GROWTH PERFORMANCE, CARCASS CHARACTERISTICS AND BLOOD PROFILE OF PIGS FED DIETS CONTAINING TWO QUALITY PROTEIN MAIZE (GOLDEN JUBILEE AND ETUBI) AND TWO NORMAL MAIZE (LOCAL WHITE AND IMPORTED YELLOW) VARIETIES

By

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DECLARATION

I, Abdul-Rahaman Saibu Salifu, hereby declare that the submission is my own work towards the award of MSc. in Animal Nutrition and it contains no material which has been published by another person or being submitted for the award of any other degree of the University or elsewhere. However, work of other researchers used as sources of information were duly acknowledged in the text.

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DEDICATION

This work is dedicated to my brother, Master Saibu Salifu Salley.

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ABSTRACT

Two experiments were conducted to determine growth performance, carcass characteristics and blood profile of growing-finishing pigs and albino rats fed diets containing four different varieties of maize. In experiment I, twenty individually-housed, Large White pigs (12 males and 8 females) with an average initial body weight of 13.3 kg were allotted to the four dietary treatments labelled, Local Normal Maize (LNM), Imported Normal Yellow Maize (INYM), Golden Jubilee Maize (GJM) and Etubi Maize (ETM) using the Completely Randomized Design (CRD). The LNM diet was used as the Control. Each treatment was replicated five times, with a pig representing a replicate. Feed and water were offered *ad-libitum*. Average daily weight gains (ADG), average daily feed intake (ADFI) and feed conversion efficiency (FCE) were monitored weekly during the experiment. Pigs were slaughtered after attaining a body weight of 70+0.5 kg to determine carcass characteristics. There were no significant effects of diets on ADFI and FCE but ADG and feed cost per kg gain were influenced by the diets. The values were 0.64, 0.61, 0.56 and 0.60 kg and GH¢1.74, GH¢1.90, GH¢1.76 and GH¢1.75 for the LNM, INYM GJM and ETM treatments respectively. The values for LNM, GJM and ETM were statistically similar ($P > 0.05$). Values for carcass length, dressing percentage, shoulder, loin, belly, thigh, and backfat thickness were not statistically different ($P > 0.05$) between the four dietary treatments. However, there were significant differences ($P < 0.05$) in the values for heart, liver, spleen, full gastrointestinal tract (GIT) and the respiratory tract. These values were 0.19, 0.17, 0.21 and 0.22 kg (heart); 1.34, 1.26, 1.51 and 1.52 kg (liver); 0.11, 0.10, 0.14 and 0.11kg (spleen) and 7.88, 7.78, 6.99 and 7.80 kg (full GIT). The haematocrit (HCT), means cell haemoglobin concentration (MCHC), means cell haemoglobin (MCH) and platelets values were not affected ($P >0.05$) by the dietary treatments but the

haemoglobin (Hb), white blood cells (WBCs) and red blood cells (RBCs) values were affected ($P < 0.05$) by the dietary treatments. The values for the LNM, INYM and ETM diets were similar for the haemoglobin and red blood cells. Significant differences were not observed ($P > 0.05$) for the albumin, globulin, total protein, high density lipoprotein (HDL) cholesterol, low density lipoprotein (LDL) cholesterol, total cholesterol and triglycerides levels recorded. In experiment II, twenty individually-caged albino rats were used. Feed and water were provided *ad-libitum*. The ADG and FCE values were significantly influenced ($P < 0.05$) by the diets but the ADFI values were not affected by the diets. The improved ADG and FCE values were in favour of the yellow maize varieties. With respect to the carcass characteristics, significant differences were not indicated ($P > 0.05$) for the empty and full GIT, heart, respiratory tract, spleen and viscera weights. However, the empty stomach, kidney and liver values were significantly influenced ($P < 0.05$) by the dietary treatments in favour of the yellow varieties. The results indicated that using GJM and ETM varieties had the potential of economic savings of GH¢10.00 per metric tonne.

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LIST OF ABBREVATIONS

ADFI	Average daily feed intake
ADG	Average daily gain
AOAC	Association of Official Analytical Chemists
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo
CP	Crude protein
CRD	Completely Randomized Design
CRI	Crop Research Institute
CSIR	Council for Scientific and Industrial Research
DM	Dry matter
EDTA	Ethylene diamine tetraacetic acid
ETM	Etubi maize
FCE	Feed conversion efficiency
GAF	*Gmelina arborea* fruit meal
GH¢	Ghana cedis
GJM	Golden Jubilee maize
Hb	Haemoglobin
HCT	Haematocrit
HDL	High density lipoprotein cholesterol
IMF	Intramuscular fat
INYM	Imported normal yellow maize
KNUST	Kwame Nkrumah University of Science and Technology
LDL	Low density lipoprotein cholesterol
LNM	Local normal maize
MCH	Mean cell haemoglobin
MCHC	Mean cell haemoglobin concentration
MCV	Mean cell volume
NRC	National Research Council

PCV	Packed cell volume
QPM	Quality Protein Maize
RBC	Red blood cells
TFI	Total feed intake
WBC	White blood cells
WFI	Weekly feed intake

CHAPTER ONE

1.0 INTRODUCTION

Grain cereals such as maize, barley, wheat and sorghum supply the majority of the energy in diets fed to swine in most countries around the world (Pedersen *et al*., 2007). In Ghana, maize is by far, the most dominant of these grains because of it being produced in large quantities at the expense of other cereals. Because of its abundance, maize constitutes about 50-60 percent of a typical commercial swine and chicken diet (Osei *et al*., 199). However, maize cannot be a sole source of protein for swine because of its relatively low protein content and low levels of essential amino acids particularly lysine and tryptophan (Maner *et al.*, 1971; Burgoon *et al.*, 1992 and Beeson *et al.*, 1996). To achieve high productivity, maize-based diets fed to monogastrics have to be supplemented with expensive protein sources including fishmeal and soyabean meal both of which are not readily always available (Osei *et al.*, 1994; Okai *et al.*, 2001b). The locally available fishmeal which is usually made from anchovy is also a major source of protein in human diets in Ghana (Okai, 1988). The resulting competition has often led to high prices of some feed ingredients and consequently the cost of feeding pigs and poultry (Okai *et al.*, 2001a).

The discovery of both opaque-2 and floury-2 maize which have substantially higher lysine and tryptophan content than normal maize strains (Mertz *et al.*, 1964; Nelson *et al.*, 1965) had led to feeding trials on animals and positive results were recorded. Weanling rats fed on a diet of 90% opaque-2 maize gained weight more than three times faster than those fed on standard hybrid maize. The opaque-2 maize could substitute for added soyabean oil meal, (Mertz *et al.*, 1965a). Although, Opaque-2 maize had higher nutritive value (lysine and tryptophan), it had numerous problems such as reduction in

yields (10% or more), and slowly drying kernels and were more susceptible to insect pests infestations.

Researchers at the International Maize and Wheat Improvement Centre in Mexico (Centro Internacional de Mejoramiento de Maiz y Trigo, CIMMYT) developed a high lysine corn variety with a modified endosperm and named it Quality Protein Maize (QPM). Sproule *et al*. (1988) and Sullivan *et al*. (1989) reported that QPM has a higher nutritive value than normal maize when fed in low protein diets containing the same level of supplemental protein. Subsequently, Obatanpa, a locally developed variety of QPM, caught the attention of animal nutritionists in Ghana and elsewhere. Okai *et al*. (1992) observed that in diets where the sole source of protein was from maize, weanling pigs performed better on an Obatanpa-containing diet than on a normal maize diet. According to Osei *et al*. (1999), a starter feeding trial also showed improved performance in pigs fed the Obatanpa-based diets. In a phase- feeding experiment using Obatanpa, Okai *et al*. (2001b) indicated a reduction in fishmeal inclusion level without any adverse effects on growth performance and carcass qualities. Earlier, Osei *et al*. (1998) in a broiler experiment, showed that chicks fed a QPM-based diets performed significantly ($P < 0.05$) better than those on normal maize.

Four new varieties of QPM have been released by the Crop Research Institute of the Council for Scientific and Industrial Research (CSIR), Kumasi. Two of these varieties are "Golden Jubilee" (GJM) and "Etubi" (ETM), which, like all QPM varieties and hybrids, have increased concentrations of lysine and tryptophan compared with normal maize. In addition, GJM is a yellow open-pollinated variety while ETM is a white flint/dent hybrid. To accurately establish the feeding value of GJM and ETM, it is necessary to compare them with other commonly available maize varieties (Local Normal Maize and

Imported Normal Yellow Maize). This study therefore seeks to compare the effects of Local normal maize, Imported normal yellow, GJM and ETM- based diets on growth performance, blood profile and carcass characteristics of pigs and albino rats.

CHAPTER TWO

LITERATURE REVIEW

2.1 Growth and Development of Pigs

Growth as applied to animal production is often considered to be synonymous with irreversible increase in body weight of the animal from conception to maturity (Pond and Maner, 1974). Brody (1945) had defined growth as "the constructive or assimilatory synthesis of one substance at the expense of another (nutrient) which undergoes dissimilation" The growth rate of individual parts of the pig is not the same. McMeekan (1940) had shown, by dissection and carcass studies, that the head and shoulders reach mature size before the posterior parts of the body. Meaning early in life, the head and shoulder represent a higher proportion of the total body weight than they do later in life. Growth of tissues, organs and of the whole pig occurs in two phases, namely increase in number of cells (hyperplasia) and increase in size of cell (hypertrophy). Soon after conception most growth is by hyperplasia. Both hyperplasia and hypertrophy occur concurrently during late prenatal and early postnatal growth. At some point in postnatal life, cell division ceases (except in some tissues) and growth is by only hypertrophy. Development on the other hand, is the change in shape, form and function of animals as growth occurs (Whittemore, 1993).

According to Pond and Maner (1974) postnatal growth is in three phases and these phases are based on the liveweight changes rather than on ages. The phases are the starter phases (5-20kg), the grower (20-45kg) and the finisher phase (45-90 kg and above). The growth rate at the various stages is not the same. It changes as the pig increases in weight. Serres (1992) gave growth rates of 0.4 kg after weaning, 0.5 kg for 30kg liveweight, 0.6kg for up to 40 kg liveweight and 0.7 kg between 60 and 70 kg liveweight. Okai *et al.*,

(2001b) recorded an average of 0.50 kg for starter (8- 20kg), 0.64 kg for grower (20-50 kg) and 0.52 kg for finisher (50-70 kg).

2.2 Factors Affecting Carcass Characteristics

Meat quality is an essential trait in meat-producing animals especially pigs. Meat quality describes the attractiveness of meat to consumers, which includes colour, tenderness, water holding capacity, marbling and flavour (Shi-Zheng and Su-Mei, 2009). Studies have shown that intramuscular fat (IMF) content is one of the most important traits influencing eating quality characteristics (Verbeke *et al*., 1999). The IMF refers to the chemically extractable fat from a muscle of meat especially from adipocytes and myocytes (Shi-Zheng and Su-Mei, 2009). Consequently, research on IMF deposition in the muscles of pigs and other meat producing animals is currently one of the most important fields of study in meat (quality) science. Major factors influencing carcass characteristics are genetic, nutritional, non-nutritional and environmental factors.

2.2. 1 Genetic factors

Breed, genetics and sex of the pig greatly affect the performance potential. Barrows consume greater amount of feed and grow faster during the growing-finisher period compared to gilts but they are less efficient in converting feed into lean gain and would accumulate greater amount of carcass fat at slaughter weight. The pig's genotype sets an upper limit to lean growth or lean growth potential. Lean growth is higher in gilts than barrows during the grower-finisher phase with a difference of 5 % between gilts and barrows (De Lange, 1998). Watkins *et al.* (1977) reported a 2.2 % advantage for gilts in percentage lean cuts. Intact males are superior to gilts andbarrows in feed conversion efficiency, lean yield, daily liveweight gain and lean tissue growth rate (Table 2.1). Newell and Bowland (1972) reported significant ($P < 0.05$) differences in feed

conversion efficiency (3.01, 3.31 and 3.40) for boars, gilts and barrows respectively but average daily weight gain was similar.

There is also evidence that indicates genetic correlation existing between IMF content and porcine carcass traits and between IMF content and meat quality (Shi-Zheng and Su-Mei, 2009). Pigs have shown genetic correlation between IMF content and back fat thickness and differences in development of IMF relative to subcutaneous fat between genetically different breeds (Kouba *et al*., 1999).

Table 2.1 Growth and carcass characteristics among genders fed *ad-lib*

Parameter	Boars	Gilts	Barrow
Average daily feed intake, kg	2.08	2.11	2.28
Daily liveweight gain, kg	0.862	0.796	0.823
Daily energy intake, kcal	7110	7210	7790
Slaughter yield (%)	75.4	76.9	76.3
Carcass Feed conversion	3.11	3.32	3.50
Hot P2 backfat, mm	11.6	12.1	14.6
Loineye depth, mm	57.8	59.2	56.0
Lean yield, %	57.2	56.4	53.0
Lean tissue growth rate, kg/day	0.388	0.360	0.343
Lean tissue feed conversion	5.42	6.01	6.89

Source: Adapted from Harding, (1993)

2.2.2 Nutritional factors

Dietary nutritional levels and sources can affect porcine IMF content (Shi-Zheng and Su-Mei, 2009). Feeding lysine-deficient diet during the finishing phase of pigs increases IMF content while having no effect on marbling scores in the *Longissimus* muscle (Witte *et al.,* 2000). Moderate long term feed restriction (low protein and energy intake) resulted in a decreased lipogenic capacity of muscle adipocytes and decreased IMF content (Grondret and Lebret, 2002).

A reduced protein level in the diet is known to increase the level of IMF in pork with a smaller effect on the amount of subcutaneous adipose tissues, which may be due to tissue-specific activation of the expression of lipogenic enzymes by the reduced protein diet. Additionally, pigs fed diets of 1/3 yellow corn and 2/3 white corn had a greater percentage of IMF than pigs feds diets containing either yellow corn or white corn (Lampe *et al*., 2006). Carcass quality is also affected by energy intake of pigs; reducing the energy intake by incorporating high level of fibrous feedstuffs in the diet produced a leaner carcass while high energy diets tend to produce fatter carcasses.

2.2.3 Non-nutritional factors

Porcine somatotropin causes changes in growth performance and carcass characteristics of pigs (Shi-Zheng and Su-Mei, 2009). The porcine somatotropin treatment results in improved growth rate, increased carcass fat content and IMF content, increased unsaturated fatty acids and decreased fat cell diameter in the backfat without any effect on other meat quality traits (Azain *et al.,* 1992; Lafauchear *et al*., 1992).

2.2.4 Environmental factors

Apart from genetic, nutritional and non- nutritional factors, environmental factors also affect IMF content. Rearing pigs at a high temperature (3 2^0C) resulted in an increased carcass length but had no effect on other measurements or IMF (Shi-Zheng and SuMei, 2009). However, rearing pigs on free-range during winter (av. temperature 5^0C) had no effect on intramuscular lipid content of the *Semitendinosus* muscle but intramuscular lipid content was lower in the *Longissimus* muscle and tended to be higher in the *Rectus femoris* than in pigs reared indoors (22^0C) (Bee *et al.*, 2004).

Lower growth rate in outdoor versus indoor rearing have also been observed independently of food supply in both commercial and local breeds (Enfalt *et al.*, 1997). These differences have been related to higher energy requirements for physical exercise and thermoregulation in outdoor pigs (Enfalt *et al.,* 1997). Generally pigs reared indoor showed greater backfat thickness than outdoor ones (Enfalt *et al*.,1997; Warris, *et al.,* 1983) due to slower growth rates which favour muscle deposition rather than fat, resulting in leaner carcasses. It is also reported that exposure to disease-causing organisms can depress lean growth rates by as much as 30% (De Lange, 1998).

2.3 Nutrient Requirements of Pigs

A nutrient is any chemical entity required by the animal, to meet metabolic needs and can be supplied by feeding or by parental administration (Pond and Maner, 1974). Regardless of the size of operation or the condition under which pigs are produced, nutrition and feeding management are very important aspects of swine production. Feed cost represents about 70-80% of the total cost of production (Okai and Boateng, 2007). Therefore, it is imperative that swine producers have a good understanding of the nutrient requirements of pigs during each phase of the life cycle; knowledge of feedstuffs that can be used in pig feeding and feeding management in order to raise pigs efficiently and economically. Generally, the nutrients required by pigs are water, fats and oils (essentially fatty acids) vitamins, proteins (amino acids), inorganic elements and carbohydrates (Okai and Bonsi, 1994).

2.3.1 Water

Water is one of the most important nutrient classes for the proper maintenance of life. In the tropics and the drier parts of the world, water is very important because the pig

requires more water to maintain its body temperature (Holness, 1991). Water is required in the body as a vehicle for moving nutrients into and waste out of the body. Water evaporation (especially in the lungs) helps to disperse surplus heat produced by metabolic process. It also lubricates the joint, protects the developing foetus and is a major component of milk. The water content of the animal's body varies with age and weight. The neonatal pig's body is made up of 80% water while the mature pig has 55% water. Swine at all ages need free access to clean water at all times. Water restriction results in reduced feed intake with a negative effect on growth rate and feed conversion efficiency. Milk production is also reduced in lactating sows. Therefore water restriction can be dangerous to pigs. The requirement for water is influenced by many factors, including environmental temperature, water content of the feed and weight of the animal. Free access to clean water results in increased feed consumption and improve growth rates of pigs.

2.3.2 Carbohydrates

Energy constitutes by far the largest component of swine diets and carbohydrate is the most abundant form of energy in plant materials and as such is the most widely available source of energy for feeding swine (Pond and Maner, 1974). Fats and oils from plants and animals are the more concentrated form of energy available and have about 2.25 times as many calories per unit weight as carbohydrates (Pond and Maner, 1974). Energy is required by the pig for body processes such as breathing, muscle movement, protein synthesis, fat deposition, milk production and other purposes.

The energy values of feed can be expressed as digestible energy which is the gross energy of the feed eaten minus the remaining energy in the waste products of digestion. Metabolizable energy (ME) and Net energy (NE) content can also be used to

express energy values. The energy requirement of pigs is influenced by weight, genetic potential and environmental temperature.

During the growing period, energy requirements increase as the pig increases in weight. This is because of its greater maintenance requirement and a faster rate of accretion of body tissue. The pig's energy requirement differs with respect to the environmental temperature. The energy requirement is greater at low temperatures than high environmental temperatures because of the need to produce heat for body warmth. This phenomenon, in cold temperatures, results in poor feed utilization. It is a fact that pigs fed *ad libitum* eat to meet their energy requirements (O'Grady and Bowland, 1972 and Pond *et al*., 1995). They will consume more of a low energy feed than that of a high energy feed. Voluntary feed intake decreases with high energy feed but results in a better feed-to-gain ratio; ie less feed is needed per unit of gain. Okai and Bonsi (1994) recommended Digestible Energy (DE) levels of 3,500kcal/kg (starter) and 3,300 kcal/kg (grower and finisher). Diets of pigs that are deficient in energy, results in stunted growth, low productivity and high mortality of piglets.

2.3.3 Protein and amino acids

Proteins are complex organic compounds of high molecular weight (McDonald *et al.*, 1995). Their supplementations generally constitute the highest-cost ingredients of finished feeds (Tisch, 2006). According to Holness (1991) protein makes up about 15% of the total bodyweight of the pig. Pig carcasses contain 45-55% muscle with approximately 22% protein. The protein is made up of amino acids which are essential for the maintenance, growth, reproduction and lactation. The amino acids forming proteins can be categorised into two groups. These are essential and non-

essential amino acids. The essential amino acids are called so, because they cannot be synthesized in sufficient quantities by the pig and must be provided in the diet. They are lysine, tryptophan, arginine, histidine, isoleucine, leucine, methionine, valine, threonine and phenylalanine. On the other hand, non-essential amino acids can be synthesized in the pig's body. They include alanine, aspartic acid, glycine, cirtrulline, hydroxyproline, serine and tyrosine. The pig's daily requirements of amino acids are determined by its body weight and rate of lean tissue accretion.

2.3.4 Vitamins

Vitamins are organic compounds essential for normal metabolic functions development of normal tissues, health, growth, and maintenance. Some vitamins can be produced within the pig's body in sufficient quantities to meet its needs. Others are present in adequate amounts in feed ingredients commonly used in swine diets. However, several vitamins need to be added to swine diets to obtain optimal growth performance. Vitamins added to swine diets can be divided into two groups i.e fat- soluble and water-soluble vitamins. The fat-soluble vitamins that are generally added are A, D, E, and K.

The water-soluble vitamins include vitamin C and B-complex vitamins. The B-complex vitamins which may be deficient in a corn or milo-based diets are pantothenic acid, riboflavin, niacin, choline, and vitamin B_{12}.

There are two sources of vitamins; namely natural and synthetic vitamins. Green leafy plants, grasses and alfalfa are excellent natural sources of vitamins for swine but confinement makes it difficult for pigs to have access to these natural sources. Synthetic vitamins are produced by many companies and are sold individually or in various combinations.

2.3.5 Lipids

Lipids are a group of substances found in the tissues of plants and animals. They are insoluble in water but soluble in organic substances such as benzene, ether and chloroform. They act as substrate carriers in enzymatic reactions, as components of biological membranes and as stores of energy. In animals, lipids may be a major form of energy storage, mainly as fats which constitute up to 97% of the adipose tissues of obese animals. The yields of energy for complete oxidation of fat is about 39MJ/kg DM compared with about 17MJ/kg DM from glycogen, the major carbohydrate form of energy storage in animals (McDonald *et al.*, 1995)

2.3.6 Minerals

Minerals are inorganic compounds that play major roles in the metabolism of livestock. Minerals are basically used in bone and tissue formation and also are important constituents of the skeleton. They are also needed in the proper regulation of the functions of body organs and tissues (Maynard and Loosli, 1969). Also, some minerals participate in the catalytic activity of enzymes, serve a structural function and others participate in the body's acid-base and electrolyte balances. Minerals are classified into two categories based on the amount required by livestock; namely major or macrominerals, and trace or microminerals. Those that are required in relative large quantities are called macro-minerals while those needed in relatively small quantities are called micro-minerals. The macro-minerals include: Ca, P, Na, Cl, S, K and Mg while the trace minerals include; Co, Cu, I, Fe, Zn, Mn, Mo, Se, Si, F and Cr. The deficiencies symptoms of some minerals may include; rickets in young and osteomalacia in adults (Ca and P), reduced growth (Na, Cl, Mn, K and S) and anaemia (Fe).

2.4 Valuable Attributes of Maize

Maize is a vital staple, particularly for the rural poor in most of the developing world (NRC, 1988). It spread quickly among countries because of its robust nature and high adaptability to a wide range of environments. Some of its valuable attributes according to NRC (1988) are:

1. Highest yields per hour of labour spent.
2. Provision of nutrients in a compact form.
3. Transportation of maize is easy.
4. Protection of gains against birds and rains.
5. Harvesting and shelling can be done by hand.
6. Properly dried maize can be stored for a long period of time.
7. Maize competes well with weeds better than other grain cereals.
8. Maize can be left standing on the field at maturity without loosing the seeds (shattering).
9. Maize has many cultivars with different maturing periods.

2.5 Importance of Maize

Maize is a major cereal crop for both livestock feed and human nutrition (Prasanna *et al.*, 2001), with high content of carbohydrates, fats and minerals. The maize grain accounts for about 15-56% of the total daily calories in Africa and Latin America (NRC, 1988). Maize is an important cereal crop in Africa serving as a source of food and industrial raw material (Olakojo *et al.*, 2007). Maize is grown to be the primary provider of calories, supplying 29% of the world food calories (Olakojo *et al.*, 2007). It also provides 15% of all food crop protein (NRC, 1988) and more than half of the dietary protein to human beings (Gupta *et al.*, 2009).

Globally, maize is an important crop and the preferred staple food for over 1 billion in Sub-Saharan Africa and Latin America (Prasanna *et al.*, 2001) and animal feed in Asia (Gupta *et al.*, 2009). Maize as a primary source of energy supplement in daily diets, can contribute up to 30, 60 and 98% of the diet's protein, net energy and starch respectively (Dado, 1999). In the manufacture of starch and glucose from maize, certain by-products are obtained which are used in feeding animals (Jones, 1987). The by-products include: germ, bran and gluten. The germ is very rich in oil, which is valued by the food industry. Many millions of people worldwide depend on maize as a staple food. In most African countries, it supplies at least one fifth of total daily calories and proteins (Table 2.2).

Table 2.2: Importance of maize in the diets of individuals in selected African countries with respect to the percentage of calories and protein in the total diets

Country	Maize as:	
	% Total Calories	% Total Protein
Lesotho	58	55
Zambia	57	60
Malawi	54	55
Zimbabwe	38	46
Kenya	36	34
Tanzania	33	33
South Africa	33	33
Togo	25	29
Cape Verde	24	26
Swaziland	23	24
Mozambique	22	31
Ethiopia	21	17

Source: Adapted from Krivanek *et al.* (2007).

2.6 Maize as Food for Humans

Maize is still the major grain used as food in most parts of the world and contributes the main bulk of the daily diets (NRC, 1988). For instance, it makes up about 85% of all cereals consumed in Mexico and Central America. It provides 65, 62 and 49% of all the calories in the diets of families in Guatemala, El Salvador and Honduras respectively. The per capita consumption of maize is about 100 kg per year in some countries in Latin America and Africa (NRC, 1988). Tortillas made from maize are the basic food for the majority of people in Latin America, particularly the poor. Tortillas (an unleavened pancake-like cornbread) are made by baking thin flat cakes of "masa" until they are crispy.

Maize is steeped with lime, boiled and ground into fine dough toform the "masa". "Tamale" is also produced from maize by steaming "masa". Maize can also be cooked in diluted forms to produce porridge, gruel, soup and even beer (NRC, 1988).

In Ghana, maize is used in the preparation of "pito", "porridge", "tuo zaafi", "banku", "kenkey", "akple" and other foods depending on the locality. As indicated in the introduction, maize is low in protein quantity and quality, which usually do not meet the protein needs of children and often predisposes them to malnutrition. Pellagra is also common in people who are heavily dependent on maize diets due to the low content of niacin in maize (NRC, 1988).

2.7 Maize as Animal Feed

The worldwide spread of maize has made it the world number one feedstuff used as animal feed (NRC, 1988). As a feed ingredient, maize is outstanding due to a high energy level and low fibre content and is easily digested by most livestock especially monogastrics (McDonald *et al*.,1 995). In the developed countries like USA, maize crops

are used mostly as animal feed. In Ghana, it is estimated that 90% of all maize grown goes into human consumption while only 10% goes into animal feed (GAIN, 2008).

2.8 Nutritive Value of Maize

According to Watson (1987) and Prandini *et al*. (2011), the kernel of maize, like any other cereal grain consists of a pericarp (6%), endosperm (82%) and germ (12%). The main structural component of the endosperm is starch, a complex carbohydrate that constitutes an average of 71% of the grain and is a source of concentrated energy (Prasanna *et al*., 2001). The bulk of the protein in the common maize kernel is in the endosperm and germ, but the germ protein is superior in both quality and quantity (Prasanna *et al*., 2001).

2.9 Factors Affecting the Chemical Composition of Maize

Many studies including Bressani *et al*. (1962) as cited by Pond and Maner (1974) on the factors affecting the quality of the protein in maize indicate that both the environment and variety have significant effects on lysine content. It has also been shown that nitrogen fertilizer application increases the protein content and decreases protein quality of maize (Pond and Maner, 1974) due to the increase in the zein fraction which causes protein quality to be reduced (Masoero *et al*., 2011). Mitchell *et al*. (1952) reported that the increase in the zein fraction of protein in high protein maize resulted in high protein content but lower biological value. They fed pigs with maize containing 12% CP which produced significantly less gain than those on maize of 9.1% CP content because the former had more crude protein but was low in biological value. Over the years, many varieties of maize have been identified and worked on to improve the chemical and physical characteristic of those varieties and this has led to the development of new varieties.

2.10 Opaque-2 Maize

A natural spontaneous maize mutant with soft and opaque grains was found in a Connecticut maize field in USA during the 1 920s (Gupta *et al.*, 2009), and was later named Opaque-2 (O_2) maize. Mertz *et al.* (1964) reported that the Opaque-2 homozygous maize contained substantially higher lysine (+69%) in the grain and germ compared to normal maize. This genotype also showed an increase in tryptophan content (Prasanna *et al.*, 2001). The increased concentration of these two essential amino acids doubles the biological value of the maize protein (Bressani,1990) and a person needs to consume only half the amount of Opaque-2 maize to obtain the same biologically usable protein of that of normal maize (NRC, (1988). Even though, this mutant maize produced soft opaque kernels instead of hard transparent kernels, it was nutritionally better than the normal maize. Because of its improved nutrient levels, feeding trials were initiated and results indicated that the new maize could significantly improve protein deficiency malnutrition in children and also prevent pellagra in adults (NRC, 1988). Unfortunately, the Opaque-2 maize also came with some problems.

2.10.1 Challenges of Opaque-2 maize

Despite the desirable characteristics of the Opaque-2 maize, it also had undesirable ones. These undesirable characteristics are: (i) soft endosperm that results in damaged kernels, (ii) increased susceptibility to pests and fungal diseases, (iii) inferior food processing quality and (iv) generally reduced yields (Bjarnason and Vasal, 1992; Vassal, 2000). The opaque-2 grain was also chalky and not shiny, had small ears with a resultant reduction in yields of 8-15%, dried more slowly than normal maize kernels, weighed less than normal maize due to air space surrounded by loosely- packed starch granules (Dilmer,

1966; Lambert *et al.*, 1969; NRC, 1988). In essence, the opaque-2 maize lost its value because of its poor performance on the field.

2.11 Development of QPM

After the discovery of the nutritional benefits of the Opaque-2 mutant, major emphasis was placed in the conversion of normal endosperm population and inbred line to Opaque-2 varieties through the standard backcross approach (Prasanna *et al.*, 2001). The soft and opaque kernel appearance of the Opaque-2 maize was a major challenge to its acceptance since farmers were accustomed to growing hard flint and dent varieties (NRC, 1988). Other mutants were also identified that had altered amino acid profile in the endosperm. They were Opaque-6, Floury-3 and Mucronate (Salamini *et al*., 1983) but none of these mutants offered an additional advantage over Opaque-2. During the process of converting normal maize populations to Opaque-2 versions partially hard endosperm or "modified" grains were observed by many researchers including a breeder at CIMMYT (Krivanek *et al.*, 2007) in Mexico.

Subsequently, hard endosperm modification was incorporated into Opaque-2 breeding programmes (Krivanek *et al*., 2007). The normal endosperm populations were converted to Opaque-2 versions through back cross, recurrent selection procedures with a focus on accumulating the hard endosperm phenotype, maintaining protein quality and increasing yield and resistance to ear rot (Villegas *et al.*, 1992). The first improved populations were open pollinated varieties and hybrids (Krivanek *et al.*, 2007). These improved maize varieties with good protein quality were developed for temperate, tropical and subtropical growing conditions. The resulting genotype with elevated lysine and tryptophan content relative to normal maize but without the negative soft endosperm phenotype were termed by CIMMYT as Quality Protein Maize (QPM) (Krivanek *et al.*, 2007).

2.11.1 Agronomic characteristics of QPM

The QPM varieties have been evaluated on the field. The agronomic characteristics considered were grain yield, kernel type, moisture content, resistance to diseases and pests (NRC, 1988), drought tolerance and storage characteristics (Dado, 1999). In India, newly converted QPM inbreds were evaluated under organic farming and they yielded at par with normal maize with 6-24% increase in tryptophan level over the normal inbreds (Gupta *et al.*, 2009). The NRC (1988) reported that QPM varieties have yields comparable to their normal counterparts in many locations in the world. The kernels of QPM are shiny, hard and transparent like those of the traditional (flint or dent) maize varieties (NRC, 1988) with kernel texture and density accepted by farmers and consumers. The excessive moisture content of Opaque-2 maize (2-4% higher than those of normal maize) means extra time of drying after harvest with the risk of the maize becoming mouldy but the QPM maize dries at a rate comparable to that of normal maize (NRC, 1988). Farmers can now cultivate QPM varieties without the fear of the maize becoming mouldy and being rejected by consumers. Resistance of QPM varieties to diseases have improved over the years. Fungal infection of QPM is not worse than the normal maize varieties. Resistance to fungal diseases has improved partly because QPM kernels are harder and dry more quickly than those of Opaque-2. (NRC, 1988). This results in reduction of storage damage by insect pests.

2.11.2 Nutritive value of QPM and Opaque-2 maize

The superior protein quality and digestibility of QPM varieties have been demonstrated by many researchers (Graham *et al*. 1980; Bressani, 1990). As indicated earlier, QPM has higher lysine and tryptophan levels compared with normal maize (NRC, 1988; Sullivan *et al.*, 1989). In general, the QPM protein contains 41% higher

tryptophan, 30% more lysine and has a 3.8% increase in methionine when compared to normal maize (Gupta *et al*., 2009). The biological value of normal maize protein is 40%, while that of Opaque-2 is 80% with a net protein utilization of 37% for normal maize and 74% for Opaque-2 maize protein. The nitrogen balance index of milk and Opaque-2 is 0.80 and 0.72 respectively, which suggests that the protein quality of Opaque-2 is 90% of that of milk (Bressani, 1966).

Also, nitrogen balance studies conducted on Colombian children recovering from calorie-protein malnutrition concluded that, children lost 54 mg and 8 mg of nitrogen per kg body weight per day for common maize and Opaque-2 maize diets respectively while gaining 2 mg per kg body weight per day for milk (NRC, 1988). Thus nutritionally, Opaque-2 maize was not as good as milk but was far better than normal maize. Besides, about 24 g of normal maize per kg body weight is required for nitrogen equilibrium, compared to only 8 g for QPM (Gupta *et al*., 2009). The protein content of high lysine corn is nearly the same as that of regular corn, but the lysine content is 54% higher (NRC, 1988; Dado, 1999).

According to Onimisi *et al*. (2009) the tryptophan in QPM is not only an essential amino acid but also a biological precursor of the B-vitamin, niacin. This increased tryptophan helps prevent pellagra in man (NRC, 1988). The availability of niacin in QPM is due to a higher tryptophan and lower leucine content (Lopes and Larkins, 1991). A QPM developed in India, showed 41% increase in tryptophan, 30% increase in lysine and 23% increase in histidine coupled with 12% reduction in leucine (Gupta *et al*., 2009) compared to normal maize varieties. The nutritional and biological superiority of QPM have been studied in rats (Mertz *et al*., 1965b; Gomez, *et al*.,1975; Maffia *et al*.,1976), pigs (Maner *et al*., 1971; Osei *et al*., 1999; Okai *et al*., 2001a,

2001b and 2007), infants, children and adults (Graham *et al.*, 1980; Graham *et al*., 1990 and Akuamoah-Boateng, 2002) and QPM have been shown to give a better conversion ratio compared to normal maize in monogastric animals like pigs and chicken (Onimisi *et al*., 2008). Furthermore, QPM varieties have higher levels of arginine and histidine but lower levels of isoleucine, leucine, methionine and phenylalanine than either feed or food corn (Sullivan *et al*., 1989).

2.12 Nutritional Evaluation of QPM

As indicated earlier, QPM varieties have superior lysine content and have yield and agronomic characteristics similar to that of normal maize and these varieties are now available at research stations (Ortega *et al.*, 1986) and have been evaluated in humans, pigs, poultry and rats to confirm this nutritional superiority.

2.12.1 Humans

Studies on the nutritional benefits of QPM and Opaque-2 maize began soon after the identification of the improved quality protein trait conferred by the Opaque-2 allele. The protein quality of Opaque-2 maize was evaluated using the nitrogen balance technique in a number of studies by researchers in Peru (Graham *et al*., 1980; Graham *et al*., 1989). In these studies the children recovering from malnutrition were fed Opaque-2 maize or QPM-based diets as their only source of protein, and the results showed the nutritional superiority of Opaque-2 and QPM varieties over normal maize in terms of apparent nitrogen retention and biological value (NRC, 1988; Krivanek *et al*., 2007). Kies and Fox (1972) reported similar results in adults.

The studies concluded that nitrogen balance and retention were higher in Opaque-2 and QPM at lower levels of total protein intake. Graham *et al*. (1973) further showed that in

children suffering from malnutrition, QPM gave the same growth as those fed modified cow's milk. A study conducted in Ghana by Akuamoa-Boateng (2002), concluded that children in the QPM group had fewer sick days and less growth stunting, compared to children on the normal maize. These QPM varieties can thus play an increasingly important role in reducing protein malnutrition in humans (Gupta *et al.*, 2009). Currently, there is an ongoing study by Mbuya *et al*. (2011) targeting malnourished children in Eastern Kasai (DR- Congo) and preliminary results showed a weight gain and less disease occurrence for children fed with QPM compared to those on normal maize.

2.12.2 Pigs

Several studies have been conducted to determine the effects of the higher lysine and tryptophan content of QPM on pig performance. Some of these would now be discussed. According to Cromwell *et al*. (1969), Opaque-2 corn supported significantly ($P < 0.01$) greater nitrogen retention than that of normal corn when pigs were fed isonitrogenous diets of 11.2 or 8.2 % protein. It was added that when equal amount of corn protein was supplied by each diet, pigs fed Opaque-2 corn absorbed significantly ($P < 0.01$) more nitrogen and retained a significantly greater percentage of it, indicating that the protein of Opaque-2 corn was more digestible and had higher biological value than normal corn protein. They again added that reducing the protein level from 16 to 14 and 11.3 % during grower-finisher periods did not significantly ($P > 0.05$) influence gains and feed conversion ratios of pigs fed Opaque-2 corn but resulted in significantly ($P < 0.01$) inferior gains and feed conversion ratios when pigs were fed normal corn. Again, earlier reports by Cromwell *et al*. (1967) and Sihombing *et al*. (1969) showed that pigs fed Opaque-2 corn diets gained significantly ($P < 0.05$) faster and more efficient than those fed the normal diets and less feed was required per unit gain than

those fed diets containing normal corn. The magnitude of differences in gains and feed/gain of pigs fed the two corns was higher at the lower protein levels. Gomez *et al*. (1975) reported that a higher lysine vitreous endosperm corn similar to QPM had a feeding value for swine equivalent to conventional Opaque-2 corns and that both had higher feeding values than normal maize.

In a starter-grower experiment by Sullivan *et al.* (1989), pigs fed the QPM diet had higher gain than those on food and feed corn diets. Also apparent ileal digestibilities of nitrogen and amino acids were highest for QPM, intermediate for food and lowest for feed corn (Table 2.3). Osei *et al*. (1999) reported that pigs fed QPM grew faster and gained an average of 13.9 kg compared with 5.9 kg by the pigs on a normal maize diet.

Table 2.3: Apparent ileal digestibilities of nitrogen and amino acids in QPM, food and feed corn diets

Item	QPM	Food	Feed
Nitrogen, %	77^{a}	74^{b}	70^{c}
Essential amino acids			
Arginine, %	88^{a}	83^{b}	80^{c}
Histidine, %	84^{a}	82^{b}	79^{c}
Isoleucine, %	72^{a}	70^{ab}	68^{b}
Leucine, %	81	80	81
Lysine, %	81^{a}	78^{b}	74^{c}
Methionine, %	87^{a}	85^{b}	85^{b}
Phenylalanine, %	83^{a}	81^{ab}	80^{b}
Threonine, %	68^{a}	65^{a}	60^{b}
Tryptophan, %	79^{a}	75^{b}	70^{b}
Valine, %	79^{a}	76^{b}	73^{c}

[ab]Values in the row without a common superscript (letter) differ (P< 0.05).
Source: Adapted from Sullivan *et al.* (1989)

This means that, the QPM pigs grew at a rate 2.36 times that of normal maize pigs. Other research works by Maner *et al*., (1971) and Beeson *et al*. (1996) showed that growing pigs gained more weight and grew faster on QPM maize than on normal maize. Okai *et al*. (2001b) also reported that Obatanpa (QPM) in pigs diets resulted in a

reduction in fishmeal inclusion levels of 33% (starter and grower diets) and 75% (finisher diets) without any adverse effects on growth performance and carcass characteristics. In an earlier experiment, Osei *et al*. (1999) had concluded that where maize was the sole source of amino acids in the diet of starter pigs, Obatanpa is of higher nutritional value than normal maize.

2.12.3 Poultry and Rats

Studies from all over the world have shown that the feeding of QPM diets improved growth in poultry and rats. Results from Liu *et al.* (1993) showed that feeding chicken with QPM-based diets improved growth rate by 20% compared to feeding normal maize. According Osei *et al*. (1998), QPM-fed birds consumed 14% more feed and gained weight at 1.7 times that of a normal maize group. Feed conversion efficiency was 20% better in the QPM group than the normal maize group. A similar study conducted in Kenya found a 5% cost reduction in substituting QPM for normal maize in broiler diets (Nyanamba *et al*., 2003). The trial also showed that broilers raised with a mixture of QPM and normal maize had feed intake, mortality and growth rate comparable to that of the QPM diets. In their recent study, Mbuya *et al*. (2011) reported that dietary inclusion of QPM for poultry increased body weight by 50% compared to normal maize. Mertz *et al*. (1964), Nelson *et al*. (1965), Bressani *et al*. (1968), Maner *et al*. (1971), and Sproule *et al*. (1988) also observed similar improved growth rates in rats.

2.13 Development of Golden Jubilee and Etubi Maize Varieties

The Crop Research Institute (CRI) of the Council of Scientific and Industrial Research (CSIR) has developed new varieties of QPM maize namely Golden Jubilee (GJM) and Etubi (ETM) to replace maize varieties which showed deficiencies in disease resistance and stalk qualities. The development of GJM and ETM was to satisfy the

demands of consumers and the poultry and livestock industries. The name “Golden Jubilee” was to commemorate the Golden Jubilee of Ghana’s Independence while “Etubi" means father's child in the Gonja language. These varieties have higher levels of lysine and tryptophan than normal maize varieties, which are critical for the normal growth and development of humans and other monogastric animals such as poultry and pigs.

Golden Jubilee, a yellow version of Obatanpa, is a dented and open-pollinated variety with potential yields of 5 tons/ha and matures in 105 to 110 days. “Etubi” on the other hand, is a white flint and dented QPM hybrid with potential yield of 6.5 tons/ha and having the same months of maturity. They would be suitable for poultry and livestock production and increase growth with the high carotene in the yellow maize (GJM) imparting yellow colour to egg yolk. Their use should reduce fish meal addition to feed for poultry and pigs and would ensure enhanced nutrition and health of humans (GhanaWeb, 2007).

2.14 Blood: Composition and Functions

Blood is a specialized body fluid that delivers necessary substances such as nutrients and oxygen to the body’s cells and transports waste products away from the same cells. Blood performs many important functions in the body including:

- Supply of oxygen to tissues (bound to haemoglobin)
- Supply of nutrients such as glucose, amino acids and fatty acids
- Removal of waste substances (CO_2, urea and lactic acid)
- Immunological functions, including circulation of white blood cells
- Messenger functions, including the transport of hormones and the signalling of tissue damage.
- Coagulation (ie. blood clotting after an open wound in order to stop bleeding)

- Thermoregulation

- Hydraulic function and

- Maintenance of pH balance inside the body (Wikipedia, 2011)

Blood is composed of red blood cells (RBC), white blood cells (WBC) and platelets. The RBC constitutes 45% of whole body by volume and contains haemoglobin which gives blood its red colour. The principal function is to deliver oxygen to different tissues of the body. High RBC count does not necessarily imply something harmful as age and sex play a part in the red blood cell count in the blood stream. Low RBC is considered as unhealthy as the RBC carry oxygen which is essential for the smooth functioning of the body.

The WBC is 1% by volume of the total blood. They protect the body against pathogens and infectious diseases. A high count indicates infection, inflammatory and tissue injury. On the other hand, low WBC indicates low viral infections, low immunity and bone marrow failure.

The platelets are also known as thrombocytes. The most important function of platelets is blood coagulation (blood clotting) and fighting infection. Low count of platelets may cause excessive bleeding while a high count is an indication of infection.

2.15. Normal haematological and biochemical values of pigs

The normal haematological and biochemical parameters of domestic pig and wild boar have been reported by many workers as shown in Table 2.4. The normal range of RBC reported by Friendship *et al*. (1984), Rispat *et al*. (1993) and Thorn (2006) were between 5.0-9.04 $x10^{12}$/l. Also, normal range of haematocrit reported by Friendship *et al*. (19984) is lower than that of Harapin *et al*. (2003) and Thorn (2006) while Rispat *et al.* (1993)

recorded lower values for mean cell haemoglobin concentration (Table 2.4). Furthermore, Friendship *et al*. (1984) reported values of 52-83 g/l for total protein while Harapin *et al*. (2003) reported slightly higher values of 76-88 g/l.

Table 2.4: Haematological values of domestic pig and wild boar

Parameter	Domestic pig Mean (Min – Max)	Reference
RBC, $X10^{12}$/l	6.5 (5.0 - 8.0)	Thorn , 2006
	5.30-9.04	Rispat *et al.*, 1993
	5.7- 8.3	Friendship *et al*., 1984
	6.87-9.03*	Harapin, *et al*.,2003
Hb, g/l	123-183*	Harapin, *et al.*,2003
	6.7-11.20	Rispat *et al.*, 1993
	10-15	Friendship *et al*., 1984
HCT, %	32-50	Thorn , 2006
	29-42	Friendship *et al*., 1984
	55.4-69.4*	Harapin *et al*., 2003
Platelets	215-898	Rispat *et al.*, 1993
WCB, $X10^{9}$/l	6.0-20.35*	Harapin *et al*.,2003
	11.0-22.0	Thorn, 2006
	7.40-26.40	Rispat *et al.*, 1993
	11.20-32.9	Friendship *et al*., 1984
MCH, pg	15-20	Friendship *et al*., 1984
MCHC, g/dl	24.0-37.20	Eze *et al.*, 2010
	17.20-22.20	Rispat *et al.*, 1993
	32.0-38.0	Friendship *et al*., 1984
Total protein, g/l	76-88	Harapin *et al*., 2003
	66-88	Rispat *et al.*, 1993
	52-83	Friendship *et al*., 1984
Albumin, g/l	36-47	Harapin *et al*., 2003
	19-42	Friendship *et al*., 1984
Total cholesterol, mmol/l	1.25-3.07	Rispat *et al.*, 1993
	1.37-3.18	Friendship *et al*., 1984
Triglycerides, mmol/l	0.05-0.76	Rispat *et al.*, 1993

*- wild boar values. Source: Adapted from Harapin *et al.* (2003)

2.16 Effect of Nutrition on Blood Composition

The blood, consisting of blood cells and plasma, fulfils transport, regulatory, protective and homeostatic functions (Eze *et al*. (2010). Mandubuike and Ekenyem (2006) reported that understanding of the haematological and biochemical values of animals could serve as an index used in predicting the effect of any ration given to the animal. Hematological profiles are also important indicators of health and disease in animals and have become indispensible in the diagnosis, treatment or prognosis of

many diseases (Mbanasor *et al*., 2003). The determination of the packed cell volume, erythrocyte count and haemoglobin (Eze *et al*., 2010) can give an idea of the level of disease conditions. Haematological and serum biochemistry assay of animals suggest the physiological disposition of the animals to nutrition (Manubuike and Ekenyem, 2006).

According to Machebe *et al*., (2010), the quality and quantity of ration given to an animal affects its physiological condition. In their experiment, they concluded that different dietary protein levels affect blood parameters (Table 2.5).

Table 2.5. The effects of varying protein levels on haematological indices of gilts

Blood Parameter	T1 (16% CP)	T2 (18% CP)	T3 (20% CP)	SEM
Hb, g/100ml	13.03[b]	14.61 [a]	13.25[b]	0.30 *
PCV, %	38.03[b]	43.53[a]	39.55[b]	0.93*
RBC, 10^6 mm^3	4.33[b]	4.89[a]	4.40[b]	0.13*
MCHC, %	32.49[b]	35.56[a]	32.50[b]	0.54*
MCH,%	30.09	29.67	30.58	0.18NS
MCV,%	89.90	90.00	90.10	0.02NS
WBC, $X10^3/mm^3$	6.70	6.49	5.94	6.37NS

[a, b]-Row means with different superscripts are statistically significantly at 5%(*$p<0.05$)

NS - Not Significant, SEM – Standard error of means,

Source: Machebe *et al.* (2010).

Esonu *et al.*, (2001) had also stated that haematological constituents reflect the physiological responsiveness of the animals to its internal and external environment which include feed and feeding. The effects of various feed on the haematology and serum biochemistry of livestock have been studied by many scientists (Awosanya *et al*., 1999; Iyayi, 2001; Annongu and Folorunso, 2003 and Madubuike and Ekenyem, 2006) and concluded that feed affects animal physiology (Ekenyem and Madubuike, 2007).

2.17 Inferences from the Literature Reviewed

In Ghana like other developing countries, maize is an indispensable cereal grain in the diets of monogastrics animals and forms about 50-60% of such diets (Osei *et al*., 1999 and Okai and Boateng, 2007). Its use is the result of a combination of desirable nutritional characteristics. It is high in energy, low in fibre, palatable and easily digested (NRC, 1988). The normal maize varieties used in Ghana and elsewhere has two major limitations, namely, low protein (9-10%) and deficiency of essential amino acids particularly lysine (0.23%) and tryptophan (0.06%) which do not meet the nutrient requirement for swine nutrition (Beeson *et al*., 1996). Monogastric maize-based diets are often supplemented with soyabean and fish meals and sometimes synthetic amino acids in order to obtain balanced diets to meet the requirements of the monogastric animal. Soyabean meal and fish meal may be limited in supply in Ghana and the bulk of these are imported thus making fish meal and soyabean meal very expensive in certain times of the year when the foreign exchange rate goes up.

The quest of scientists for finding natural ways of improving maize varieties which possess a better balance of essential amino acids led to the discovery of Opaque-2 and floury-2 and later, the development of QPM varieties. These varieties have nutritional superiority over the normal maize varieties (NRC, 1988) and elsewhere they have been evaluated with pigs (Sullivan *et al*., 1989 and Liu *et al*., 199). In growth trial, pigs fed the QPM diets utilized feed more efficiently and grew faster than their counterparts on the normal maize diets containing an equal amount of protein. In Ghana, similar studies were carried on Obatanpa (QPM) when it was released by the breeders at the Crop Research Institute, Kumasi in the 1990's. Osei *et al*., (1999) conducted a study to investigate the value of QPM as the sole source of protein and amino acids in the starter

diets of pigs compared with normal maize. Pigs on the QPM diets grew 2.36 times faster than those on the normal maize and it was concluded that QPM is of higher protein quality than that of normal maize. Other studies looked at situations where QPM replaced normal maize with varying levels of fish meal and in all cases; positive results were recorded on the use of QPM in pig nutrition (Okai *et al*., 2001a, 2001b and 2007). The Obatanpa (QPM) varieties have been tested for their nutritional value for pigs and humans in Ghana (Osei *et al*., 1999; Okai *et al*., 2001a, 2001b and Akuamoa-Boateng, 2002). Since the release of Golden Jubilee (GJM) and Etubi (ETM) maize varieties in 2007 by the Crop Research Institute based in Kumasi, no work on GJM and ETM evaluation has been reported in Ghana either for pigs or rats. Therefore, this study is to investigate the effects of GJM and ETM (QPM) varieties on the growth performance, carcass characteristics and blood profile of pigs and rats.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area and Duration of Experiment

The studies were conducted at the Livestock Section of the Department of Animal Science, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. The Department is located on latitude 06˚41' N and longitude 01˚33' W of the Equator and 261.4 m above Mean Sea Level (MSL). The average rainfall in the area is about 1400 mm with temperature ranging between 21.5 and 35˚C while relative humidity is between 67 and 89%. The pigs feeding trial lasted for a duration of 17 weeks while the rats trial lasted for 4 weeks.

3.2 Experiment I: Pigs

3.2.1 Experimental animals and design of experiment

Twenty Large White starter pigs (12 males and 8 females) weighing between 10 and 16 kg with an average age of 11 weeks were obtained from the Livestock Section of the Department of Animal Science, Kwame Nkrumah University of Science and Technology. They were randomly alloted to four dietary treatments namely, Local Normal Maize (LNM), Imported Normal Yellow Maize (INYM), Golden Jubilee Maize (GJM) and Etubi (ETM). The allocations were on the basis of sex, litter origin, age and weight. The LNM diet was used as the Control. The mean initial weights of the starter pigs were 13.3, 13.2, 13.3 and 13.2 kg for the LNM, INYM, GJM and ETM dietary treatments respectively. Each treatment was replicated five times. The design used was the Completely Randomized Design.

3.2.2 Housing

The pigs were housed individually in concrete-floored wire mesh cages measuring 160 x 65 x 103 cm (Plate 3.1). The cages were constructed within roofed pens measuring 365 x 315 x 100 cm and each pen had four of the individual cages. Wooden feed and concrete water troughs were provided in each cage. The dimensions were 60 x 31 x 26 cm and 50 x 24 x 13 cm for the feed and water troughs respectively. All the feed troughs had wooden battens across the top to reduce feed wastage.

Plate 3.1: Some of the pigs housed in the individual wire-mesh cages

3.2.3 Sources of feed ingredients

The ingredients used in the formulation of the experimental diets were maize, fishmeal, soya bean meal, wheat bran, oyster shell, common salt and vitamin / trace mineral premix. The LNM, ETM and GJM were provided by Alpha Seeds Enterprise, Kumasi. The other ingredients including INYM were bought from open markets in the Kumasi Metropolis.

3.2.4 Diet formulation and compounding

The percentage composition of the diets is shown in Table 3.1 below. The diets were calculated to have crude protein levels of 17% and 17.50% for the QPM and normal maize-based diets respectively. The fish meal inclusion levels decrease in the QPM-based diets but the lysine levels were similar because the QPM maize varieties have higher levels of lysine content compare to normal maize varieties. The feed compounding was done mechanically at 7-10 days intervals and representative samples of each batch of compounded feed were taken and kept in a freezer for subsequent laboratory analysis.

3.2.5 Feeding

The diets shown in Table 3.1 were offered to the pigs during the experimental period. The diets were isocaloric and isonitrogenous. Feed and water were given *ad libitum*. Feeding was terminated and pigs were slaughtered when each pig attained a liveweight of 70 + 0.5 kg at the weekly weighing.

3.2.6 Health and medication

All the experimental pigs were washed with Gammatox[1] solution (5ml/4.5 litres of water) before the start of the experiment. This was to destroy mange mites. All the experimental male pigs were open castrated 2 weeks to the start of the study. Immediately after the castration they were given 2 ml each of an antibiotic (Oxytetracycline[2]) by intramuscular injection and an antibiotic spray (Pederipra spray[3]) was applied to their wounds.

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1. Gammatox: A chemical for controlling ectoparasites in farm animals with benzene hexachloride as active ingredient. 5ml/4.5 litres of water. Bayer, Germany.
2. Oxytetracycline 20% (an antibiotic). Dosage 1ml per 10 kg body weight. Active ingredients: Each ml contains 200mg oxytetracycline dehydrate and 50mg magnesium oxide. Manufactured by Tilvet International, Belgium.
3. Pederipra spray for wounds and pododermatitis. Active ingredients: 20mg chlortetracycline with gention violet. Manufactured by Laboratories Hipra, Spain.

Multivite[4] and antibiotic injections were administered to pigs when signs of inappetence and /or ill health were observed. The pigs were also dewormed when their average liveweight was 35.5 kg to kill any worms in them.

Table 3.1: Percentage composition of the experimental diets

Ingredients	LNM	INYM	GJM	ETM
LNM	60	-	-	-
INYM	-	60	-	-
GJM	-	-	60	-
ETM	-	-	-	60
Fishmeal	9	9	8	8
Soyabean meal	6	6	6	6
Wheat bran	23.5	23.5	24.5	24.5
Oyster shell	1.00	1.00	1.00	1.00
Common salt	0.25	0.25	0.25	0.25
Vitamin-Traced mineral premix	0.25	0.25	0.25	0.25
Total	100	100	100	100
Nutrient composition (%, calculated)				
CP	17.50	17.50	17.00	17.00
Ca	0.81	0.81	0.80	0.80
P	0.72	0.72	0.71	0.71
Lysine	0.94	0.94	0.95	0.95
Tryptophan	0.19	0.19	0.21	0.21
DE(kcal/kg)	3184	3184	3176	3176
Analysed composition (%, as fed-basis)				
Crude protein	17.10	16.90	16.50	15.60
Ether extract	7.00	2.50	6.50	3.50
Crude fibre	3.80	3.68	3.72	3.68
Moisture	15.50	14.00	16.50	15.00
Ash	3.00	4.50	5.50	6.00
Nitrogen free extract	53.60	58.42	51.28	56.22
Dry matter	84.50	86.00	83.50	85.00

Vitamin Trace Mineral Premix: Inclusion rate is 2.5g/kg to supply Vit. A = 8000 IU, Vit. D = 500 IU, Vit. E = 2.5 mg, Vit. K_3 = 1mg, Vit. B_2 = 2 mg, Vit. B_{12} = 0.005 mg, Folic Acid = 0.5 mg, Nicotinic Acid = 8 mg, Calcium Panthotenate = 2 mg, Choline Chloride = 50 mg, Manganese = 50 mg, Zinc = 4 mg, Copper = 4.5 mg, Cobalt = 0.1 mg, Iodine = 1 mg, Selenium = 0.1 mg.

3.2.7 Sanitation and management of experimental pigs

A week to the start of the experiment, all the pens and cages were swept clean and all cobwebs were removed. Three days before the commencement of the study, the pens, cages, feed and water troughs were scrubbed and washed with a mild powdered detergent (Omo). Subsequently the pens, cages and water troughs were washed while

4. Multivite: Treatment of vitamin deficiencies and as a supplement to inadequate diet and a supportive therapy. Dosage: 0.5-1ml/10kg body weight. Active ingredients: Vit.A 50000 IU, Vit.D_3 25000 IU,Vit. B_2 10 mg, Vit.B_{12} 0.04 mg, Vit. B_6 1 mg, Nicotinic acid 5 mg. Manufactured by Kela N.V, Belgium.

the pigs were clean by splashing water on them once every morning and the water troughs re-filled with fresh water 2-3 times daily throughout the experiment. Water was sprinkled on the pigs when the weather was considered warm using a rubber hose.

3.2.8 Sample collection-blood

At the end of the experiment, blood samples were taken from each pig from an ear-vein using 2ml syringes as shown in Plate 3.2. The drawn blood was quickly transferred into vacutainers containing ethylene diamine tetraacetic acid (EDTA), an anticoagulant. The blood samples were then analysed for their haematological and serum biochemical parameters.

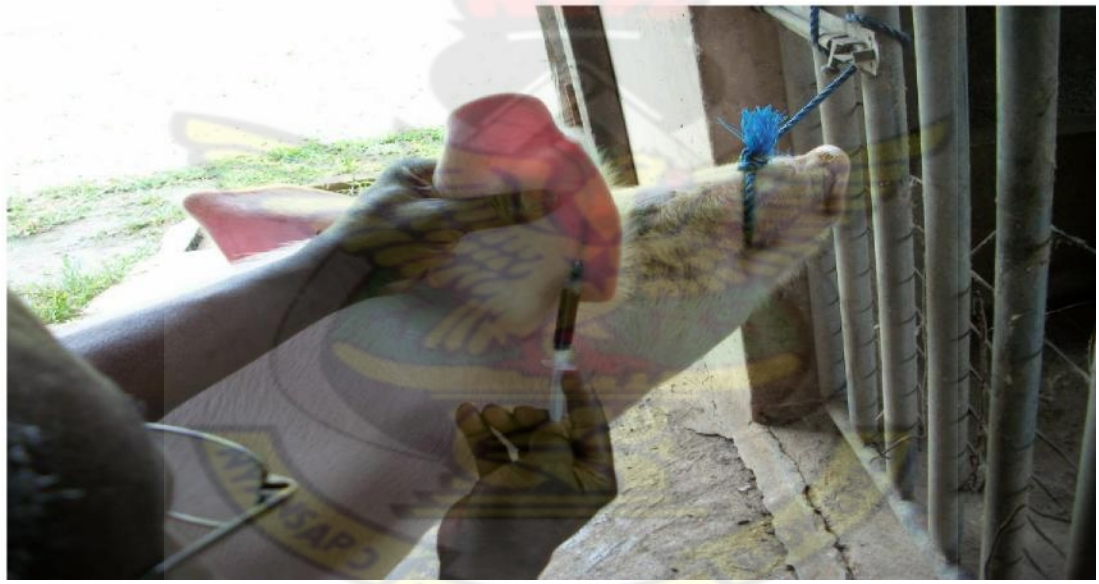

Plate 3.2: Taking blood sample from an experimental pig

3.2.9 Parameters measured

3.2.9.1 Feed intake

Feed intake was measured once a week (Mondays) ie. on the day when the pigs were weighed. The weekly feed intake was calculated by deducting the left-over feed from the quantity offered throughout the previous week. Total feed intake (kg/pig) for the

experiment was also determined and this was the sum of the weekly feed intakes for the period during which each particular pig was on the experiment. The average daily feed intake (ADFI) for each pig was determined by dividing the total feed intake by number of days the pig stayed on the experiment. ie

$$ADFI = \frac{Total\ feed\ intake\ (kg/pig)}{Number\ of\ days}$$

3.2.9.2 Live weight changes

Liveweight changes of the pigs were measured individually every Monday morning using the Gascoigne[5] precision scale as shown in Plate 3.3. Average daily weight gain (ADG) was obtained by dividing total weight gained by each pig by the number of days it stayed on the experiment. ie.

$$ADG = \frac{Total\ weight\ gained(kg)}{Number\ of\ days}$$

Plate 3.3: Weighing a pig using the Gascoigne precision scale

5. Gascoigne precision scale. Capacity 150 kg x 5 00g. Manufactured by Precision weighters, Reading, England.

3.2.9.3 Feed conversion efficiency

Feed conversion efficiency (FCE) was defined as the total feed consumed (kg) by a pig to produce a unit (kg) weight gain.ie

$$FCE = \frac{Total\ feed\ consumed\ (kg)}{Total\ weight\ gained (kg)}$$

3.2.9.4 Carcass evaluation

The experimental pigs were removed and slaughtered for carcass evaluation after each pig attained a liveweight of 70 + 0.5 kg at the weekly weighing. The pigs were stunned, bled, scalded, singed and eviscerated. The dressed weights and weights of the viscera, head, trotters and the internal organs were recorded on the day of slaughter. The eviscerated carcasses were chilled in a coldroom at a temperature of 4^{o}C for 24 hours. The details of measurements taken are described below:

3.2.9.5 Dressed weight and dressing percentage

Dressed weight is the weight of the whole carcass including the weights of the head and trotters. This was described as warm dressed weight. After storing the eviscerated carcass for a day, the weight was again taken to determine the quantity of moisture loss as a result of the chilling and this was referred to as chilled dressed weight. The dressing percentage was calculated as the dressed weight expressed as a percentage of the live weight at slaughter. It was done for both the warm and chilled carcasses.

3.2.9.6 Absolute and relative weights of viscera

The viscera were collected into a container, washed and the weights (absolute values) taken while the relative weights were also calculated as the weight of the viscera expressed as a percentage of the live weight at slaughter.

3.2.9.7 Carcass length and backfat thickness

Carcass length was determined from the right half of the chilled, hanging carcass from the edge of the first rib to the aitch bone (os pubis). Measurement of the backfat thickness was taken from the right half of the hanging chilled carcass and was determined as the average of the three backfat measurements taken from the first rib, last rib and last lumbar vertebra.

3.2.9.8 Weights of primal cuts

The right half of the chilled carcass was reduced into shoulder, loin, belly and thigh and the absolute weight of these components were recorded accordingly.

3.3 Laboratory Analysis of Feed and Blood Samples

The maize and feed samples from the various treatments were taken and milled to pass through a 1mm mesh sieve using laboratory grinder. Duplicate samples were then subjected to analysis for dry matter, crude protein, crude fibre, crude fat and ash contents described by AOAC (1990).

The blood samples from the pigs were immediately stored in a freezer. The stored samples were then siphoned into haematological Autoanalyser (Sysmex, Japan) after thawing. The haematological parameters studied were red blood cell count, haemoglobin, haematocrit, white blood cell counts, mean cell haemoglobin, mean cell haemoglobin concentration, platelets and mean cell volume. The total protein, albumin, total cholesterol, triglycerides, high density lipoproteins, low density lipoprotein and globulins were the biochemical parameters considered.

3.4 Experiment II: Rats

A parallel experiment was undertaken to provide information on the response of rats to the four dietary treatments which were tested on the pigs. The experiment lasted for four weeks.

3.4.1 Experimental rats and design of the experiment

Twenty albino rats of 5 weeks of age were obtained from the Small Animal Unit of the Department of Animal Science, KNUST for the experiment. The rats were randomly allocated to the same dietary treatments, as in the pigs' study, on the basis of weight. The mean initial weights of the rats were 71, 71.2, 71 and 71 g for the LNM, INYM, GJM and ETM dietary treatments respectively and Completely Randomized Design was used.

3.4.2 Housing

Transparent plastic containers measuring 27 x 20 x 16 cm served as cages for the rats. Uniform empty tomato paste cans were fitted to the corners of the cages to serve as feed troughs while flat bottles with glass pipes served as nipple drinkers. There were welded wire mesh covers at the top of the cages to ensure proper ventilation. The plastic cages had perforations at the bottom to allow for the flow of urine and faeces out of the cages on to flat asbestos sheets which were regularly cleaned. The cages were randomly arranged on metallic shelves.

3.4.3 Feeding

The feed was weighed using an electronic scale into plastic jars with a weekly allocation of 200 g/rat. The plastic jars with tight lids were labelled according to the treatments. Feed and water were provided *ad libitum*. The bottles were placed on top of the welded wire mesh at an angle of 45˚. Each morning, any droppings in the feed troughs

were removed and additional feed was provided if necessary. Fresh clean water was also given each morning.

3.4.4 Sanitation

Four days to the start of the experiment, the cages, feed troughs and water troughs were washed with a mild detergent (Omo) and the metallic shelves were cleaned with a wet rag soaked in the detergent. The experimental room was also swept regularly to ensure good hygiene. Any faecal droppings in the cages were removed every two days and there was total cleaning of the cages on the weighing days (Fridays).

3.5 Parameters measured

3.5.1 Feed intake

Weekly feed intake (WFI) was determined by adding feed leftovers in the feeding troughs and the jars and subtracting it from the weekly allocation and total feed intake (TFI) was determined by adding the weekly feed intakes for the 4 weeks duration while average daily feed intake (ADFI) was determined by dividing the TFI by the number of days the experiment lasted.

3.5.2 Liveweight changes

Liveweights changes were determined by weighing the rats individually with an electronic[6] scale. The previous weights were subtracted from current weights to give the weekly weight changes. The total weight gained was determined by subtracting the initial weight from the final weight while daily weight gained was obtained by dividing total weight gained by the duration of the study.

6. Electronic scale. Capacity 400g x 0.0 1g. Ohaus, USA.

3.5.3 Evaluation of internal organs

At the end of the 4-week period, the experimental rats were chloroformed for 5 minutes. They were dissected and the viscera removed and weighed with an electronic scale. The liver, spleen, kidney, respiratory tract and full GIT were also individually weighed after separation. The empty GIT and the empty stomach were cleaned and also weighed accordingly.

3.6 Statistical Analysis

All data collected during the two experiments were analyzed to see if there were any significant differences between the treatments means. The General Linear Model of Gen Stat (Discovery edition 3) was used. All the statistical tests were done at a significance level of 5% and the Least Significance Difference (LSD) procedure was used to separate treatment means.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Experiment I: Pigs

4.1 Health of the Pigs

The pigs enjoyed good health throughout the experiment but signs of inappetence and/or ill health were controlled by the administration of injectable multivite and antibiotic as stated earlier. No mortality was recorded.

4.2 Proximate composition of Local Normal Maize (LNM), Imported Normal Yellow Maize (INYM), Golden Jubilee Maize (GJM) and Etubi Maize (ETM)

The proximate composition of the four maize varieties is shown in Table 4.1.

Table 4.1: Proximate composition (%) of the four maize varieties used in the experiment (as-fed basis)

Item	Maize variety			
	LNM	INYM	GJM	ETM
Crude protein	10.00	7.90	9.10	8.10
Ether extract	5.50	3.00	7.00	5.50
Crude fibre	1.56	2.06	1.63	1.04
Ash	1.00	0.50	0.50	0.50
Moisture	15.00	12.00	15.00	14.00
Nitrogen free extract	66.94	74.54	66.77	70.86
Dry matter	85.00	88.00	85.00	86.00

The ETM and INYM maize varieties have almost the same levels of crude protein (8.10 vrs 7.90 %) while GJM had a higher value (9.10 %) than the two mentioned earlier. The highest value was 10.0 % CP obtained from LNM. Cromwell *et al*. (1983) reported similar

higher values for normal maize but De Oliveira *et al*. (2011) reported 7.70, 9.87 and 7.36 % for common corn, high lysine corn and high oil corn respectively. These differences could be due to the differing environments in which the maize were cultivated and the variety as reported by Bressani *et al.* (1962). The GJM variety had higher ether extract content than the other three varieties and those varieties studied by O'Quinn *et al*. (2000) and De Oliveira *et al*. (2011). The dry matter content of the maize varieties were 85.0, 88.0, 85.0 and 86.0 % for the LNM, INYM, GJM and ETM varieties respectively. These values are comparable to the values reported by Asche *et al*. (1985), O'Quinn et al. (2000) and De Oliveira *et al*. (2011). The ash percentages were lower than those recorded by De Oliveira *et al*. (2011).

4.3 Analysed Composition of the Experimental Diets

The analysed composition of the diets is shown in Table 3.1. The percentage dry matter contents of the diets were 84.50, 86.00, 83.50 and 85.00 % for LNM, INYM, GJM and ETM diets respectively. These values were lower compared to those obtained by Okai *et al*. (2001b) who had 88.10, 86.70, 86.60 and 86.80 % for normal maize and 3 Obatanpa-based diets. The differences observed in the current study may be attributed to the differences in moisture content of the maize varieties used.

The crude protein values of the diets were slightly lower than the calculated values.This may be attributed to the crude protein level of the fish meal used in the experiment, because the source of the fish meal has an effect on the crude protein level. This problem could have been avoided if the crude protein of the fish meal and other ingredients were determined first before the start of the experiment.

4.4 Feed Intake, Liveweight Gain, FCE and Duration of the Experiment

The mean total feed intake values were 205.60, 213.30, 207.90 and 207.20 kg for the LNM, INYM, GJM and ETM diets respectively (Table 4.2). These values were not significantly ($P > 0.05$) different and the corresponding mean daily feed intake values were 2.27, 2.26, 2.06 and 2.19 kg. Again, they were not significantly ($P > 0.05$) different but it is clear that there were numerical differences. The similarities in feed intake suggest that the energy content of the diets were similar as most animals eat to satisfy their energy requirements (Pond *et al*., 1995). Low energy diets increase feed intake.

The initial liveweights were not significantly ($P > 0.05$) different. The values recorded were 13.30, 13.20, 13.30 and 13.20 kg for the LNM, INYM, GJM and ETM dietary treatments respectively. This happened because uniformity was ensured during the allotment of the pigs at the beginning of the experiment. The corresponding mean final liveweights were 71.30, 70.50, 70.20 and 70.10 kg ($P > 0.05$). The mean weight gains were 56.90, 56.90, 57.30 and 58.00 kg for the LNM, INYM, GJM and ETM diets respectively. Again, these values were not influenced by the dietary treatments. The average daily weight gains (ADG) were 0.64, 0.61, 0.56 and 0.60 kg for LNM, INYM, GJM and ETM diets respectively (Table 4.2). However in this instance, there were significant ($P < 0.05$) differences among the treatment means with the LNM, INYM and ETM values being similar but higher ($P < 0.05$) than the value for GJM. The results obtained in this study are similar to the results obtained by Rosa *et al*. (1977). They reported that pigs fed Opaque-2 maize tended to grow slower than those fed non-opaque 2 maize but the differences in growth rate were not significant. Again, the results partly agree with the assertion by Sullivan *et al*. (1989) that QPM diets reduced growth rate of starter pigs compared with pigs fed normal maize. Cromwell *et al*. (1969), Asche *et al*. (1985), Burgoon *et al*. (1992), Okai *et al*. (2001a, 2001b and 2007), De Oliveira *et al*. (2011), did

not observe significant (P > 0.05) differences in the ADG. Furthermore, *Gomez et al*. (1975), Cromwell *et al*. (1983) and Osei *et al*. (1999) reported improved ADG of pigs fed QPM diets compared to normal maize diets. Osei *et al.* (1998) stated that broiler chickens fed a QPM diet grew faster and gain weight 1.7 times that of their counterparts on a normal maize diet.

Table 4.2: Growth performance of pigs on the 4 dietary treatments

Parameter	Dietary treatments				LSD	Sign.
	LNM	INYM	GJM	ETM		
No. of pigs	5	5	5	5	-	-
Mean initial weight, kg	13.30	13.20	13.30	13.20	1.368	NS
Mean final weight, kg	71.30	70.50	70.20	70.10	1.242	NS
Total feed intake, kg	205.60	213.30	207.90	207.20	14.28	NS
Mean daily feed intake, kg	2.27	2.26	2.06	2.19	0.272	NS
Mean weight gain, kg	56.90	56.90	57.30	58.00	1.724	NS
Average daily weight gain, kg	0.64^{a}	0.61^{a}	0.56^{b}	0.60^{ab}	0.079	*
Mean feed conversion efficiency (feed/gain)	3.55	3.72	3.66	3.64	0.206	NS
Mean duration (days)	91.00	95.20	102.20	95.20	14.170	NS
Feed cost/kg, GH¢	0.49	0.51	0.48	0.48	-	-
Feed Cost/kg liveweight gain, GH¢	1.74^{b}	1.90^{a}	1.76^{b}	1.75^{b}	0.101	*

LSD-Least significant difference, Sign.-Level of significance, a,b: Values in the same row with different letters are significantly different (P < 0.05)

The feed conversion efficiency values were 3.55, 3.72, 3.66 and 3.64 for the LNM, INYM, GJM and ETM diets respectively. It is apparent that the dietary treatments did not influence this parameter. Okai *et al.* (2001a) had reported similar non-significant results for FCE i.e 3.36, 3.53, 3.47 and 3.46 for pigs during a phase feeding experiment using normal maize and Obatanpa-based diets. Furthermore, Okai *et al.* (2001b) did not observe any significant differences among treatment means for feed conversion

efficiencies when diets containing normal maize and Obatanpa (QPM) were fed to pigs. The current results confirmed this. On the other hand, Maner *et al*. (1971) and Osei *et al*. (1999) reported results which showed improved FCE with the use of QPM varieties. The mean duration of the experiment for the pigs fed the LNM, INYM, GJM and ETM diets were 91.00, 95.20, 102.20 and 95.20 days respectively as indicated in Table 4.2. There were no significant ($P > 0.05$) differences among treatment means but a pig on the GJM diet stayed a week longer to reach the required slaughter weight and this fact probably brought about the numerical differences

4.5 Feed Cost and Economy of Gain

The costs of the various diets were GH¢0.49, GH¢0.51, GH¢0.48 and GH¢0.48/kg for the LNM, INYM, GJM and ETM diets respectively (Table 4.2). The feed cost reduction in the GJM and ETM diets was due to the reduction in the fish meal inclusion levels into the diets in view of higher lysine and tryptophan levels in the GJM and ETM. The reduction in fish meal use apparently had no detrimental effects on the main performance parameters studied ie feed intake, feed conversion efficiency, growth rate and carcass dressing yield. Feed cost was reduced in QPM diets up to GH¢ 10.00 per metric tonne. Similar observation was made by Osei *et al*. (1998). They stated a reduction of US$21.00 per metric tonne when QPM was incorporated in broiler diets. It was attributed to reduction in the fishmeal in the diets.

The feed cost per kg liveweight gain values were GH¢ 1.74, GH¢ 1.90, GH¢ 1.76 and GH¢ 1.75 for LNM, INYM, GJM and ETM diets respectively (Table 4.2). There were significant ($P < 0.05$) differences among treatment means. Feed cost per kg liveweight gain was higher for the INYM group than the rest due to the higher price of the INYM (GH¢ 0.55/ kg vrs GH¢ 0.50/kg) for GJM, ETM. The LNM, GJM and ETM feed cost per gain values were

similar (P > 0.05). The results obtained in this study disagrees with the findings of Osei *et al*. (1999) and Okai *et al*. (2001b) who reported cheaper feed cost per kg weight gain values for the Obatanpa-containing diets. The disagreement may be as a result of the differences in the prices of maize and the composition of the diets used.

4.6 Carcass traits

The summary of the mean carcass traits for the pigs fed the four dietary treatments are shown in Table 4.3.

Table 4.3: Carcass traits of pigs fed the 4 diets

Parameter	Dietary treatment				LSD	Sign.
	LNM	INYM	GJM	ETM		
No. of pigs	5	5	5	5	-	-
Mean liveweight @ slaughter, kg	71.30	70.50	70.20	70.10	1.242	NS
Mean dressed weight, kg	52.93	52.87	53.22	52.49	2.039	NS
Mean dressing %	74.22	74.98	75.80	74.87	2.032	NS
Mean chilled dressed weight, kg	51.59	51.11	51.82	51.69	2.025	NS
Mean chilled dressing %	72.34	72.49	73.81	72.87	1.951	NS
Mean carcass length, cm	72.48	72.78	73.22	72.94	1.882	NS
Mean shoulder weight, kg	4.01	3.92	4.14	3.98	0.481	NS
Mean loin weight, kg	6.46	6.43	6.48	6.53	0.699	NS
Mean belly weight, kg	4.57	4.69	4.81	4.53	0.361	NS
Mean thigh weight, kg	6.45	6.47	6.20	6.40	0.400	NS
Mean backfat thickness, cm	3.18	3.25	3.07	3.14	0.449	NS

LSD-Least significant difference, Sign.-Level of significance (P < 0.05)

4.6.1 Weight at slaughter, dressed weight and dressing percentage

The weights at slaughter were the final weights of the pigs at the end of the experiment. As stated earlier, the values were 71.30, 70.50, 70.20 and 70.10 kg for the LNM, INYM, GJM and ETM diets respectively (Table 4.2). There were no significant (P > 0.05) differences between the treatment means for the final weight since the feeding experiment was terminated when each pig attained a liveweight of 70 + 0.5 kg. Mean warm dressed weights were 52.93, 52.87, 53.22 and 52.49 kg with corresponding

dressing percentages of 74.22, 74.98, 75.80 and 74.87 % for the LNM, INYM, GJM and ETM diets respectively. No significant differences (P > 0.05) were observed in the means for warm dressed weights and carcass dressing percentages.

These observations confirm earlier findings by Okai *et al*. (2001a, 2001b) and De Oliveira *et al.* (2011). It is quite interesting to note that pigs on the yellow maize treatments (ie. INYM and GJM) recorded relatively higher dressed weights resulting in higher dressing percentages.

The mean chilled dressed weights values were 51.59, 51.11, 51.82 and 51.69 kg with corresponding mean chilled dressing percentages of 72.34, 72.49, 73.81 and 72.87 % for the LNM, INYM, GJM and ETM diets respectively. Again, there were no significant differences (P > 0.05) between the treatment means for both parameters (Table 4.3). It was observed that the highest water loss values were recorded in the INYM group, the values were intermediate for the ETM and GJM groups and lowest for the LNM group respectively.

4.6.2 Weights of primal cuts

As presented in Table 4.3, there were no significant (P > 0.05) differences among treatment means of the shoulder, loin, belly and thigh weighs. The values were 4.01, 3.92, 4.14, and 3.98 kg (shoulder), 6.46, 6.43, 6.48 and 6.53 kg (loin), 4.57, 4.69, 4.81and 4.53 kg (belly) and 6.45, 6.47, 6.20 and 6.40 kg (thigh). These results are similar to those of Okai *et al*. (2001a, 2001b and 2007) when Obatanpa (QPM) and normal maize varieties were used in grower-finisher diets of pigs. Earlier, Cromwell *et al*. (1969) had similar results and concluded that pigs on normal or high lysine corn diets formulated on an equal lysine-basis produced the similar growth performance in

weanling, and the similar growth rates and meat quality in growing-finishing pigs. The results again tallied with the works of De Oliveira *et al*. (2011). They found no differences in all carcass parameters measured between pigs fed diets containing common corn, high lysine corn and high oil corn.

4.6.3 Carcass length and backfat thickness

The mean carcass lengths of the pigs fed LNM, INYM, GJM and ETM diets were 72.48, 72.78, 73.22 and 72.94 cm respectively (Table 4.3). There were no significant ($P > 0.05$) differences among treatment means for carcass length even though, an increasing trend was observed among the means (Table 4.3). The lower values for normal maize diets compared to QPM diets observed in this study, was also observed by Spurlock *et al*. (1997), Okai *et al*. (2001a, 2001b, 2007) and De Oliveria *et al*. (2011) but this was contrary to the findings made by Asche *et al*. (1985) when weanling and grower-finisher pigs were fed high lysine and normal corn ($P < 0.01$).

The mean backfat thickness values were 3.18, 3.25, 3.07 and 3.14 cm for the LNM, INYM, GJM and ETM diets respectively. It was not affected ($P > 0.05$) by the dietary treatments (Table 4.3). Again, this finding agrees with previous works (Spurlock *et al*. 1997; Okai *et al*. 2001a, 2001b, 2007 and De Oliveira *et al*. 2011). With respect to standards, the values fell within grade 3 category of USDA (1985) stipulations for pork carcass and above the maximum backfat thickness of 2.80 cm, a standard for pork carcass fat thickness (Sterle, 2000). Nevertheless, the backfat thickness values apparently met the guidelines for the regulation of livestock products by FDL (1992). This means that the pork carcasses could have been sold in the open market without contravening any consumer protection law in Ghana.

4.6.4 Absolute and relative weight of some organs

The mean absolute weights of the head for the four dietary treatments were 4.93, 4.67, 4.85 and 4.90 kg with corresponding relative values of 6.92, 6.63, 6.91 and 6.99 % for the LNM, INYM, GJM and ETM diets respectively. There were no significant ($P > 0.05$) differences among the treatment means for both absolute and relative weights. The means for both absolute and relative values of trotters weights were 0.90, 0.90, 0.97 and 0.89 kg; and 1.26, 1.28, 1.38 and 1.27 % for LNM, INYM, GJM and ETM diets respectively. In both cases the values were statistically similar ($P > 0.05$) (Table 4.4).

Table 4.4: Absolute and relative weights of some organs of the pigs on the 4 dietary treatments

Parameter	Dietary treatments				LSD	Sign.
	LNM	INYM	GJM	ETM		
Absolute weights (kg)						
Mean head weight	4.93	4.67	4.85	4.90	0.352	NS
Mean trotters weight	0.90	0.90	0.97	0.89	0.096	NS
Mean viscera weight	11.26	11.14	10.72	11.34	0.935	NS
Mean GIT weight (full)	7.88^{a}	7.78^{ab}	6.99^{b}	7.80^{ab}	0.829	*
Mean GIT weight (empty)	2.89	2.96	2.87	2.86	0.398	NS
Mean heart weight	0.19^{b}	0.17^{c}	0.21^{ab}	0.22^{ab}	0.030	*
Mean liver weight	1.34^{b}	1.26^{c}	1.51^{a}	1.52^{a}	0.167	*
Mean kidney weight	0.20^{a}	0.17^{b}	0.21^{a}	0.20^{a}	0.026	*
Mean spleen weight	0.11^{b}	0.10^{b}	0.14^{a}	0.11^{b}	0.026	*
Mean Resp. Tract weight	1.00^{ab}	0.99^{b}	1.11^{a}	0.97^{b}	0.114	*
Relative weights (%)						
Mean head weight	6.92	6.63	6.91	6.99	0.482	NS
Mean trotters weight	1.26	1.28	1.38	1.27	0.132	NS
Mean viscera weight	15.79	15.79	15.28	16.18	1.326	NS
Mean GIT(Full) weight	11.05	11.03	9.96	11.13	1.175	NS
Mean GIT (Empty)	4.05	4.20	4.09	4.08	0.55 1	NS
Mean liver weight	1.88^{b}	1.79^{b}	2.15^{a}	2.17^{a}	0.244	*
Mean kidney weight	0.28^{a}	0.24^{b}	0.30^{a}	0.29^{a}	0.039	*
Mean heart weight	0.27^{bc}	0.24^{c}	0.30^{ab}	0.31^{a}	0.044	*
Mean respiratory tract	1.40^{b}	1.41^{b}	1.58^{a}	1.38^{b}	0.161	*

LSD-Least significant difference, Sign.-Level of significance, a,b,c, values in the same row with different letters are significantly different at ($P < 0.05$).

Furthermore, the mean absolute weight of the viscera were 11.26, 11.14, 10.72 and 11.34 kg with corresponding relative values of 15.79, 15.79, 15.28 and 16.18 % for the LNM, INYM, GJM and ETM diets respectively. Again, no statistically significant ($P > 0.05$) differences were observed. Okai *et al*. (2001a, 2007) made similar observations.

The mean absolute and relative weights of the full GIT were 7.88, 7.78, 6.99, and 7.80 kg; and 11.05, 11.03, 9.96 and 11.13 % for the LNM, INYM, GJM and ETM diets respectively. There were significant ($P < 0.05$) differences among the treatment means for the absolute but not the relative weights.

The means for the LNM, INYM and ETM, and that of INYM, GJM and ETM were statistically similar ($P > 0.05$) but the differences between the means for LNM and GJM were statistical different ($P < 0.05$) (Table 4.4). Okai *et al*. (2001b) did not observed any significant ($P > 0.05$) differences among treatment means when Obatanpa was fed to pigs. The differences observed in the full GIT weights in this current study are difficult to explain. The means for the empty GIT for both absolute and relative weights were not significantly ($P > 0.05$) influenced by the dietary treatments and this tallied with the findings of Okai *et al*. (2007) and De Oliveira *et al*. (2011).

The mean absolute weights of the heart, liver, kidney and respiratory tract for the LNM, INYM, GJM and ETM diets were; 0.19, 0.17, 0.21 and 0.22 kg (heart), 1.34, 1.26, 1.51 and 1.52 kg (liver) and 0.20, 0.17, 0.21, and 0.20 kg (kidney) and 1.00, 0.99, 1.11 and 0.97 kg (respiratory tract) respectively. The respective relative weights were 0.27, 0.24, 0.30, and 0.31 % (heart), 1.88, 1.79, 2.15, and 2.17 % (1iver), 0.28, 0.24, 0.30 and 0.29 % (kidney) and 1.40, 1.41, 1.58 and 1.38 % (respiratory tract). There were significant ($P < 0.05$) differences among treatments means for both absolute and relative weights of the heart, liver, kidney and respiratory tract. This work contradicts

the findings by Okai *et al*. (2001a, 2001b) of non-significant (P > 0.05) differences in the treatment means for the heart, liver, kidney and respiratory tract when normal and QPM-based diets were used.

4.7 Haematological and Serum Biochemical Profiles of the Pigs Fed the 4 Diets

As haematological profiles are good indicators of health and disease conditions in farm animals, blood samples were analyzed to ascertain whether the dietary treatments had any effect on the blood profile of the pigs (Table 4.5).

Table 4.5: Haematological and biochemical profile of blood of pigs fed the 4 diets

Parameter	Dietary treatments				LSD	Sign.
	LNM	INYM	GJM	ETM		
Haematological profile						
HCT, (%)	44.84	47.18	48.94	48.38	4.549	NS
Hb, (g/dl)	12.80^{bc}	13.36^{b}	14.52^{a}	13.40^{ab}	1.151	*
MCHC (g/dl)	28.56	28.28	26.38	27.10	2.219	NS
MCH (pg)	17.92	17.68	17.96	17.50	0.649	NS
Platelets (×10^{9}/l)	298	295	248	251	95.8	NS
RBC (×10^{12}/l)	7.12^{b}	7.52^{ab}	7.84^{a}	7.50^{ab}	0.668	*
WBC (×10^{9}/L)	11.28^{b}	14.86^{a}	11.26^{b}	14.74^{a}	2.973	*
Biochemical profile						
Albumin (g/l)	45.60	46.60	50.00	43.00	7.74	NS
Globulin (g/l)	28.60	26.40	25.40	34.40	11.18	NS
Total protein (g/l)	74.20	73.00	75.40	77.40	8.46	NS
Total cholesterol (mmol/l)	3.10	2.98	2.88	3.02	0.528	NS
HDL cholesterol (mmol/l)	0.86	0.86	0.66	0.76	0.365	NS
LDL cholesterol (mmol/l)	1.92	1.80	1.88	1.96	0.454	NS
Triglycerides (mmol/l)	0.72	0.68	0.66	0.68	0.236	NS

a,b, c: Values in the same row with different letters are significantly different (P < 0.05)

The mean haematocrit (HCT) values were 44.84, 47.18, 48.94 and 48.38 % for the LNM, INYM, GJM and ETM dietary treatments respectively. They were similar (P > 0.05) but there was a trend towards higher values with the INYM, GJM and ETM diets.

This means that the dietary treatment did not impose any influence on the HCT.

The mean cell haemoglobin concentration (MCHC) for the LNM, INYM, GJM and ETM diets were 28.56, 28.28, 26.38 and 27.10 g/dl. There were no significant differences ($P > 0.05$) among treatment means but the pigs on the normal maize diets (ie. LNM and INYM) had slightly higher values. The MCHC values were within the normal ranges for pigs as stated by Eze *et al.* (2010), but lower than those reported by Friendship *et al.* (1984) and higher than those recorded by Rispat *et al.* (1993). The difference could be as result of the environment, season and diet (Harapin *et al.* 2003).

The mean cell haemoglobin (MCH) and platelets were similar ($P > 0.05$) among the dietary treatments. The values for MCH were 17.92, 17.68, 17.96, and 17.50 pg for LNM, INYM, GJM and ETM diets respectively. The values were again within the normal range for pig of that age and weight (Friendship *et al.*, 1984). The haemoglobin (Hb) level, red blood cells (RBC) and white blood cells (WBC) counts showed significant ($P < 0.05$) differences between treatment means. The values for haemoglobin were 12.80, 13.36, 14.52 and 13.40 g/dl for LNM, INYM GJM and ETM diets respectively. The difference observed may be due to individual differences in haemotopoiesis (haemoglobin synthesis) and/or differences in RBC counts. The results also indicate that the GJM treatment with highest haemoglobin had highest RBC counts. Davies (1961) noted that, haemoglobin is found in the RBC and make up to 90% of the protein found in those cells. It is worth noting that all the values obtained were within the normal range for pigs as stated by Friendship *et al*. (1984).

The RBC values fell within the normal ranges as reported by Friendship *et al.* (1984), Rispat *et al*. (1993), Harapin *et al*. (2003), and Thorn (2006) for pigs. The reason for the significant differences ($P < 0.05$) in WBC counts among treatments means was uncertain

since those with higher values did not show any disease condition during the experiment. The results of Rispat *et al.* (1993) and Thorn (2006) were similar to those obtained here.

The biochemical parameters of the blood of pigs fed the 4 dietary treatments are also shown in (Table 4.5). The mean values of the parameters measured were 45.60, 46.60, 50.00 and 43.00 g/l (Albumin), 28.60, 26.40, 25.40 and 34.40 g/l (Globulin), 74.20, 73.00, 75.40 and 77.40 g/l (Total protein) and 3.10, 2.98, 2.88 and 3.02 mmol/l (Total cholesterol) for the LNM, INYM, GJM and ETM dietary treatments respectively. Other values obtained were 0.86, 0.86, 0.66 and 0.76 mmol/l (HDL cholesterol), 1.92, 1.80, 1.88 and 1.96 mmol/l (LDL cholesterol) and 0.72, 0.68, 0.66, and 0.68 mmol/l (Triglycerides) for the LNM, INYM, GJM and ETM dietary treatments respectively. All above-mentioned parameters were not significantly ($P > 0.05$) influenced by the dietary treatments.

The Albumin values fell within the normal ranges stated by Harapin *et al.* (2003) and are in agreement with the results obtained by Annongu and Folorunso (2003) who fed *Gmelina arborea* fruit meal (GAF) as swine feedstuff. On the contrary, the values in this study were higher than the normal ranges proposed by Friendship *et al*. (1984) and Kaneko *et al*. (1977). The differences could be as a result of the differences in the environment, season, breed, age, sex and diets (Friendship *et al*., 1984; Rispat *et al*., 1993 and Harapin *et al*., 2003).

According to Stukelj et al. (2010), the total serum protein concentration is an indicator of adequacy of protein in terms of quality and quantity in the diet. Earlier experiments by Ekenyem and Madubuike (2007) and Hellwing *et al*. (2007) had elicited similar assertions. It is difficult to compare the results as total serum protein may vary greatly due to different feeding practices and genotype (Stukelj *et al*., 2010). Nevertheless, total

protein values fell below the normal ranges suggested by Kaneko *et al*. (1977), but were within those indicated by Friendship *et al*. (1984), Rispat *et al*. (1993) and Harapin *et al*. (2003) but are similar to the values reported by Miller *et al*. (1961) and Stukelj *et al*. (2010). Again, breed and diet differences could explain the above scenario. The values for total cholesterol and LDL cholesterol were higher in the pigs fed the white maize varieties than those fed the yellow maize varieties. It is not clear what could have led to this development. Again, the QPM varieties (GJM and ETM) had lower values for triglycerides levels than the normal maize varieties. Despite the numerical differences, the values are in agreement with the findings of Miller *et al*. (1961), Annongu and Folorunso (2003) and Stukelj *et al*. (2010).

4.8 Experiment II: Rats

The rats were apparently in good health throughout the experimental period. One rat in the INYM dietary treatment had wounds on the foot and was treated with antibiotic spray. Also, there were a lot of worms found in the GIT of those fed on the white maize varieties but it is unclear what might have brought about this observation. No mortality was recorded.

4.8.1 Growth performance and carcass characteristics of rats

The summary of the growth performance and carcass characteristics of the rats on the 4 dietary treatments is shown in Table 4.6.

The mean initial weights of rats were 71.00, 71.20, 71.00 and 71.00 g for the LNM, INYM, GJM and ETM diets respectively. There were no significant ($P > 0.05$) differences among the treatment means because allotment was done taking into consideration, the individual weights of the rats.

Table 4.6: Growth performance and carcass characteristics of rats on the 4 dietary treatments

Parameter	Dietary treatments				LSD	Sign.
	LNM	INYM	GJM	ETM		
Mean initial weight, g	71.00	71.20	71.00	71.00	3.538	NS
Mean final weight, g	131.80^{b}	157.20^{a}	162.60^{a}	131.40^{b}	14.760	*
Mean total feed intake., g	341.00	387.20	385.80	348.40	47.870	NS
Mean daily feed intake, g	12.18	13.83	13.78	12.44	1.710	NS
Mean gain weight, g	60.80^{b}	86.00^{a}	91.60^{a}	60.40^{b}	14.000	*
Mean daily gain, g	2.17^{b}	3.07^{a}	3.27^{a}	2.16^{b}	0.525	*
Mean feed conversion efficiency	5.61^{a}	4.53^{b}	4.31^{b}	5.91^{a}	0.536	*
Mean full GIT, g	20.42	23.07	18.56	20.02	4.636	NS
Mean empty GIT, g	7.92	8.85	8.66	8.36	1.224	NS
Mean empty stomach, g	1.02^{ab}	1.10^{a}	1.03^{ab}	0.93^{b}	0.137	*
Mean heart weight, g	0.47	0.54	0.56	0.44	0.057	NS
Mean kidney weight, g	0.95^{c}	1.07^{b}	1.24^{a}	0.96^{bc}	0.113	*
Mean liver weight, g	5.10^{b}	6.47^{a}	7.06^{a}	5.00^{b}	0.960	*
Mean respiratory tract weight, g	1.37	1.41	1.58	1.48	0.178	NS
Mean spleen weight, g	0.50	0.61	0.58	0.58	0.2 15	NS
Mean viscera weight, g	28.96	34.10	30.19	28.90	5.160	NS

, a,b, c values in the same row with different letters are significantly different ($P < 0.05$)

The mean final weights were 131.80, 157.20, 162.60 and 131.40 g with corresponding mean weight gains of 60.80, 86.00, 91.00 and 60.40 g for the LNM, INYM, GJM and ETM diets respectively. There were significant ($P < 0.05$) differences between treatment means. The treatment means of LNM and ETM diets were statistically lower than that of INYM and GJM diets. The mean daily weight gain were statistically ($P < 0.05$) different. The values were 2.17, 3.07, 3.27 and 2.16 g for the LNM, INYM, GJM and ETM diets respectively.

The GJM diet had the highest mean daily weight gain while ETM diet recording the lowest gain. The cause of the observed differences in the performance of the rats fed these two QPM based-diets is not known but it could be attributed to differences in the

rats' feed conversion efficiencies. These results also confirmed the report by Mertz *et al.* (1964), Nelson *et al*. (1965), Bressani *et al*. (1968) and Maner *et al.* (1971), of higher growth rates in favour of Opaque-2 maize in diets containing Opaque-2 and common maize varieties. Contrarily, Veum *et al*. (1973) reported non-significant ($P > 0.05$) differences in average daily gain when growing rats were fed Opaque-2 or normal maize diets supplemented with soyabean meal and/or amino acids but Opaque-2 maize diet did support slightly faster gains. Omage *et al*. (2009) also did not find any significant ($P > 0.05$) difference among treatment means when rabbits were fed graded levels of QPM based-diets. In the same vein, Serna-Saldivar *et al*. (1991) reported that weight gains of rats fed calcium- supplemented QPM diets were similar to their counterparts fed the normal maize calcium- supplemented diets.

The mean daily feed intake were 12.18, 13.83, 13.78 and 12.44 g with corresponding total feed intakes of 341.00, 387.20, 385.80 and 348.40 g for LNM, INYM, GJM and ETM diets respectively. The feed intakes were similar ($P > 0.05$). These results are in agreement with Maffia *et al*. (1976), Serna-Saldivar *et al*. (1991) and Omage *et al.* (2009).

The feed conversion efficiencies (FCE) were 5.61, 4.53, 4.31 and 5.91 for the LNM, INYM, GJM and ETM diets respectively. The FCE were influenced ($P < 0.05$) by the dietary treatments with the GJM and INYM diets (yellow maize) showing better feed conversion efficiencies over their white counterparts (ie. LNM and INYM diets). These significant ($P < 0.05$) differences support the results from feeding trial with rats (Mertz *et al*., 1964; Nelson *et al*., 1965; Bressani *et al*., 1968 and Rosa *et al*., 1977) but contradicts the findings of Gomez *et al*., (1975), Serna-Saldivar *et al*.,(1991) and rabbits (Omage *et al*., 2009).

The carcass parameters measured were the viscera, spleen, heart, kidney, liver, full and empty GIT, respiratory tract and empty stomach weights. The mean weights of the heart, full and empty GIT, respiratory tract, spleen and viscera were not influenced ($P > 0.05$) by the dietary treatments as shown in Table 4.6.

The mean values for the kidneys were 0.95, 1.07, 1.24 and 0.96 g for the LNM, INYM, GJM and ETM diets respectively. There was significant difference ($P < 0.05$) between the treatment means. These differences may be attributable to differences in growth rates rather than any disease condition because no observable disease conditions were detected during the physical examination of the internal organs. The mean weights of liver were 5.10, 6.47, 7.06 and 5.00 g for the LNM, INYM, GJM and ETM diets respectively and again the means were significantly ($P < 0.05$) different with higher value for the rats fed the GJM diet. Omage *et al*. (2009) reported higher value for liver weight in favour of normal maize when rabbits were fed graded levels of QPM maize. The differences observed in these two studies are attributable to diet composition and species differences. The treatment means of the empty stomach were 1.02, 1.10, 1.03 and 0.93 g for the LNM, INYM, GJM and ETM diets respectively and again the differences between these means were significant ($P < 0.05$). The differences observed in the treatment means among treatments may be due to differences in feed intakes. The INYM group which recorded 387.20 g of feed consumed also recorded a corresponding higher value of 1.10 g in empty stomach.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

The results from the studies suggest that, the use of the QPM diet (ETM) resulted in similar feed intake, growth rate and feed conversion efficiencies in pigs. The reduction in the inclusion levels of fish meal in the QPM diets (GJM and ETM) also resulted in economic savings of GH¢ 10.00 per metric tonne. All carcass and biochemical parameters were similar for all the dietary treatments but GJM and ETM diets gave slightly lower values in backfat thickness in the carcasses of the pigs. The studies also revealed that rats fed the GJM diet out-performed their counterparts in all the parameters measured. It can therefore, be concluded that the use of GJM and ETM varieties may offer an advantage of economic savings and the production of lean pork in Ghana.

I recommend that follow-up experiments should be conducted to validate the findings in this work and should include the determinations of essential amino acid profile and digestibility of the GJM and ETM varieties.

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APPENDIX: ANALYSIS OF VARIANCE (ANOVA) TABLES PIGS GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS

TABLE 1: ANOVA FOR INITIAL WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	58.3750	14.5938	14.81	
Replicate .*Units* stratum					
Treatment	3	0.0500	0.0167	0.02	0.997
Residual	12	11.8250	0.9854		
Total	19	70.2500			

TABLE 2: ANOVA FOR FINAL WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	11.0500	2.7625	3.40	
Replicate .*Units* stratum					
Treatment	3	4.4375	1.4792	1.82	0.197
Residual	12	9.7500	0.8125		
Total	19	25.2375			

TABLE 3: ANOVA FOR DURATION

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	671.3	167.8	1.59	
Replicate .*Units* stratum					
Treatment	3	323.4	107.8	1.02	0.418
Residual	12	1269.1	105.8		
Total	19	2263.8			

TABLE 4: ANOVA FOR TOTAL FEED INTAKE

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	1135.8	284.0	2.64	
Replicate .*Units* stratum					
Treatment	3	165.4	55.1	0.51	0.681
Residual	12	1289.4	107.5		
Total	19	2590.7			

TABLE 5: ANOVA FOR AVERAGE DAILY FEED INTAKE

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.12114	0.03029	0.78	
Replicate .*Units* stratum					
Treatment	3	0.14729	0.04910	1.26	0.331
Residual	12	0.46610	0.03884		
Total	19	0.73452			

TABLE 6: ANOVA FOR TOTAL WEIGHT GAIN

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	91.925	22.981	14.69	
Replicate .*Units* stratum					
Treatment	3	4.037	1.346	0.86	0.488
Residual	12	18.775	1.565		
Total	19	114.737			

TABLE 7: ANOVA FOR AVERAGE DAILY WEIGHT GAIN

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.010046	0.002511	0.77	
Replicate .*Units* stratum					
Treatment	3	0.016311	0.005437	1.66	0.228
Residual	12	0.039319	0.003277		
Total	19	0.065676			

TABLE 8: ANOVA FOR FEED CONVERSION EFFICENCY

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.08385	0.02096	0.94	
Replicate .*Units* stratum					
Treatment	3	0.08146	0.02715	1.22	0.345
Residual	12	0.26729	0.02227		
Total	19	0.43260			

TABLE 9: ANOVA FOR FEED COST/kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.00000000	0.00000000		
Replicate .*Units* stratum					
Treatment	3	0.00300000	0.00100000		
Residual	12	0.00000000	0.00000000		
Total	19	0.00300000			

TABLE 10: ANOVA FOR FEED COST/kg WEIGHT GAIN

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.019425	0.004856	0.90	
Replicate .*Units* stratum					
Treatment	3	0.088209	0.029403	5.46	0.013
Residual	12	0.064659	0.005388		
Total	19	0.172294			

TABLE 11: ANOVA FOR WARM DRESSED WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	22.625	5.656	3.03	
Replicate .*Units* stratum					
Treatment	3	1.438	0.479	0.26	0.855
Residual	12	22.375	1.865		
Total	19	46.438			

TABLE 12: ANOVA FOR WARM DRESSING PERCENTAGE

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	17.836	4.459	2.36	
Replicate .*Units* stratum					
Treatment	3	5.988	1.996	1.06	0.404
Residual	12	22.674	1.889		
Total	19	46.497			

TABLE 13: ANOVA FOR CHILLED DRESSED WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	15.970	3.993	2.06	
Replicate .*Units* stratum					
Treatment	3	1.346	0.449	0.23	0.872
Residual	12	23.214	1.935		
Total	19	40.530			

TABLE 14: ANOVA FOR CHILLED DRESSING PERCENTAGE

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	10.439	2.610	1.35	
Replicate .*Units* stratum					
Treatment	3	4.895	1.632	0.84	0.495
Residual	12	23.174	1.931		
Total	19	38.508			

TABLE 15: ANOVA FOR CARCASS LENGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	7.217	1.804	0.97	
Replicate .*Units* stratum					
Treatment	3	1.433	0.478	0.26	0.855
Residual	12	22.379	1.865		
Total	19	31.029			

TABLE 16: AN0VA F0R BACKFAT THICKNESS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.5037	0.1259	1.18	
Replicate .*Units* stratum					
Treatment	3	0.0909	0.0303	0.28	0.835
Residual	12	1.2764	0.1064		
Total	19	1.8710			

TABLE 17: ANOVA F0R P2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.23200	0.05800	2.56	
Replicate .*Units* stratum					
Treatment	3	0.04550	0.01517	0.67	0.587
Residual	12	0.27200	0.02267		
Total	19	0.54950			

TABLE 18: ANOVA FOR THIGH WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.74700	0.18675	2.22	
Replicate .*Units* stratum					
Treatment	3	0.22900	0.07633	0.91	0.467
Residual	12	1.01100	0.08425		
Total	19	1.98700			

TABLE 19: ANOVA FOR SHOULDER WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.1675	0.0419	0.34	
Replicate .*Units* stratum					
Treatment	3	0.1294	0.0431	0.35	0.787
Residual	12	1.4625	0.1219		
Total	19	1.7594			

TABLE 20: ANOVA FOR LOIN WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	1.8487	0.4622	1.80	
Replicate .*Units* stratum					
Treatment	3	0.0265	0.0088	0.03	0.991
Residual	12	3.0873	0.2573		
Total	19	4.9625			

TABLE 21: ANOVA FOR BELLY WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.64625	0.16156	2.35	
Replicate .*Units* stratum					
Treatment	3	0.24000	0.08000	1.17	0.363
Residual	12	0.82375	0.06865		
Total	19	1.71000			

TABLE 22: ANOVA FOR FILLET WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.0042500	0.0010625	1.65	
Replicate .*Units* stratum					
Treatment	3	0.0003750	0.0001250	0.19	0.899
Residual	12	0.0077500	0.0006458		
Total	19	0.0123750			

TABLE 23: ANOVA FOR VISCERA WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	1.7593	0.4398	0.96	
Replicate .*Units* stratum					
Treatment	3	1.1415	0.3805	0.83	0.504
Residual	12	5.5248	0.4604		
Total	19	8.4255			

TABLE 24: ANOVA FOR FULL GASTROINTESTINAL TRACT WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	3.5620	0.8905	1.23	
Replicate .*Units* stratum					
Treatment	3	4.6363	1.5454	2.13	0.150
Residual	12	8.7217	0.7268		
Total	19	16.9200			

TABLE 25: ANOVA FOR EMPTY GASTROINTESTINAL TRACT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.46075	0.11519	1.38	
Replicate .*Units* stratum					
Treatment	3	0.03050	0.01017	0.12	0.946
Residual	12	1.00325	0.08360		
Total	19	1.49450			

TABLE 26: ANOVA FOR TROTTERS WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.031750	0.007937	1.64	
Replicate .*Units* stratum					
Treatment	3	0.020500	0.006833	1.41	0.289
Residual	12	0.058250	0.004854		
Total	19	0.110500			

TABLE 27: ANOVA FOR SPLEEN WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.0017500	0.0004375	1.24	
Replicate .*Units* stratum					
Treatment	3	0.0045000	0.0015000	4.24	0.029
Residual	12	0.0042500	0.0003542		
Total	19	0.0105000			

TABLE 28: AANOVA FOR RESPIRATORY TRACT WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.084500	0.021125	3.07	
Replicate .*Units* stratum					
Treatment	3	0.059375	0.019792	2.88	0.080
Residual	12	0.082500	0.006875		
Total	19	0.226375			

TABLE 29: ANOVA FOR LIVER WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.08825	0.02206	1.51	
Replicate .*Units* stratum					
Treatment	3	0.24738	0.08246	5.63	0.012
Residual	12	0.17575	0.01465		
Total	19	0.51138			

TABLE 30: ANOVA FOR LEAFFAT WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.13425	0.03356	0.52	
Replicate .*Units* stratum					
Treatment	3	0.31500	0.10500	1.62	0.237
Residual	12	0.77875	0.06490		
Total	19	1.22800			

TABLE 31: AVONA FOR KIDNEY WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.0007500	0.0001875	0.53	
Replicate .*Units* stratum					
Treatment	3	0.0045000	0.0015000	4.24	0.029
Residual	12	0.0042500	0.0003542		
Total	19	0.0095000			

TABLE 32: ANOVA FOR HEART WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.0092500	0.0023125	4.83	
Replicate .*Units* stratum					
Treatment	3	0.0073750	0.0024583	5.13	0.016
Residual	12	0.0057500	0.0004792		
Total	19	0.0223750			

TABLE 33: ANOVA FOR HEAD WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.39625	0.09906	1.51	
Replicate .*Units* stratum					
Treatment	3	0.20337	0.06779	1.04	0.411
Residual	12	0.78475	0.06540		
Total	19	1.38437			

TABLE 34: ANOVA FOR EMPTY STOMACH WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.018250	0.004562	1.53	
Replicate .*Units* stratum					
Treatment	3	0.018000	0.006000	2.01	0.166
Residual	12	0.035750	0.002979		
Total	19	0.072000			

TABLE 35: ANOVA FOR RELATIVE VISCERA WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	1.5680	0.3920	0.42	
Replicate .*Units* stratum					
Treatment	3	2.0478	0.6826	0.74	0.550
Residual	12	11.1084	0.9257		
Total	19	14.7242			

TABLE 36: ANOVA FOR RELATIVE TROTTERS WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.084308	0.021077	2.29	
Replicate .*Units* stratum					
Treatment	3	0.048088	0.016029	1.74	0.212
Residual	12	0.110679	0.009223		
Total	19	0.243075			

TABLE 37: ANOVA FOR RELATIVE SPLEEN WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.0029102	0.0007275	1.06	
Replicate .*Units* stratum					
Treatment	3	0.0094066	0.0031355	4.59	0.023
Residual	12	0.0082004	0.0006834		
Total	19	0.0205172			

TABLE 38: ANOVA FOR RELATIVE RESPIRATORY TRACT WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.18806	0.04702	3.43	
Replicate .*Units* stratum					
Treatment	3	0.12884	0.04295	3.13	0.065
Residual	12	0.16440	0.01370		
Total	19	0.48131			

TABLE 39: ANOVA FOR RELATIVE LIVER WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.12551	0.03138	0.99	
Replicate .*Units* stratum					
Treatment	3	0.55507	0.18502	5.86	0.011
Residual	12	0.37882	0.03157		
Total	19	1.05940			

TABLE 40: ANOVA FOR RELATIVE KIDNEY WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.0010711	0.0002678	0.33	
Replicate .*Units* stratum					
Treatment	3	0.0092384	0.0030795	3.82	0.039
Residual	12	0.0096741	0.0008062		
Total	19	0.0199837			

TABLE 41: ANOVA FOR RELATIVE HEART WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.015365	0.003841	3.70	
Replicate .*Units* stratum					
Treatment	3	0.016163	0.005388	5.18	0.016
Residual	12	0.012475	0.001040		
Total	19	0.044003			

TABLE 42: ANOVA FOR RELATIVE HEAD WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.8531	0.2133	1.76	
Replicate .*Units* stratum					
Treatment	3	0.3828	0.1276	1.05	0.406
Residual	12	1.4572	0.1214		
Total	19	2.6931			

TABLE 43: ANOVA FOR RELATIVE EMPTY STOMACH WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.036204	0.009051	1.66	
Replicate .*Units* stratum					
Treatment	3	0.029841	0.009947	1.83	0.196
Residual	12	0.065349	0.005446		
Total	19	0.131395			

TABLE 44: ANOVA RELATIVE GASTROINTESTINAL TRACT WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.6319	0.1580	0.99	
Replicate .*Units* stratum					
Treatment	3	0.0619	0.0206	0.13	0.941
Residual	12	1.9216	0.1601		
Total	19	2.6154			

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TABLE 45: ANOVA FOR ALBUMEN

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	249.70	62.42	1.98	
Replicate .*Units* stratum					
Treatment	3	125.80	41.93	1.33	0.311
Residual	12	378.70	31.56		
Total	19	754.20			

TABLE 46: ANOVA FOR GLOBULIN

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	156.70	39.18	0.59	
Replicate .*Units* stratum					
Treatment	3	243.40	81.13	1.23	0.341
Residual	12	790.10	65.84		
Total	19	1190.20			

TABLE 47: ANOVA FOR HIGH DENSITY LIPOPROTEIN

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.28800	0.07200	1.03	
Replicate *Units* stratum					
Treatment	3	0.13750	0.04583	0.65	0.595
Residual	12	0.84000	0.07000		
Total	19	1.26550			

TABLE 48: ANOVA FOR LOW DENSITY LIPOPROTEIN

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.4680	0.1170	1.08	
Replicate *Units* stratum					
Treatment	3	0.0700	0.0233	0.22	0.884
Residual	12	1.3000	0.1083		
Total	19	1.8380			

TABLE 49: ANOVA FOR TRIGLYCERIDES

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.14300	0.03575	1.22	
Replicate .*Units* stratum					
Treatment	3	0.00950	0.00317	0.11	0.954
Residual	12	0.35300	0.02942		
Total	19	0.50550			

TABLE 50: ANOVA FOR TOTAL CHOLESTEROL

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.8820	0.2205	1.50	
Replicate *Units* stratum					
Treatment	3	0.1255	0.0418	0.28	0.835
Residual	12	1.7620	0.1468		
Total	19	2.7695			

TABLE 51: ANOVA FOR TOTAL PROTEIN

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	262.50	65.62	1.74	
Replicate *Units* stratum					
Treatment	3	52.80	17.60	0.47	0.711
Residual	12	452.70	37.73		
Total	19	768.00			

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TABLE 52: ANOVA FOR HEAMATOCRIT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	52.02	13.00	1.19	
Replicate *Units* stratum					
Treatment	3	49.09	16.36	1.50	0.264
Residual	12	130.78	10.90		
Total	19	231.89			

TABLE 53: ANOVA FOR HAEMOGLOBIN

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	3.4220	0.8555	1.23	
Replicate *Units* stratum					
Treatment	3	7.7920	2.5973	3.72	0.042
Residual	12	8.3780	0.6982		
Total	19	19.5920			

TABLE 54: ANOVA FOR MEAN CELL HAEMOGLOBIN

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.6230	0.1557	0.70	
Replicate *Units* stratum					
Treatment	3	0.2400	0.0800	0.36	0.783
Residual	12	2.6650	0.2221		
Total	19	3.5280			

TABLE 55: ANOVA FOR MEAN CELL HAEMOGLOBIN CONCENTRATION

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	16.612	4.153	1.60	
Replicate *Units* stratum					
Treatment	3	15.604	5.201	2.01	0.167
Residual	12	31.116	2.593		
Total	19	63.332			

TABLE 56: ANOVA FOR PLATELETS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	15388.	3847.	0.78	
Replicate *Units* stratum					
Treatment	3	11197.	3732.	0.76	0.539
Residual	12	59178.	4932.		
Total	19	85763.			

TABL 57: ANOVA FOR RED BLOOD CELLS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.4520	0.1130	0.48	
Replicate *Units* stratum					
Treatment	3	1.3015	0.4338	1.85	0.192
Residual	12	2.8160	0.2347		
Total	19	4.5695			

TABLE 58: WHITE BLOOD CELLS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	32.678	8.170	1.76	
Replicate *Units* stratum					
Treatment	3	62.342	20.780	4.47	0.025
Residual	12	55.846	4.654		
Total	19	150.865			

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TABLE 59: ANOVA FOR INITIAL WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	1045.700	261.425	39.66	
Replicate *Units* stratum					
Treatment	3	0.150	0.050	0.01	0.999
Residual	12	79.100	6.592		
Total	19	1124.950			

TABLE 60: ANOVA FOR FINAL WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	2176.5	544.1	4.74	
Replicate *Units* stratum					
Treatment	3	4077.8	1359.2	11.84	<.001
Residual	12	1377.5	114.8		
Total	19	7631.8			

TABLE 61: ANOVA FOR TOTAL FEED INTAKE

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	8818.	2204.	1.83	
Replicate *Units* stratum					
Treatment	3	8878.	2959.	2.45	0.114
Residual	12	14481.	1207.		
Total	19	32177.			

TABLE 62: ANOVA FOR AVERAGE DAILY FEED INTAKE

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	11.247	2.812	1.83	
Replicate *Units* stratum					
Treatment	3	11.324	3.775	2.45	0.114
Residual	12	18.471	1.539		
Total	19	41.042			

TABLE 63: ANOVA FOR TOTAL WEIGHT GAIN

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	2091.2	522.8	4.59	
Replicate *Units* stratum					
Treatment	3	4055.0	1351.7	11.87	<.001
Residual	12	1366.0	113.8		
Total	19	7512.2			

TABLE 64: ANOVA FOR AVERAGE DAILY WEIGHT GAIN

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	42.678	10.669	4.59	
Replicate *Units* stratum					
Treatment	3	82.755	27.585	11.87	<.001
Residual	12	27.878	2.323		
Total	19	153.310			

TABLE 65: ANOVA FOR FEED CONVERSION EFFICIENCY (FCE)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	3.2027	0.8007	5.30	
Replicate*Units* stratum					
Treatment	3	9.3361	3.1120	20.59	<.001
Residual	12	1.8134	0.1511		
Total	19	14.3522			

TABLE 66: ANOVA FOR DURATION

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.	0.		
Replicate *Units* stratum					
Treatment	3	0.	0.		
Residual	12	0.	0.		
Total	19	0.			

TABLE 67: ANOVA FOR VISCERA

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	69.97	17.49	1.25	
Replicate *Units* stratum					
Treatment	3	89.90	29.97	2.14	0.149
Residual	12	168.26	14.02		
Total	19	328.13			

TABLE 68: ANOVA FOR FULL GASTROINTESTINAL TRACT WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	53.86	13.47	1.19	
Replicate *Units* stratum					
Treatment	3	53.12	17.71	1.56	0.249
Residual	12	135.80	11.32		
Total	19	242.78			

TABLE 69: ANOVA FOR EMPTY GASTROINTESTINAL TRACT WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	11.4821	2.8705	3.64	
Replicate*Units* stratum					
Treatment	3	2.5078	0.8359	1.06	0.402
Residual	12	9.4682	0.7890		
Total	19	23.4581			

TABLE 70: ANOVA FOR EMPTY STOMACH WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.077450	0.019362	1.96	
Replicate *Units* stratum					
Treatment	3	0.092120	0.030707	3.10	0.067
Residual	12	0.118830	0.009903		
Total	19	0.288400			

TABLE 71: ANOVA FOR HEART WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.029080	0.007270	4.30	
Replicate *Units* stratum					
Treatment	3	0.050620	0.016873	9.98	0.001
Residual	12	0.020280	0.001690		
Total	19	0.099980			

TABLE 72: ANOVA FOR KIDNEY WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.127330	0.031833	4.78	
Replicate *Units* stratum					
Treatment	3	0.271200	0.090400	13.57	<.001
Residual	12	0.079950	0.006662		
Total	19	0.478480			

TABLE 73: ANOVA FOR LIVER WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	3.1950	0.7988	1.65	
Replicate *Units* stratum					
Treatment	3	15.6863	5.2288	10.77	0.001
Residual	12	5.8249	0.4854		
Total	19	24.7062			

TABLE 74: ANOVA FOR RESPIRATORY TRACT WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.13123	0.03281	1.96	
Replicate *Units* stratum					
Treatment	3	0.12362	0.04121	2.46	0.113
Residual	12	0.20121	0.01677		
Total	19	0.45606			

TABLE 75: ANOVA FOR SPLEEN WEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	4	0.09463	0.02366	0.97	
Replicate *Units* stratum					
Treatment	3	0.02926	0.00975	0.40	0.755
Residual	12	0.29217	0.02435		
Total	19	0.41606			