.f.	s.s.	m.s.	v.r.	Fpr.

Replication	2	2.0000	1.0000	2.25	
Treatment	3	0.3958	0.1319	0.30	0.827
Residual	6	2.6667	0.4444		
Total	11	5.0625			