AKENTEN APPIAH- MENKA UNIVERSITY OF SKILLS TRAINING AND

ENTREPRENEURIAL DEVELOPMENT

EFFECTS OF REGULAR MAIZE AND DIFFERENT CERTIFIED MAIZE VARIETIES ON THE GROWTH AND CARCASS TRAITS OF BROILER CHICKENS

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A thesis in the Department of Animal Science Education, Faculty of Agriculture Education, submitted to the School of Graduate Studies in partial fulfillment of the requirements for the award of the degree of
Master of Education
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DECLARATION

STUDENT'S DECLARATION

I, Cynthia Amoabea Pimpong, declare that this thesis, with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE: ……………………………….

DATE: …………………………………………

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of thesis as laid down by the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development.

DR. HOLY KWABLA ZANU (Supervisor)

SIGNATURE: ……………………………………………

DATE: ……………………………………………………

DEDICATION

I dedicate this work to my parents (Mr. and Mrs. Pimpong), my uncle and his wife (Mr. and Mrs. Pimpong) at Kumasi, my siblings (Sylvia, Prince, Ophelia, and Francis), and all my nephews.

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GLOSSARY

DDG	Distilled Dried Grains
RM	Regular maize
OBM	Obatanpa
ABM	Abontem
HOM	Honampa
QPM	Quality Protein Maize
CSIR	Council for Scientific and Industrial Research
CRI	Crops Research Institute
FAO	Food and Agriculture Organisation
DM	Dry Matter
GGDP	Ghana Grain Development Project
CIDA	Canadian International Agency
SARI	Savanna Agricultural Research Institute
IITA	International Institute of Tropical Agriculture
OPV	Open Pollinated Varieties
FCR	Feed conversion ratio

ABSTRACT

The effects of Obatanpa, Abontem, and Honampa maize varieties or their mixture and regular maize on the growth performance of broiler chickens was evaluated over a 6-week experimental period using 180 cobb 500 broilers. There were 5 treatments arranged in a completely randomized design (CRD). The treatments were as follows: regular maize-based diet; Obatampa maize-based diet; Abontem maize-based diet; Honampa maize-based diet and a mixture of Obatanpa, Abontem, and Honampa maize varieties. Each treatment was replicated 5 times with 9 birds per replicate. Growth performance and carcass traits data were collected. The findings of the study revealed that the metabolize energy content of QPM and Regular maize was similar. Results showed that the nutritional composition of the maize varities used were similar to that of Regular maize, although maize varities tended have higher levels of crude protein and crude fat. Treatment effects after 7, 14, 21, and 28, 35 days was not significant for livability, body weight, weight gain, feed conversion ratio and feed intake. Abontem had the lowest FCR. However, the treatments did not affect livability and feed intake at the end of day 42. Obatanpa, Honampa, Abontem or their mixture influence growth performance at the initial stages of growth but did influence growth performance at the latter stages. Birds fed regular diet tended to consume more feed compared to the birds receiving QPM-based diet. The breast muscle yield of the chickens fed with regular maize diet was lower compared to those fed with QPM maize diet. However, higher breast meat yield and lower duodenal, jejunum and ileum weight were noticed in the diet in which QPM was used. Further, weights of breast, thigh, heart, duodenum, liver, gizzard, jejunum, ileum and caeca) expressed as % of live weight were not significant ($p > 0.05$) except proventriculus ($p<0.05$). It is concluded that Obatanpa, Abontem, and Honampa used in

broiler feed improved the growth performance and carcass traits of the birds than regular maize.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the study

Poultry has been recognized as an affordable source of high-quality protein worldwide in the form of meat and eggs. The poultry sector has been shown to become the world's largest meat sector by 2022. The rapid growth of the poultry sector is fueled by several factors such as an increasing human population, greater purchasing power in developing economies, increased urbanization and industrialization in developing countries, development and transfer of feed, relatively short production cycle, and advances in poultry breeding, and improved processing technologies. Of these factors, the feed has been recognized as the most important factor in controlling profitability and product quality (Dei, 2017).

Protein and carbohydrate are by far the two most important nutrients in poultry diets due not only to their marked effect on voluntary feed intake of the bird but also the fact that they represent approximately 90% of the total cost of the ingredients in a ration (Moreki & Tiroesele, 2012). Cereal grains constitute a large proportion (>50%) of poultry diets and contribute largely to carbohydrates and some extent proteins. They are mainly dietary sources of energy but can vary widely between grain types and animal species (Black, 2001). The common feed grains for poultry are corn or maize (*Zea mays*), wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), and sorghum or milo (Sorghum bicolor).

Maize is by far the major feed grain grown in Africa, particularly in Ghana. Although it is the preferred grain for feeding poultry (Advised & Latshaw, 2010), it is found to be low in protein content as well as protein quality (Vasal, 2000), thereby limiting its nutritional value. This has necessitated a search for nutritionally improved maize varieties as well as alternative feed ingredients. The former has resulted in extensive research on the world maize germplasm collection to improve its nutritive value, particularly the protein quality for poultry.

1.2 Problem Statement

In Ghana, maize is the major source of cereal grain in broiler diets. However, farmers do not use pure varieties of maize during feed formulation (Donkoh & Attoh-Kotoku, 2009). In practical feed formulation and mixing, poultry farmers use grains of unknown varieties from the market which is mostly a mixture of different varieties from unknown sources (Dei, 2017). It is not known the effects some of these specific varieties have on the growth performance of broilers or whether a mixture of the varieties would confer better growth performance. For example, diets could be formulated using different varieties of maize to meet the nutrient requirements of an animal regardless of their nutrient profile, factors such as texture, fibre (non-starch polysaccharides), β-carotene, etc. which are not normally factored in in feed formulation could make a difference. In this study, it was hypothesized that the mixture of different maize varieties in broilers' diets would improve growth performance and carcass traits more than those fed diets containing only one variety.

1.2 Aim and Specific Objective

1.2.1 Aim

The main objective of the study was to compare the effect of Obatanpa, Abontem, and Honampa maize varieties or their mixture and regular maize on the growth performance of broiler chickens.

1.2.2 Specific Objectives

The specific objectives of this study were to:

1. Determine the proximate composition of Obatanpa, Abontem, and Honampa varieties and regular maize.
2. Determine the effect of Obatanpa, Abontem, Honampa varieties or their mixture and regular maize in the growth performance of broiler chickens
3. Determine the effect of Obatanpa, Abontem, Honampa varieties or their mixture and regular maize on the carcass traits of broiler chickens.
4. Cost benefits

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Importance of maize in human and animal nutrition

Maize (*Zea mays* L.) tops other cereals in terms of worldwide production, accounting for more than 50 per cent of Ghana's total cereal production. On a worldwide basis, much of the maize produced is fed to livestock, whereas only a small portion goes directly to human food (Potter & Hotchkiss, 2012). Grain provides the world with 19% of its food calories and 15% of its annual production of food crop protein (Dei, 2017). It is the basic staple cereal grain for large groups of people in the middle-southern part (Ashanti and Brong-Ahafo regions), with an estimated 15% grown in the northern regions of the country (Darfour & Rosentrater, 2016), where the grain is consumed directly or in modified form as a major item of the diet.

Maize provides more feed for livestock than any other cereal grain (Orhun *et al*., 2013). For instance, livestock feed accounts for 65% of the world's maize production (FAO, 2005). The rapid rise in poultry production in developing nations in Asia, Africa, and Latin America is another important factor driving the use of maize for animal feed. Maize is the grain of choice for domestic birds because it has the highest dietary energy value among cereals with the least amount of year-to-year variation for a given region (Dei, 2017).

The main by-products of the "wet milling" process of starch and nutritive sweeteners yield over five hundred products from the industrial processing of maize (Refiners Association, 2006). The by-products are suitable for feeding farm animals and include germ, bran, and gluten (Zhang *et al*., 2021). Gluten contains a concentrated source of xanthophyll pigments and is particularly high in protein and metabolizable energy which is widely used in the production of poultry (Dei, 2017).

Additionally, maize has long been a vital component in the production of alcoholic beverages, such as whiskey and beer (Potter & Hotchkiss, 2012). The production of industrial alcohols also requires maize as a necessary raw material (25,4 kg of maize can produce 9.7 L of anhydrous ethanol plus useful byproducts) (Potter & Hotchkiss, 2012). Due to rising fuel prices, ethanol has the potential to be used as a partial substitute for gasoline. "Draff " or "distilled dried grains" (DDG) is the main by-product, and it is high in protein. Another by-product known as "solubles" which is made up of the smallest residues of yeast and maize particles, can also be added to the DDG. DDG is a popular feed ingredient for poultry production because it is high in protein, trace elements, and vitamins as well as increased availability of phosphorus. (Dei, 2017).

2.2 Nutritive value of normal hybrid maize grain

On a dry matter basis, the maize grain contains 82.9% endosperm, 11.1% germ, 5.2% pericarp, and 0.8% tip cap (Serna-Saldivar & Espinosa-Ramírez, 2018). Table 2.1 shows the per cent chemical composition of the maize grain and grain fractions. When considered on a dry matter basis, maize grain has a relatively low protein content (9.1%), oil content (4.4%), and ash content (1.4%) but a very high starch content (73.4%).

Table 2. 1 Chemical composition of normal maize grain and grain fractions (%DM).

	Starch	Protein	Oil	Sugar	Ash (Minerals)	Crude Fibre
Whole Grain	73.4	9.1	4.4	1.9	1.4	
Endosperm	87.6	8.0	0.8	0.6	0.3	2.7
Germ	8.3	18.4	33.2	10.8	10.5	8.8
Pericarp	7.3	3.7	1.0	0.3	0.8	86.7
Tip cap	5.3	9.1	3.6	1.6	1.6	

Source: (Singh *et al*., 2013)

2.2.1 Carbohydrate content of maize grain

The relative proportions of the various carbohydrates are 77% starch, 2% sugars, 5% pentosans (Iken & Amusa, 2004), and 1.2% crude fibre (Iken *et al*., 2002). The two starchy fractions of the endosperm (floury and flinty) form more than 70% of the carbohydrate which is concentrated in the maize grain (Allen *et al*., 2001). Dietary fibre and sugar are both present in the bran and germ, respectively (Hamaker *et al*., 2018).

The endosperm consists of starch granules which are found in a protein matrix. The protein content of flinty endosperm is high and also has a more rigid protein structure than that of floury endosperm (Dei, 2017). The floury endosperm's starch is made up of about 27% amylose (linear molecules) and 73% amylopectin, compared to the flinty endosperm, which is 100% amylopectin (large branched molecules) (Singh *et al*., 2019). The nutritional value of maize for poultry is unaffected by this variation in starch structure (Dei, 2017). A variety of maize is considered either flint or floury (dent) maize based on the distribution of the endosperm in the grain. Starch is the main source of energy in the grain and has a digestible energy content ranging from 3.75 to 4.17 kcal/g dry matter, thereby making maize one of the highest in energy among cereal grains (Miao *et al*., 2009).

The average dry matter content of crude fibre in maize grain is 2.7% (Radosavljević *et al*., 2012). The crude fibre interferes with the nutrient availability of the grain (Suswati & Sagiman, 2015). For instance, the range of protein digestibility of maize is 83–90% (Joye, 2019), while the digestibility of carbohydrates is 99% (Liu *et al*., 2015). However, due to its low content of crude fibre, the maize grain is very digestible (Panfilov *et al*., 2020).

2.2.2 Lipid content of maize grain

Maize oil is good quality oil both from a nutritional standpoint and in terms of cooking quality (Shende & Sidhu, 2014). Another advantageous feature of maize oil is its high level of natural antioxidants and very low concentration of linolenic acid (Singh *et al*., 2014), which reduces the grain's susceptibility to rancidity during storage.

The alpha-tocopherol (Vitamin E) content of maize grain is fair, ranging from 0.6 to 2.1 mg/100 g grain (Widj & Coker, 2006). Only yellow maize grain contains xanthophylls, which make up about 12,511 mg/100 g of the carotenoids found in maize lipids (Kean *et al*., 2008). Yellow maize is one of the best sources of pro-retinal carotenoids (Rojas & Pixley, 2010). These pigments give broiler skin, egg yolks, and shanks a yellow colour (Perez-Vendrell *et al*., 2001).

2.2.3 Protein content of maize grain

Although the protein content of maize grain is low, its variability is average, with a standard error of about 7 g/kg of crude protein (Dei, 2017). Maize grain contains 8 to 11 g of protein per 100 g of dry matter (Shewry, 2007). The amount of protein in the various grain fractions varies greatly.

Although the endosperm contains the majority of the protein in the grain, the germ has a higher protein content (184 g/kg DM) than the endosperm (80 g/kg DM) (Shewry, 2007). The low content of protein typically reduces its nutritional value as it is the only source of nutrition for both livestock and livestock. The relative proportions of the various protein fractions and the amino acid makeup of each fraction are what determine the whole maize grain amino acid composition (Dei, 2017). Based on their solubility in different solvent systems, maize grain endosperm proteins are generally referred to as albumins, globulins, prolamins, and glutelins (Dei, 2017). Albumins and globulins (water-soluble proteins) are present in the aleurone layer and the germ, whereas prolamins and glutelins (storage proteins) are confined to the endosperm.

The prolamin content exceeds that of glutelin and represents about 50–60% of the total protein in normal maize grain (Dei, 2017). Each protein fraction typically has a distinct composition of amino acids, and the relative proportion of each fraction greatly influences the level of each amino acid in the total amount of grain protein (Sidi *et al*., 2007). Lysine is a prolamin that is deficient, making the nutritional quality of maize protein poor. The main cause of the general deficiency of lysine in maize grain is the low level of albumin and globulin, which, in addition to having a high lysine content exhibits a well-balanced amino acid composition similar to that of animal proteins with greater nutritional value (Dei, 2017). Moreover, maize prolamins have higher levels of leucine than isoleucine, resulting in the normal amino acid imbalance that further lowers the protein quality of maize (Sikdar *et al*., 2016).

Therefore, the true significance of maize protein poor in nutritional quality is that other food items in livestock and human diets may not be able to make up for the lack of lysine or other important amino acids in maize protein in a sufficient manner (Obiri-Danso *et al*., 1997).

2.2.4 Vitamin content of maize grain

Vitamins in maize grain are concentrated mainly in the aleurone layer and the germ (Ndolo, 2015). Research on the vitamin composition of maize shows that the grain provides large amounts of riboflavin, pantothenic acid, choline, and pyridoxine, which are sufficient to meet the needs of most livestock (Dei, 2017). The low niacin content of maize vitamin pattern is a most significant feature. Furthermore, a large portion of the niacin found in grains is bonded (niacytin) and is not available to monogastric animals (Awulachew, 2022).

Additionally, the high concentration of leucine which is an essential amino acid in maize grain increases the niacin requirement in humans (Nuss & Tanumihardjo, 2010). As a result, those who primarily consume maize as a food source experience pellagra, a condition linked to niacin deficiency (Wan *et al*., 2011). Nevertheless, niacin shortage alone would not cause pellagra if normal maize were rich in tryptophan (Badawy, 2014) or heat-treated with alkali (Titcomb & Tanumihardjo, 2019). Complementing a diet high in maize with either legumes or animal products is one strategy for increasing niacin consumption (Prasanna *et al*., 2001).

Table 2. 2 Vitamin content of regular maize grain.

Vitamin	Concentration (g/kg)
Carotene	4.6
Vitamin E	0.46
Thiamine (B1)	4.83
Riboflavin (B2)	1.61
Nicotinic acid	25.29
Pantothenic acid	6.44
Pyridoxine	8.74
Choline	655.17

Source: (Dei, 2017)

Yellow maize shows vitamin A activity, whereas white maize does not (Muzhingi *et al*., 2011). The abundance of carotenes in yellow maize is primarily responsible for vitamin A potency.

Yellow maize has a carotene content of 0.46 mg/100 g of grain (Suri & Tanumihardjo, 2016). The presence of vitamins in the aleurone layer and the germ indicates that food preparations that do not retain these parts of the grain will further reduce vitamins in the diet.

2.2.5 Mineral content of maize grain

There is less than 2% of the inorganic or mineral component (ash) of maize grain (Hussaini *et al*., 2008). Of this, about 75% is found in the germ. The grain is most abundant in phosphorus and potassium, but deficient in calcium and trace minerals except iron (Table 2.3). However, most of the phosphorus is contained as phytic phosphorus, which monogastric animals cannot digest (Kuwano *et al*., 2009). The small amount of calcium that is normally present also has low bioavailability (Champagne, 1988) because it forms complexes with phytic phosphorus.

Table 2. 3 Mineral content of normal maize grain.

Minerals	Concentration (mg/100g)
Calcium	6.0
Phosphorus	300.0
Magnesium	160.0
Sodium	50.0
Potassium	400.0
Chlorine	70.0
Sulphur	140.0
Choline	655.17
Iron	2.5
Manganese	6.8
Copper	4.5

Source: (IITA, 1982)

2.2.6 Moisture content of maize grain

The moisture content of 10–14% is typical of properly ripened and dried maize grain (Los *et al*., 2018). Therefore, the grain provides a significant amount of dry matter. If the grain has a moisture content above this, mould growth may be induced and the grain may rot in storage. Some of these moulds produce hazardous by-products, such as aflatoxins, that can cause disease in both humans and animals who consume the grain (Los *et al*., 2018).

2.3 Maize grain as animal feed

The grain is what is important most when it comes to feeding livestock. Ruminants feed on the stalks, leaves, and immature ears as forage (Chaudhary *et al.*, 2011). In comparison to other cereal grains, maize grain is recognized as giving the highest conversion of dry matter into meat, milk, and eggs (Olaniyan, 2015). It is widely used as the primary source of calories for the feeding of pigs, cattle, and poultry (Dei, 2011).

Maize grain has a digestible energy content of 3.75–4.17 kcal/g (Jan *et al.*, 2008). When maize was fed to pigs and chickens, the metabolizable energy values were 3.6 and 3.8 kcal/g, respectively (Dei, 2017), and corresponding gross energy digestibility were 86% in chickens and 92% in pigs (Lammers *et al.*, 2008). Therefore, maize is preferred for feeding monogastric animals, especially poultry. For instance, maize serves as the basis for the high-energy poultry feeds that are used to fatten "broilers" across the country (Puntigam *et al.*, 2018).

Maize grains are either fed directly to poultry or fully blended with other ingredients after being milled and compounded. The resulting combination is subsequently fed to or converted into the forms preferred by particular animals. The by-products obtained from both wet-milling and dry-milling industrial processes of maize grain are potential feed ingredients for poultry (Lakshmi *et al.*, 2017) as depicted by the favourable nutrient composition of these by-products, particularly in terms of protein content. Germ, bran and gluten are the major by-product ingredients (Zhang *et al.*, 2021). These maize by-products are mixed to produce a feed ingredient called maize gluten feed (Rausch *et al.*, 2019). Even though maize gluten offers nutritional potential as a feed for poultry, its usage has been limited for a variety of reasons, including the lack of readily available research information (Dei, 2017), unknown quality of the protein (Butts-Wilmsmeyer *et* *al*., 2019) even though the protein content is fairly high and perceived low metabolizable energy content (Majdeddin *et al*., 2018).

2.4 Nutritional improvement of maize grain

Since 1914, it has been observed that the lack of necessary amino acids (lysine and tryptophan) causes maize proteins to be of poor quality (Babu & Prasanna, 2014). The high zein fraction of maize protein in the majority of varieties of maize grains was cited for these deficits (Maqbool *et al*., 2021). According to Wu *et al*. (2010) zein contains very low levels of lysine and tryptophan. In a study of the factors affecting the protein quality of maize, various researchers found that the environment and the variety of maize had a substantial impact on the lysine content of the grain in some instances (Dei, 2017; Tandzi *et al*., 2017). It has been demonstrated that the opaque-2 gene in maize contributed to a genetic rise in the lysine content of maize protein (Gibbon & Larkins, 2005). These researchers further reported, the increase in lysine in opaque-2 maize was caused by a change in the distribution of endosperm protein fractions, of which opaque-2 maize contained about 22% zein as compared to 50% zein in normal maize. Chemical analysis of maize protein for amino acids (Sumbo & Victor, 2014) showed that opaque-2 maize contained 60– 130% more lysine than did normal maize, plus a 12–40% reduction in leucine as well as an elevated level of tryptophan. More mutant maize genes have been discovered after these discoveries. All of the "high-lysine" genes regulate the amount of zein accumulation throughout the formation of the endosperm. These "high-lysine" genes include most importantly floury-2 (Sofi *et al*., 2009); opaque-7 (Pukalenthy *et al*., 2019); opaque-6, and floury-3 (Prasanna *et al*., 2001). Opaque-2 has proven superior in zein reduction among them (Huang *et al*., 2004). For individuals who depend on maize as a staple food and animal feed, the development of these nutritionally improved maize varieties is very important since it can increase the nutritional quality of such diets without incurring additional costs.

2.5 Maize improvement research in Ghana

2.5.1 Open Pollinated Varieties (OPV)

The Ghana Grain Development Project (GGDP), funded by the governments of Ghana and Canada through CIDA, carried out the single most extensive research project on maize (Al-Hassan *et al*., 2007). The project, which has several goals including increased grain yields and resistance to diseases, pests, and lodging, was started in 1979 to promote research for the enhancement of maize and legumes. Additional objectives included addressing various growing conditions and enhancing nutritional quality (Azinu, 2014). The most important technologies developed and promoted by the project include 15 enhanced maize varieties, fertilizer recommendations, and plant layout recommendations (Azinu, 2014). The Crops Research Institute began working on quality protein maize (QPM) in 1989, and as a result, the open-pollinated variety Obatanpa was first released and quickly gained popularity in Ghana and other parts of Africa and beyond (Sallah *et al*., 2007). In 1991, a program to develop QPM hybrid maize was started alongside the development of Obatanpa. The three 3-ways QPM hybrids that were developed as part of this program, GH110-5 (Mamaba), GH132-28 (Dadaba), and GH2328-88 (CIDA-ba), were highly productive, generating between 6.3 and 7.3 t/ha on the experimental site, representing an increase of 19 to 38% over obatanpa. In 1997, the QPM hybrids were made available for production (Sallah *et al*., 2003).

2.5.2 Synthetic Varieties

To increase maize productivity in places where *Striga harmonica* and drought are endemic, four quality protein maize (QPM) cultivars were also produced in 2010. The early and extra-early maturing cultivars were jointly issued by the Crops Research Institute (CRI) and the Savanna Agricultural Research Institute (SARI) of the Council for Scientific and Industrial Research (CSIR) of Ghana. Three of the four varieties—EV DT-W 99 STR QPM Co; TZE-W Pop STR QPM C0; and TZEE-W Pop STR QPM C0—were created by IITA as part of the earliness program (an extra-early maturing variety). The fourth, a QPM hybrid with intermediate maturation and drought tolerance, was developed in the national maize program of Ghana.

2.5.3 Hybrid Maize Varieties

In 1997, there were four new varieties developed, three of which were high-yielding QPM hybrids (Mamaba, Cida-ba, and Dada-ba), and the other one was an OPV that matured extra-early (Dodzi). In 2007, four new varieties were released. These varieties are Aziga and Golden Jubilee (two high-yielding, QPM, open-pollinated yellow maize varieties), Akposoe (QPM, extra-early maturing, drought-tolerant variety), and Etubi (QPM, drought-tolerant hybrid variety). Three drought-tolerant, Striga-tolerant, QPM OPVs and one drought-tolerant, QPM hybrid (Enibi) are additional four varieties that were released in 2010. In general, CRI and SARI jointly developed and released five hybrid varieties: Mamaba, Cida-ba, Dada-ba, Etubi, and Enibi. Six varieties were officially released in 2012: five hybrids and one OPV containing pro-vitamin A. In Ghana, private companies have also begun to promote hybrid maize cultivars. An example is the Pannar varieties promoted by Wienco (Chapoto & Ragasa, 2013).

2.6 Nutrient levels in QPM

Except for the amounts of lysine, tryptophan, leucine, and isoleucine, the nutritional composition of QPM is similar to that of normal maize (Diaz, 2004). In QPM grains, the protein content ranges from 7.4% to 10.5% of dry matter (Tandzi *et al*., 2017), which is about the same as that of normal maize (Dei, 2017).

QPM grains have about twice as much lysine and tryptophan as compared to regular maize. There is also a reduced imbalance between isoleucine and leucine. The majority of QPM cultivars have grains with an average protein content of 3.5–4.5% lysine (Dei, 2017). Additionally, the gluten of QPM grain has a higher lysine content than normal maize grains (Shobha *et al*., 2022).

QPM grains produce starch that is comparable to that of normal maize grains (Twumasi-Afriyie *et al*., 2011). Starch content has been reported to be 56.6% for QPM grain and 55.0% for normal maize grain (Shobha *et al*., 2022). QPM grains have a fat content that ranges from 3% to 7% (Shobha *et al*., 2022). Compared to normal maize grains, QPM grains had significantly higher levels of palmitic acid and linoleic acid in the triglycerides, but lower levels of stearic, oleic, and linolenic acids (Shobha *et al*., 2022). Yellow grain varieties of QPM and normal maize both have similar amounts of carotenoids (Nuss & Tanumihardjo, 2010).

2.7 Varieties of certified maize

2.7.1 Obatanpa

This is an open-pollinated type of variety that takes 110 days to mature and has a potential yield of 4.6 tons/ha. It produces white seeds and takes 55 days to the formation of 50% cream-purple silk. It attains a plant height of 175 cm, ear height of 80 cm, and a cream-purple shade open tassel alternatively arranged. It also has a stem colour green with a purple shade, a cob length of 15.2 cm, cob diameter of 4.8 cm. The kernel depth is 1.3 cm which is dent and arranged in a straight line. It tolerates drought and stress conditions. It is excellent in enhancing the nutrition and health of humans, poultry, and livestock. It contains 72% starch, 10% protein, 4.8% oil, 8.5% fibre, 3.0% sugar and 1.7% ash (National Variety Release Catalogue, 2019).

2.7.2 Abontem

This is also an open-pollinated type of variety that takes 75-80 days to mature and has a potential yield of 4.7 tons/ha. It produces yellow seeds and takes 54 days to the formation of 50% purple silk. It attains a plant height of 162 cm, an ear height of 82 cm, and a cream-purple shade open tassel alternatively arranged. It also has a stem colour green with a purple shade, a cob length of 15.5 cm, cob diameter of 4.4 cm. The kernel depth is 1.1 cm which is flint or dent and arranged in a straight line. It tolerates drought and stress conditions (fungus, bacteria, and viruses). It is good for poultry and livestock. It contains 70% starch, 12% protein, 4.8% oil, 8.5% fibre, 3.0% sugar and 1.7% ash (National Variety Release Catalogue, 2019).

2.7.3 Honampa

This is a variety of maize having a seed colour of yellow-orange. It takes 56 days for the formation of 50% purple silk. It also has a plant height of 171 cm and an ear height of 91 cm. The colour of the tassel is purple with an open and alternate arrangement. The stem colour is green with a purple shade, cob length of 15.8 cm, cob diameter of 4.3 cm, and a kernel depth of 1.0 cm which is flint and arranged in a straight line. It is a source of Pro-vitamin A for improved nutrition and health which makes it suitable for human, poultry, and livestock consumption. It takes 110-115 days to mature. It has a potential yield of 5.2 tons/ha and is excellent for industrial preparations such as grits and kenkey. It contains 13.1% moisture, 10.7% protein, 1.1% fibre, 4.4% fat, 1.3% ash, 71.9% carbohydrate, 311.2% water binding capacity, 17.8% solubility, 9.6% swelling power, and 7.0 μg/g pro-vitamin A (National Variety Release Catalogue, 2019).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study site and design

The experiment was conducted at the Animal Science Department experimental station, University of Education Winneba, Asante-Mampong campus. It involves the construction of 20 pens of dimensions 1 m length, 0.8 m width, and 0.8 m height (0.64 m^3) (Plate 3.1). The pens were constructed in a larger pen with homogenous conditions to control variation caused by non-uniform environmental conditions on treatment performance. Wood shavings were spread on the floor to provide insulation against heat loss and to enhance pen cleaning. A completely randomized design (CRD) with four (4) replications was the experimental design used.

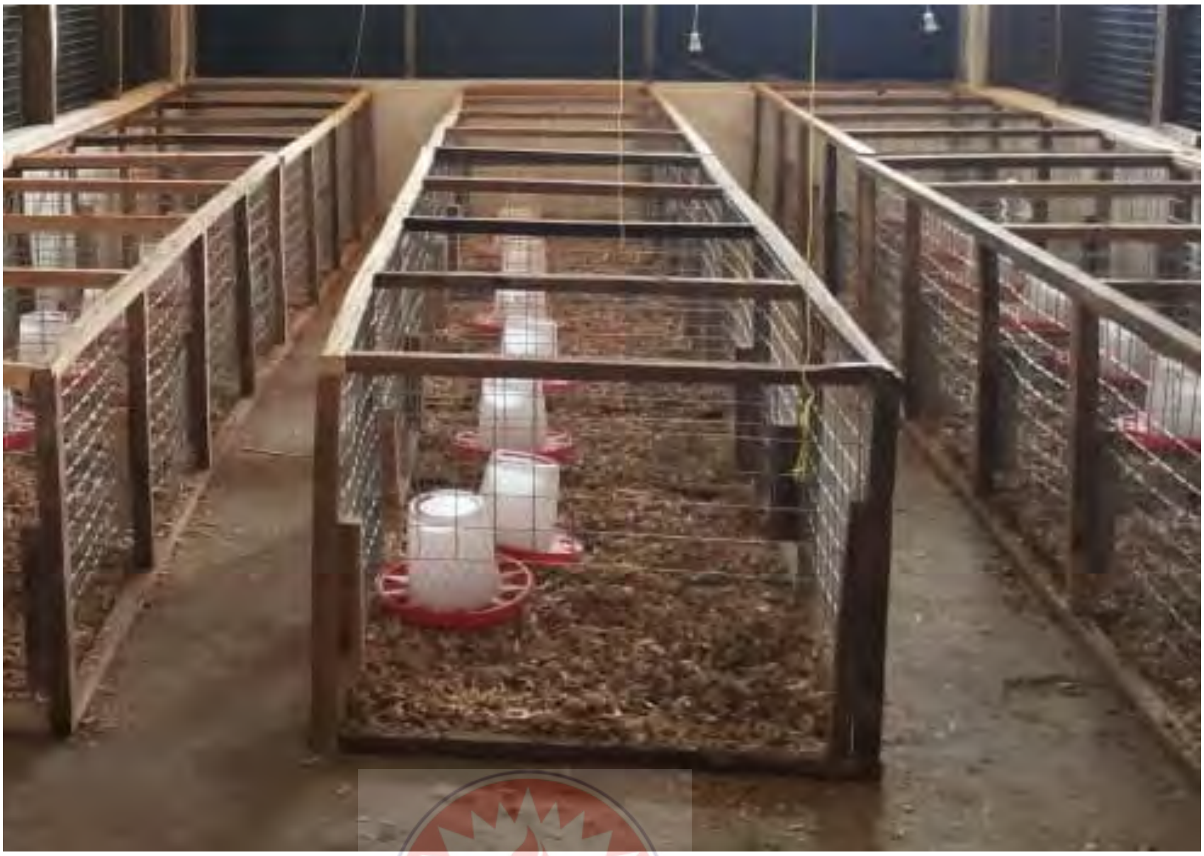

Plate 3.1: Pens used for the experiment arranged in a larger pen

3.2 Experimental material and treatments

The experimental birds used in this study were cobb 500 chicks obtained from Chicks and Chicken hatchery in Kumasi, Ghana. Each replicate pen contains 9 birds. Treatments include five (5) different diets namely:

1. dietary treatment 1 (control): regular maize-based diet,
2. dietary treatment 2: Obatanpa-based diet,
3. dietary treatment 3: Abontem-based diet,
4. dietary treatment 4: Honampa-based diet,
5. dietary treatment 5: a mixture of Obatanpa + Abontem + Honampa

The diets are shown in Table 3.1

Table 3. 1 Characteristics of maize varieties used in treatment design

Treatment	Maize variety	Characteristics
1	Regular maize (mixture of unknown varieties)	Unknown characteristics
2	Obatanpa	Quality protein maize (QPM), white seed colour, dent kernel
3	Abontem	QPM, yellow seed colour, flint/dent kernel
4	Honampa	QPM, yellow seed colour
5	A mixture of Honampa, Obaatampa and Abontem	Have qualities of all used varieties

Source: (National Variety Release Catalogue, 2019).

Table 3. 2 Ingredients and nutrient composition of grower diets (%), as-fed

Ingredient	Regular maize-based diet	Obatanpa-based diet	Abontem-based diet	Honampa-based diet	OBM[1]+ABM[2]+HOM[3]
[4]Regular maize	58.00	-	-	-	-
Obatanpa	-	58.00	-	-	20.00
Abontem	-	-	57.71	-	20.00
Honampa	-	-	-	58.00	19.50
Wheat bran	12.50	13.00	13.93	12.50	13.00
Soybean meal	16.00	15.50	14.93	16.00	14.00
Fishmeal	11.00	11.00	10.95	11.00	11.00
Vitamin/mineral Premix	0.50	0.50	0.498	0.50	0.50
Oyster shell	0.50	0.50	0.498	0.50	0.50
Salt	0.50	0.50	0.498	0.50	0.50
Dicalcium Phosphate	1.00	1.00	0.995	1.00	1.00
	100	100	100	100	100
Calculated Nutrient compositions					
Protein %	23	23	23	23	23
Energy kcal ka^{-1}	3000	3000	3000	3000	3000
Calcium	0.9	0.9	0.9	0.9	0.9
Au phosphorusa	0.45	0.45	0.45	0.45	0.45

[1]Obatanpa, [2]Abontem, [3]Honampa, [4]Regular maize: the maize is normally sold out in the market and used for feeding chickens.

Vitamin mineral premix provided the per following per kg diet: vitamin A, 10,000IU:D, 400,0001U,E,3,000IU:K,2000IU: B1 200mg B2, 900mg: B12,2400mg: niacin,5,000mg: Fe,9,000mg: Cu, 500mg:Mn, 12000mg: Co, 1000mg: Zn,10,000mg: Se, 4

Table 3. 3 Ingredients and nutrient composition of finisher diets (%), as-fed

Ingredient	**Regular maize-based diet**	**Obatanpa-based diet**	**Abontem-based diet**	**Honampa-based diet**	**OBM[1]+ABM[2]+HOM[3]**
Regular maize (%)	60.00	-	-	-	-
Obatanpa (%)	-	59.99	-	-	20.04
Abontem (%)	-	-	60.597	-	20.04
Honampa (%)	-	-	-	60.585	20.04
Wheat bran (%)	18.00	15.998	16.184	16.181	16.058
Soybean meal (%)	11.00	12.999	12.00	12.117	12.025
Fishmeal (%)	9.00	8.999	12.119	9.088	9.777
Premix (%)	0.50	0.502	0.507	0.507	0.503
Oyster shell (%)	0.50	0.502	0.507	0.507	0.503
Salt (%)	0.50	0.502	0.507	0.507	0.503
Dicalcium phosphate (%)	0.50	0.502	0.507	0.507	0.50
Calculated Nutrient compositions					
Protein %	18	18	18	18	18
Energy Kcal Kg-1	3200	3200	3200	3200	3200
Calcium	0.8	0.8	0.8	0.8	0.9
Au Phosphorusa	0.35	0.35	0.35	0.35	0.35

[1]Obatanpa
[2]Abontem
[3]Honampa
[4]Regular maize: the maize is normally sold out in the market and used for feeding chickens.

3.3 Management

The experiment started on the 2nd of March, 2021 and lasted for 42 days. Feed and water were provided using feed and water troughs, respectively. Forty-eight (48) hours before the arrival of the birds, the pens were disinfected. Upon arrival, the birds were administered glucose (Gluco-vet vitamin C fortified) to enhance their energy and were done continuously during the first three (3) days. The heat was provided in the pens using charcoal and lighting. Vaccination against Newcastle and Gumboro and administration of coccidiostats were the same for each replicate pen.

3.4 Data collection

3.4.1. Performance

Feed consumption, body weight, gain, feed conversion ratio (feed: gain) and livability were calculated weekly. Feed consumption was calculated by subtracting feed fed from feed leftovers. The body weight was determined by dividing the cumulative pen weight by the number of birds in the pen. The gain was calculated as the difference between the birds' body weight and their initial body weight. FCR was calculated by dividing the difference between the pen weight and the sum of the initial bird weight and dead bird weight by the feed consumption for the same period. Livability was calculated by dividing the number of birds by the initial total number of birds and multiplying by a factor of 100. The pens were monitored for mortality twice daily and post-mortem examinations were conducted on dead birds throughout the study period. Feed intake and feed conversion ratio (feed intake/weight gain) were corrected for mortality Weight of edible carcass, giblet (liver + heart + gizzard) and breast meat. At the end of the finisher phase, a chicken was taken from each treatment, which represented the average weight of the group for carcass evaluation. Live weight for each chicken was taken before slaughter and the weight of organs was measured All the organs were expressed as a percentage of the pre-slaughter weight of the same bird.

3.4.2 Carcass trait

The liver, breast, thigh, heart, proventriculus, empty gizzard and intestines (duodenum, jejenum, ileum and caeca) were taken from two-sampled birds and were expressed as a percentage of live bodyweight.

3.5 Statistical Analysis

Data collected on growth performance and carcass traits were subjected to analysis using the General Linear Models (GLM) procedure of Minitab 17.0 statistical software. The means of different treatments were compared with Tukey Pairwise Comparison tests. Significance was considered at $P < 0.05$ levels.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Proximate composition of Regular, Obatanpa, Abontem and Honampa maize as feed for broiler chicken.

All the maize varieties except the one obtained from the market are quality protein maize (QPM), that is, have higher protein content than normal maize (Table 4.1). From the nutritional quality analysis, crude protein range between 11.38 and 13.13 % (Table 4.1). Moisture content was within the optimal range (9.3 to 11.10 %) with nitrogen-free extract ranging between 71.87 and 74.83 %. Metabolizable energy also ranged between 3088.33 and 3187.23 Kcal kg^{-1}.

Table 4. 1 Nutritional quality of Regular maize, Obantanpa, Abontem and Honampa

Parameter (%)	Regular maize	Obatanpa	Abontem	Honampa
Moisture content	11.1	9.3	10.5	9.4
Ash content	0.9	1.1	0.7	0.78
Crude protein	11.38	12.92	13.13	12.04
Crude fat	1.15	1.0	2.05	1.5
Crude fibre	1.95	1.91	1.75	1.45
Nitrogen free extract	73.52	74.07	71.87	74.83
ME[1], Kcal kg^{-1}	3088.33	3160.47	3168.95	3187.23

[1]Predicted

Results showed that the nutritional composition of QPM (Abontem) and the hybrid maize were similar to that of Regular maize, although QPM tended to have higher levels of crude protein and crude fat. Similar observations had been made by Osei *et al*. (1999) and Qi *et al*. (2004). This finding is contrary to the research performed by Tiwari *et al*.

(2013) who recorded a higher crude fibre percentage (6.26%) for the certified maize than Regular maize (2.34%). The findings of the study revealed that the metabolised energy content of QPM and Regular maize was similar and the values obtained were within the range reported by Osei *et al*. (1999) and Tyagi *et al*. (2008). However, the protein contents of QPM were 6.34% (Obatanpa), 7.14% (Abontem) and 2.82% (Honampa) higher than Regular maize. Several other researchers have also reported higher protein quality of QPM over Regular maize (Onimisi *et al*., 2009; Osei *et al*., 1999; Tiwari *et al*., 2013).

4.2 Effect of regular, Obatanpa, Abontem and Honampa maize used in feed formulation on the growth performance of broiler chicken.

Treatment effects after 7 days were not significant statistically for livability, initial body weight, weight gain, feed conversion ratio and feed intake respectively ($p > 0.05$) (Table 4.2). This indicates that the treatments did not affect the growth performance of the broilers after 7 days.

Table 4. 2 Effects of regular, Obatanpa, Abontem and Honampa maize varieties on the growth performance per bird, 0 to 7 days

Treatment	Livability %	BW g	WG g	FCRc	FI g
Regular maize-based diets	97.22	117.70	79.67	0.83	66.32
Obatanpa-based diets	91.67	125.26	84.71	1.20	101.10
Abontem-based diets	91.67	127.13	87.57	0.80	71.00
Honampa-based diets	100.00	125.72	86.89	1.08	93.20
OBM[1]+ABM[2]+HOM[3]	97.22	117.24	76.60	0.92	70.82
P-value	0.455	0.312	0.247	0.437	0.436
SEM	1.69	1.91	1.82	0.08	6.96

SEM = Standard Error of Means. BW = Body Weight., WG = Weight Gain, FCR = Food Conversion Ratio. FI = Feed Intake.

Treatment effects after 14 days were not significant statistically for livability, initial body weight, weight gain, feed conversion ratio and feed intake respectively ($p > 0.05$) (Table 4.3). This indicates that the treatments did not affect the growth performance of the broilers after 14 days.

Table 4. 3 Effect of regular, Obatanpa, Abontem and Honampa maize used in feed formulation on the growth performance per bird, 0 to 14 days

Treatment	Livability %	BW g	WG g	FCRc	FI g
Regular maize-based diets	91.67	236.37	198.35	1.47	291.92
Obatanpa-based diets	91.67	256.80	216.20	1.58	341.30
Abontem-based diets	88.89	264.60	225.10	1.39	313.60
Honampa-based diets	97.22	264.01	225.18	1.47	333.20
OBM[1]+ABM[2]+HOM[3]	97.22	243.30	202.60	1.51	304.50
P-value	0.723	0.322	0.292	0.456	0.559
SEM	2.19	5.16	4.97	0.03	10.10

NS = Not significant. SEM = Standard Error of Means. Init BW = Initial Body Weight. WG = Weight Gain. FCR = Food Conversion Ratio. FI = Feed Intake.

Treatment effects after 21 days were not significant statistically for livability, initial body weight, weight gain, feed conversion ratio and feed intake respectively ($p > 0.05$) (Table 4.4). This indicates that the treatments did not affect the growth performance of the broilers after 21 days.

Table 4. 4 Effect of regular, Obatanpa, Abontem and Honampa maize used in feed formulation on the growth performance per bird 0 to 21 days

Treatment	Livability %	BW g	WG g	FCRc	FI g
Regular maize-based diets	91.67	403.90	365.80	1.70	616.50
Obatanpa-based diets	88.89	437.30	396.80	1.64	645.40
Abontem-based diets	86.11	469.30	429.80	1.58	679.80
Honampa-based diets	97.22	448.20	409.40	1.55	632.50
OBM[1]+ABM[2]+HOM[3]	94.44	431.80	391.20	1.53	586.60
P-value	0.525	0.207	0.210	0.836	0.405
SEM	2.11	8.83	8.72	0.05	15.00

NS = Not significant. SEM = Standard Error of Means. Init BW = Initial Body Weight. WG = Weight Gain. FCR = Food Conversion Ratio. FI = Feed Intake.

Treatment effects after 28 days were significant statistically for livability ($p < 0.05$). Honampa had the highest livability (94.44 %) and was similar to all other treatments except Abontem (58.33%) (Table 4.5). However, the treatments did not statistically affect the initial body weight, weight gain, feed conversion ratio and feed intake respectively after 28 days ($p > 0.05$) (Table 4.5).

Table 4. 5 Effect of regular, Obatanpa, Abontem and Honampa maize used in feed formulation on the growth performance per bird 0 to 28 days

Treatment	Livability %	BW g	WG g	FCRc	FI g
Regular maize-based diets	86.11^{ab}	585.10	547.00	1.87	1014.80
Obatanpa-based diets	77.80^{ab}	706.30	665.70	1.66	1099.30
Abontem-based diets	58.33^{b}	779.20	739.60	1.60	1165.30
Honampa-based diets	94.44^{a}	686.80	648.00	1.67	1080.60
OBM[1]+ABM[2]+HOM[3]	88.89^{ab}	667.50	626.90	1.69	1056.10
P-value	0.022	0.068	0.069	0.358	0.305
SEM	4.04	22.10	22.00	0.04	22.40

* = Significant. *NS* = Not significant. SEM = Standard Error of Means. Means with the same superscript do not differ significantly (p>0.05) and means with different superscript differ significantly (p<0.05) according to the Tukey Pairwise Comparison tests between treatments within the week. Init BW = Initial Body Weight. WG = Weight Gain. FCR = Food Conversion Ratio. FI = Feed Intake.

Treatment effects after 35 days were significant statistically for livability ($p < 0.05$). Honampa had the highest livability (91.67%) and was similar to all other treatments except Abontem (52.78%) (Table 4.6). However, the treatments did not statistically affect the initial body weight, weight gain, feed conversion ratio and feed intake respectively after 35 days ($p > 0.05$) (Table 4.6).

Table 4. 6 Effect of regular, Obatanpa, Abontem and Honampa maize used in feed formulation on the growth performance per bird, 0 to 35 days

Treatment	Livability %	BW g	WG g	FCRc	FI g
Regular maize-based diets	72.22[ab]	689.40	651.30	2.37	1490.90
Obatanpa-based diets	72.20[ab]	780.20	739.70	1.94	1423.60
Abontem-based diets	52.78[b]	900.80	861.30	1.77	1523.20
Honampa-based diets	91.67[a]	845.80	807.00	1.93	1555.60
OBM[1]+ABM[2]+HOM[3]	86.11[ab]	812.80	772.20	1.95	1490.40
P-value	0.029	0.092	0.092	0.100	0.547
SEM	4.41	25.80	25.70	0.07	24.00

* = Significant. *NS* = Not significant. SEM = Standard Error of Means. Means with the same superscript do not differ significantly (p>0.05) and means with different superscript differ significantly (p<0.05) according to the Tukey Pairwise Comparison tests between treatments within the week. Init BW = Initial Body Weight. WG = Weight Gain. FCR = Food Conversion Ratio. FI = Feed Intake.

Treatment effects after 42 days were significant statistically for initial body weight, weight gain and food conversion ratio ($p < 0.05$). However, Abontem recorded the highest initial body weight (1130g) and weight gain (1090.40g). On the other hand, Regular maize had the lowest initial body weight (804.4g) and weight gain (766.30g), although it was similar to that of Obatanpa, Honampa and mixture, respectively (Table 4.7). Regular maize had the highest FCR (3.50) and was similar statistically to that of Obatanpa, Honampa, and mixture respectively (Table 4.7). -Abontem had the lowest FCR. However, the treatments did not statistically affect the livability and feed intake respectively after 42 days ($p > 0.05$) (Table 4.7).

Table 4. 7 Effect of regular, Obatanpa, Abontem and Honampa maize used in feed formulation on the growth performance per bird, 0 to 42 days

Treatment	**Livability %**	**BW g**	**WG g**	**FCR**	**FI g**
Regular maize-based diets	58.30	804.40^{b}	766.30^{b}	3.50^{a}	2625.00
Obatanpa-based diets	61.10	947.10^{ab}	906.50^{ab}	2.68^{ab}	2415.00
Abontem-based diets	52.78	1130.00^{a}	1090.40^{a}	2.40^{b}	2605.00
Honampa-based diets	80.56	1002.60^{ab}	963.70^{ab}	2.67^{ab}	2569.00
OBM^{1}+ABM^{2}+HOM^{3}	80.56	1054.00^{ab}	1014.00^{ab}	2.44^{ab}	2410.50
P-value	0.183	0.050	0.050	0.046	0.787
SEM	4.70	37.50	37.30	0.14	67.00

* = Significant. *NS* = Not significant. SEM = Standard Error of Means. Means with the same superscript do not differ significantly ($p>0.05$) and means with different superscript differ significantly ($p<0.05$) according to the Tukey Pairwise Comparison tests between treatments within the week. Init BW = Initial Body Weight. WG = Weight Gain. FCR = Food Conversion Ratio. FI = Feed Intake.

The amount of feed eaten by the birds in a week was similar across the treatments up to week five (Day 35), beyond which statistically significant ($p < 0.05$) treatment differences were recorded in weight gain. A similar observation was made for feed conversion ratio and initial body weight per bird. It is therefore possible varietal differences in maize used to formulate broiler feed do not influence growth performance at the initial stages of growth but does influence growth performance at the latter stages. Hence, it comes as no surprise that treatment differences concerning weekly body weight per bird were significant at the latter stage of the birds' growth (Table 4.3). This is similar to the research by Onimisi *et al.* (2009) which stated that there was no statistical difference in weight gain and feed conversion ratio after 28 days. However, a statistically significant difference was observed in the performance of the broiler finishers. As a result, attention should be paid to the type of maize used to formulate finisher feed during broiler production.

Feed conversion ratio (FCR) which is a feed efficiency parameter determines the quantity of feed required to produce a unit weight of a bird (de Almeida Santana *et al*., 2016). As a result, the lower the FCR, the higher the weight gain per unit of feed consumed. It is therefore not surprising that treatments with lower FCR (Table 4.5) had higher weight gain (Table 4.4). For example, Abontem which has the lowest FCR of 2.401 had the highest weekly weight gain of 1090.4g on Day 42.

Various reasons have also been attributed to the beneficial effects of QPM on the growth performance of broilers by researchers. Onimisi *et al*. (2009) reported that a QPM-based diet increased Lysine concentration in feed compared to a Regular maize-based diet, as discussed above. Lysine is known to be the first critical and limiting amino acid in maize and the second limiting amino acid in broiler chicken diets based on the maize-soybean meal. Lysine is crucial in protein synthesis for the growth of tissues. It is also found to be important in the absorption of calcium from the intestinal mucosa (Civitelli *et al*., 2001) and is involved in the cross-linking process of bone collagen and the biosynthesis of carnitine and elastin (Flodin, 1997). Additionally, tryptophan increased in diets formulated with QPM, and is not only an essential amino acid but provides the biological precursor of the B-vitamin, niacin. Besides dietary nutrient composition, its availability is crucial for the regulation of muscle metabolism and development, which in turn influences growth (Grizard *et al*., 1995). It has been reported that the apparent digestibility of Lysine and Threonine in QPM is significantly higher than in Regular maize (Panda *et al*., 2011), and that the biological value of Regular maize protein is 45% compared to 80% in QPM (Graham *et al*., 2001). Panda *et al*. (2012) reported significantly higher digestibility of crude protein (60.19% in Regular maize *vs*. 63.96% in QPM) and calcium (43.08% in Regular maize *vs*. 44.24% in QPM) in broiler chicken diets. Thus, improved performance from the above studies may be attributed not only to higher amino acid content but also to higher bioavailability of nutrients, resulting in better performance (Onimisi *et al*., 2009; Panda *et al*., 2012). The higher levels of leucine and isoleucine in Regular maize are known to interfere with protein synthesis (Onimisi *et al*., 2009). QPM has less leucine and isoleucine than Regular maize, which reduces the preponderance of leucine, and may contribute to the better broiler performance observed from QPM diets.

There were no significant dietary treatment effects observed in terms of the average feed intake (P>0.05) of the birds (Table 4.6). Birds on a normal corn diet tended to consume more feed compared to the birds receiving either QPM-based diet. This could not be attributed to energy because the diets are formulated to have the same Metabolizable energy. It could not also be attributed to the slightly higher crude protein content of the normal corn diet. Ferket & Gernat (2006) stated that growth can be very sensitive to daily amino acid intake and changes in feed intake may reflect only changes in production response rather than being a primary response to protein. Despite the lower feed intake of broilers in the QPM-based diet, the response on live weight gain was better, which would show that it was not a palatability factor but rather because of a possibly higher intake of essential amino acids other than lysine.

Statistical analysis of the data revealed significant differences at Day 28 and 35 in the livability of broilers among treatments. This indicated that mortality values were dependent on the treatment effects. The study of Osei *et al*. (1999) do not conform to the results of this study.

4.3 Effect of regular, Obatanpa, Abontem and Honampa maize used in feed formulation on the weight of carcass of broiler chicken

Mean live weight and proventriculus weight was significant statistically ($p < 0.05$) on Day 42 for the carcass. At Day 42, Abontem maize recorded the highest mean live weight (1750g) and was similar statistically to that of Honampa, and mixture respectively (Table 4.8). Regular maize had the lowest mean live weight at Day 42 (875g) and was similar statistically to that of Obatanpa and Honampa. However, Obatanpa maize recorded the highest mean proventriculus weight (0.667g) was similar statistically to that of Regular maize and Honampa. -Abontem maize had the lowest mean proventriculus weight (0.451g) and was similar statistically to that of Honampa and Regular maize.

There was no statistical significance of the treatment effects for mean breast, thigh, heart, duodenum, liver, gizzard, jejunum, ileum and caeca weight at Day 42 (Table 4.8). Honampa maize had the highest mean weight while Regular maize had the lowest mean wight for breast, liver and gizzard respectively. Abontem maize had the highest mean weight while Obatanpa recorded the lowest mean weight for thigh and Caeca respectively. Regular maize recorded the highest mean weight while mixture recorded the lowest for heart and duodenum respectively. Regular maize recorded the highest mean weight while Abontem maize recorded the lowest for jejunum and ileum respectively (Table 4.8).

Table 4. 8 Effect of regular, Obatanpa, Abontem and Honampa maize used in feed formulation on the carcass traits of broiler after day 42

Parameters	Regular maize	Obatanpa (OBM)	Abontem (ABM)	Honampa (HOM)	OBM+ABM +HOM	P-VALUE	SEM
Live weight	875.00^{a}	1104.00^{ab}	1750.00^{b}	1572.00^{ab}	1653.00^{a}	0.006*	101.00
Breast (%)	5.23	5.73	6.84	6.94	6.88	0.140^{NS}	0.273
Thigh (%)	9.56	9.45	10.24	9.99	9.80	0.374^{NS}	0.137
Heart (%)	0.59	0.57	0.46	0.53	0.43	0.052^{NS}	0.021
Duodenum (%)	1.36	1.26	0.95	0.99	0.91	0.262^{NS}	0.078
Liver (%)	2.88	2.76	2.31	2.22	2.40	0.075^{NS}	0.093
Proventriculus (%)	0.66^{a}	0.67^{a}	0.45^{b}	0.50^{ab}	0.46^{b}	0.002*	0.027
Gizzard (%)	2.48	2.31	2.17	2.12	2.26	0.367^{NS}	0.059
Jejunum (%)	2.07	1.81	1.56	1.63	1.74	0.256^{NS}	0.076
Ileum (%)	1.44	1.27	1.07	1.19	1.12	0.191^{NS}	0.053
Caeca (%)	0.63	0.67	0.39	0.46	0.43	0.057^{NS}	0.039

* = Significant. *NS* = Not significant. SEM = Standard Error of Means. Means with the same superscript do not differ significantly ($p>0.05$) and means with different superscript differ significantly ($p<0.05$) according to the Tukey Pairwise Comparison tests between treatments within the week.

Most researchers did not find any difference in carcass characteristics (dressed meat yield, giblet, abdominal fat and cutoff parts) in broiler chickens in response to the dietary replacement of Regular maize by QPM (Onimisi *et al*., 2009; Osei *et al*., 1998; Tyagi *et al*., 2008). However, Bai (2002) reported statistically significant in proventriculus weight and lower abdominal fat content in broiler chickens fed by QPM-based diets compared to Regular maize-based diets. This is in agreement with the finding of Bai (2002).

Breast muscle growth has become a variable of interest in recent years because of its high economic value (Tang *et al*., 2007). Dietary composition and nutrient content are potent regulators of muscle metabolism and development (Grizard *et al*., 1995). Dietary lysine concentrations have a large influence on breast muscle development (Kerr *et al*., 1999). It has been reported that a Regular maize base diet not only leads to poor performance but also reduces breast muscle yield (Bastianelli *et al*., 2007; Kidd, 2004). A similar finding was observed in this study. The breast muscle yield of the chickens fed with a Regular maize diet was lower compared to those fed with the a QPM maize diet. However, higher breast meat yield and lower duodenal, jejunum and ileum weight were noticed in the diet in which QPM was used. Replacement of Regular maize with QPM increased the protein level in the diet compared to those fed the Regular maize. Similarly, Renden *et al*. (1994) reported improved performance and breast muscle yield and reduced duodenal, jejunum and ileum weight due to elevating lysine concentration in the diet.

Dietary replacement of Regular maize with the QPM diet did not influence gizzard weight (Table 4.7). This is in agreement with the finding of (Lucas *et al*., 2007). The protein content of different organs such as the gizzard, thigh and liver did not vary significantly due to the dietary treatments employed.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In this study, an experiment was conducted over an eight (6) a weeks (42 days) period to understand the effect of some different kinds of maize available in Ghana on the growth and physiological performance of broiler birds. Different kinds of maize varieties/sources including Silo maize, Obatanpa, Abontem, Honampa and a Mixture of Honampa, Obaatampa and Abontem all with different characteristics were tested.

Treatment differences were largely recorded after the six weeks (Day 42) of the experiment. The performance of Honampa and Mixture treatments were largely similar suggesting that, if broiler farmers have Honampa but it is not enough to feed the birds, other varieties can be added and still get similar bird performance as though Honampa only was used. Obatanpa and Silo maize also clustered suggesting similar bird responses to both treatments. However, they were among the low-performing treatments. Abontem had a high feed intake and was most efficient with the lowest feed conversion ratio leading to a high weight gain.

Quality protein maize in poultry diet improves the growth performance of broilers. Generally, feed formulated with Abontem resulted in higher weight gains than Regular maize. Statistically, QPM did not result in significant changes in carcass and organ development of broilers.

5.2 Recommendation

The study, therefore, recommend the use of Obatanpa,Abontem,honampa and a mixture of all the three varieties in the diets of broilers to increase the weight of the poultry birds. Future studies involving other monogastric species must also be conducted to confirm the result of this study.

REFERENCES

Advised, B. S., & Latshaw, D. (2010). *Feed Preference Index on Cereal Grains for*

Poultry. https://core.ac.uk/download/pdf/159564152.pdf

Al-Hassan, R., Jatoe, J. D. B., & Awere, A. D. (2007). Productivity Impact of Improved Maize Varieties in the Eastern Region of Ghana. *The IUP Journal of Agricultural Economics*, *4*(2), 7–22. https://www.researchgate.net/profile/John-Jatoe/publication/5105187_Productivity_Impact_of_Improved_Maize_Varieties_in_the_Eastern_Region_of_Ghana/links/5a525724458515e7b72caa46/Productivity-Impact-of-Improved-Maize-Varieties-in-the-Eastern-Region-of-Ghana.pdf

Allen, S. G., Schulman, D., Lichwa, J., Antal, M. J., Laser, M., & Lynd, L. R. (2001). A comparison between hot liquid water and steam fractionation of corn fiber. *Industrial and Engineering Chemistry Research*, *40*(13), 2934–2941. https://doi.org/10.1021/ie990831h

Awulachew, M. T. (2022). A Review of anti-nutritional factors in Plant Based Foods. *Advance Nutrition of Food Science*, *7*(3), 223–236. www.opastonline.com

Azinu, A. R. (2014). *Evaluation of Hybrid Maize Varieties in Three Agro-Ecological Zones in Ghana.* [University of Ghana]. http://localhost:8080/handle/123456789/7148

Babu, R., & Prasanna, B. M. (2014). Molecular breeding for Quality Protein Maize (QPM). In *: Tuberosa, R., Graner, A., Frison, E. (eds) Genomics of Plant Genetic Resources* (Vol. 2, pp. 489–505). Springer Netherlands. https://doi.org/10.1007/978-94-007-7575-6_21

Badawy, A. A. B. (2014). Pellagra and alcoholism: a biochemical perspective. *Alcohol and Alcoholism*, *49*(3), 238–250. https://academic.oup.com/alcalc/article-abstract/49/3/238/210446

Bai, X. F. (2002). MSc Thesis, Chinese Academy of Agricultural Sciences, Beijing 100081, P.R. China.

Bastianelli, D., Quentin, M., Bouvarel, I., Relandeau, C., Lescoat, P., Picard, M., & Tesseraud, S. (2007). Early lysine deficiency in young broiler chicks. *Animal*, *1*(4), 587–594. https://www.cambridge.org/core/journals/animal/article/early-lysine-deficiency-in-young-broiler-chicks/519D5406DF52CFF04173C161EC439246

Black, J. L. (2001). Variation in nutritional value of cereal grains across livestock species. In *Proceedings of the Australian Poultry Science Symposium* (Vol.

13). https://ses.library.usyd.edu.au/handle/2123/2285

Butts-Wilmsmeyer, C. J., Seebauer, J. R., Singleton, L., & Below, F. E. (2019). Weather During Key Growth Stages Explains Grain Quality and Yield of Maize. *Agronomy*, *9*(1), 16. https://doi.org/10.3390/agronomy9010016

Champagne, E. T. (1988). Effects of pH on Mineral-Phytate, Protein-Mineral-Phytate, and Mineral-Fiber Interactions. Possible Consequences of Atrophie Gastritis on Mineral Bioavailability from High-Fiber Foods. *Journal of the American College of Nutrition*, *7*(6), 499–508. https://doi.org/10.1080/07315724.1988.10720266

Chapoto, A., & Ragasa, C. (2013). Moving in the Right Direction? Maize Productivity and Fertilizer Use and Use Intensity in Ghana. *SSRN Electronic Journal*, 44. https://doi.org/10.2139/SSRN.2405711

Chaudhary, D., Kumar, A., Mandhania, S., & Srivastava, P. (2011). *Maize as fodder? An alternative approach*. https://krishi.icar.gov.in/jspui/bitstream/123456789/2103/1/Maize as Fodder.pdf

Civitelli, R., Villareal, D. T., Agnusdei, D., Nardi, P., Avioli, L. V., & Gennari, C. (2001). Dietary L-lysine and calcium metabolism in humans. *Nutrition (Burbank, Los Angeles County, Calif.)*, 400–405. https://europepmc.org/article/med/1486246

Darfour, B., & Rosentrater, K. A. (2016). MAIZE IN GHANA: AN OVERVIEW OF CULTIVATION TO PROCESSING. *American Society of Agricultural and Biological Engineers Annual International Meeting*, 1-. https://doi.org/10.13031/AIM.20162460492

de Almeida Santana, M. H., Junior, G. A. O., Cesar, A. S. M., Freua, M. C., da Costa Gomes, R., da Luze Silva, S., & Ferraz, J. B. S. (2016). Copy number variations and genome-wide associations reveal putative genes and metabolic pathways involved with the feed conversion ratio in beef cattle. *Journal of Applied Genetics*, *57*(4), 495–504. https://link.springer.com/article/10.1007/s13353-016-0344-7

Dei, H. K. (2011). *Soybean as a Feed Ingredient for Livestock and Poultry*. IntechOpen. https://doi.org/10.5772/17601

Dei, H. K. (2017). Assessment of Maize (Zea mays) as Feed Resource for Poultry. In *Poultry Science*. InTech. https://doi.org/10.5772/65363

Diaz, A. M. L. (2004). Food quality and properties of quality protein maize. *(Doctoral Dissertation, Texas A&M University).* https://oaktrust.library.tamu.edu/handle/1969.1/171

Donkoh, A., & Attoh-Kotoku, V. (2009). Nutritive value of feedstuffs for poultry in Ghana: chemical composition, apparent metabolizable energy and ileal amino acid digestibility. *Livestock Research for Rural Development*, *21*(3), 1–9. http://www.lrrd.cipav.org.co/lrrd21/3/donk21032.htm

Ferket, P. R., & Gernat, A. G. (2006). Factors that affect feed intake of meat birds: A review. *A Review. International Journal Poultry Science*, *5*(10), 905–911. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.600.2964&rep=rep1&type=pdf

Flodin, N. W. (1997). The metabolic roles, pharmacology, and toxicology of lysine. *Journal of the American College of Nutrition*, *16*(1), 7–21. https://doi.org/10.1080/07315724.1997.10718644

Food and Agriculture Organizaton (FAO). (2005). *Statistical Yearbook of FAO*. FAO Publications.

Gibbon, B. C., & Larkins, B. A. (2005). Molecular genetic approaches to developing quality protein maize. *TRENDS in Genetics*, *21*(4), 227–233. https://www.sciencedirect.com/science/article/pii/S0168952505000491

Graham, G. G., Placko, R. P., & MacLean Jr, W. C. (2001). Nutritional value of normal, opaque-2 and sugary-2 opaque-2 maize hybrids for infants and children: 2. plasma free amino acids. *The Journal of Nutrition*, *110*(5), 1070–1075. https://academic.oup.com/jn/article-abstract/110/5/1070/4771110

Grizard, J., Dardevet, D., Papet, I., Mosoni, L., Patureau Mirand, P., Attaix, D., Tauveron, I., Bonin A N D, D., & Arnal, M. (1995). Nutrient regulation of skeletal muscle protein metabolism in animals. The involvement of hormones and substrates. *Nutrition Research Reviews*, *8*, 67–91. https://doi.org/10.1079/NRR19950007

Hamaker, B. R., Tuncil, Y. E., & Shen, X. (2018). Carbohydrates of the Kernel. In *Corn: Chemistry and Technology, 3rd Edition* (pp. 305–318). Elsevier. https://doi.org/10.1016/B978-0-12-811971-6.00011-5

Hassan, N. (2016). *Analysis of Chicken Ration and its Effect on the Quality of Chicken Manure*. http://repository.sustech.edu/handle/123456789/15730

Huang, S., Adams, W. R., Zhou, Q., Malloy, K. P., Voyles, D. A., Anthony, J., Kriz, A.

L., & Luethy, M. H. (2004). Improving Nutritional Quality of Maize Proteins by Expressing Sense and Antisense Zein Genes. *Journal of Agricultural and Food Chemistry*, *52*(7), 1958–1964. https://doi.org/10.1021/jf0342223

Hussaini, M. A., Ogunlela, V., Ramalan, A. A., Ogunlela, V. B., Hussaini, M. A., & Falaki, A. M. (2008). Mineral Composition of Dry Season Maize (Zea mays L.) in Response to Varying Levels of Nitrogen, Phosphorus and Irrigation at Kadawa, Nigeria Oilseed rape nitrogen nutrition View project Dryland Paprika Research Programme, Zimbabwe View project Mineral Composition of Dry Season Maize (Zea mays L.) in Response to Varying Levels of Nitrogen, Phosphorus and Irrigation at Kadawa, Nigeria. *World Journal of Agricultural Sciences*, *4*(6), 775–780. https://www.researchgate.net/publication/242117941

Iken, & Amusa, N. A. (2004). Maize research and production in Nigeria. *African Journal of Biotechnology*, *3*(6), 302–307. http://www.academicjournals.org/AJB

Iken, J., Amusa, N., & Obatolu, V. (2002). Nutrient Composition and Weight Evaluation of some Newly Developed Maize Varieties in Nigeria. *Journal of Food Technology in Africa*, *7*(1), 27–29. https://www.ajol.info/index.php/jfta/article/view/19315

International Institute of Tropical Agriculture. (1982). MAIZE PRODUCTION MANUAL. In *Manual series No. 8* (Vol. 2).

Jan, B., Olga, L., & Augustyn, R. (2008). Energy utilization and nutritive value of maize grain cultivars for broiler chickens. *Journal of Central European Agriculture*, *9*(1), 225–228. www.statsoft.com.

Joye, I. (2019). Protein Digestibility of Cereal Products. *Foods*, *8*(6), 199. https://doi.org/10.3390/foods8060199

Kean, E. G., Hamaker, B. R., & Ferruzzi, M. G. (2008). Carotenoid bioaccessibility from whole grain and degermed maize meal products. *Journal of Agricultural and Food Chemistry*, *56*(21), 9918–9926. https://doi.org/10.1021/jf8018613

Kerr, B. J., Kidd, M. T., Halpin, K. M., McWard, G. W., & Quarles, C. L. (1999). Lysine level increases live performance and breast yield in male broilers. *Journal of Applied Poultry Research*, *4*(1999), 381–390. https://www.sciencedirect.com/science/article/pii/S1056617119309018

Kidd, M. T. (2004). Nutritional modulation of immune function in broilers. *Poultry Science*, *83*(4), 650–657.

https://www.sciencedirect.com/science/article/pii/S0032579119444027

Kuwano, M., Mimura, T., Takaiwa, F., & Yoshida, K. T. (2009). Generation of stable "low phytic acid" transgenic rice through antisense repression of the 1D-myo-inositol 3-phosphate synthase gene (RINO1) using the 18-kDa oleosin promoter. *Plant Biotechnology Journal*, *7*(1), 96–105. https://doi.org/10.1111/j.1467-7652.2008.00375.x

Lakshmi, R. K. S., Kumari, K., & Reddy, P. (2017). Corn germ meal (CGM)-potential feed ingredient for livestock and poultry in India-a review. *International Journal of Livestock Research*, *7*(8), 39–50. https://www.academia.edu/download/63464777/5_Corn_Germ_meal20200529-129741-ljpj1j.pdf

Lammers, P. J., Kerr, B. J., Weber, T. E., Iii, W. A. D., Kidd, M. T., Bregendahl, K., & Honeyman, M. S. (2008). Digestible and metabolizable energy of crude glycerol for growing pigs 1,2. *Journal of Animal Science*, *86*(3), 602–608. https://doi.org/10.2527/jas.2007-0453

Liu, X. H., Ye, C. X., Zheng, L. M., Ou, C. C., Wang, A. L., Ye, J. D., & Kong, J. H. (2015). Dietary maize starch influences growth performance, apparent digestibility coefficient, and hepatic enzyme activities of carbohydrate metabolism in obscure puffer, takifugu obscurus (Abe). *Journal of the World Aquaculture Society*, *46*(1), 102–113. https://doi.org/10.1111/jwas.12168

Los, A., Ziuzina, D., & Bourke, P. (2018). Current and Future Technologies for Microbiological Decontamination of Cereal Grains. *Journal of Food Science*, *83*(6), 1484–1493. https://doi.org/10.1111/1750-3841.14181

Lucas, D. M., Taylor, M. L., Hartnell, G. F., Nemeth, M. A., Glenn, K. C., & Davis, S. W. (2007). Broiler performance and carcass characteristics when fed diets containing lysine maize (LY038 or LY038× MON 810), control, or conventional reference. *Poultry Science*, *86*(10), 2152–2161. https://www.sciencedirect.com/science/article/pii/S0032579119392478

Majdeddin, M., Golian, A., Kermanshahi, H., De Smet, S., & Michiels, J. (2018). British Poultry Science Guanidinoacetic acid supplementation in broiler chickens fed on corn-soybean diets affects performance in the finisher period and energy metabolites in breast muscle independent of diet nutrient density. *British Poultry Science*, *59*(4), 443–451. https://doi.org/10.1080/00071668.2018.1476678

Maqbool, M. A., Issa, A. R. B., & Khokhar, E. S. (2021). Quality protein maize (QPM): Importance, genetics, timeline of different events, breeding strategies and varietal adoption. *Plant Breeding*, *140*(3), 375–399. https://doi.org/10.1111/pbr.12923

Miao, M., Jiang, B., & Zhang. T. (2009). Effect of pullulanase debranching and recrystallization on structure and digestibility of waxy maize starch. *Carbohydrate Polymers*, *76*(2), 214–221. https://www.sciencedirect.com/science/article/pii/S0144861708004797

Moreki, J. C., & Tiroesele, B. (2012). Prospects of utilizing insects as alternative sources of protein in poultry diets in Botswana Poultry Nutrition for sustainable production View project. In *researchgate.net*. https://www.researchgate.net/publication/291159541

Muzhingi, T., Gadaga, T. H., Siwela, A. H., Grusak, M. A., Russell, R. M., & Tang, G. (2011). Yellow maize with high β-carotene is an effective source of vitamin A in healthy Zimbabwean men. *The American Journal of Clinical Nutrition*, *94*(2), 510–519. https://academic.oup.com/ajcn/article-abstract/94/2/510/4597890

National Variety Release Catalogue. (2019). *CATALOGUE OF CROP VARIETIES RELEASED & REGISTERED IN GHANA*. https://nastag.org/docx/resources/2019 NATIONAL CROP VARIETY CATALOGUE.pdf

Ndolo, V. U. (2015). *Characterisation of chemical components in manually isolated Aleurone and associated layers from maize, wheat and barley kernels. Doctor of Philosophy, University of Manitoba, Department of Food Science. Winnipeg, Manitoba*. Elsevier.

Nuss, E. T., & Tanumihardjo, S. A. (2010). Maize: A Paramount Staple Crop in the Context of Global Nutrition. *Comprehensive Reviews in Food Science and Food Safety*, *9*(4), 417–436. https://doi.org/10.1111/j.1541-4337.2010.00117.x

Obiri-Danso, K., Ellis, W. O., Simpson, B. K., & Smith, J. P. (1997). Suitability of high lysine maize, Obatanpa for ’kenkey’production. *Food Control*, *8*(3), 125–129. https://www.sciencedirect.com/science/article/pii/S0956713596000771

Olaniyan, A. B. (2015). Maize: Panacea for hunger in Nigeria. *African Journal of Plant Science*, *9*(3), 155–174. https://academicjournals.org/journal/AJPS/articlefull-text/B19DE4F51746

Onimisi, P., Omage, J., Dafwang, I., & Bawa, G. (2009). Replacement value of normal maize with quality protein maize (Obatampa) in broiler diets. *Pakistan Journal of Nutrition*, *8*(2), 112–115. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.581.6333&rep=rep1&type=pdf

Orhun, G. E., Onsekiz, Ç., Üniversitesi, M., & Orhun, G. E. (2013). Maize for Life. *International Journal of Food Science and Nutrition Engineering*, *2013*(2), 13–16. https://doi.org/10.5923/j.food.20130302.01

Osei, S. A., Atuahene, C. C., Okai, D. B., Donkoh, A., & Tuah, A. K. (1998). The nutritive value of quality protein maize in the diets of broiler chickens. *Ghana Journal of Agricultural Science*, *31*(1), 1–5. https://www.ajol.info/index.php/gjas/article/view/1938

Osei, S. A., Dei, H. K., & Tuah, A. K. (1999). Evaluation of quality protein maize as a feed ingredient for layer pullet. *Journal of Animal and Feed Sciences*, *8*, 181–189. http://41.66.217.101/handle/123456789/1041

Panda, A. K., Raju, M. V. L. N., Rama Rao, S. V., Lavanya, G., Pradeep, K. R. E., & Shyam, S. G. (2012). Substitution of normal maize with quality protein maize on growth performance, serum biochemical parameters and carcass characteristics of coloured broiler. *Indian Journal of Poultry Science*, *46*, 183–187. https://www.researchgate.net/profile/Lavanya-Goodla/publication/236317152_Substitution_of_normal_maize_with_quality_protein_maize_on_growth_performance_serum_biochemical_parameters_and_carcass_characteristics_of_broiler_chickens/links/580dc30a08aea8ecfaf1ddcf/Substitution-of-normal-maize-with-quality-protein-maize-on-growth-performance-serum-biochemical-parameters-and-carcass-characteristics-of-broiler-chickens.pdf

Panda, A. K., Raju, M. V. L. N., Rao, S. V. R., Lavanya, G., Reddy, E. P. K., & Sunder, G. S. (2011). Nutritional evaluation and utilisation of quality protein maize, Nityashree hybrid maize, and normal maize in broiler chickens. *British Poultry Science*, *52*(5), 632–638. https://doi.org/10.1080/00071668.2011.626758

Panfilov, A. E., Zezin, N. N., Kazakova, N. I., & Namyatov, M. A. (2020). Adaptive approach in maize breeding for the Urals region. *International Journal of*

Biology and Biomedical Engineering, *14*, 55–62. https://doi.org/10.46300/91011.2020.14.9

Perez-Vendrell, A., Hernandez, J., science, L. L.-P., & 2001, undefined. (2001). Influence of source and ratio of xanthophyll pigments on broiler chicken pigmentation and performance. *Poultry Science*, *80*(3), 320–326. https://www.sciencedirect.com/science/article/pii/S0032579119417380

Potter, N., & Hotchkiss, J. (2012). *Food science*. https://books.google.com/books?hl=en&lr=&id=GRQJAgAAQBAJ&oi=fnd&pg=PR12&dq=Food+Science,+5th+edn&ots=Yh8kyWGPaH&sig=cedvpg6n2Sb9vSUQWeZdcfLNITM

Prasanna, B. M., Vasal, S. K., Kassahun, B., & Singh, N. N. (2001). Quality protein maize. *Current Science*, 1308–1319. https://www.jstor.org/stable/24105845?casa_token=UWFNvKgcPogAAAA A:C8alGU4u2dhsA6hVqSv06cdXMGLurydRT15BIJhknLK9ZxysjPDFOp2ZaBMZTovto38yqc_LrchP1j_3Sbos7_DdqC3Erj3Wp1PfeuTbXcvSacD7QHR7

Pukalenthy, B., Manickam, D., Chandran, S., Adhimoolam, K., Sampathrajan, V., Rajasekaran, R., Arunachalam, K., Ganapathyswamy, H., Chocklingam, V., & Muthusamy, V. (2019). Incorporation of opaque-2 into "UMI 1200", an elite maize inbred line, through marker-assisted backcross breeding. *Biotechnology & Biotechnological Equipment* , *33*(1), 144–153. https://doi.org/10.1080/13102818.2018.1556121

Puntigam, R., Schedle, K., Schwarz, C., Wanzenböck, E., Eipper, J., Lechner, E. M., & Gierus, M. (2018). Very high expander processing of maize on animal performance, digestibility and product quality of finishing pigs and broilers. *Journal of Animal*, *12*(7), 1536–1546. https://www.cambridge.org/core/journals/animal/article/very-high-expander-processing-of-maize-on-animal-performance-digestibility-and-product-quality-of-finishing-pigs-and-broilers/395A95D98BB667E7835AEE2BB468E4B9

Qi, G., Diao, Q., Tu, Y., Wu, S. G., & Zhang, S. H. (2004). Nutritional evaluation and utilization of quality protein maize (QPM) in animal feed. *FAO Animal Production and Health Proceedings. Protein Sources for the Animal Feed*

Industry, 185–198. https://www.researchgate.net/profile/Yan-Tu-7/publication/266416630_Protein_Sources_for_the_Animal_Feed_Industry_Nutritional_evaluation_and_utilization_of_quality_protein_maizeQPMin_animal_feed/links/54b645560cf26833efd36b8d/Protein-Sources-for-the-Animal-Feed-Industry-Nutritional-evaluation-and-utilization-of-quality-protein-maizeQPMin-animal-feed.pdf

Radosavljević, M., Milašinović-Šeremešić, M., Terzić, D., Todorović, G., Pajić, Z., Filipović, M., Kaitović, Ž., & Mladenović Drinić, S. (2012). Effects of hybrid on maize grain and plant carbohydrates. *Genetika*, *44*(3), 649–659. https://doi.org/10.2298/GENSR1203649R

Rausch, K. D., Hummel, D., Johnson, L. A., & May, J. B. (2019). Wet milling: The basis for corn biorefineries. *In Corn*, 501–535. https://www.sciencedirect.com/science/article/pii/B9780128119716000188

Refiners Association, C. (2006). Corn Wet Milled Feed Products. In *corn.org*. www.corn.org

Renden, J. A., Moran Jr, E. T., & Kincaid, S. A. (1994). Lack of interactions between dietary lysine or strain cross and photoschedule for male broiler performance and carcass yield. *Poultry Science*, *73*(11), 1651–1662. https://www.sciencedirect.com/science/article/pii/S0032579119521058

Rojas, N. P., & Pixley, K. (2010). Provitamin A Carotenoid Bioavailability: What Really Matters? Quality Protein Maize Development View project Seeds of Discovery-MasAgro Biodiversidad View project. *Article in International Journal for Vitamin and Nutrition Research*. https://doi.org/10.1024/0300-9831/a000042

Sallah, P. Y. K., Obeng-Anti, K., Asiedu, E. A., Ewoll, M. B., & Dzah, B. D. (2003). Recent advances in the development and promotion of quality protein maize in Ghana. *Maize Revolution in West and Central Africa. Ed B. Badu-Apraku. Wecaman, IITA Ibadan*, 410–424. https://books.google.com/books?hl=en&lr=&id=ByOsC04kC5sC&oi=fnd&pg=PA410&dq=The+QPM+hybrids+were,+therefore,+released+for+production+in+1997&ots=BQPnXCCDcX&sig=WWD_xlvJwrVo-kEa2UsvMZ3vHm0

Sallah, P. Y. K., Twumasi-Afriyie, S., Ahenkora, K., Asiedu, E. A., Obeng-Antwi, K., Osei-Yeboah, S., Frimpong-Manso, P. P., Ankomah, A., & Dzah, B. D.

(2007). Agronomic potentials of quality protein maize hybrids developed in Ghana. *Ghana Journal of Agricultural Science*, *40*(1), 81–89. https://www.ajol.info/index.php/gjas/article/view/2157

Serna-Saldivar, S. O., & Espinosa-Ramírez, J. (2018). Grain structure and grain chemical composition. In *Sorghum and Millets: Chemistry, Technology, and Nutritional Attributes* (pp. 85–129). Elsevier. https://doi.org/10.1016/B978-0-12-811527-5.00005-8

Shende, D., & Sidhu, E. (2014). *Methods used for extraction of maize (zea mays, l.) Germ oil-a review*. http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.677.4574

Shewry, P. (2007). Improving the protein content and composition of cereal grain. *Journal of Cereal*, *46*(3), 239–250. https://www.sciencedirect.com/science/article/pii/S073352100700118X

Shobha, D., Joshi, N., & Benherlal, P. S. (2022). Spirulina enriched gluten free quality protein maize (QPM) pasta as functional food. *Emirates Journal of Food and Agriculture*, *34*(4), 279–288. https://ejfa.me/index.php/journal/article/download/2853/1582

Sidi, Y. R., Ben, M., Martos, V., & Royo, C. (2007). Environmentally Induced Changes in Amino Acid Composition in the Grain of Durum Wheat Grown under Different Water and Temperature Regimes in a Mediterranean Environment RESEARCH LINE: Plant phenotyping of ecophysiological traits in crops and forest species View project Drought tolerance in durum wheat and its relation with industrial and nutritional grain quality View project. *Article in Journal of Agricultural and Food Chemistry*, *55*(20), 8144–8151. https://doi.org/10.1021/jf063094q

Sikdar, M. S. I., Bowra, S., Schmidt, D., Dionisio, G., Holm, P. B., & Vincze, E. (2016). Targeted modification of storage protein content resulting in improved amino acid composition of barley grain. *Transgenic Research*, *25*(1), 19–31. https://doi.org/10.1007/s11248-015-9911-7

Singh, N., Kaur, A., & Shevkani, K. (2013). Maize: Grain structure, composition, milling, and starch characteristics. In *Maize: Nutrition Dynamics and Novel Uses* (pp. 65–76). Springer India. https://doi.org/10.1007/978-81-322-1623-0_5

Singh, N., Singh, S., & Shevkani, K. (2019). Maize: Composition, bioactive constituents, and unleavened bread. In *Flour and Breads and Their Fortification in Health and Disease Prevention* (pp. 111–121). Elsevier. https://doi.org/10.1016/B978-0-12-814639-2.00009-5

Singh, N., Vasudev, S., Yadava, D. K., Chaudhary, D. P., & Prabhu, K. V. (2014). Oil improvement in maize: potential and prospects. *In Maize: Nutrition Dynamics and Novel Uses*, *9788132216230*, 77–82. https://doi.org/10.1007/978-81-322-1623-0_6

Sofi, P. A., Wani, S. A., Rather, A. G., & Wani, S. H. (2009). Quality protein maize (QPM): Genetic manipulation for the nutritional fortification of maize. *Journal of Plant Breeding and Crop Science*, *1*(6), 244–253. http://www.academicjournals.org/jpbcs

Sumbo, A., & Victor, I. A. (2014). Comparison of chemical composition, functional properties and amino acids composition of quality protein maize and common maize (Zea may L). *African Journal of Food Science and Technology*, *5*(3), 81–89. https://doi.org/10.14303/ajfst.2014.024

Suri, D. J., & Tanumihardjo, S. A. (2016). Effects of Different Processing Methods on the Micronutrient and Phytochemical Contents of Maize: From A to Z. In *Comprehensive Reviews in Food Science and Food Safety* (Vol. 15, Issue 5, pp. 912–926). Blackwell Publishing Inc. https://doi.org/10.1111/1541-4337.12216

Suswati, D., & Sagiman, S. (2015). EFFECT OF COASTAL SEDIMENT TO NUTRIENT AVAILABILITY AND MAIZE PRODUCTIVITY ON ENTISOLS. *AGRIVITA VOLUME*, *37*(3). https://doi.org/10.17503/Agrivita-2015-37-3-p258-264

Tandzi, L. N., Mutengwa, C. S., Ngonkeu, E. L. M., Woïn, N., & Gracen, V. (2017). Breeding for Quality Protein Maize (QPM) Varieties: A Review. *Agronomy*, *7*(4), 80. https://doi.org/10.3390/agronomy7040080

Tang, M. Y., Ma, Q. G., Chen, X. D., & Ji, C. (2007). Effects of dietary metabolizable energy and lysine on carcass characteristics and meat quality in arbor acres broilers. *Asian-Australasian Journal of Animal Sciences*, *20*(12), 1865–1873. https://doi.org/10.5713/AJAS.2007.1865

Titcomb, T. J., & Tanumihardjo, S. A. (2019). Global Concerns with B Vitamin Statuses: Biofortification, Fortification, Hidden Hunger, Interactions, and Toxicity. *Comprehensive Reviews in Food Science and Food Safety*, *18*(6), 1968–1984.

https://doi.org/10.1111/1541-4337.12491

Tiwari, M. R., Chapagain, P. B., Shah, M. K., & Shrestha, Y. K. (2013). Evaluation of Quality Protein Maize (QPM) and Normal Mazie for Growth Performance of Crossbred piglets in Wester Hills of Nepal. *Global Journal of Science Frontier Research Agriculture and Veterinary*, *13*(6), 1–7.

Twumasi-Afriyie, S., Friesen, D., & Pixley, K. (2011). Quality protein maize: Progress and prospects. *Plant Breed Rev.*, *34*, 83. https://books.google.com/books?hl=en&lr=&id=N7siqRQiPX8C&oi=fnd&pg=PA83&dq=starch+yielded+by+QPM+grains+is+comparable+to+normal+maize+grains&ots=FmU5HE5onv&sig=0r0cIPup71R22sYeDL4ycHpnXk4

Tyagi, P. K., Shrivastav, A. K., Mandal, A. B., Tyagi, P. K., Elangovan, A. V., & Deo, C. (2008). The apparent metabolizable energy and feeding value of quality protein maize for broiler chicken. *Indian Journal of Poultry Science*, *43*(2), 169–174. https://www.indianjournals.com/ijor.aspx?target=ijor:ijps&volume=43&issue=2&article=010

Vasal, S. K. (2000). The quality protein maize story. *Food and Nutrition Bulletin*, *21*(4), 445–450. https://doi.org/10.1177/156482650002100420

Wan, P., Moat, S., & Anstey, A. (2011). Pellagra: A review with emphasis on photosensitivity. In *British Journal of Dermatology* (Vol. 164, Issue 6, pp. 1188–1200). https://doi.org/10.1111/j.1365-2133.2010.10163.x

Widj, K., & Coker, J. (2006). *The Stability of Alpha-Tocopherol in Whole-Wheat Flour and Corn Meal During Heating*. https://minds.wisconsin.edu/bitstream/handle/1793/42195/2006widjajak.pdf?sequence=1

Wu, Y., Holding, D. R., & Messing, J. (2010). γ-Zeins are essential for endosperm modification in quality protein maize. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(29), 12810–12815. https://doi.org/10.1073/pnas.1004721107

Zhang, R., Ma, S., Li, L., Zhang, M., Tian, S., Wang, D., Liu, K., Liu, H., Zhu, W., & Wang, X. (2021). Comprehensive utilization of corn starch processing by-products: A review. In *Grain and Oil Science and Technology* (Vol. 4, Issue 3, pp. 89–107). KeAi Communications Co. https://doi.org/10.1016/j.gaost.2021.08.003.

APPENDICES

Appendix 1 ANOVA table for the livability from day 0-7

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	222.2	55.56	0.96	0.455^{nt}
Error	15	864.2	57.61		
Total	19	1086.4			

nt = not significant

Appendix 2 ANOVA table for the initial body weight from day 0-7

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	360.1	90.03	1.31	0.312^{nt}
Error	15	1032.7	68.85		
Total	19	1392.8			

nt = not significant

Appendix 3 ANOVA table for the body weight gain from day 0-7

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	363.5	90.87	1.52	0.247^{nt}
Error	15	897.9	59.86		
Total	19	1261.4			

nt = not significant

Appendix 4 ANOVA table for the food conversion ratio from day 0-7

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	0.4468	0.1117	0.89	0.495^{nt}
Error	15	1.8870	0.1258		
Total	19	2.3338			

nt = not significant

Appendix 5 ANOVA table for the intake from day 0-7

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	3887	971.7	1.00	0.436^{nt}
Error	15	14522	968.2		
Total	19	18409			

nt = not significant

Appendix 6 ANOVA table for the livability from day 8-14

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	222.2	55.56	0.52	0.723^{nt}
Error	15	1604.9	107.00		
Total	19	1827.2			

nt = not significant

Appendix 7 ANOVA table for the initial body weight from day 8-14

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	2568	642.1	1.28	0.322^{nt}
Error	15	7539	502.6		
Total	19	10107			

nt = not significant

Appendix 8 ANOVA table for the body weight gain from day 8-14

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	2503	625.8	1.37	0.292^{nt}
Error	15	6869	457.9		
Total	19	9372			

nt = not significant

Appendix 9 ANOVA table for the food conversion ratio from day 8-14

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	0.07746	0.01936	0.96	0.456^{nt}
Error	15	0.30148	0.02010		
Total	19	0.37894			

nt = not significant

Appendix 10 ANOVA table for the intake from day 8-14

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	6614	1653	0.77	0.559^{nt}
Error	15	32023	2135		
Total	19	38637			

nt = not significant

Appendix 11 ANOVA table for the livability from day 15-21

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	308.6	77.16	0.83	0.525^{nt}
Error	15	1388.9	92.59		
Total	19	1697.5			

nt = not significant

Appendix 12 ANOVA table for the initial body weight from day 15-21

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	9167	2292	1.68	0.207^{nt}
Error	15	20479	1365		
Total	19	29646			

nt = not significant

Appendix 13 ANOVA table for the body weight gain from day 15-21

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	8888	2222	1.67	0.210^{nt}
Error	15	20001	1333		
Total	19	28889			

nt = not significant

Appendix 14 ANOVA table for the food conversion ratio from day 15-21

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	0.08064	0.02016	0.36	0.836^{nt}
Error	15	0.84841	0.05656		
Total	19	0.92906			

nt = not significant

Appendix 15 ANOVA table for the intake from day 15-21

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	19062	4765	1.07	0.405^{nt}
Error	15	66670	4445		
Total	19	85732			

nt = not significant

Appendix 16 ANOVA table for the livability from day 22-28

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	3173	793.2	3.93	0.022^{*}
Error	15	3025	201.6		
Total	19	6198			

* = Significant

Appendix 17 ANOVA table for the initial body weight from day 22-28

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	78457	19614	2.75	0.068^{nt}
Error	15	107145	7143		
Total	19	185602			

nt = not significant

Appendix 18 ANOVA table for the body weight gain from day 22-28

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	77248	19312	2.73	0.069^{nt}
Error	15	106012	7067		
Total	19	183260			

nt = not significant

Appendix 19 ANOVA table for the food conversion ratio from day 22-28

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	0.1607	0.04017	1.18	0.358^{nt}
Error	15	0.5095	0.03397		
Total	19	0.6702			

nt = not significant

Appendix 20 ANOVA table for the intake from day 22-28

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	49679	12420	1.33	0.305^{nt}
Error	15	140402	9360		
Total	19	190081			

nt = not significant

Appendix 21 ANOVA table for the livability from day 29-35

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	3642	910.5	3.66	0.029*
Error	15	3735	249.0		
Total	19	7377			

* = Significant

Appendix 22 ANOVA table for the initial body weight from day 29-35

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	99574	24893	2.44	0.092^{nt}
Error	15	152829	10189		
Total	19	252402			

nt = not significant

Appendix 23 ANOVA table for the body weight gain from day 29-35

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	98546	24636	2.44	0.092^{nt}
Error	15	151505	10100		
Total	19	250051			

nt = not significant

Appendix 24 ANOVA table for the food conversion ratio from day 29-35

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	0.7922	0.19805	2.36	0.100^{nt}
Error	15	1.2600	0.08400		
Total	19	2.0523			

nt = not significant

Appendix 25 ANOVA table for the intake from day 29-35

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	38340	9585	0.79	0.547^{nt}
Error	15	181036	12069		
Total	19	219377			

nt = not significant

Appendix 26 ANOVA table for the livability from day 36-42

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	2716	679.0	1.79	0.183^{nt}
Error	15	5679	378.6		
Total	19	8395			

nt = not significant

Appendix 27 ANOVA table for the initial body weight from day 36-42

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	240585	60146	3.06	0.050*
Error	15	295036	19669		
Total	19	535621			

* = Significant

Appendix 28 ANOVA table for the body weight gain from day 36-42

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	238199	59550	3.06	0.050*
Error	15	291438	19429		
Total	19	529637			

* = Significant

Appendix 29 ANOVA table for the food conversion ratio from day 36-42

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	3.154	0.7885	3.15	0.046*
Error	15	3.756	0.2504		
Total	19	6.910			

* = Significant

Appendix 30 ANOVA table for the intake from day 36-42

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	174454	43614	0.43	0.787^{nt}
Error	15	1531576	102105		
Total	19	1706030			

nt = not significant

Appendix 31 ANOVA table for the mean live weight of the broiler chicken after day 56

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	2317834	579459	5.63	0.006*
Error	15	1543486	102899		
Total	19	3861320			

* = Significant

Appendix 32 ANOVA table for the breast weight of the broiler chicken after day 56

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	9.954	2.488	2.04	0.140^{ns}
Error	15	18.306	1.220		
Total	19	28.260			

ns = Not Significant

Appendix 33 ANOVA table for the thigh weight of the broiler chicken after day 56

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	1.654	0.4134	1.14	0.374^{ns}
Error	15	5.427	0.3618		
Total	19	7.081			

ns = Not Significant

Appendix 34 ANOVA table for the heart weight of the broiler chicken after day 56

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	0.07728	0.019321	3.02	0.052^{ns}
Error	15	0.09590	0.006394		
Total	19	0.17319			

ns = Not Significant

Appendix 35 ANOVA table for the duodenum weight of the broiler chicken after day 56

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	0.6454	0.1613	1.47	0.262^{ns}
Error	15	1.6511	0.1101		
Total	19	2.2965			

ns = Not Significant

Appendix 36 ANOVA table for the liver weight of the broiler chicken after day 56

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	1.348	0.3370	2.64	0.075^{ns}
Error	15	1.914	0.1276		
Total	19	3.262			

ns = Not Significant

Appendix 37 ANOVA table for the proventriculus weight of the broiler chicken after day 56

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	0.18142	0.045355	6.86	0.002*
Error	15	0.09916	0.006611		
Total	19	0.28058			

* = Significant

Appendix 38 ANOVA table for the gizzard weight of the broiler chicken after day 56

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	0.3131	0.07828	1.16	0.367ns
Error	15	1.0128	0.06752		
Total	19	1.3259			

ns = Not Significant

Appendix 39 ANOVA table for the jejunum weight of the broiler chicken after day 56

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	0.6227	0.1557	1.49	0.256ns
Error	15	1.5713	0.1048		
Total	19	2.1940			

ns = Not Significant

Appendix 40 ANOVA table for the ileum weight of the broiler chicken after day 56

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	0.3330	0.08326	1.75	0.191ns
Error	15	1.7125	0.04750		
Total	19	1.0455			

ns = Not Significant

Appendix 41 ANOVA table for the caeca weight of the broiler chicken after day 56

Source	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-value	P-value
Treatment	4	0.2499	0.06247	2.92	0.0.57^{ns}
Error	15	0.3210	0.02140		
Total	19	0.5709			

ns = Not Significant