USE OF SELECTED AGRO-INDUSTRIAL BY-PRODUCTS IN THE FEEDING SYSTEM OF PIGS.

BY

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CERTIFICATION

I hereby certify that this research was carried out by me and that this thesis is entirely my own account of the research. The work has not been submitted to any other University for a degree. However, works of other researchers and authors which served as sources of information were duly acknowledged.

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ABSTRACT

A 13-week feeding trial was conducted using 24 weaner entire male and female pigs to study the effects of some agro-industrial by-product (AIBP)-based diets on growth performance and economics of production of pigs. The weaner pigs were randomly selected and distributed over four dietary treatments (i.e. A_1, A_2, A_3 and A_4) containing various amounts of selected AIBPs such as pito mash, cassava leaves, cassava peel and dried cashew pulp. The diets were formulated to be isocaloric and isonitrogenous. A completely randomized design was used and each treatment was replicated three times with two pigs per replicate. The piglets had unrestricted access to feed and water during the experimental period. Results of the study indicated no significant ($P>0.05$) differences in mean feed intake. The average daily gain (ADG) for the four treatments were 0.46, 0.23, 0.26, and 0.34 kg/day respectively while the corresponding feed conversion ratio (FCR) values were 3.38, 5.29, 5.59 and 4.64 respectively. The FCR and ADG results showed significant ($P<0.05$) differences among the dietary treatments with the pigs on the control diet performing better than those on the AIBP-based diets. Significant ($P<0.05$) differences also occurred in the carcass parameters such as carcass length, back-fat thickness, loin-eye area, abdominal fat, GIT (full and empty), viscera etc. Feed cost (GH¢/kg) was lower for the AIBP-based diets while the cost of feed to produce a kg weight was lowest for pigs on the control diet. The study showed that pigs fed the control diet, had a better economy of production than pigs fed on the AIBP-based diets. However, pigs fed the A_4 diet perfomed better than those fed the A_2 and A_3 diets.

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CHAPTER ONE

1.0 INTRODUCTION

In the past, pig production in Ghana was of the subsistence type. Pig was regarded as unclean and infested with worms and not fit human consumption. This to some extent was supported by some taboos. The Ashanti Black pig, an indigenous, smallish, hardy and long-snouted animal that produces small litters (usually 4 - 8 piglets) was the commonest breed of pigs reared in Ghana . These animals were fed mainly, porridge chaff (a by-product from maize porridge production), sorghum spent grain (pito mash) from sorghum processing and sun–dried cassava or kitchen leftovers. The above-mentioned ingredients were generally not supplemented with other nutrient-rich feedstuffs, especially protein feedstuffs. In effect, the production system was to a large extent the extensive type where pigs scavenged to satisfy their nutritional demands. They received no medication and were not properly housed .

In urban and peri-urban areas such as Nima, Lagos Town, Pig Farm Achimota, Kwabenya and Teshie-Nungua, all in the Greater Accra Region, few improved male breeds of pigs (Large White or Duroc) were imported and used to upgrade the indigenous stock of Ashanti –black. The pigs were mostly fed on kitchen left overs and agro industrial by products. The Universities, Research Stations, Ministry of Food and Agriculture (MOFA), NGO's etc. organized Seminars, Workshops, Agricultural Shows and other sensitization campaigns to create awareness and arouse the interest of Ghanaians in pig production. In recent years, those Ghanaians engaged in commercial pig production experienced serious set-backs due to high feed cost. The cost of feed could account for between 70 and 80% of the total cost of pig production in Ghana and other developing countries (Okai, 1998)., Even though well established commercial units, universities and research centers have made strenuous efforts to formulate and use well-balanced diets for various categories of pigs, farmers still practicing the semi-intensive and extensive systems of management, continue to feed their animals on poor quality diets. The poor productivity of pigs in the subsistence sector is blamed on non-scientific methods of feeding and management of the animals (Okai, 1998).

In view of the problems highlighted, there is the need to continue to search for alternate sources of feedstuffs that could supply pigs with adequate energy, protein, minerals and vitamins. Agro-industrial by-products (AIBPs) such as cocoa pod husk, oil palm slurry, groundnut skin meal, pito mash, cassava leaf, etc. which are cheaper but equally rich in energy, protein and other nutrients are some examples of alternative feedstuffs available for use in Ghana. According to Okai *et al.* (1995) their use could lead to reductions in feed cost and in some cases improvements in live-weight gain. In most studies, these agro-industrial by-products have been used individually with maize and other ingredients to meet the energy and protein requirements of pigs. However, there is paucity of information on the effect of combining these ingredients to partially or wholly replace the expensive feed resources used for weaner- grower pig diet.

This study, therefore, was undertaken to ascertain whether a combination of some agro-industrial by-products, namely, sorghum spent grain (pito mash), cassava peels, cassava leaf meal, and dried cashew pulp can reduce the levels of maize, soyabean meal and wheat bran normally included in pig diets thereby providing pig farmers with feed package at affordable prices.

The specific objectives of the study were to:

(a) Evaluate the growth performance and carcass characteristics of pigs fed diets containing pito mash, cassava peels, cassava leaf meal and dried cashew pulp.

(b) Assess the economics of production when varying levels of these ingredients are added to pig diets.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 IMPORTANCE OF NUTRIENT REQUIREMENTS OF WEANER-GROWER PIGS

The success of pig production depends mainly on feeding the pigs well balanced diets. Feeding of young growing pigs on diets that do not contain the requisite amounts of the six nutrient classes would have adverse effects on their growth performance. A knowledge of the nutrient requirements of growing animals is essential in the formulation and compounding of diets that would meet their needs (Bearden *et al.*, 1980).

Table 1.0 Some Nutrient Requirements of Pigs

Stage of the Life Cycle

	Weaner	Grower	Finisher	Gestating/breeding boars	Lactating sows
Live-weight (kg)	7-20	20-45	45-90	-	-
Nutrient (%)					
CP	18-22	16	13-14	14	15-16
Ca	0.8	0.7	0.5	0.6	0.6
P	0.6	0.5	0.4	0.5	0.5
Common salt	0.5	0.5	0.5	0.5	0.5
DE (kcal./kg)	3500	3300	3300	3300	3300

Source: Okai *et al.*(2003)

2.2 SOURCES OF NUTRIENTS

Feeds constitute an important factor in commercial pig production, being about 70% or more of total cost of production (Cameron, 1970).

2.2.1 ENERGY REQUIREMENT FOR PIGS:

Energy for pigs is obtained from maize, cassava, sorghum, pito mash, maize bran, rice bran, "koko" chaff, cassava peels, yam peels, cassava foliage or leaf, oil palm slurry, dried bakery waste products, dried coffee pulp, dried cashew pulp, cocoa pod-husk, ripe plantain peels and oil seeds (Okai *et al.,* 1994). Energy is needed for growth of body tissues, performance of vital physical activities and maintenance of constant body temperature. According to Card and Neshien (1966), the most important nutritional factor limiting utilization of a well balanced diet is its energy component. Different feedstuffs vary in their chemical composition and as such their supply of metabolizable energy (ME) vary accordingly.

2.2.2 FACTORS INFLUENCING THE CALORIC NEEDS OF PIGS:

There are many factors such as body size, growth rate, level of production etc that influence energy requirement of pigs. With increase in body weight, there is concomitant increase in feed intake; assuming all environmental factors being equal larger animals need more energy for body maintenance. In order to maximize growth rate, higher energy rations are fed to pigs. A high energy diet can be described as one containing over 2860Kcal./kg and a low energy diet has between 2530 – 2640 Kcal/kg of ME (Sainsbury, 1984).

2.3 EFFECT OF PROTEIN ON PIG PERFORMANCE

Proteins are complex organic compounds formed as a result of polymerization of simple monomers of amino acids bound together by peptide bonds to form complex compounds of high molecular weights. All living cells are made of protein. The life of the cell (protoplasm) and all its phases of activities are intimately connected with protein and amino acids (McDonald *et al.*, 1990,1995; Gillespie, 1992). The quality or Biological Value of protein can be ascertained by how effectively its amino acid content satisfies the nutrient requirements of animals (Mess, 1992). The most important amino acids required by pigs are methionine, lysine, tryptophan, cysteine, arginine, leucine, isoleucine, phenyalanine, tyrosine, etc. (Table 2.1)

Table 2.1: Essential and Non-Essential Amino Acids for Swine and Poultry

Essential	Non-Essential
Arginine	Alanine
Histidine	Aspartic acid
Isoleucine	Citrulline
Leucine	Cysteine
Methionine*	Glutamic acid
Phenylalanine**	Glycine
Threonine	Hydroxy glutamic acid
Tryptophan	Hydroxy praline
Valine	Proline
Lysine	Tyrosine
	Serine

Source Gillespie (1992): *Part can be replaced with cystine. **Part can be replaced with Tyrosine.

Although plant proteins supply most of the amino acids required by animals, they are limited in their composition of some or have some in low concentrations. Animal proteins supply amino acids and minerals in higher proportions and quality than most plant proteins. Also, in plants, some of the nutrients are bound to phytic acids. As a result they are not available to monogastric animals, such as pigs, which unlike ruminants lack phytase, an enzyme produced by ruminal microbes which can hydrolyze phytic acids to release the nutrients. Synthetic phytase can, however, be used to solve the problem.

Protein requirements of weaner pigs range between 16-22% CP (Church and Pond, 1988). The crude protein requirement of growing animals varies according to age, size, breed of animals, composition and rate of gain, the quality of protein fed etc. According to March and Bieley (1972), the supply of essential amino acids is very vital in the performance of pigs, since when it is in limited supply, growth, production and efficiency of feed utilization are adversely affected. Growth of organs could be inhibited when protein and amino acids are inadequate.

Protein sources in Ghana include, fish meal, groundnut cake, copra cake, cotton seed cake, soyabean meal, dried spent yeast, concentrates, feather meal, palm kernel cake, cassava foliage, discarded skimmed milk, groundnut skin meal (Okai *et al.*, 1994; Gillespie, 1992).

2.3.1 IMPORTANCE OF PROTEIN-ENERGY BALANCE IN PIG DIET

There is a specific protein to energy ratio for optimum growth and feed efficiency of pigs. As the energy content of the feed increases the protein content must equally increase to maintain a balanced ratio for optimum growth since the two nutrients are closely linked (Matterson *et al.*, 1955). According to Banerjee (1988), common energy sources are low in protein and also, protein supplements are expensive, so protein deficiency in diets is frequently reported. Protein deficiency manifests in pigs as slow growth, inefficient feed utilization, unthriftness, fatty liver, depression of blood serum protein etc.

2.4 RELEVANCE OF MINERALS AND VITAMINS IN PHYSIOLOGICAL FUNCTIONS, GROWTH AND DEVELOPMENT OF PIGS.

Minerals and vitamins though needed in small amounts by animals are very vital in the proper functioning of the body. Biochemical activities, health status and reproductive performance of pigs require these nutrients in their right proportions. Their deficiencies result in serious physiological, health and other related problems in pigs. Minerals and vitamins are obtained from the feed fed to the animals. When in short supply supplementation must be made from the feed or synthetic sources. There are two kinds of minerals, namely, macro minerals and micro minerals. Macro minerals comprise calcium, phosphorus, sodium, potassium, magnesium and chlorine. The micro minerals are, molybdenum, iodine, selenium, copper, cobalt, zinc, manganese, etc. (Gillespie, 1992).

Sources of mineral elements in Ghana are, common salt, bone meal, dicalcium phosphate, oystershell, calcium carbonate, commercial trace mineral supplements (Okai *et al.*, 1994). The vitamins are of two kinds: fat soluble (A, D, E, K) and water soluble (B –complex vitamins, i.e. riboflavin, thiamin, niacin, folic acid etc and ascorbic acid.) vitamins (Gillespie, 1992).

Deficiency of minerals and vitamins in pigs manifests in different forms: Iron, copper, cobalt and B_{12} deficiencies cause anaemia in pigs; Zinc deficiency causes reproductive failures; sodium and potassium deficiencies result in osmotic imbalance within and outside the cells while iodine deficiency causes growth retardation, goiter and hairlessness. Calcium, phosphorus and vitamin D deficiency cause bone malformation, tooth decay, weak joints and stiff muscles. Vitamin A deficiency causes poor eye sight, scaly skin and poor feed utilization while vitamin K deficiency result in prolonged blood clotting time(Banerjee, 1988; McDonald *et al.*, 1995).

2.5 AGRO-INDUSTRIAL BY-PRODUCTS (AIBPs) AVAILABLE IN GHANA

In some parts of the world (especially, the western world) where livestock production has become more intensive, animal performance has steadily improved and the traditional human foods have become the raw materials for animal production. The system was not so about a century ago when mostly livestock obtained parts, if not all, of their feed requirements from scavenging for waste by-products, crop residue, etc (Ranjhan, 1997). As the world human population increases there is decrease in reserved stock of feed grains for animals, hence the introduction AIBPs to feed pigs.

The AIBPs can be grouped according to their nutritional content such as energy rich sources (i.e. molasses, rejected banana, pineapple waste, cassava by-products) ; protein rich sources(i.e. oil seed cakes, fish and meat meals and pulses); mineral sources (i.e. bone meals and oyster shell) and miscellaneous by-products which supply energy and protein such as by-products from the brewery, fruit and vegetable industries (Ranjhan, 1997).

Nelson *et al.* (2007) fed laying chickens on locally available AIBPs and found out that there was significant increase in egg production and reduction in feed cost/kg of diet.

Rhule *et al.* (2007) performs feeding trial using AIBPs to feed different categories of pigs and found out that it was economically feasible to eliminate maize completely from the diet of the three categories of pigs and thus reduce feed cost and other major constraints in pig production.

2.5.1 PLANTATION CROPS, AND OTHER TREE CROPS, AND THEIR BY-PRODUCTS.

2.5.1.1 COPRA CAKE

Say (1987) reported high fibre levels of 9 - 24% and CP levels of 19 – 23% in copra cake. However, it is poor in lysine and histidine (Banerjee, 1988). Because of its poor content of lysine and histidine, Banerjee (1988) has suggested that its use should be restricted in swine and poultry rations and if fed to monogastrics, it should be supplemented with lysine and methionine. He added that the fat content of copra cake is very low in unsaturated fatty acids hence feeding of copra cake produces firm or hard body fat in pig. Say (1987) indicated that copra cake might be freely used in the diets of layers and pigs. At an inclusion level of 20% of the diet, performances remained comparable with those obtained with standard rations.

2.5.1.2 PALM KERNEL CAKE (PKC)

Oil palm processing techniques are not only inefficient but they also produce a product with a doubtful quality because of the extreme heat applied and also the by-product is quite moist (about 25% moisture) and easily goes mouldy (Okai, 1998). Okai and Opoku-Mensah (1988) included locally produced PKC (0, 10 and 20% levels) at the expense of some maize, soyabean meal and wheat bran in the diets of pigs fed for a period of 28 days and reported that all growth performance criteria with the exception of feed intake (higher for the palm kernel cake diets) were found to be similar for all the treatments. However, the palm kernel cake (PKC) containing diets were cheaper. Gohl (1981) reported that good results have been obtained from pig rations containing 20 - 30% palm kernel meal. However, higher proportions usually cause scours. Young pigs do not always like it and in pig feeding it must be introduced gradually. PKC tends to produce firm pork of good quality (Gohl, 1981).

2.5.1.3 OIL PALM SLURRY (OPS)

Oil palm slurry (OPS) is the liquid left when palm oil is produced. It is regarded as a pollutant in certain areas where it has been found to destroy flora and fauna of the streams and rivers into which it is discharged. Its protein level is low (4.5% CP, DM basis) but it is high in ether extract (73.3%, DM basis) and could help reduce the demand for maize in poultry and pig diets (Atuahene *et al.*, 1987; Okai, 1998). Abu *et al.* (1984) indicated that growing-finishing pigs fed up to 30% fresh OPS performed as well as those fed a control (0% OPS) diet. However, the OPS-containing diets were cheaper mainly because they contained less maize. Carcass traits were not adversely affected by the inclusion of up to 30% OPS in the diets.

Okai and Bonsi (2003) conducted feeding trials on pigs using oil palm slurry (OPS) and found out that at inclusion levels of 0-20% feed intake and ADG improved over the performance of pigs fed the usual maize-based diet. Chemical analysis had shown that OPS is high in lipids (66%) and ash (5.1%) but low in CP. They suggested that OPS could be used at 15% level to replace maize but should be supplemented with high protein sources.

2.5.1.4 PALM PRESS FIBRE (PPF)

Cottage-scale palm press fibre (PPF), which is quite abundant, has also been found to be a useful feed resource for pigs, because its ether extract content is quite high (35.5%). The crude fibre content is also high (21.3%). Okai *et al.* (1994 unpublished) observed that up to 10% PPF can be included in growing pig diets, at the expense of maize without any adverse effects on pig performance and carcass characteristics. Also, the PPF diets were cheaper but it took such pigs nearly a week extra to attain the desired weight. This could be due to the slightly lower average daily gain (Okai *et al.*, 1992 unpublished). Gohl (1981) reported that the crude protein and crude fibre digestibility decreased when the level of inclusion exceeds 25 - 30%.

2.5.1.5 SHEANUT CAKE (SNC)

Sheanut is gradually becoming a major foreign exchange earner for Ghana, however, sheanuts are also processed locally to obtain the fat known as sheabutter, which is used for domestic and industrial purposes. The by-product obtained is known as sheanut cake (SNC) (Okai, 1998). Okai *et al.* (1994 b) reported that SNC contains 14.5% CP, 4.3% Ash, 5.8% CF and 49.8% EE suggesting that it could be a useful protein/energy source in livestock and poultry diets. Unfortunately, studies with poultry, pigs and rats have shown that despite the reasonably good CP and EE contents of 14.5% and 12%, respectively, SNC may not support good growth performance if more than 10% is included in monogastric diets. Such diets were however, cheaper (Atuahene *et al.*, 1989; Okai and Bonsi, 1989 ; Gohl, 1981; Okai *et al.*, 1994b; Okai and Bonsi, 1989)

Okai *et al.* (1995) observed that simple processing techniques such as soaking and boiling of SNC gave a better growth performance in rats due to improved diet digestibility as a result of the removal of some of the tannins (the basic anti-nutritive factors in SNC are tannin and saponin).

2.5.1.6 MANGO SEED KERNEL MEAL (MSKM)

Mango is a large spreading tree that is native to tropical Asia but is cultivated in most tropical countries. The fruit has in its centre a large fibrous flat seed containing a kernel. The kernel constitutes about 15% of the weight of the fruit and may well be used for livestock feeding (Gohl, 1981). Ruminants could tolerate concentrates with up to 50% mango kernels without adverse effects. A preliminary trial with rats showed that MSKM with a CP content of 8.2% was a useful alternative energy source in diets in which it was incorporated at levels of 0, 10 and 20% as a direct replacement for maize (Okai and Aboagye, 1990). Gohl (1981) had earlier reported that the kernels are fairly rich in tannins, which progressively lead to reduced growth rates and less efficient feed utilization when included in diets for pigs and poultry.

2.5.1.7 DRIED COFFEE PULP (DCP)

Dried coffee pulp is normally obtained after mechanical removal of the beans. The material is then milled ready to be used as a feed ingredient. The DCP contains 10.4% CP, 3.8% EE and 68.5% NDF (Okai *et al.*, 1984a,b). The ash and CF contents are 8.3% and 21%, respectively. In experiments with pigs, it has been found that up to 30% DCP can be used as a replacement for wheat bran in their diets, despite the presence of theobromine and caffeine, without any adverse effects on pig growth performance. The DCP-containing diets led to a significantly lower back fat thickness while relative liver weights were higher (Okai and Dabo, 1991).

Gohl (1981) reported that for lactating cows, coffee pulp can be fed at levels below 20% of the diet without affecting milk production. Beef animals, however, show a decrease in feed intake and weight gain directly related to the level of pulp in the diet. Also, up to 16% DCP from the wet process has been included in diets for swine with good results. With broiler chickens, DCP could be included in diets at concentrations up to only 2.5% without an adverse effect on performance (Donkoh *et al.*, 1988).

2.5.1.8 COCOA POD HUSK (CPH)

Cocoa pod – husk is a by-product obtained after the extraction of the beans from the pod. Okai *et al.* (1994b) reported that dried CPH contains 8.1% CP, 34.8% CF and 3.3% EE, 7.6% Ash and 33.6% NFE. They also mentioned that the high CF content could limit its use in non-ruminant diets. 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. Such CPH diets were generally cheaper. Gohl (1981) had earlier stated that cocoa pod meal has been fed without toxic effects to cattle up to 7 kg per day and to pigs in quantities up to 2 kg per day. For dairy cows, cocoa pod meal seems to be comparable in value to corn-on-cob meal. For pigs, cocoa pod meal can replace some of the maize and can constitute up to 35% of the ration without decreasing weight gains (Gohl, 1981). For poultry, CPH can be included in broiler diets up to a level of 10% without any adverse effect on growth performance (Donkoh *et al.*, 1991).

2.5.1.9 COCOA BEAN SHELLS (CBS) AND OTHER COCOA BY-PRODUCTS

Cocoa bean shells and oil cakes all have moderate nutritive values and could serve as feedstuff for livestock except for their theobromine contents (Gohl, 1981). The shells are a good source of vitamin D. They are acceptable to ruminants in small amounts (up to 0.8 kg per day for dairy cows), but have negative impacts on pigs and poultry. Okai (1998) stated that there has not been any major study to establish the nutritive value of the CBS for pigs in Ghana, perhaps the high theobromine content of CBS would be a major consideration in deciding whether it is useful or not for monogastrics such as pigs and poultry. The CBS can be rendered harmless by cooking in water for one and half hours, filtering and drying. Pig rations can include up to 25% of this treated material without reducing weight gains or feed efficiency (Gohl, 1981).

Cocoa expeller cake (CEC) is a by-product of cocoa butter manufacture. Recently, scientists have attempted to determine its usefulness as a feed resource. Notwithstanding its high crude protein content of 24%, CEC did not support any good growth performance in pigs (Okai *et al.*, 1992 Unpublished). They recommended further processing of CEC to remove any toxic or anti-nutritional factors (ANFs) such as theobromine and tannins.

2.5.1.10 BAOBAB LEAF MEAL

Alenyorege *et al.*, (2007) performed feed trials to determine the effects of Baobab leaf meal on weaner pigs at Babile Pig Breeding Station. They found out that Ashanti Black pigs fed on varying levels of the meal have higher daily feed intake, average daily gain (ADG) and feed conversion ratio (FCR) than the control without the leaf meal.

2.5.1.11 CASSAVA AS AN ENERGY SOURCE IN PIG DIET

Cassava is one of the major root crops of humid and semi–humid tropical countries. It can tolerate high level of drought and soils with marginal fertility. It is an important food crop for many communities in tropical Africa, Latin America and the Caribbean. It produces higher level of energy than other food crops such as rice, maize, wheat and sorghum. According to Coursey and Hayes (1970) its energy production is rated at 250 Kcal./ha/day, as compared to 140, 176 and 110 Kcal/ha/day for sorghum, rice and wheat respectively. Cassava is a good substitute for maize meal in terms of energy supply for all classes of pigs (Oyenuga and Opeke, 1957; Modebe, 1963; Maner,1972; Tewe,1982; Adegbola, 1977 and Nghi, 1986). Its main problem is the presence of hydrocyanic acid which is poisonous to the animals when consumed in large quantities and in the fresh state. However, with heat treatment or fermentation the cyanide level is reduced to acceptable level of less than 100 ppm. Cassava, when fed as a sole source of energy, gave an average growth rate in the range of 533-556 g/day for restricted fed pigs and 551-737 g/day for those fed *ad-libitum*. Comparing the performance of pigs fed on cassava- based diet with those fed on a commercial diet, there were no significant differences in daily weight gain (ADG) and feed conversion ratio (FCR). Also, carcass characteristics were not significantly influenced by the diet (Kekule, 1988). Babyegewa (1980) reported improved dressing percentage with increasing levels of cassava in pig diet.

2.5.1.12 CASSAVA LEAF MEAL

Okai *et al.* (1984) on analysis of cassava leaf found it to be rich in nutrients and recommended its use to feed pigs and other livestock to supply protein, energy, minerals and vitamins. The leaves contain high levels of essential and non-essential amino acids, proteins and minerals. Cassava leaf contains, 21.4% CP; 11.9% EE; 7.9% Ash; 37.3% NDF; 28.1% ADF; 3.41% Ca, 0.72% P and 4807.4 kcal./kg (Okai, et al., 1984). The fresh leaves contain some amount of hydrogen cyanide but when dry the level reduces from 1210 pmm to 30 ppm (Tewe, O.O., 1982).

2.5.1.13CASSAVA PEEL MEAL

Cassava peel is a major by-product of cassava root processing. It is used to feed pigs, poultry and other livestock. It is reported to contain 4.2% CP; 10% CF and 86% DM (Okai, 1998).

2.5.1.14 CASHEW (*Anarcadium occidentale*)

It is a hardy, drought resistant plant commonly grown in Latin America, Cuba, Africa, Spain, etc. it thrives well in a variety of soils and climatic conditions. The most suitable soils are sandy and lateric soils. The average annual rainfall should range between 87.5 cm-375cm. it needs dry spell during fruiting period.

The nut is used to make confectionary products or as dessert. The juice is used to make wine when left to ferment. Cashew nut contains fatty acids such as myristic, oleic, linoleic and linolenic acids; and amino acids such as lysine, methionine, histidine, arginine, valine, etc. Also, it contains vitamins C, carotenoids and minerals such as Cu, Mg and P.

2.5.1.15 CASHEW APPLE WASTE (DRIED CASHEW PULP)

Cashew apple waste is a by-product obtained when the juice is extracted from the apple. It contains 47.2% CF, 4.0% ash, 1.0% Ca, 1.36% P and 18.7% CP (La Van Kinh *et al*., 1997)

2.5.2 FIELD CROPS AND THEIR BY-PRODUCTS

2.5.2.1 GROUNDNUT CAKE (GNC)

Groundnuts are treated in one of two ways to produce groundnut cake; the continuous pressure and solvent extraction treatment. Groundnut cake has moderate cellulose content of 5 to 7%. Residual oil contents are variable, according to the technique of preparation: from 4 – 8% for the expellers and 1% for the extraction cakes. Crude protein contents are fairly high: i.e. 45% on the average for expellers and 50% for extraction cakes. However, the latter are poor in methionine and lysine (Say, 1987). 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 the animals that eat these cakes. However, if it is aflatoxin-free, it can be used extensively; up to 30% in feed intended for pullets and layers. However, 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. In addition, groundnut cake can help to reduce the demand for the major protein source, fish meal and thus reduce the cost of feeding pigs and poultry.

2.5.2.2 GROUNDNUT SKIN MEAL (GSM)

Groundnut skin meal is obtained after roasting the seed and removing the skin. The product contains a very small fraction of broken pieces of kernel and some of the groundnut 'eye' (germ). The GSM contains 18.8% CP, 24.8% EE and 4.4% Ash. Aflatoxins, which are toxic substances, have been detected in GSM and its accumulation in GSM could result in poor growth performance. It must also be well stored to prevent the material from going rancid (Okai *et al.*, 1994b). However, rat, poultry and pig experiments have shown that it can be a satisfactory feed ingredient providing both protein and energy. Unfortunately, it contains tannins and therefore diets containing GSM have poorer CP digestibility (Okai *et al.*, 1984; Atuahene *et al.*, 1989). Gohl (1981) stated that GSM has a bitter taste and can only be used in small quantities in pig feeds.

Okai *et al.* (1998) used Groundnut skin meal (GNS) to feed pigs. The experimental result showed reduction in feed cost. GNS was found to contain 18.8% CP, 24.8% EE, and 4.4% ash.

2.5.2.3 SOYABEAN MEAL (SBM)

Soyabean meal or soybean cake plays an important role in animal production especially, in industrialized countries. In the U.S.A. and Europe for instance, soyabean cake is a common feedstuff as explained by its use instead of other cakes in poultry feeding, in which it covers 95% of the cake requirement (Say, 1987).

Soyabean meal is rich in 'indispensable' amino acids, notably, lysine. It contains about 42% CP, 2% fat and 7% cellulose. This cellulose is partly digested by monogastric animals. Soyabean cake must, however, be supplemented with methionine. It can be used in large proportions or quantities of the order of 30% and 20% for growing poultry and layers, respectively.

Banerjee (1988) reported that SBM is a poor source of the B-Vitamins, which must be provided either as supplement or in the form of an animal protein such as fish meal. He cautioned that failure to supplement, results in sows producing weak litters, which grow slowly because of reduced milk yield. Older pigs show in-coordination and failure to walk. On such diets, breeding hens produce eggs of poor hatchability and poor quality chicks; such chicks may also have an increased susceptibility to haemorrhages owing to shortage of Vitamin K.

Soyabean meal also contains a number of toxic, stimulatory and inhibitory substances, which are:

(i) goitrogenic material found in the meal. Its long-term use may result in goiter in some animal species.

(ii) It contains antigens, which are especially toxic to young pre-ruminant livestock.

(iii) A trypsin inhibitor which affects the digestibility of protein especially in monogastric animals.

(iv) Haemogglutinin, which agglutinates red blood cells in rats (Banerjee, 1988)

2.5.2.4 COTTON SEED CAKE (CSC)

Cotton seed cake contains protein of high quality but its content of cystine, lysine and methionine is low (Banerjee, 1988). McDonald *et al.* (1995) added that lysine is the first limiting amino acid in CSC and it has a high phosphorus (P) to calcium (Ca) ratio (6:1). This material contains variable (0.3 – 20 g/kg DM) amounts of a toxic compound, gossypol, a polyphenolic substance (McDonald *et al.*, 1995).

In monogastric animals, toxicity is indicated by symptoms including anorexia, emaciation and death. Death may result from both acute and chronic effects. For poultry and pigs, it is generally accepted that the level of free gossypol should not exceed 50 – 100 kg/tonne (McDonald *et al.*, 1995). Banerjee (1988) indicated 0.03% as the level of free gossypol that should not be exceeded in pig ration. If the percentage of cottonseed meal exceeds 9%, it will lead to mortality of the growing swine due to the presence of gossypol. In laying chickens, even low levels of free gossypol may cause an olive discoloration of the yolk if eggs are stored (Atuahene *et al.*, 1989; McDonald *et al.*, 1995). However, gossypol may be inactivated by the use of ferrous sulphate and other iron salts (Banerjee, 1988 and McDonald *et al.*, 1995).

2.5.2.5 PLANTAIN/BANANA

Bananas are mainly used in feeding pigs; which eat them with relish when they are ripe. The organic matter digestibility of green bananas in pig diets is 70% for the whole green fruit, 90% for the peels of the green fruit and is even higher for the ripe fruit. However, ripe bananas fed in large amounts may cause diarrhoea (Gohl, 1981). However, in Ghana bananas are mainly for human consumption. Banana is usually fed to pigs *ad libitum* with about 1.2 kg of concentrate (10 – 22% CP). However, pigs fed banana tends to have less carcass fat. Mature plantains could be fed in the same way. Okai (1998) reported that Ghana is a major producer of plantains, the bulk of which is processed in the green (mature) or yellow (mature, ripe) form to make local dishes. He added that the green peels which are usually discarded is utilized as feed supplement by both ruminants and non-ruminants livestock producers. However, data obtained at KNUST indicate that the peels from the ripe plantain (RPPM) can be a good source of energy for growing pigs. In an experiment, the RPPM constituted 0, 10 and 20% of the diet as direct replacement for maize and the growth performance data after four (4) weeks of feeding were similar. The RPPM diets were cheaper because it is a by-product, which is usually discarded (Okai *et al.*, 1991). Banana leaves can be used as an emergency feed for ruminants, however, owing to the presence of tannins, the digestibility progressively decreases. Banana pseudostems (trunks) can be also fed fresh or chopped and ensiled to feed cattle and pigs (Gohl, 1981).

2.6 CEREAL CROPS AND THEIR BY-PRODUCTS

Energy in animal diets is derived from three sources: cereals, root crops and animal/plant lipids. Cereal grains are the most important sources of energy in animal diets; they are without exception, rich sources of carbohydrates, primarily starch. They include maize, sorghum, millet, rice, oats, barley and wheat bran (McDonald *et al.*, 1995). The general characteristics of cereal grains are as follows:

- Moisture: 80-90% (fresh grain), or 12-14% (well-dried).
- Crude protein: generally from 8 to13%. However, some wheat cultivars may have as high as 20% protein or more. Cereal proteins are generally deficient in essential amino acids, especially lysine and methionine. Maize is also

deficient in tryptophan. This can however, be corrected by the use of high quality protein maize called Obatanpa.

- Ether extracts: It is very low from 2 to 5% only. The lipids are highly unsaturated and are mainly oleic and linolenic acids.
- Crude fibre: It is variable; low in maize but high in rice and oats due to the presence of haulm.
- Minerals: Phosphorus in grains are largely unavailable due to formation of complexes with phytic acid; other minerals are present in highly varying amounts.
- Vitamins: Cereals are generally good sources of vitamins E and B_1.

Sorghum is rich in cellulose and less in fat. However, it may contain tannins. Cereal by-products are the discarded "waste" resulting from the processing of cereal grains to produce human food and pito mash. Among the most common ones in Ghana are brewers' spent grains, sorghum spent grains (pito mash), wheat bran, rice bran, and bakery waste including discarded biscuits. With the exception of bakery waste and maize, this items have high fibre content, thus making them poor sources of energy (McDonald *et al.*, 1995).

2.6.1 SORGHUM AND SORGHUM BY-PRODUCTS AS CEREAL ENERGY SOURCE IN PIG DIET

Sorghum is a crop of the dry tropics. Its embryo is rich in protein, lipid, minerals and vitamin B. Processing methods that remove the outer pericarp proportionately decrease the protein, cellulose, lipid and mineral contents. In matured seeds the proportion of protein nitrogen in the endosperm increases, the composition of the endosperm storage protein changes, glutamic acid and proline levels increase while lysine, methionine and other basic amino acid levels decrease in proportion to the total nitrogen (Hulse *et al.*, 1980). Lysine is the limiting amino acid in sorghum. Digestibility of normal sorghum protein is varied. Sorghum, if solely fed to animals lead to high excretion of nitrogen, calcium and phosphorus. The nutritional quality can however, be improved if there is supplementation with synthetic lysine or supplementary ingredients such as rice meal, legume flours or when animal proteins are added (Hulse *et al.*, 1980).

Okai (1998) reported that sorghum or guinea corn is readily available in Ghana but usually, its high price does not encourage its use as an alternative feedstuff by livestock farmers. This is because of a high demand for the brewing of the local beer called "Pito". Sorghum contains tannins, which depresses the digestibility of feeds (Say, 1987). The tannin content varies from 0.2 to 3% depending on the cultivar. It therefore follows that performances obtained with sorghum- based rations are variable, and on the whole, not as good as those obtained with maize. Sorghum spent grains, also called "Pito" mash, is the fibrous residue obtained in the production of the local beer called "Pito". This by-product is very common in the Northern sector of Ghana. It is usually available in the wet form for use by livestock and poultry farmers. The limited research data on this by-product would tend to suggest that it is a reasonably good feed ingredient for both pigs and poultry. However, its high moisture content could limit the dry matter intake of pigs and also serve as a good medium for mould growth (Okai, 1998).

The nutrient composition of pitomash vary according to the variety of sorghum and the accuracy of the analysis. Analytical results obtained from research work carried out at the Department of Animal Science, KNUST (Okai *et al.*, unpubl.) show the following composition of nutrients: 11.4-24.3% CP, 2.6-8.9%CF; 2.6-15.9% EE; 0.03% Ca; 0.28% P; 90.0% DM and 3333 kcal./kg DE.

2.6.2 WHEAT BRAN

Wheat bran is produced in large quantities as a by-product of the flour milling industries in Ghana (Okai, 1998). Wheat bran contains about 11% CF and 15-16% CP (McDonald *et al.*, 1995). Wheat bran is highly palatable and has a laxative effect. Its amino acid balance is superior to that of the whole wheat and improves with increasing rate of milling. It is extremely high in P, but low in Ca, so that nutritional imbalance occurs if wheat bran is a major component of the diet.
It contains niacin, but the niacin present is almost completely unavailable (Pond *et al.*, 1991).

Wheat bran is regarded as a good feed ingredient and a source of fibre in pig and poultry diets (McDonald *et al.*, 1995). It is quiet common to have pig diet containing at least 25% wheat bran. Data available from KNUST indicates that finishing pigs can be fed diets containing as much as 70% wheat bran. Though there was a significant decline in growth rate, carcass traits were better and such diets were found to be cheaper and led to reductions in feed cost per kg weight gain (Okai *et al.*, 1995). Say (1987) also reported that wheat bran may be included in broiler feeds at a rate of less than 25% and in layers and 8-20 week-old pullets, a maximum rate of 40% wheat bran is acceptable. Donkoh *et al.*, (1999) concluded in their study with broiler chickens that under some price conditions, slower and less efficient gains from low-cost diets can be more economical than fast and more efficient gains from high-cost diets based on high amounts of conventional feedstuffs such as maize and fish meal.

2.6.3 RICE BRAN (RB)

Rice bran (11% CP) is readily available in Ghana. It is used as a substitute for wheat bran and also as a partial replacement for maize or the cereal component of the diet (Okai, 1998). Rice bran includes the pericarp and aleurone layers, germ and some endosperm. The proportion of these fractions determines its composition but generally it contains 13% crude fibre 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 characteristics 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. It was 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) found that up to 50% RB diets were satisfactory for growing-finishing pigs while Tuah *et al.*, (1974) had earlier reported reduced growth rate ($P<0.05$) when RB levels of 40%, 50% and 60% were fed to finishing pigs. For young, growing pigs (5 - 15kg), not more than 15 - 20% could be included in the diet (Pond *et al.*, 1991). Okai (1998) reported that for younger pigs, levels of more than 20% RB should not be exceeded. Say (1987) reported that RB 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 40%. However, RB tends to become rancid rapidly because of its relatively high content of unsaturated fats. However, defatted rice bran is available for use in some other countries (Banerjee, 1988 and McDonald *et al.*, 1995).

2.6.4 WET BREWERS' SPENT GRAINS (WBSG)/DRIED BREWERS' SPENT GRAINS (DBSG)

Brewers' grains are composed mainly of the insoluble barley (malt) residue resulting from the brewery industry after the extraction of the useful broth (McDonald *et al.*, 1995). The insoluble residue extraction can be achieved with or without pressure (Say, 1987). In its usual wet state, it contains up to 80% moisture and can be fed as such to pigs and ruminants (McDonald *et al.*, 1995). Say (1987) reported 80% water for the unpressed brewers' grains and 45% for the pressed residue. Moreover, it is a by-product, which has high level of protein (16 to 24% CP) and a high cellulose content (9 to 20% CF). Banerjee (1988) reported that the dried grains contain 18% CP and 15% CF. The dried brewers' grains contain 10% moisture and may be fed to poultry in limited amounts (McDonald *et al.*, 1995). Say (1987) stated that introduction of brewers' spent grains in large quantities (20%) increases the feed consumption per egg without reducing laying, and could reduce excessive liver fat. Also, layers can consume diets containing up to 40% of brewers' grains, while maintaining only a slightly reduced laying rate, but with an appreciably increased feed consumption. Okai and Lamptey (1983) reported that overdependence on fresh/wet brewers' spent grain for feeding pigs may not elicit any reasonable growth performance.

2.6.5 BAKERY WASTES INCLUDING DISCARDED BISCUITS

Dried bakery product is produced from reclaimed (unused) bakery products (Church and Pond, 1988). This product consists of flour sweepings, caked flour, discarded dough, and trimmings of dough, stale bread, buns, cakes and discarded biscuits. The nutrient composition, however, of these by-products vary with the relative amounts and the different kinds of ingredients used in the dough preparation. (Okai *et al.*, 1994a) defined dried bakery product as the product obtained from reclaimed bakery products that have been blended and processed to provide a product that contains 9.0 – 9.5% CP, 11 – 13% EE, 1.0 – 1.5% CF and 3.5% Ash.

Even though no accurate figures are as yet available, the few biscuit factories in the country produce substantial quantities of various by-products which are usually discarded as waste. These may contain about 10.6% CP, 0.7% CF, 4.0% EE, 72.3% NFE and 2.2% Ash. These bakery by-products could be useful as a replacement for some or all of the maize in pig diets (Okai *et al.*, 1994a). Church and Pond (1988) and Pond and Maner (1974) have reported that dried bakery products are excellent feed in starter rations for pigs as most of the energy is derived from starch, sucrose and fat. Research at KNUST has shown that a Dried Bakery Waste Products (DBWP) containing 10.6% CP can constitute up to 30% of the diet of pigs as a direct replacement for maize and thereby reduced feed cost. In another trial, discarded stale biscuits (DSB) were incorporated into pig diets at levels of 0, 15, 30 and 40%. Pig performances were similar but the DSB-containing diets were slightly cheaper. Carcass trait measurements were also similar for the four dietary treatments. Church and Pond, (1988) suggested that where dried bakery product is available, it could be used in dairy feed mixes.

2.6.6 MAIZE BRAN

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 the by-product obtained from the milling of maize, i.e. the removal of the hull. According to them, the hull contains about 1.5% CF. Okai (1998) mentioned that maize bran is very much sought after by both small and medium scale pig and poultry farmers. Also, it is a very good partial replacement for maize for poultry and pigs partly because the 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, 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, it can be scarce and the price may be prohibitive.

2.6.7 MILLET

The name 'millet' is frequently applied to some species of cereals, which produce small grains and are widely cultivated in the tropics and warm temperate regions of the world (McDonald *et al.*, 1995). Examples are *Pennisetum americanum* (Pearl or bulrush millet), *Panicum miliaceum* (Proso or broom corn millet), *Sectaria italica* (foxtail or birdfoot millet), *Paspalum scorbiculatum* (Kodo or ditch millet and *Echinochlo crusgalli* (Japanese or barnyard millet).

The composition of millet is very variable; the CP content being generally in the range of 100-120 g/kg DM, the EE 20 – 50 g/kg DM and CF 20 – 90 g/kg DM.

Millet has a nutritive value very similar to that of oats and contains a high content of fibre owing to the presence of hulls which are not removed by ordinary harvesting methods (McDonald *et al.*, 1995). Gohl (1981) reported that in spite of the varied chemical composition, all millet are used similarly. It was advised that the hard seeds should be ground or crushed before being fed to cattle and hogs, however, whole seeds or unthreshed bundles can be fed to poultry, although whole seeds are about 5% less digestible for poultry than ground seeds are. In addition, millet is relished by all kinds of livestock. Gohl (1981) however warned that *Paspalum scrobiculatum* variety seeds are reported to cause poisoning; it seems that the husk and testa of the small seeded varieties as well as unripe seeds can be toxic. Finger millet is inferior in feeding value and should not constitute more than 50% of the grain content of the ration.

2.7 INFERENCE FROM LITERATURE REVIEW

- Pig production is highly influenced by feed cost and level of nutrition to satisfy the requirements of the animal.
- There are different sources of nutrients for pigs.
  - (i) Carbohydrates and fats and oils supply the needed energy for physical and physiological activities.
  - (ii) Protein sources supply the necessary amino acids for growth, repair and development of cells and tissues of pigs.
  - (iii) Minerals and vitamins play key roles in the biochemical activities of pigs. The enzyme system needs minerals and vitamins in small amounts to regulate bodily functions and when deficient results in abnormalities and malfunctioning of organs of pig.

- Plant leaves, legumes and some AIBPs serve as important sources of feed for monogastric animals such pig and poultry, e.g. cassava leaves, *Leucaena* leaves, *centrosema*, copra cake, sorghum spent grain, cashew pulp etc.
- More research is going on with other AIBPs not yet used in feeding trials.

2.8 OBJECTIVES

- To evaluate the growth performance and carcass characteristics of pigs fed diets containing some selected AIBPs.
- To assess the economics of production when the formulated diets are fed to the pigs.

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 from 19th September to 19th December 2007. Kumasi is located in the south-central part of the country. The climate is hot and humid with mean temperatures varying from 24.5^{0}C in August to 28.0^{0}C in February with an annual mean of 26.3^{0}C. The mean minimum monthly temperature (20^{0}C) is recorded in December while the maximum monthly temperature (34.0^{0}C) occurs in February. Rainfall is bimodal. The major rains occur 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%.

3.2 SOURCES OF FEED INGREDIENTS USED IN THE STUDY

The dried cashew pulp (DCP) used in this study was obtained from the Cocoa Research Institute's Station at Bole in the Northern Region of Ghana. The processing involves sun-drying, during which the sliced pulps (sliced when fresh) were constantly turned over. They are dried to a moisture content of about 15%. Cassava leaves were obtained from local cassava farmers, and air-dried (dried under shade) to a moisture content of 13%, Cassava peels and "pito" mash were obtained from various "gari" processors and "pito" brewers respectively in and around the Kumasi Metropolis and sun dried. All the dried selected AIBPs used in the study were then ground in a hammer mill to produce the various meals which were then stored in polythene sacks until used in compounding the feed. The contents of all sacks were thoroughly mixed. One kilogram of each of the AIBPs were then taken and stored in air-tight jars for chemical analysis.

Table 3.0 shows the chemical analysis of the selected AIBPs used in the experiment.

FEED TYPE (AIBP)			NUTRIENTS (%)			
-	DM	CP	EE	CF	Ca	P
Cassava leaf	83.8	24.9	12.0	18.2	3.6	0.8
Cassava peel	85.8	4.6	0.9	4.6	0.4	0.8
Pito mash	88.1	24.8	15.9	8.9	0.05	0..3
Cashew pulp	82.7	7.9	10.0	11.6	1.4	1.7

3.3 EXPERIMENTAL ANIMALS, HOUSING, DIETARY TREATMENTS AND MANAGEMENT

Twenty-four (24) Large White weaner pigs comprising 16 entire males and 8 females with a mean initial live-weight of 11.0 kg were used in the study. The pigs were divided into four groups with six pigs in each group. They were balanced for sex, litter origin and live weight. There were four dietary treatments designated, A_1(control), A_2, A_3 and A_4. The diets were prepared to be isonitrogenous and isocaloric. The pigs were randomly allocated to the four dietary treatments. There were three replications with two pigs per replicate. They were housed in concrete floored pens measuring 3.6 m x 3.1 m x 1.0 m. They were provided with concrete feeders and watering troughs. The design used was completely randomized design (CRD). At the start of the study the pigs were dewormed with "Levamisol" at a dosage of 3 ml per pig and treated of ectoparasites using "Drastic Deadline" (pouron) at an application dosage of 5 ml per pig. Thereafter, they were given monthly treatments for worms and ectoparasites.

Table 3.1 shows the composition of the experimental diets. The pigs were housed in pairs to encourage group feeding (Pigs normally feed better in groups). The pigs were fed *ad-libitum*. Throughout the study period. All the diets were offered to the pigs in weighed quantities once daily at 08.00 hours throughout the trial period. The animals had free access to water.

Pigs were housed in pairs in pens to encourage group feeding, collection of left over feed, weighing and observation and thus, enhance their growth performance. Pigs were fed *ad libitum.* 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 to the amount of daily feed intake.

Table 3.1: Composition of Experimental Diets

INGREDIENTS, (g kg^{-1})	TREATMENTS			
	A_1 (control)	A_2	A_3	A_4
Maize	600	240	180	0
Dried Cashew Pulp	0	100	120	150
Fishmeal	50	100	100	60
Soyabean meal	110	0	0	60
Wheat Bran	230	0	0	50
Cassava leaf meal	0	140	150	160
Pito mash	0	350	360	370
Cassava peels	0	60	80	140
Oyster Shell	4.0	4.0	4.0	4.0
Common Salt	4.0	4.0	4.0	4.0
[1]Vitamin/Mineral Premix	2.0	2.0	2.0	2.0
Composition calculated, (g/kg DM)				
Crude Protein	182.0	181.0	181.3	181.1
Crude Fibre	42.0	52.0	56.0	62.0
Ether Extract	41.0	53.0	54.0	52.0
Calcium	7.0	10.0	14.0	13.0
Phosphorus	7.0	5.0	5.0	6.0
DE (MJ kg^{-1})	17.64	16.62	16.42	16.42
Analyzed Composition, (g/kg DM)				
Crude Protein	188.0	185.0	179.0	186.0
Ether Extract	56.9	57.4	58.7	59.1
Crude Fibre	38.0	96.0	120.0	150.0
NDF	461.0	463.0	463.0	505.0
ADF	73.0	184.0	277.0	249.0
Ash	61	101	101	107

1 Vt. A (800IU), Vit. D (300IU), Vit E (81IU), Vit K (2mg), Vit B_1 (1mg), vit B_2(2.5mg), VitB $_{12}$(5mcg), Niacin (10mg), Panthothenic acid (5mg), Anti oxidant (6mg), Folic acid (0.5mg), Choline (150mg), Iron (20mg), Manganese (80mg), Zinc (50mg), Cobalt (0.225mg), Iodine (2mg), Selenium (0.1mg)

3.4 CHEMICAL ANALYSES

The empirical proximate composition of the ingredients used were obtained from McDonald *et al.*, (1990) and NRC (1998). The proximate analysis of the selected AIBPs were carried out using the standard procedures of the Association of Official Analytical Chemists (1990). Acid Detergent Fibre (ADF) and Neutral Detergent Fibre (NDF) contents (Georing and Van Soest, 1970) were also analyzed for the AIBPs samples. Calcium and Phosphorus were not analyzed but calculated from empirical data. The metabolizable energy values of the samples of AIBPs were calculated from their chemical composition using the equation of Noblet and Perez

(1993); ME= 4.369-10.9 x ash% + 4.1 x EE% - 6.5 x CF%. Digestible energy (DE) values were estimated using the equation, DE=ME/0.96. or DE = 4.443 – 6.9 x ash% + 3.9 x EE% - 4.0 x NDF.

3.5 PARAMETERS MEASURED

The performance of the animals was monitored in terms of feed consumption, weight gain and feed to gain ratio throughout the 91-day period. Economics of production was also computed.

3.5.1 AVERAGE DAILY FEED INTAKE

This was calculated as ∑ (FS - FL) kg/TND where FS is the amount of feed allowed daily to pigs in each pen, FL is the feed left over after feeding each day, TND is the total period under review in days and ∑ is a summation. In the calculation for ADFI the average for the two pigs were taken.

3.5.2 AVERAGE DAILY GAIN (ADG)

This was calculated as ∑ (FW - IW) kg/TND 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 TND is the total period under review in days.

3.5.3 FEED CONVERSION RATIO

This was calculated as ∑ (FS-FL) kg/TND/ ∑ (FW-IW)kg/TND. i.e. total feed intake/total weight gain.

3.5.4 ECONOMICS OF PRODUCTION

Economics of production was calculated based on the feed cost per kg diet and feed cost per kg live weight gain. Feed cost per kg for each of the experimental diets was calculated based on the prices of the ingredients at the time of the trial. 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.

3.5.5 CARCASS CHARACTERISTICS

At the end of the 91-day feeding period, 12 of the best performing pigs (3 from each the treatment) were slaughtered to evaluate the carcass quality. Prior to slaughtering, the pigs were fasted overnight but had access to water. After slaughter, carcasses (without the head and trotters) were eviscerated, weighed and chilled in cold room (4 °C) for about 24 hours. Each carcass without the head and trotters, was then cut into two equal halves and measurements taken from the left half as recommended by Eusebio (1980). The following carcass data were determined:

3.5.6 DRESSING PERCENTAGE

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

3.5.7 CARCASS LENGTH

After splitting the carcass into two, the distance between the first rib of the left half and the anterior edge of the pubis symphysis gave the carcass length.

3.5.8 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.

3.5.9 LOIN EYE MUSCLE AREA

This was obtained from a tracing of a cross-sectional area of the loin eye muscle area (*Longissimus dorsi*) taken on the muscle between the 12th and 13th rib. The area was described on a tracing paper and was later measured with a [2]planimeter.

3.5.10 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 live weights to obtain relative weights.

3.5.11 WEIGHT OF HAM, SHOULDER, THIGH AND BELLY

The weight of the ham, shoulder, thigh, belly and organ characteristics were also measured in absolute weights.

3.5.12 STATISTICAL ANALYSES

The dietary treatment effects on the parameters measured were statistically analyzed. The computations were performed using the general linear models procedure of the Statistical Analysis System Institute Inc. (1987). Differences between means were determined by the use of the Duncan's Multiple Range Test (Steel *et al*., 1997).

[2] Planimeter: Instrument used to measure loin eye area. Manufacturers: Albrit Company, Great Britain.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 CHEMICAL COMPOSITION OF EXPERIMENTAL DIETS.

The crude protein contents of the analyzed experimental diets were similar (Table 3.1). The dietary protein levels for the weaner pigs with average initial weight of 11.0kg was 18%. This protein level falls within the range of 16-22% for weaner pigs within the weight range of 10-20 kg recommended by NRC (1998). The crude fibre contents of the dietary treatments of A_2 , A_3 , and A_4 which were meant to replace maize were higher than that of the control diet. Feed resources such as pito mash, dried cashew pulp, cassava peel and cassava leaf meal contain relatively high amounts of fibre. The ash content of dietary treatments A_2, A_3 and A_4 were generally higher than that of the control diet. The ether extract contents of the control diet (A_1) and diets based on "pito" mash, dried cashew pulp, cassava leaves and cassava peels (A_2, A_3 and A_4) were however, similar.

4.2 HEALTH OF EXPERIMENTAL PIGS

The pigs, in general, consumed their daily allowances of experimental diets and remained in apparent good health throughout the period of study with the exception of two pigs, (one each from A_2R_2 and A_3R_3) that develop minor ill – health of abscess and brown scaly patches on the face and skin respectively. The abscess was opened and the pig treated with 1.0ml of Penstrep and Oxytetracycline spray while 1.0ml each of Chloramphenicol (40%) and Penstrep were administered on the other pig. They recovered in few days. Feed intake was not affected by the sickness. There were no health-related problems or mortalities during the experiment that could be attributed to the various dietary treatments.

4.3 GROWTH PERFORMANCE OF PIGS

The general performance of pigs is presented in Table 4.1

Table 4.1: The Growth Performance and Economy of Gain of Pigs on the Dietary Treatments

	DIETARY TREATMENT				
PARAMETER	A_1	A_2	A_3	A_4	SEM
No. of pigs	6	6	6	6	-
Initial weight (kg)	11.08	10.83	10.83	11.00	0.768
Mean final weight (kg)	52.91^a	31.58^c	34.83^{bc}	41.67^b	2.505
Mean total weight gain(kg)	41.84^a	20.75^c	24.00^{bc}	30.67^b	2.017
Mean total feed intake (kg)	142.24	109.81	134.19	143.01	10.580
Duration of expt.(days	91	91	91	91	-
Daily feed intake (DFI) (kg/day)	1.56	1.21	1.47	1.57	0.118
Average daily gain (ADG) (kg/day)	0.46^a	0.23^c	0.26^c	0.34^b	0.042
Feed Conversion Ratio (FCR) – Feed/kg live weight gain	3.38^b	5.29^a	5.59^a	4.64^{ab}	0.340
Cost/kg of diet (GH¢)	0.3294	0.2972	0.2898	0.2578	-
Feed cost/kg gain (GH¢)	1.11^c	1.57^a	1.62^a	1.20^b	0.783

- a,b,c: Means in the same row followed by different letters are significantly different (P< 0.05)
- SEM – standard error of means.

4.3.1 FEED INTAKE

The different dietary treatments did not exert any significant (P>0.05) influence on the daily feed intake of pigs. The daily feed intake ranged from 1.21 kg for pigs on dietary treatment A_2 to 1.57 kg for those on dietary treatment A_4. Results of the study indicated that pigs on the control diet (A_1) consumed similar amount to those on dietary treatment A_4 but A_2 consume less. The non-significant effect of dietary treatments on feed intake of the pigs suggests that pigs will readily consume diets in which the maize portion has been wholly replaced by agro-industrial by-products.

4.3.2 LIVEWEIGHTS, BODY WEIGHT GAINS AND FEED CONVERSION RATIO

The mean final body weights of pigs after the 91-day feeding period were 52.9, 31.6, 34.8 and 41.7 kg for the pigs fed the control diet (A_1) and those on dietary treatments A_2, A_3 and A_4, respectively. The differences were significant at ($P<0.05$) level Average daily gain (ADG) values also differed significantly (<0.05) among the four dietary treatments. Comparing the performance of pigs fed the four diets, it is quite clear that the lowest rates of gain were observed in pigs fed dietary treatments A_2, A_3 and A_4. The mean values recorded were 0.46, 0.23, 0.26 and 0.34 kg/day for pigs fed the control and those on dietary treatments A_2, A_3 and A_4, respectively. Similarly, inclusion of various amounts of the agro-industrial by-products had significant impact on the efficiency of feed utilization with pigs on dietary treatments A_2, A_3 and A_4. The poorer feed conversion ratios of 5.29, 5.59 demands improvement on A_2 and A_3.

Even though there were no significant differences in feed intake among pigs on the various dietary treatments, the poorer ADG and feed conversion values observed in the pigs, especially for those on treatments A_2 and A_3, may be due to the slightly lower feed intake and poorer feed quality. The poorer growth performance with the inclusion of high amounts of AIBPs in pig diets to replace maize, a high energy feed ingredient, might be partly due to the high contents of fibre and decreased energy concentrations in diets A_2, A_3 and A_4 (Table 3.1) Various studies (Kovesdy, 1967; Baskett, 1969) have indicated that with additional crude fibre in the diet, reduction in weight gains occurs in pigs. The recommended crude fibre level in the diet of grower – finisher pigs is 6% (NRC, 1998). In the case of weaners it should be lower than this value since their GIT is not well developed to handle higher levels of fibre.

McDonald *et al.* (1995) reported that the fibre fraction of a food is one of the factors which have the greatest influence on its digestibility. According to Graham and Aman, (1987 a,b) higher amount of fibre in a diet decreases digestibility of starch, fat, crude protein and minerals. In addition, Sauer *et al.* (1991) have reported that fibre may also absorb amino acids and peptides, and withhold them from absorption. Furthermore, the water-binding capacity of fibre has been reported to reduce diffusion of the products of digestion towards mucosal surface (Dierick *et al.*, 1989). Thus, the lower growth rates and the reduced efficiency of feed served to pigs on diets containing various amounts of agro-industrial by-products might be due to the reduced amount of protein and other nutrients available for growth, particularly when true growth is considered as deposition of protein. This defect ultimately affected the efficiency of feed conversion into tissue.

4.4 FEED COST AND ECONOMY OF GAIN

Feed cost per kg declined with the inclusion of the various agro-industrial by-products to replace maize in pig diets. The values for diets A_1, A_2, A_3 and A_4 were GH¢0.3294, GH¢0.2972, GH¢0.2898 and GH¢0.2578 respectively. The decline in feed cost as the amount of maize in the diet was reduced by replacement with agro-industrial by-product, was due solely to the huge price disparities between maize and the agro-industrial by-products. On the other hand, feed cost per kg live-weight gain did not follow the trend observed for the dietary cost of feed/ kg. Pigs on the control diet (A_1) recorded better economy of gain than those fed the agro-industrial by-product-based diets. The control diet though numerically higher than A_4 diet, the weight gain value for A_4 was close (i.e. 1.11 versus 1.20). The appreciable growth rates of pigs on the control diet (A_1) and dietary treatment A_4 might have accounted for the superior economy of gain observed. The lower growth rates as well as the poor feed efficiencies, might have contributed to the poor economies of gain of pigs fed dietary treatments A_2 and A_3.

4.5 CARCASS CHARACTERISTICS

Table 4.2 shows the results for carcass parameters measured in this study. In almost all instances, except for the organ weight, there were significant ($P<0.05$) differences in the parameters measured for the pigs fed the control diet as compared to those on the other diets. Substitution of maize with various agro-industrial by-products significantly ($P<0.05$) decreased carcass weight.

With regards to dressing percentage, there were no significant ($P>0.05$) differences in pigs fed on AIBP-based diets. This result generally agree with other studies (Hochstetler *et al.*, 1959; Robinson *et al* 1964; Kovesdy, 1967), Hutagalung *et al* 1977, Seerley *et al.*, 1978) which stated that with increasing fibre levels in pig diets, there may be little or no effect on dressing percentage of pigs.

Table 4.2: Carcass Traits of Pigs Fed the Four Experimental Diets

Parameters	Dietary Treatments				
	Control (T_1)	T_2	T_3	T_4	SEM
No. of Pigs	3	3	3	3	-
Live weight at slaughter (kg)	56.80^a	34.50^b	38.33^b	45.33^b	2.46
Chilled dressed weight	36.33^a	17.83^b	19.33^b	23.83^b	2.09
Warm dressing percentage	65.44^a	52.67^b	51.73^b	54.78^b	2.17
Chilled dressing percentage	63.96^a	51.68^b	50.43^b	52.57^b	3.01
Carcass length (cm)	77.00^a	64.33^c	66.33^b	71.20^{ab}	1.43
Back fat thickness (cm)	1.84^a	0.78^c	1.04^b	1.00^b	0.18
Loin eye area (cm^2)	22.79^a	13.50^b	10.31^b	14.44^b	1.73
Shoulder weight (kg)	3.33^a	1.78^b	1.98^b	2.39^{ab}	0.25
Thigh weight	5.36^a	2.83^b	2.93^b	3.50^b	0.25
Loin weight	5.47^a	2.61^b	2.77^{bc}	3.57^c	0.24
Belly weight	3.49^a	1.54^b	1.75^b	2.32^b	0.25
Abdominal fat (kg)	1.32	0.29	0.52	0.44	0.306

Absolute values of some body components, kg

Head	3.87^{a}	2.66^{b}	2.75^{b}	3.11^{b}	0.18
Trotters	0.88^{a}	0.62^{b}	0.65^{b}	0.77^{ab}	0.39
Viscera	7.73^{c}	9.02^{b}	9.26^{b}	9.63^{a}	0.40
Full GIT	5.60^{c}	5.97^{bc}	6.23^{b}	7.27^{a}	0.37
Empty GIT	2.01^{c}	2.46^{ab}	2.50^{ab}	2.67^{a}	0.14
Heart	0.15	0.12	0.11	0.13	1.25
Liver	1.15	0.83	0.83	0.95	0.27
Kidney	0.11	0.12	0.13	0.14	0.02
Spleen	0.08	0.06	0.05	0.07	0.01

SEM - standard error of means
a,b,c - means in the same row followed by different letters are significantly ($P<0.05$) different.

Maize is high energy feed and when fed to pigs produces high back –fat thickness and carcass length as compared to the results had on pigs fed the AIBP-based diets (Table 4.2). The results agree with the findings of Skitsko and Bowland (1970b), Larsen *et al.,* (1960), and Hochstetler *et al.,* (1959). A possible explanation may be due to the lower energy content of the AIBP –based diets as compared to the basal diet. Higher concentration of NDF and ADF in diets bind water and limit diffusion of nutrients into tissues thus causing poor digestibility (Graham and Aman, 1987a,b; Sauer *et al.,* 1991)

The loin eye muscle areas for pigs fed the AIBP-containing diets were lower ($P<0.05$) than for those fed the control diet. It is likely that this is due to the relatively smaller sizes and the slower gain in weight of these animals.

The other carcass traits measured in this study (i.e. absolute weight of shoulder, thigh, loin, belly and head, with the exception of the weight of heart, liver, kidney and spleen) were significantly ($P<0.05$) affected by the dietary treatments, with pigs on the control diet registering higher values compared to those for the other treatments. This may be a reflection of the poor growth performance recorded by pigs fed the AIBP-based diets.

The absence of relatively high fibre AIBPs except wheat bran in the control diet could account for the lower values of full and empty gastro-intestinal tract weights of pigs fed the control diet. Maize is generally known to be less fibrous than the agro-industrial by-products used in this study, and the high fibre diets have been reported to cause thickening and enlargement and therefore increased weight of the GIT (Deaton *et al*., 1979; Okai *et al*., 1994b).

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

The objective of this experiment was to determine the effects of the use of selected agro-industrial by-products (AIBPS) in pig starter diets on feed cost, growth performance, carcass characteristics and economics of production.

After the 91-day trial period the following observations, conclusions and recommendations can be drawn;

1. The growth rate, weight gain and carcass characteristics of pigs fed on this diet (A_1) was superior to those fed on the AIBP- based diets. Pigs on A_4 diets showed good performance in terms of ADG, FCR, and economics of production among all the AIBP-based diets.
2. The comparatively high level of fibre in the AIBP- based diets led to development of heavier GIT for A_3 and A_4 fed pigs. The high fibre content of the AIBP – based diet produced less abdominal fat and back –fat thickness and less loin eye area (Table 4.2).
3. The inclusion of cassava peels, dried cashew pulp and pito mash to replace maize resulted in lower feed cost. The feed cost index for A_1, A_2, A_3, and A_4 were 100%, 90.22%, 87.97% and 78.26% respectively. The results showed that the control diet was most expensive while the A_4 diet was the least in terms of cost. The economy of gain was best for A_1 diet, while it was least for A_3 diet (GH¢1.11 versus GH¢1.62). The A_4 diet may be described as a diet with a high potential for achieving reduction in feed cost, increases in growth performance and economy of gain.

   In conclusion, though the A_1 diet was expensive it produced better economy of gain among all the treatments. Among the AIBP – based diets A_4 was superior to A_2 and A_3 in terms of ADG, FCR, and economy of gain and could lead to reduction in feed cost when all the diets were considered. The A_4 diet could be preferred to A_1 diet since the prices for conventional feedstuffs are normally high during the period of scarcity and at times are not available, in which case the better economy of gain for the A_1 diet would not be attainable at all times. A_2 and A_3 diets are not economical to use due to poor weight gains and economics of production.

It is recommended that the experiment be repeated to confirm the usefulness or otherwise of the selected AIBPs in feed formulation to reduce feed cost, increase growth rate and obtain an improvement in economy of gain. Exogenous enzymes and or microbes should be added to the diet to enhance digestibility of the fibre component of the diets. Also, enzymes such as phytase when added could hydrolyze phytic acids contained in predominantly plant diets which bind nutrients especially phosphorus and do not make them available to monogastric animals like pigs.

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7.0 APPENDICES

Appendix I

File name: 1 way completely randomized
ANOVA for initial weight of weanling pigs

Sources of variation	df	ss	Ms	F	p
Main effects					
Treatments	3	0.149625	0.046875	0.0198675	.9959 ns
Error	8	18.875	2.359		
Total	**11**	**19.016**			

Root MS error = sqrt (MS error) = 1.536
Mean Y = 10.938
Coefficient of variation (CV) = (Root MS error)/abs.(MY)* 100% = 14.045%
Lsd 0.05 = 2.892
Variance = 2.359375

Appendix II

File name: 1 way completely randomized
ANOVA for final weight of weanling pigs

Sources of variation	df	ss	ms	F	p
Main effects					
Treatments	3	800.708	266.90	10.634	.0036 **
Error	8	200.792	25.098		
Total	11	1001.5			

Root MS error = sqrt (MS error) = 5.0098
Mean Y = 40.25
CV = (Root MS error)/abs (Mean Y)* 100%= 12.446%
Variance = 25.0989
Lsd 0.05 = 9.433

Appendix III

File name: 1 way completely randomized
ANOVA for total feed intake

Sources of variation	df	ss	ms	F	p
Main effects					
Treatments	3	2168.225	722.741	1.614	.2612 ns
Error	8	3581.704	447.713		
Total	11	5749.929			

Root MS error = sqrt (MS error) = 21.159
Mean Y = 132.3108
CV = (Root MS error)/abs (Mean Y)* 100% = 15.992
Variance = 447.718
Lsd 0.05 = 39.839

Appendix IV

File name: 1 way completely randomized
ANOVA for weight gain

Sources of variation	df	ss	ms	F	p
Main effects					
Treatments	3	781.02	260.34	15.991	.0010 **
Error	8	130.246	16.281		
Total	11	911.266			

Root MS error = sqrt (MS error) =4.0349
Mean Y = 29.333
CV = (Root MS error)/abs (Mean Y)* 100% = 13.756%
Variance = 16.281
Lsd 0.05 = 7.597

Appendix V

File name: 1 way completely randomized
ANOVA for intestine (Full)

Sources of variation	df	ss	ms	F	p
Main effects					
Treatments	3	6.642	2.214	4.141	.0480 *
Error	8	4.278	0.535<		
Total	11	10.920			

Root MS error = sqrt (MS error) = 0.731
Mean Y = 6.516
CV =` (Root MS error)/abs (Mean T)* 100% = 11.223%
Variance = 0.535
Lsd 0.05 = 1.377

Appendix VI

File name: 1 way completely randomized
ANOVA for intestine (empty)

Sources of variation	**df**	**ss**	**ms**	**F**	**p**
Main effects					
Treatments	3	0.701	0.234	2.764	.1112
Error	8	0.676	0.084<		
Total	11	1.376			

Root MS error = sqrt (MS error) = 0.291
Mean Y = 2.409
CV = (Root MS error)/abs (Mean Y)* 100% = 12.064
Variance = 0.084
Lsd 0.05 = 0.547

Appendix VII

File name: 1 way completely randomized
ANOVA for loin eye area

Sources of variation	**df**	**ss**	**ms**	**F**	**p**
Main effects					
Treatments	3	25.0029	85.0009	7.081	.0122 *
Error	8	96.029	12.0036<		
Total	11	351.032			

Root MS error = sqrt (MS error) = 3.465
Mean Y = 15.26
CV = (Root MS error)/abs (Mean Y)* 100% = 22.704%
Variance = 12.0036
Lsd 0.05 = 6.523

Appendix VIII

File name: 1 way completely randomized
ANOVA for offal (whole)

Sources of variation	df	ss	ms	F	p
Main effects					
Treatments	3	6.117	2.039	3.119	.088 ns
Error	8	5.229	0.654<		
Total	11	11.347			

Root MS error = sqrt (MS error) = 0.809
Mean Y = 8.911
CV = (Root MS error)/abs (Mean Y)* 100% = 9.073%
Variance = 0.654
Lsd 0.05 = 1.522

Appendix IX

File name: 1 way completely randomized
ANOVA for lung

Sources of variation	df	ss	ms	F	p
Main effects					
Treatments	3	0.081	0.027	1.447	.2997 ns
Error	8	0.150	0.019<		
Total	11	0.231			

Root MS error = sqrt (MS error) = 0.137
Mean Y = 0.619
CV = (Root MS error)/abs (Mean Y)* 100% = 22.081%
Variance = 0.018
Lsd 0.05 = 0.257

Appendix X

File name: 1 way completely randomized
ANOVA for heart

Sources of variation	df	ss	ms	F	p
Main effects					
Treatments	2	0.00269	8.97e-4	1.436	.303 ns
Error	8	0.005	6.25e-4<		
Total	11	0.00769			

Root MS error	=	sqrt (MS error)	= 0.025
Mean Y	=	0.129	
CV	=	(Root MS error)/abs (Mean Y)* 100% = 19.35%	
Variance	=	6.25e-4	
Lsd 0.05	=	0.0471	

Appendix XI

File name: 1 way completely randomized

ANOVA for liver

Sources of variation	**df**	**ss**	**ms**	**F**	**p**
Main effects					
Treatments	3	0.2009	0.067	2.226	.1626
Error	8	0.241	6.25e-4<		
Total	11	0.442			

Root MS error	=	sqrt (MS error) = 0.0349	
Mean Y	=	0.129	
CV	=	(Root MS error)/abs (Mean Y)* 100% = 31.0%	
Variance	=	0.00122	
Lsd 0.05	=	0.0657	

Appendix XII

File name: 1 way completely randomized

ANOVA for kidney

Sources of variation	**df**	**ss**	**Ms**	**F**	**p**
Main effects					
Treatments	3	0.00249	8.3056e-4	0.683	.5871 ns
Error	8	0.00249	0.00122<		
Total	11	0.0122			

Root MS error	=	sqrt (MS error)	= 0.0349
Mean Y	=	0.129	
CV	=	(Root MS error)/abs (Mean Y)* 100% = 31.005%	
Variance	=	0.00122	
Lsd 0.05	=	0.0657	

Appendix XIII

File name: 1 way completely randomized

ANOVA for spleen

Sources of variation	df	ss	ms	F	p
Main effects					
Treatments	3	0.00149	4.972e-4	1.326	.332/ns
Error	8	0.003	3.75e-4-<		
Total	11	0.00449			

Root MS error = sqrt (MS error) = 0.0194
Mean Y = 0.0658
CV = (Root MS error)/abs (Mean Y)* 100% = 29.415%
Variance = 3.75e-4
Lsd 0.05 = 0.0365

Appendix XIV

File name: 1 way completely randomized
ANOVA for loin

Sources of variation	df	ss	ms	F	p
Main effects					
Treatments	3	15.480	5.160	21.640	.0003
Error	8	1.908	0.238<-		
Total	11	17.388			

Root MS error = sqrt (MS error) = 0.488
Mean Y = 3.603
CV = (Root MS error)/abs (Mean Y)* 100% = 13.555%
Variance = 0.239
Lsd 0.05 = 0.919

Appendix XV

File name: 1 way completely randomized
ANOVA leaf/Abdominal fat

Sources of variation	df	ss	ms	F	p
Main effects					
Treatments	3	0.773	0.258	6.404	.0161
Error	8	0.322	0.040<-		
Total	11	1.094			

Root MS error = sqrt (MS error) = 0.101
Mean Y = 0.413
CV = (Root MS error)/abs (Mean Y)* 100% = 24.455%
Variance = 0.0402
Lsd 0.05 = 0.378

Appendix XVI

File name: 1 way completely randomized
ANOVA for Back fat thickness

Sources of variation	**Df**	**ss**	**ms**	**F**	**p**
Main effects					
Treatments	3	1.929	0.643	5.076	.0294 *
Error	8	1.013	0.127<_		
Total	11	2.942			

Root MS error = sqrt (MS error) = 0.356
Mean Y = 1.165
CV = (Root MS error)/abs (Mean Y)* 100% = 30.549%
Variance = 0.127
Lsd 0.05 = 0.670

Appendix XVII

File name: 1 way completely randomized
ANOVA for carcass length

Sources of variation	**Df**	**ss**	**ms**	**F**	**p**
Main effects					
Treatments	3	287.023	95.674	91.637	.0027 **
Error	8	65.773	8.222<-		
Total	11	352.797			

Root MS error = sqrt (MS error) = 2.867
Mean Y = 69.717
CV = (Root MS error)/abs (Mean Y)* 100% = 4.113%
Variance = 8.222
Lsd 0.05 = 5.399