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EFFECT OF DIET COMPOSITION ON THE UTILIZATION OF COPRA MEAL BY FINISHING BROILER CHICKENS

by
Ashika Devi

A thesis submitted in fulfillment of the
requirements for the degree of
Master of Agriculture

School of Agriculture and Food Technology
Faculty of Business and Economics
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DECLARATION OF ORIGINALITY

Statement by Author

I, Ashika Devi, declare that this thesis is my own work and literature cited has been duly acknowledged.

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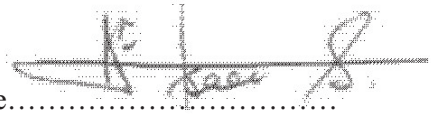
I hereby confirm the declaration of originality of this work by the author, Ms. Ashika Devi (s02002322), who worked under my direct supervision.

Signature  Date: 26/9/2016

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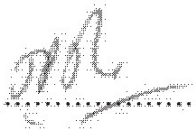
Signature  Date: 26/09/2016

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ABSTRACT

The scarcity and high cost of traditional protein sources call for more research into improving the utilization of alternative sources. The effect of dietary protein sources on the utilization of copra meal by broilers was investigated. Five finisher diets (D1, D2, D3, D4 and D5) containing 20% crude protein were formulated. The control diet (D1) was based on three traditional protein sources (fish meal, meat and bone meal and soybean meal). The other diets (D2, D3, D4, and D5) contained copra meal with different combinations of these traditional protein sources. A total of 100, 21-day old Cobb 500 broilers (777.2 ± 11.4g; 1.5 CV) were allocated to 20 floor pens. Each diet was fed to birds in 4 pens in a completely randomized design for 3 weeks. During week one, feed intake increased on D5 and weight gain increased on D2 and D5 ($P<0.05$). The best feed conversion ratio ($P<0.05$) occurred on D2. Birds fed D1 and D5 gained more weight ($P<0.05$) during week two. Feed conversion ratio was not affected by the diet in weeks 2 and 3. In week three, gain was maximized on diet 2 ($P<0.05$) and there were no dietary effects on feed intake and feed conversion ratio ($P>0.05$). Dressing percentage was depressed ($P<0.05$) on D4. Breast yield was reduced on D3 and D4 ($P<0.05$). There were no dietary effects on thigh and drumstick yields ($P>0.05$). Most segments of the gut and their digesta content weighed lighter ($P<0.05$) on D5. There were no dietary effects on weight of proventriculus, gizzard, and caeca. Feed cost per kilogram carcass was reduced ($P<0.05$) on D2. Digestibility of DM, CP, CF and Fat was improved ($P<0.05$) on diet 2. It was concluded, that animal protein-based diets improve the utilization of 15% copra meal by finishing broilers compared to diets containing soybean meal. Further research into higher levels of copra meal in animal protein-based diets is warranted.

LIST OF ACRONYMS

AAA	Amino Acid Analysis
ALFID	Australian Livestock Feed Ingredient Database
AOAC	Association of Official Analytical Chemists
CYS	Cystine
FAO	Food and Agriculture Organization
GLM	Generalized Linear Model
IFFOO	International Fishmeal and Fish Oil Organization.
MET	Methionine
NRC	National Research Council
NSP	Non Starch Polysaccharides
OECD	Organization for Economic Cooperation and Development
OM	Organic matter
RP-HPLC	Reserved-phase High-performance Liquid Chromatography
SPSS	Statistical Package for Social Sciences
SSF	Solid State Fermentation
ST$	Samoan Tala
US$	United States Dollar

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CHAPTER ONE: INTRODUCTION

1.1 Background information

World human population is reported to have increased steadily over the years with the current figure standing at 7.4 billion (Roser, 2016). Growth rate is reported to be increasing at 1.13% per annum (Roser, 2016). This increase in human population means more food for survival particularly protein for growth and development of human body. The rapid population growth, income rise and standard of living have increased the demand for animal proteins which are good sources of essential nutrients (FAO, 2010). The needed animal protein by the world's human population however, cannot be met from ruminant animals because of their high requirement for grazing land, high energy cost of production and low reproductive efficiency.

In order to meet the animal protein needs of the ever growing world human population in the short-term, efforts should be directed to the production of animals with short generation interval, high reproductive efficiency and early maturity such as poultry (Mahmood *et al.*, 2005; FAO, 2012). A poultry enterprise can produce meat within seven weeks and have the first egg produced within eighteen weeks of the first chick being hatched (Smith, 2001). The broiler industry has been a progressive one and is quick to adopt innovations (Ravindran, 2012). Poultry has been reported to be the most successful industry than any other animal industry and production standards have continually improved over the past 50 years (Ravindran, 2012). Broilers are ready for market between 6 to 7 weeks with male broilers currently reaching a live weight of 2.5 kg at 33-35 days of age and white egg layers capable of producing 330 eggs in 52 weeks of lay (Ravindran, 2012). In addition to their short generation time and high rate of reproduction, poultry are able to adapt to most areas of the world and have a low economic value.

Poultry production is a major contributor to food security worldwide. Poultry is reported to be the most consumed meat in the world accounting for two thirds of all animal meat products (Poultry trends, 2013; OECD/ FAO, 2013). Poultry meat production increased from 56 million in 1996 to 104 million metric tons in 2012 and was projected to further increase to 108 million metric tons in 2013 (Poultry trends, 2013). World poultry egg production increased by 28.4% from 2000 to 2012 with

China and the United States being the largest producing countries (Poultry trends, 2013). Poultry meat accounted for 30% (FAO, 2010) and 37% (FAO Food outlook, 2013) of global meat consumption. The production and consumption trends of poultry meat are expected to continue due to fast turnover rate, low energy and land requirements for production, feed efficiency, cheaper products, changing life styles, health attributes, consumer preference, and the price advantage (Vepa, 2004; Ali and Pappa, 2015).

World per capita consumption of poultry meat increased about four times from 3kg in 1963 to 11kg in 2003 (FAOSTAT, 2009). The greatest consumption of poultry products is reported to occur in developing countries (Ravindran, 2012). In these countries, meat production has increased resulting in expansion of the industry (Hossain *et al*., 2015). Increased production of white meat is evident in Asian countries while red meat markets are stagnating (Chemnitz, 2014). Poultry play an important role in bridging the worlds' protein consumption gap (Ravindran 2012).

However, high feed cost is a major constraint to poultry production increase (Glatz, 2012; Hossain *et al.*, 2015). The growth in the poultry industry is having a profound effect on the demand for feed and raw materials (Ravindran, 2011). Feed accounts for about 65 to 75% of the total cost involved in poultry production depending on the diet and management system (Mahmood *et al.*, 2005; Daghir, 2008; Glatz, 2012; Sittiya and Yamauchi, 2014; Diarra, 2015; Hossain *et al.*, 2015).

In the South Pacific countries the cost of feed is still higher as the traditional ingredients for diet formulation are not available in the region; thus expensive. The traditional plant protein sources used for poultry feeding are not grown at all in most countries and farmers depend on imported feed (Diarra, 2015) or where they may be grown the cultivation is insignificant to meet the demand of the livestock industry (FAO, 2012; Diarra, 2015). This is a major hindrance to the expansion of the poultry industry despite the increasing demand for poultry products in the region. Ayalew (2011) reported a 56 to 100 % increase in retail prices of commercial pig and poultry feeds in Papua New Guinea (PNG) from 2003 to 2011.

Samoa does not have a broiler industry at the moment mainly on account of the high feed cost. This results in a low domestic production of poultry meat which has led to massive importation of poultry products. The value of meat imports in Samoa from July 2012 to June 2013 was reported to be SAT$ 45 million representing 87% of total cost of meat import in the country (APHD Annual report, 2014). This massive importation has caused loss of foreign exchange, income and employment opportunities. This necessitates the need to increase research into locally available feed materials of low economic value which can be used to reduce feed cost in the region (Ochetim, 1988; ALFID, 2002; FAO, 2012; Diarra, 2015).

1.2 Problem statement

Copra meal, a by-product of coconut oil extraction, produced by expeller or solvent extraction is readily available in most countries of the South Pacific region. Pacific Oil Samoa produces an average of 800 metric tonnes of copra meal annually. In addition, reasonable quantities of copra meal are available from small scale oil extraction plants in the country. At the moment, copra meal has little or no industrial use in the country making it readily available for livestock feeding. The protein content of copra meal ranges from 15 to 25% (Thomas and Scott, 1962; Sauvant *et al.*, 2004; Mondal *et al.*, 2008) but the protein has a poor essential amino acid profile especially in respect of lysine and methionine (NRC, 2012). The residual oil content is reported to range from 3.5 to 7% (Canapi *et al.*, 2005; Kurian *et al.*, 2007). Crude fibre content of 11.3 to 33% have been reported in the meal (Nieuwkoop, 2004; Dairo and Fasuyi, 2008; Diarra *et al.*, 2014). The fibre of copra meal is mainly in the form of non -starch polysaccharide (NSP) (Sundu *et al.*, 2006; 2009). The NSP of copra meal is mostly present as pure mannan, galactomannan, glucomannan, galactoglucomannan (Sundu *et al.,* 2006) and cellulose (Balasubramaniam, 1976; Saittagaroon *et al.*, 1983; Dusterhoft *et al.,* 1992; Knudsen, 1997; Sundu *et al.,* 2009). The method of oil extraction is known to affect the nutritional quality of copra meal with solvent extracted meal being of better quality than expeller extracted meal (Thomas and Scott, 1962). The poor essential amino acid profile, high fibre content, and poor palatability due to rancidity are the major factors limiting the utilization of copra meal by poultry (Creswell and Brooks 1971; Thorne, 1992; NRC 1994; Kim *et al.*, 2001; Siebra *et al.,* 2008; Sundu *et al.,* 2009).

Recommendations of copra meal in broiler diets are variable (Sundu *et al*., 2006; Bastos *et al*., 2007). Sundu *et al*. (2006) observed reduced performance (feed intake, weight gain, feed conversion ratio and nutrient digestibility) of broiler chickens fed 10% dietary copra meal. Bastos *et al.* (2007) observed growth depression in young broilers fed as low as 5% copra meal in the diet. Although exogenous enzyme supplementation is reported to allow utilization of higher dietary levels of copra meal (Sundu *et al.,* 2009), these enzyme products may not be reachable by small scale poultry farmers in the South Pacific region. In addition, there is a gradual ban on the use of synthetic amino acids in poultry diets (USDA, 2012); thus the need to investigate into more adapted technologies for improving utilization of copra meal in the diet. Factors such as fibre source and composition, processing method and diet composition have all been reported to influence the utilization of dietary fibre by monogastric animals (Low, 1993). Currently there is little or no information on the effect of diet composition on the utilization of copra meal by broiler chickens. Since low nutrient density is a major factor affecting its utilization by poultry, it may be worth investigating the feeding of copra meal with different combinations of nutrient dense traditional protein sources in finishing broiler diets. The present study is a preliminary investigation on the effect of feeding a higher (15%) level of copra meal with different combinations of traditional protein sources on broiler performance.

1.3 Hypothesis

Broiler chickens would perform equally well on copra meal-based diets containing different combinations of traditional protein sources.

1.4 Objectives

The main objective of this study was to investigate the effect of feeding copra meal with different protein sources on the performance of finishing broiler chickens with the specific objectives of studying the effects on:

i. Growth parameters (feed intake, weight gain, feed conversion ratio);
ii. Nutrient digestibility;
iii. Carcass measurements and organ weights; and
iv. Feed cost of broiler meat production.

CHAPTER TWO: LITERATURE REVIEW

2.1 Nutritional requirements of broilers

The diet of broilers under confinement should contain essential materials for growth. These materials are grouped into energy, protein, vitamins and minerals. Broilers maybe fed starter and finisher (Gajana, *et al.*, 2011, Omid, *et al.*, 2011 and Ullah, *et al.*, 2012) or starter, grower and finisher (Skinner, *et al.*, 1992) diets.

2.1.1 Energy requirement

Energy from feed is needed for all metabolic processes. The energy in broiler feed comes from carbohydrates, mainly from cereals. Corn and wheat are the reference energy sources in broiler diets. Fats are concentrated forms of energy which are used to boost the energy level of diets. Fats also improve the physical consistency of diets and dispersion of micro-ingredients in feed mixtures (NRC, 1994). Supplemental fats may also increase energy utilization in adult chickens in association with a decreased rate of food passage through the gastro-intestinal tract (NRC, 1994). Fats are also sources of glycerol and fatty acids and serve as medium for fat-soluble vitamins (Oluyemi and Roberts, 2000). However, young chickens do not metabolize the oil in full-fat oil seeds as well as adult birds do (Askbrant and Farrell, 1987).

Deficiency of energy in the diet affects productive performance of birds. A dietary metabolizable energy (ME) concentration of 3,200kcal/kg has been recommended for broiler chickens (NRC, 1994; Aftab *et al.*, 2006; Klasing, 2015). However, the age of broiler seems to be an important factor affecting its requirement. A ME of about 2,900Kcal/Kg has been reported to support broiler growth (Farrell, 2005). Leeson *et al.* (1992) observed that feeding a diet containing about 1,900 Kcal ME/kg gave satisfactory growth in broilers aged 35 days.

An absolute requirement for energy in terms of kilocalories per kilogram (Kcal ME/Kg) of diet cannot be stated because poultry adjust their feed intake to obtain their necessary daily requirement (NRC, 1994). Poultry tends to eat to satisfy their energy requirements if fed *ad-libitum* (Oluyemi and Roberts, 2000).

2.1.2 Protein and amino acid requirements

The protein requirement of a bird is defined as requirement for a supply of each essential amino acid together with a sufficient supply of suitable nitrogenous compounds from which non-essential amino acids can be synthesized (Smith, 2001). Proteins, formed from amino acids, are required for growth and development of muscles, bones, feathers and organs. Both essential and non-essential amino acids are needed by broilers for growth and development.

Kekeocha (1984) recommended 21-24% crude protein for broiler starter and 18-20% for the finishing broiler. Dietary protein concentration can affect the requirement for individual essential amino acids (NRC, 1994). Dietary essential amino acid concentration has been reported to affect protein requirement of broilers. Dietary protein levels of 16.6 and 15.3% in the starter and finisher diets respectively have been reported to maintain performance of broilers when essential and non-essential amino acid ratio was maintained at 50: 50 (Aftab *et al.*, 2006).

When diets are formulated on the basis of feed analysis data, the assumption is generally made that amino acids are 80-90% available from the feed protein (NRC, 1994). However, most feed proteins are deficient in methionine (Serres, 1999). Methionine is a primary sulphur-containing amino acid in the diet of the domestic fowl (Yalcin *et al.*, 1999). Methionine primarily serves as a methyl donor for transmethylation reactions; especially in the biosynthesis of lipids and other compounds and is involved in lipid transport in the blood (Patterson and Kung, 1988). Methionine also serves as a sulphur donor (Pesti *et al.*, 1981). Within these two roles, methionine is a major component in protein synthesis (Kim *et al.*, 2006). According to Leeson and Summers (2001) methionine serves as a methyl donor for creatine, choline and carnitine.

The requirement of broiler chicks for methionine and total sulphur amino-acids is well established (Schutte and Pack, 1995; Baker *et al.,* 1996; Huyghebaert and Pack, 1996). Huyghebaert and Pack (1996) observed that slaughter yield and breast meat yield were clearly increased while fat deposition was decreased by sulphur containing amino acid addition from 2 to 5 weeks of age. Leyden and Balnave (1987) and Balnave and Oliva (1990) estimated that the methionine

requirement of broilers from 21 to 24 days was 0.35% or 0.26 g/MJ of ME. Damron *et al.* (1977), Schutte and Pack (1995) and Esteve-Garcia and Llaurado (1997) found an improvement in feed conversion in broilers with methionine supplementation. Body weight and breast meat yield were also improved and abdominal fat weight relatively reduced in a linear manner by increments in dietary methionine concentration (Yalcin *et al.*, 1999). Finishing broilers grown from 1.8 to 2.6 Kg required about 0.72% of total sulphur amino acids to optimize feed conversion efficiency, but responded favorably to concentrations close to 0.8% in terms of breast meat deposition (Yalcin *et al.*, 1999). Abasiekong and Tyokpat (2000) recommended 2.4% of combined supplementation of both lysine and methionine for optimum performance in broiler chickens. The requirements of poultry for protein and amino acids also differ among breeds and strains (NRC, 1994) and age (Baeza and Leclercq, 1998). According to Pond *et al.* (1995) and Bartov (1998), chickens are sensitive to dietary balance in amino acid in terms of weight gain and feed efficiency. Methionine is normally supplemented only when crude protein cannot provide the required levels of methionine as excess dietary methionine depresses growth (Kim *et al.*, 2006). Lysine concentrations of 1.2 and 1% have been recommended for starting and finishing broilers respectively (NRC, 1994).

2.1.3 Vitamins and minerals requirements

Vitamins are organic compounds not synthesized by the body tissues and are required in very small amounts in diets (Oluyemi and Roberts, 2000). Vitamins are generally classified under two headings: fat-soluble vitamins A, D, E and K and water soluble vitamins which include the B-complex vitamins and vitamin C. The requirements for most vitamins are given in terms of milligrams per kilogram of diet, with the exception of vitamins A, D and E for which the requirements are commonly stated in international units (I.U.). According to Leeson (2009), vitamins are not always found in sufficient quantities or available forms in the feedstuffs usually used for poultry diets and therefore have to be supplied in the diets using vitamin and mineral premixes. Increasing dietary vitamin E level above NRC (1994) recommendations has been shown to improve the immune response of broilers of all ages and the performance of broilers under heat-stress (Leeson, 2007). Castaing *et al.* (2003) also observed that higher vitamin fortification results in superior growth and

meat yield in broilers. However, withdrawal of vitamin and mineral premix at 42 days (Skinner *et al.*, 1992) or even at 35 days (Farrell, 2005) did not affect growth rate or feed conversion ratio in broilers.

Minerals are required for the formation of the skeleton, as components of various compounds with particular functions within the body, as activators of enzymes and for the maintenance of necessary osmotic relationships within the body of the bird (NRC, 1994). The major minerals are calcium (Ca), phosphorus (P), sodium (Na), potassium (K), magnesium (Mg) and chlorine (Cl). Most of the Ca in the diet of the growing bird is used for bone formation, whereas in the mature laying fowl most dietary Ca is used for eggshell formation (NRC, 1994). The Ca requirement of the laying hen is difficult to define. However, 3.4% (NRC, 1994), 4.0 to 4.25% (Grizzle *et al.*, 1992) and 4.0% (Smith, 2001) are believed to represent the mean dietary concentration for the quantities of feed likely to be consumed (110 grams per hen per day) over a considerable range of environmental temperature (NRC, 1994). An excess of dietary Ca interferes with the availability of other minerals such as magnesium, manganese and zinc (NRC, 1994). According to Smith (2001), the requirements of poultry for calcium and phosphorus are influenced by the amount of vitamin D in the diet. He however, recommended that the ratio of Ca: P be within the range of 1:1 and 2:1 for growing birds and up to 6:1 for laying birds. In feeding poultry, the source of Ca is also important. NRC (1994) reported that high concentrations of calcium bicarbonate (limestone) and calcium phosphates might make the diet unpalatable.

The trace elements needed by the fowl are iron, manganese, copper, molybdenum, zinc and selenium (Oluyemi and Roberts, 2000). The same authors reported that the likely deficient mineral elements in poultry diets are calcium, phosphorus, sodium, chlorine, manganese, iodine, iron, copper and cobalt. The requirements of chickens of different strains and ages for selected nutrients are shown in Table 1.

Table 1: Nutrient requirements of broilers fed with diets of two feeding phases

	Broilers		
Energy Base [1]	0-3 weeks	3-6 weeks	6-8 weeks
Kcal ME/kg diet	3,200	3,200	3,200
Protein (%)	23.0	20.0	18.0
Lysine (%)	1.20	1.00	0.85
Methionine (%)	0.50	0.38	0.32
Calcium (%)	1.00	0.90	0.80
Phosphorous (available) (%)	0.45	0.4	0.35
Potassium (%)	0.4	0.35	0.3
Sodium (%)	0.15	0.15	0.15
Chlorine (%)	0.15	0.15	0.15
Magnesium (mg)	600	600	600
Zinc (mg)	40	40	40
Iron (mg)	80	80	80
Iodine (mg)	0.35	0.35	0.35
Vitamin A (IU)	1,500	1,500	1,500
Vitamin D (IU)	200	200	200
Vitamin E (mg)	10	10	10
Vitamin K (mg)	0.5	0.5	0.5
Niacin (mg)	27	27	27
Thiamin (mg)	1.8	1.8	1.8

[1] These are typical dietary energy concentrations.

Source: National Research Council (NRC, 1994).

2.2 Feed consumption and weight change in broilers

Because feed represents the highest cost of producing poultry meat and eggs (Aduku, 1992; Perez *et al.*, 1999) data on feed consumption together with information on body weight and feed conversion ratio of individual flocks are important. Many factors have been reported to affect feed intake and performance of poultry. Smith (2001) reported that birds of broiler strains consume more feed than birds of egg laying strain.

Dietary effects on feed intake have also been reported. An increase in dietary energy concentration results in a decrease in feed intake (NRC, 1994; Smith, 2001). If the diet is deficient in one or more essential nutrients, appetite is depressed and this is associated with a decline in growth and reproductive performance (Smith, 2001; Cobb Management Guide, 2010). The intake of pelleted feed is greater than that of the same feed in the form of meal (Oluyemi and Roberts, 2000; Smith, 2001). Feed intake has been reported to decrease with increasing environmental temperature. NRC (1994) observed that feed intake decreases by about 1.5% for each rise of 1^{o}C above the thermo-neutral zone in poultry. Feeding diets containing low metabolizable energy (ME) and increased concentrations of protein and amino acids has been reported to minimize the deleterious effect of heat on feed intake (Daghir, 1995; Balnave and Brake, 2005).

According to NRC (1994), feed consumption and body weight are higher in the male than the female chicken. Light management program has also been reported to affect broiler performance (Cobb Management Guide, 2010). Table 2 shows the body weight and feed consumption of Cobb broilers as affected by age and sex of the bird.

Table 2: Average feed consumption and body weight change of Cobb Broilers

Age (weeks)	Feed intake (g)		Daily weight gain (g)		Body weight (g)		Feed conversion ratio	
	Male	Female	Male	Female	Male	Female	Male	Female
1	151	150	29	29	179	175	0.844	0.876
2	475	456	51	47	475	443	1.000	1.029
3	1,106	1,001	74	66	938	844	1.179	1.186
4	2,085	1,840	92	77	1,531	1,341	1.362	1.372
5	3,435	2,994	101	85	2,217	1,914	1.549	1.564
6	4,994	4,317	109	86	2,953	2,511	1.691	1.719
7	6,646	5,717	95	81	3,660	3,084	1.816	1.854
8	8,375	7,159	85	79	4,275	3,641	1.959	1.966

Adapted from Cobb Management Guide (2010)

2.3 Broiler carcass

There are several published data on carcass traits of meat chickens. Dressing percentages of 65-86% (Say, 1992; Deschepper and Degroote, 1995; Iheukwumere *et al.*, 2001) have been reported for broiler chickens. Iheukwumere *et al.* (2001) observed no sex difference in dressing percentage in broiler chicken. Mack *et al.* (1999) reported a breast meat yield of 14-17% in broilers. Laseinde and Oluyemi (1994) reported lower liver and gizzard weights in male broiler compared to female. Breast meat yield has been found to decrease linearly with increasing ambient temperature (Smith, 2001). Nutritional and dietary manipulations exert several influences on the development of carcass traits, organs and setting muscles in broilers. Fanimo *et al.* (2005) observed higher dressing percentage in broilers fed low fibre diets compared to those fed high fibre diets probably due to the lower energy content of the latter diets. Low protein diets have been reported to have adverse effects on dressing percentage and the yield of different cut-up parts (Salami *et al.*, 2004). Yalcin *et al.* (1999) reported an increased breast meat yield and reduced abdominal fat weight with increasing dietary methionine concentration. Parr and Summers (1991) also reported increase carcass fat on low protein diets. Substitution of soybean meal with Sunflower meal was reported to have no adverse effects on growth and dressing percentage, but improved breast and thigh muscle yield in turkeys (Laudadio *et al.*, 2014). Iyayi *et al.* (2005) reported a significant reduction in dressing percentage in broiler chickens fed mucuna bean meal above 33% as replacement of soybean meal. Dogo (2001) observed that optimum dressing percentage was achieved when 8% of fish meal was replaced with palm kernel cake in broiler diets. These studies suggest that different protein sources with different amino acid composition affect the development of carcass traits differently. Addition of copra meal at 0.1% in the diet of broilers has been found to reduce abdominal fat deposition and total cholesterol (Kannan *et al.*, 2005).

2.4 Some traditional protein sources for poultry

Ingredients such as fish meal, meat and bone meal, poultry by-product meal and soybean meal have been traditionally used as protein sources in poultry diets. These ingredients are characterized by high protein content, good balance of essential amino acids and high digestibility. Traditional feed proteins are grouped

into plant and animal sources. The use of plant protein sources in poultry diets is increasing mainly due to the high cost of animal proteins.

Several factors including the physical nature, dietary level of inclusion and presence of anti-nutritional factors (ANF) affect the utilization of plant protein sources by poultry. Cancherini *et al.* (2004) reported that corn/soybean meal-based diets promoted better growth than other diets. Vieira and Lima (2005) also found no significant differences in body weight gain of broilers fed animal proteins sources compared to vegetable protein. However, Hossain *et al.* (2012; 2013) observed better growth performance of broiler chickens fed diets containing fish meal compared to those fed vegetable protein diets. Bhuiyan *et al.* (2012a) reported a 10% reduction in feed intake of broilers fed vegetable protein compared to animal protein diets. Ojewola *et al.* (2005) observed growth depression in broilers fed diets without animal protein sources. Poor performance of broilers on plant proteins maybe due to reduced feed intake and poorer amino acid profile and digestibility compared to animal protein sources.

2.4.1 Fish meal

Fish meal is obtained by cooking, pressing, drying and milling fresh raw fish or fish trimmings (IFFOO, 2006). There are several types of fish meal in the market depending on the source of fish or fishery by-products used and on the processing technology involved. Fish meal contains between 60-70% crude protein (NRC, 1994; Smith, 2001; Sauvant *et al.*, 2004; Blair, 2008) and a high amino acid quality (Médale and Kaushik, 2009).

Although known to be inorganic in a strict sense, fish meal is reported to be approved for use in organic poultry diets (Blair, 2008). Fish meal is an excellent feedstuff for poultry. It is also a good source of minerals especially calcium, phosphorous and B vitamins. Fish meal is however, scarce in most developing countries, thus expensive for use in poultry feeds (Serres, 1999; Smith 2001). According to Smith (2001), the quality of fish meal may deteriorate in hot climates and inclusion levels above 10% in diet causes spoilage, poor palatability and low quality of meat and eggs. However, the use of antioxidants has been reported to reduce spoilage and oxidation (Smith, 2001; Blair, 2008).

Fishmeal is reported to be the best protein source for young poultry. The protein of fish meal has high digestibility coefficient (over 90%) (Zhou *et al.*, 2004). Karimi (2006) fed diets containing 0, 2.5, 5% and 0, 1.25, 2.5% fish meal to broiler starter and grower respectively and observed significant increase in body weight gain and feed intake as fish meal level increased. However, higher inclusion levels above 10% may produce a fishy smell in meat and eggs. The high cost of fish meal is another limitation to its higher inclusion levels in the diets. Processing fish meal above 120^{o}C for 2-4 hours has been reported to produce a toxic substance Gizzerosine which causes gizzard erosion in poultry (Blair, 2008).

2.4.2 Meat and bone meal

Meat and bone meal is a by-product of abattoir obtained by cooking, drying and grinding waste bones, tendons, and trimmings. The quality of meat and bone meal depends on the ratio of meat and bones processed. It is reported to contain 40-50% crude protein depending on the processing method (Serres, 1999; Smith, 2001). Meat and bone meal protein has a good level of amino acids (lysine, methionine, cysteine and tryptophan) and is rich in minerals especially calcium and phosphorous (Smith, 2001). However, Zhou *et al.* (2004) reported lower protein digestibility in meat and bone meal compared to fish meal and poultry by-product meal.

2.4.3 Soybean meal

Soybean (*Glycine max*) is a tropical oil seed widely used in animal feeding. Full fat soybean contains 35-38% crude protein but after oil extraction the cake contains 40-45% (Smith, 2001). A protein digestibility of about 82% was reported for soybean (Woodworth *et al.*, 2001). The carbohydrates in soybean meal is however, reported to be incompletely digested by monogastric animals (Kerley and Allee, 2003). Removal of raffinose and stachyose has been found to improve metabolizable energy content by 12% (Graham *et al.*, 2002).

Raw soybean however, contains anti-nutritional factors mainly trypsin inhibitor which depresses growth in poultry and prevent the action of trypsin (a proteolytic enzyme). There is increased use of soybean in animal feed due to new cultivars with low ANF levels (Gu *et al.*, 2010). Heat processing (roasting and

cooking are known to inactivate trypsin inhibitors. However, higher processing temperatures may lead to loss of amino acids especially lysine through Maillard reaction (Sundu *et al.,* 2009; Hurrell, 1990). Araba and Dale (1990) reported an improved performance of monogastric animals with properly processed soybean meal. Arends *et al*. (1971) and Lalshaw and Clayton (1976) however, recommended that diets containing roasted full fat soybean meal must be balanced for energy/amino acid ratio because birds on high energy full fat roasted soybean meal will consume less feed. Dewan and Gleaves (1969) similarly reported that heated full fat soybean meal significantly reduced feed intake by layers.

2.5 Copra meal (CM) as protein source in broiler diets

Copra meal is a by-product of coconut oil extraction. World copra meal production is reported to be 2 million tonnes per year (FAO, 2002). The amount is reported to be 480,000 tonnes of crude protein from copra meal available for animal feed (Sundu *et al.*, 2009). The protein content of copra meal depends on origin and method of oil extraction. Copra meal has been reported to be poor in lysine and sulphur amino acids (Creswell and Brooks, 1971; NRC, 1994) due to heat damage (Butterworth and Fox, 1962). High fibre content (Knudsen, 1997; Diarra *et al.,* 2008; Mateos *et al.,* 2014) is another factor affecting its feeding value. Rancidity is also a factor affecting copra meal utilization due to the oil content it gets transformed to peroxide which becomes unpalatable for birds. Attempts have been made to address these problems by either carefully formulating diets to meet requirements of poultry, particularly amino acids (Sundu *et al.,* 2009) or by the inclusion of enzymes (Choct, 2006; Diarra *et al.*, 2014). Sundu *et al.* (2009) observed that broilers 4 to 14 day old can tolerate up to 30% copra meal in the diet provided the diet is supplemented with essential amino acid. Enzymes and synthetic amino acids come at an additional cost and may not be practicable on medium scale farms. Most synthetic amino acids have been banned in poultry diets, especially in organic poultry production. The use of methionine (the last synthetic amino acid) is also being restricted and may be banned in the near future (USDA, 2012). Factors such as fibre source and composition, processing method and composition of the diet have all been reported to influence the utilization dietary fibre by poultry (Low, 1993).

2.5.1 Composition of copra meal

The crude protein content of copra meal is between 20-25% dry matter (DM), but it is relatively high in fibre mainly non starch polysaccharides (NSP) which exert anti-nutritional properties (Sundu *et al.*, 2009). The NSP of copra meal is in the form of mannan and galactomannan (25-30%) (Sundu *et al.*, 2009). Depending on oil extraction method CM is relatively high in residual oil which makes it a valuable energy source (Daghir, 2008). Residual oil contents of 3 and 20% have been reported in solvent extracted and mechanically extracted copra meal respectively (Feedipedia, 2011; Sundu *et al.,* 2009). Copra meal is low in essential amino acids mainly lysine and sulphur amino acids (Sundu *et al.*, 2009) which makes amino acid supplementation of copra meal based broiler diets necessary.

2.5.2 Recommendations of copra meal in broiler diets

Recommendations of copra meal in broiler diets have been variable. Inclusion levels higher than 10-20% have been reported to negatively affect broiler performance (Jacome *et al.*, 2002; Sundu *et al.*, 2004a; 2005a; 2006). For optimum performance a limit of 10% has been recommended for adult birds and 2-5% for chicks (Bastos *et al.*, 2007; Daghir, 2008). Low density and high water holding capacity of copra meal are the main reasons for lower intake of copra meal-based diets (Sundu *et al.*, 2005a). Bastos *et al.* (2007) reported a depressed growth in chicks fed as low as 5% dietary copra meal. High inclusion of copra meal has been reported to result in 30-50% depressed weight gain (Sundu *et al.*, 2006). Thomas and Scott (1962) attributed the detrimental effect of copra meal on poultry performance to nutritional deficiency rather than the presence of toxic or growth depressing factors.

2.5.3 Factors affecting utilization of copra meal by broilers

As mentioned earlier, the high fibre content and low essential amino acid profile of the protein have been the major factors affecting utilization of copra meal in broiler diets. The high residual oil content also makes copra meal susceptible to rancidity making it unpalatable (Ehrlich *et al.*, 1990). Animals fed rancid copra meal may also develop diarrhoea (Göhl, 1982). The presence of mycotoxins (Ravindran, 2011) may also affect the utilization of copra meal by poultry.

2.5.4 Feed technologies for improving utilization of copra meal by broilers

Several feed technologies have been used to improve the utilization of copra meal in broiler diets. These include enzyme and amino acid supplementation, diet dilution and choice feeding among others.

2.5.4.1 Enzyme supplementation

Several enzyme products have been found to improve performance of broilers fed copra meal based diet. Sundu *et al.* (2006) reported improved weight gain feed conversion ratio, feed digestibility and decreased jejunal digesta viscosity of broiler chickens fed copra meal-based diets supplemented with enzymes (Hemicell®, Allzyme SSF® and combination of Gamanase, Hemicell and Allzyme SSF). The use of mannanase has also been shown to improve animal performance on copra meal-based diet (Sundu *et al.*, 2004a; 2009). However, enzyme supplementation has not resulted in performance improvement equivalent to the control with no copra meal (Sundu *et al.*, 2006; 2008).

2.5.4.2 Amino acid supplementation

Amino acids are used as supplements to improve copra meal-based diets by poultry. Thomas and Scott (1962) observed improved body weights in broilers fed copra meal based diets supplemented with lysine. Panigrahi *et al.* (1987) observed that up to 25% copra meal is safe for broilers maintained to 6 weeks provided diets are supplemented with methionine and lysine. In a later study, Sundu *et al.* (2005b) increased inclusion level of copra meal to 30% with lysine and methionine supplementation and observed that performance deterioration above 25%. Supplementation of copra meal-based diets with amino acids in chicks does not improve feeding value due to small capacity of their digestive system (Sundu *et al.*, 2004b).

2.5.4.3 Soaking

Soaking the diet has been reported to improve birds' performance (Yalda and Forbes, 1996). Performance improvement on soaked diets has been attributed to activation of endogenous enzymes (Forbes, 2003), increased ingredient solubilisation

(Yasar and Forbes, 2000) and increased bulk density (Sundu *et al.,* 2005a). Sundu *et al*. (2005a) reported a significant increase in body weight gain of broilers fed a 30% soaked CM based diet in a ratio 1:1. The improvement in body weight gain of broilers fed soaked CM-based diets has been mainly attributed to increased feed intake (Forbes, 2003).

2.5.4.4 Pelleting

The beneficial effect of feeding pelleted diets is well documented (Callet, 1965; Thomas and Van der Poel, 1996; McCracken, 2002). Increased feed intake of pelleted diets compared with a mash has been reported (Proudfoot and Hulan, 1982; Nir *et al.,* 1995; Sundu *et al.,* 2005a). Sundu *et al.* (2005a) observed higher body weight gain in broilers fed pelleted CM diets compared to the control corn-soybean diets. At the moment however, pelleting is not an affordable option by small scale farmers of the South Pacific region.

2.5.4.5 Diet dilution

Copra meal has been used to dilute expensive commercial broiler feeds in order to reduce cost of production. Diluting a broiler finisher diet with 20-40% copra meal resulted in similar growth as the control diet and inclusion of 60% copra meal resulted in acceptable growth of village broilers (Pandi, 2005). The extent of dilution that is practiced depends on the availability and cost of copra meal.

2.5.4.6 Choice feeding

Choice feeding is a feeding system where the three feed groups; protein, carbohydrates, minerals and vitamins are provided separately every day so that the birds can choose feed according to their requirements. Ancestors of broilers lived on self-selected feed but modern birds are being fed single-feed under intensive system (Hossain *et al.,* 2015). In choice feeding, birds self-select nutrients using their innate abilities to balance their nutritional needs for the day (Cumming, 1992a; Ciszuk, *et al.,* 1998; Olver and Malan 2000; Haskell *et al.,* 2001; Dana and Ogle 2002; Henuk and Dingle 2002; Pousga *et al.,* 2005; Glatz 2012; Hossain *et al.,* 2015). There is evidence that both wild and domesticated poultry are able to adjust their nutrient intake by selecting from a range of feedstuffs a diet that matches their physiological

requirements (Pousga *et al.*, 2005). Grayson and Campbell (2004) reported that free-choice feeding system can be used successfully for village poultry in the Solomon Islands. Birds have an inherent capability to select feed and capacity to regulate their separate intakes of energy, protein, minerals and vitamins to meet requirements. However, the intake may be affected by color, smell, odor, flavor, taste and texture (Cruz *et al.*, 2005). If feed from the three food groups are provided in separate containers, the birds will choose feed according to their requirements. If one of the feed groups is eaten quickly, then more of that feed should be provided. Bhuiyan *et al.* (2012a; 2012b) reported that choice fed broilers had preference for animal protein over vegetable protein sources. Nano (2015) concluded that 50% copra meal concentrate in a choice feeding with local feed ingredients will maintain performance of laying hens and reduce cost of egg production.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Site of experiment

The study was conducted at the Poultry Unit of the University of the South Pacific's School of Agriculture and Food Technology, Alafua Campus, Samoa. Samoa consists of two main islands namely, Upolu and Savaii with a humid tropical climate. There are eight smaller islands on this independent nation and a total land area of 1,100 sq. miles (2,830 sq. km). Agriculture in Samoa is mostly village type and community based where interdependent farming system of crop (root crops, vegetables, fruits, coconut and cocoa), livestock (cattle, pigs, poultry with sheep being new initiative), fisheries and forestry. Production is for home consumption and for cash (Samoa Bureau of Statistics, 2014). Copra industry waste, copra meal is readily available after oil extraction process from industries in Samoa.

3.2 Traditional protein sources and diet formulation

Three traditional protein sources; fish meal (FM), meat and bone meal (MBM) and full-fat soybean meal (SBM) and test ingredient copra meal (CM) were analyzed for proximate composition and amino acid profile. Soybean meal and CM were also analyzed for total, insoluble and soluble non-starch polysaccharides (NSP) (Tables 3 and 4). Five broiler finisher diets containing 20% crude protein were formulated (Table 5). The diets consisted of a control diet based on three traditional protein sources and four other diets containing on 15% copra meal with different combinations of these protein sources as follows:

Diet 1(control): FM, SBM and MBM.

Diet 2: CM, FM and MBM

Diet 3: CM, FM and SBM

Diet 4: CM, FM, SBM and MBM.

Diet 5: CM, SBM and MBM.

Table 3: Proximate composition, and NSP contents of experimental protein sources (%DM)

Constituents (%)	Protein sources			
	FM	MBM	SBM	CM
Dry matter	96.9	96.8	96.9	97
Crude protein	48.1	57.6	34.5	21.1
Ether extract	12.4	11.0	18.7	11.4
Crude fibre	0.6	1.8	16.4	16.4
Ash	30.3	28.1	5.6	5.6
Total NSP	-	-	20.32	52.33
Insoluble NSP	-	-	19.08	38.65
Soluble NSP	-	-	1.24	13.68

FM: fish meal; MBM: meat and bone meal; SBM: soybean meal; CM: copra meal, NSP: non-starch polysaccharides

Table 4: Amino acid composition of the experimental protein sources (mg/100mgDM)

Amino acid	Protein sources			
	MBM	FM	SBM	CM
Aspartic acid	4.99	4.36	3.95	1.80
Threonine	2.4	2.14	1.48	0.67
Serine	2.92	1.95	1.79	0.92
Glutamic acid	7.59	5.84	5.48	3.96
Proline	4.29	2.96	1.79	0.75
Glycine	6.42	4.95	1.55	0.98
Alanine	4.0	3.48	1.55	0.92
Valine	3.26	2.58	1.77	1.20
Isoleucine	2.35	2.03	1.60	0.75
Leucine	4.20	3.33	2.58	1.39
Tyrosine	1.73	1.47	1.29	0.47
Phenylalanine	2.32	1.88	1.69	0.92
Histidine	1.14	1.1	0.94	0.44
Lysine	3.51	3.02	2.20	0.47
Arginine	4.17	3.09	2.39	2.40
Cysteine	0.86	0.36	0.70	0.26
Methionine	1.20	1.30	0.56	0.29

FM: fish meal; MBM: meat and bone meal; SBM: soybean meal; CM: copra meal, NSP: non-starch polysaccharides

Table 5: Ingredient composition, calculated and analysed composition of broiler finisher diets (as fed basis)

Ingredients (%)	Diets				
	D_1	D_2	D_3	D_4	D_5
Corn	46.88	41.13	38.1	39.13	37.66
Mill mix	23.44	20.40	18.84	19.40	18.65
Soybean meal	8.01	-	11.19	6.92	11.49
Fish meal	8.01	8.88	11.19	6.92	-
Meat and bone meal	8.01	8.88	-	6.92	11.49
Copra meal	-	15	15	15	15
*Fix ingredients	5.65	5.71	5.72	5.71	5.71
Calculated (%DM)					
Lysine	1.14	1.13	1.13	1.14	1.14
Methionine	0.43	0.44	0.44	0.44	0.44
Methionine+cysteine	0.63	0.63	0.64	0.63	0.65
Total NSP	8.1	13.51	15.36	14.64	15.37
ME (Mj/kg)	12.46	12.52	13.02	12.66	12.76
ME/protein	151	151.5	157.22	152.69	154.54
Total NSP	8.1	13.51	15.36	14.64	15.37
Analyzed composition (%DM)					
Dry matter	95.36	95.25	95.25	96.03	95.67
Crude protein	19.79	19.78	19.81	19.83	19.76
Ether extract	4.64	6.01	6.41	6.16	7.28

*Fix ingredients: coral sand and snail shell meal (4%), Vitamin-Mineral Premix from Image Blend (0.25%), lysine HCl (D1: 0.8%, D2-D5:1%), DL methionine (D1: 0.3%, D2-D5: 0.5%), salt (0.3%). NSP: non-starch polysaccharides.

D1: Control diet with no CM, D2: CM fed with FM + MBM, D3: CM fed with FM + SBM, D4: CM fed with FM + SBM + MBM, D5: CM fed with SBM + MBM.

3.3 Experimental broilers and management

A total of 100 day-old Cobb broiler chicks were brooded together for a period of 20 days on commercial broiler starter feed. On day 21, the birds were weighed individually (777.2 ± 11.4g; 1.5 CV) and allotted to 20 open-sided floor pens (238 cm x 109 cm) containing 5 birds each with wood shaving as litter material. The formulated diets were fed each to birds in 4 randomly selected pens in a completely randomized design (CRD) for a period of 22 days (from 21 to 42 days). Feed and water were provided *ad-libitum* throughout the duration of the experiment**.** The birds were exposed to 22 hours lighting during the experimental period.

3.4 Data collection

3.4.1 Growth performance data

Data were collected on growth parameters. A weighed quantity of feed was fed daily and the left-over weighed the next day to account for the quantity consumed by difference. Birds were weighed at the start of the experiment and weekly thereafter. Weekly weight change was monitored by difference between two consecutive weighing. Average daily live weight change was calculated by dividing the weekly gain by 7 (number of days in the week). Feed conversion ratio (FCR) was calculated weekly as the ratio of feed consumed by weight gained for four weeks.

3.4.2 Nutrient digestibility

At day 35, one bird was randomly selected from each pen (4 birds per treatment) and placed in individual cages (with bamboo floor) for digestibility studies. The birds were adapted to the cages for 3 days during which they were fed their respective diets *ad-libitum*. From day 4, weighed quantities of feed were fed and faecal samples collected from each bird for a period of 4 days. Faecal samples collected were air-dried for 48 hours and ground. Samples from each bird were pooled, weighed, and analyzed for proximate composition. Apparent nutrient digestibility was calculated as:

$$\% \text{ digestibility} = \frac{\text{Nutrient intake} - \text{nutrient in the faeces}}{\text{nutrient intake}} \times 100$$

3.4.3 Carcass and organ measurements

At the end of the experiment (day 42), all the birds were fasted overnight, weighed early in the morning and euthanized by decapitation for carcass and organ measurements. Slaughtered birds were scalded in hot water (about 50C), plucked manually and eviscerated. The eviscerated chickens (carcasses) were weighed and dressing out percentage calculated as:

$$\% \text{ dressing} = \frac{\text{Carcass weight}}{\text{Live weight}} \times 100$$

Some carcass cut-up parts (thighs, drumstick and breast) were also removed, weighed and expressed as percentages of the live weight of the bird. The skin in the crease between the thigh and the body was cut from cranial to caudal to expose and dislocate the hip joint (*Articulation coxae*). The tendons and ligaments around the joint were then cut to remove the thighs. The thighs and drumsticks were separated at the stifle joint (*articulation genus*). The breast muscle was gently separated from the sternum using a scalpel blade.

Segments of the gut (crop, proventriculus, gizzard, small intestine and caeca) and annex glands (liver, pancreas) were also removed and weighed using an electronic scale sensitive to 0.1g. The segments of the gut were weighed full and empty and digesta content calculated by difference between the full and empty weights.

3.4.4 Feed cost of meat production

The cost of the kg of each diet was computed based on the market price of the ingredients and feed cost of kg of live weight gain and kg carcass calculated as follows:

Feed cost/kg live weight = cost of kg feed × feed conversion ratio

Feed cost/kg carcass = feed cost/kg live weight ÷ dressing percent

3.5 Data analysis

3.5.1 Chemical analysis

The protein sources (FM, MBM, SBM and CM), diets and faecal samples were analyzed for proximate composition. The protein sources were analyzed for amino acid profile. Soybean and copra meal were also analyzed for NSP at the same laboratory. Chemical analysis was carried out at Massey University, Palmerston North, New Zealand.

3.5.1.1 Proximate analysis

Proximate analysis was carried out according to the methods of AOAC (1990).

3.5.1.1.1 Dry matter and ash determination

Dry matter + Ash/OM were determined according to AOAC (ID 930.15/925.10/942.05). Two grams of the sample was oven dried at 105^{o}C until constant weight was achieved. The weight loss was that of moisture and the dry matter (DM) was calculated as:

% DM = 100- % moisture.

The ash or total mineral content was determined by incinerating 10 g of the dried sample in a furnace at 600C for 3 h. The residue after incineration (ash) was cooled in a desiccator and then weighed. The percentage ash for each sample was calculated as:

$$\% \text{ Ash} = \frac{\text{weight of residue}}{\text{weight of sample}} \times 100$$

3.5.1.1.2 Determination of crude protein (CP) and amino acid profile

Crude protein was determined using the Kjeldahl procedure (AOAC, 1990) (nitrogen-protein conversion = 6.25). The procedure consisted of 3 stages namely digestion, distillation and titration. For digestion, 2.0 g of the sample was placed into a digestion tube. Two (2) digestion tablets, which served as catalysts and 25 ml of concentrated sulphuric acid, were added. The tube was then placed on a digestion

block covered with the exhaustion cap and switched on. Digestion started with a low temperature to avoid rapid reaction, which would cause the sample to over boil. Digestion continued for about 2 h. The digested sample was allowed to cool at room temperature, and then diluted with distilled water to a volume of 100 ml.

Distillation was carried out in a distillation machine. Fifty (50 ml) of NaOH was added to the digested sample which now consists of protein + H_2SO_4 to form $(NH_4)_2SO_4$. This ammonium sulphate reacted with NaOH to give NH_4OH + Na_2SO_4. The distillation machine has a provision for water that is heated to give steam. The steam is passed through the digested sample + NaOH to carry over the NH_4OH that is condensed into a receiver flask containing boric acid + indicators (bromocresol green + methyl red). The NH_4OH in boric acid changed the initial reddish color of boric acid to green indicating the presence of a base (NH_3).

After distillation the NH_3 in boric acid was then carried to a machine (burette) for titration with 0.1 ml HCl. Nitrogen was then obtained by calculation as follows:

$$\% \text{ N} = \frac{(14.01 \text{ (ml of titrant sample} - \text{ml of titrant of blank)} \times \text{molarity of standard acid}}{\text{(g) sample} \times 10} \times 100$$

Nitrogen-protein conversion was taken at 6.25.

The amino acid profile of the samples was determined using Standard AAA hydrochloric acid hydrolysis followed by RP-HPLC separation using AccQ-Tag derivatization (AOAC 994.12). CYS/MET was separated using Performic acid oxidation method (AOAC 994.12).

3.5.1.1.3 Determination of crude fibre (CF)

Crude fibre was determined according to AOAC 962.09/978.10. A prepared sample weighing 1g was digested in a flask on a heating mantle with a digestion reagent consisting of trichloroacetic acid (20 g), glacial acetic acid (500 ml) and NH_3 (50 ml) all diluted to 1 litre with distilled water.

Each sample was digested with 100 ml of the digestion reagent above for 40 minutes. The digested sample was removed and allowed to cool at room temperature and then filtered through an ash less filter paper that was weighed initially. The filtered sample was washed 6 times with hot distilled water to remove carbohydrates

and proteins and once with petroleum spirit to remove fats. The paper was then placed in an oven at 80 C overnight to remove all the moisture and then weighed. The residue after drying (paper + fibre + ash) was ashed in a muffle furnace at 550 C for 3 h and the ash weighed. The fibre was determined by calculation using the formula of Van Soest and Wine (1967).

$$\% \text{ CF} = (\text{weight after oven drying} - (\text{weight of ash} + \text{weight of paper}) \times 100$$

3.5.1.1.4 Determination of ether extracts (EE) or fat

Fat extraction was done according to the method of Mojonnier (AOAC 954.02). Two (2) grams of the sample was placed in a thimble and the mouth closed with a piece of cotton wool. The thimble was placed into an extraction chamber of the Soxhlet system. The chamber was fixed onto an extraction flask (round bottom flask of 500 ml) in which 200 ml of petroleum ether was placed. The two units were fixed onto a heating mantle and a condenser placed on top of the unit.

The heating mantle was turned on at a temperature of 60C. As the ether in the flask evaporates it follows the side arm and goes to the condenser of the Soxhlet where it condenses and comes down into the extraction chamber. As it drips on the sample in the thimble it extracts the fat and when the chamber is full, the siphon arm fills up also and when it cannot go up any more, it follows the bench and pours down in the flask. As the process is repeated (refluxing), the whole fat in the sample is removed and received into the flask. After about 5 hours, the ether coming down is received into a beaker leaving the flask with only extracted fat. The flask is then oven-dried at 100 C for 1 h, cooled in a desiccator and weighed. Ether extract is then calculated as follows:

$$\% \text{ EE} = \frac{\text{weight of dry flask} - \text{weight of empty flask}}{\text{weight of dry material}} \times 100$$

3.5.1.1.5 Nitrogen-free extract (NFE) and metabolizable energy (ME)

Nitrogen free extract, which represents the soluble carbohydrate, was calculated by difference of the other constituents from one hundred (100).

$$\% \text{ NFE} = 100 - \% (\text{CP} + \text{EE} + \text{CF} + \text{Ash} + \text{moisture})$$

The metabolizable energy (ME) in Kcal/Kg was calculated according to Fisher and Boorman (1986) as:

$$\text{ME (Kcal/Kg)} = 37\times \text{CP} + 81\times \text{EE} + 35.5 \times \text{NFE}$$

Where:

CP = Crude Protein

NFE = Nitrogen-Free Extract

EE = Ether Extract.

3.5.2 Statistical analysis

Data collected were subjected to ANOVA (Steel and Torrie, 1980) of GLM of SPSS (2013). Individual bird was the experimental unit for weight change, carcass and organ measurements and nutrient digestibility whereas pen was the experimental unit for feed intake. Treatment means were compared using the Least Significant Difference (LSD) and significant differences were reported at 5% level of probability.

CHAPTER FOUR: RESULTS

4.1. Growth performance of the broiler chickens

The growth performance results of the birds are presented in Table 6. During the first week (21-28 days) birds fed diet 5 (CM, SBM and MBM) consumed significantly more feed than those fed the other diets ($P<0.05$). Daily weight gain was significantly ($P<0.05$) higher for birds on diets 2 (CM, FM and MBM) and 5. Birds on diet 2 converted their feed into weight more efficiently ($P<0.05$) compared to those fed diets 1 (SBM, FM and MBM), 3 (CM, SBM and FM) and 4 (CM, SBM, FM and MBM). During the second week (29-35 days) daily feed intake and daily weight gain were significantly affected by the diet ($P<0.05$). Feed intake was significantly higher for birds on diet 5 and depressed for birds on diet 3 ($P<0.05$). There was no significant difference ($P>0.05$) in daily feed intake among diets 1, 4 and 5 as well as among diets 1, 2, and 4. Birds fed diets 1 and 5 gained markedly ($P<0.05$) more weight daily. Daily gain was not different ($P>0.05$) among diets 1, 2, 3 and 4. Feed conversion ratio was not affected by treatment ($P>0.05$). In the last growth phase (day 36 to 42), daily feed intake and feed conversion ratio were not affected by the diet ($P>0.05$). Daily weight gain was maximized ($P<0.05$) on diet 2 compared to diet 3 and diet 4. There was no marked difference ($P>0.05$) in daily gain between diets 1, 2 and 5 as well as between diets 3 and 4. At the end of the experiment (day 42) birds fed the control, diets 2 and 5 weighed significantly heavier ($P<0.05$) than those on diet 3.

The mean growth performance results of the birds (21-42 days) in Table 2 showed significant differences among all parameters measured ($P<0.05$). Feed intake was significantly higher for diet 5 ($P<0.05$) compared to diets 2 and 3 but did not differ among diets 1, 2, 3 and 4 as well as among 1, 4 and 5. Daily weight gain was improved on diets 1 and 5 compared to diets 3 and 4. A poorer FCR was recorded on diet 3 compared to diet 2. Statistically, there was no difference in FCR among diets 1, 2, 4 and 5 as well as among diets 1, 3, 4 and 5. Final body weight of birds was heavier on diets 1, 2 and 5 compared to those fed diet 3. There was no difference in final body weight among diets 1, 2, 4 and 5 as well as between diets 3 and 4.

Table 6: Growth performance of finishing broilers fed copra meal in different combinations of traditional protein sources

Diets	Feed intake (g)				Daily weight gain (g)				FCR (feed: gain)				Final body weight (g)
	21-28d	29-35d	36-42d	21-42d	21-28d	29-35d	36-42d	21-42d	21-28d	29-35d	36-42d	21-42d	
D_1	102.14^{b}	157.32^{ab}	181.14	146.87^{ab}	34.29^{b}	63^{ab}	81.25^{ab}	59.51^{ab}	3.01^{a}	2.52	2.26	2.6^{ab}	$1,866.25^{a}$
D_2	99.54^{b}	147.86^{b}	163.72	137.04^{b}	42^{a}	60.64^{b}	94.7^{a}	65.78^{a}	2.27^{b}	2.45	1.81	2.17^{b}	$1,970.97^{a}$
D_3	95.43^{b}	143.57^{c}	159.09	132.7^{b}	28.57^{b}	55.64^{b}	57.63^{b}	47.28^{b}	3.4^{a}	2.62	3.16	3.06^{a}	$1,646.95^{b}$
D_4	97.86^{b}	152.32^{abc}	175.03	141.74^{ab}	33.89^{b}	59.39^{b}	79.81^{ab}	57.7^{b}	2.9^{a}	2.56	2.21	2.56^{ab}	$1,821.56^{ab}$
D_5	111.68^{a}	163.75^{a}	185.34	153.34^{a}	43.71^{a}	71.36^{a}	70.91^{ab}	62^{a}	2.58^{ab}	2.3	3.21	2.7^{ab}	$1,943.03^{a}$
SEM	2.666	4.340	10.015	4.353	2.264	3.139	11.062	4.070	0.163	0.125	0.498	0.175	65.091

FCR: feed conversion ratio, SEM: standard error of mean, FCR: feed conversion ratio. Values in the same column with the same superscript are not significantly different (P=0.05) D1: Control diet with no CM, D2: CM fed with FM + MBM, D3: CM fed with FM + SBM, D4: CM fed with FM + SBM + MBM, D5: CM fed with SBM + MBM.

4.2 Nutrient digestibility

From the results of nutrient digestibility (Table 7), all nutrients studied were better digested on diet 2 compared to diet 3 ($P<0.05$). Dry matter digestibility did not differ ($P>0.05$) between diets 1 and 2 and among diets 1, 3, 4 and 5. The lowest value for crude protein digestibility was recorded on diets 3 and 5. Crude fibre digestibility was depressed ($P<0.05$) on diets 1, 3, 4 and 5 compared to diet 2. The digestibility of dietary fat did not differ ($P>0.05$) among diets 2, 4 and 5. However, dietary fat digestibility was significantly lower ($P<0.05$) on the control diet.

Table 7: Nutrient digestibility of the broiler chickens fed copra meal with different combinations of traditional protein sources (%DM)

Nutrients	Diets					
	D_1	D_2	D_3	D_4	D_5	SEM
DM	81.43^{ab}	84.18^{a}	79.69^{b}	78.83^{b}	79.19^{b}	1.422
CP	81.22^{a}	84.10^{a}	75.73^{b}	80.99^{a}	76.71^{b}	1.407
CF	65.42^{b}	80.58^{a}	65.51^{b}	57.37^{b}	66.29^{b}	3.506
Fat	78.95^{c}	91.08^{a}	85.11^{b}	89.56^{a}	90.23^{a}	0.787

SEM: standard error of the mean

Values in the same row with the same superscript are not significantly different (P=0.05

D1: Control diet with no CM, D2: CM fed with FM + MBM, D3: CM fed with FM + SBM, D4: CM fed with FM + SBM + MBM, D5: CM fed with SBM + MBM.

4.3 Dressing out percentage and some carcass cut-up parts

From the results of carcass studies presented in Table 8, there were significant dietary effects on dressing out percentage and the yield of breast muscle ($P<0.05$). Dressing percentage was markedly increased ($P<0.05$) on diet 2 compared to diet 4. There was no difference ($P>0.05$) in dressing percentage among diets 1, 2, 3 and 5 as well as among diets 1, 3, 4 and 5. Breast weight yield was depressed on diets 3 and 4 ($P<0.05$). The yields of thighs and drumsticks were not affected by dietary treatment ($P>0.05$).

Table 8: Dressing out percentage and some carcass cut-up parts (% live weight) of broiler chickens fed copra meal in combination of different protein sources

Parameters	Diets					
Parameters (% live weight)	D1	D2	D3	D4	D5	SEM
Dressing per cent	68.49[ab]	69.56[a]	66.90[ab]	66.27[b]	66.95[ab]	0.944
Breast	19.83[a]	20.15[a]	15.92[b]	15.55[b]	19.85[a]	1.279
Thigh	12.23	13.49	12.84	11.95	12.53	0.525
Drumstick	8.98	8.94	7.39	9.40	9.51	1.070

SEM: standard error of the mean

Values in the same row with the same superscript are not significantly different (P=0.05)

D1: Control diet with no CM, D2: CM fed with FM + MBM, D3: CM fed with FM + SBM, D4: CM fed with FM + SBM + MBM, D5: CM fed with SBM + MBM.

4.4 Organ weights

The weights of gut segments and their digesta content are shown in Table 9. There was marked difference (P<0.05) in liver weights among the dietary treatments. Birds fed diet 2 had a significantly heavier liver compared to those fed diets 3 and 4. The weight of liver did not differ among the groups fed diets 1, 2 and 5 as well as among diets 1, 3, 4 and 5 (P>0.05). The heaviest pancreas was recorded on diet 3 (P<0.05) compared to diets 2, 4 and 5. Pancreas weight was not different between diets 1 and 3 and among diets 1, 2, 4 and 5. The weight of empty crop was significantly reduced (P<0.05) on diet 2. There were no treatment effects on the weights of empty proventriculus, gizzard, caeca, and digesta in the gizzard and caeca (P>0.05). The digesta in the proventriculus was significantly heavier (P<0.05) in birds fed diet 4. Empty small intestine and its digesta content weighed lighter (P<0.05) on diet 2.

Table 9: Organ weights (% live weight) of broilers fed copra meal with different combinations of traditional protein sources

Parameters	Diets					
Parameters (%)	D1	D2	D3	D4	D5	SEM
Liver	2.03^{ab}	2.31^{a}	1.93^{b}	1.89^{b}	2.04^{ab}	0.111
Pancreas	0.27^{ab}	0.22^{b}	0.33^{a}	0.23^{b}	0.22^{b}	0.025
Empty crop	0.24^{a}	0.11^{b}	0.22^{a}	0.23^{a}	0.19^{a}	0.025
Digesta in the crop	0.02^{a}	0.01^{b}	0.01^{ab}	0.02^{a}	0.01^{a}	0.002
Empty proventriculus	0.44	0.44	0.46	0.50	0.49	0.030
Digesta in the Proventriculus	0.01^{b}	0.04^{b}	0.06^{b}	0.08^{a}	0.06^{b}	0.018
Empty gizzard	2.34	2.42	2.49	2.57	2.26	0.153
Digesta in the gizzard	0.52	0.38	0.52	0.48	0.57	0.065
Empty small intestine	2.62^{a}	1.94^{b}	2.71^{a}	2.72^{a}	2.78^{a}	0.155
Digesta in small intestine	0.15^{a}	0.11^{b}	0.16^{a}	0.16^{a}	0.16^{a}	0.011
Empty caeca	0.38	0.38	0.38	0.37	0.41	0.039
Digesta in the caeca	0.24	0.18	0.23	0.19	0.21	0.045

SEM: standard error of the mean

Values in the same row with the same superscript are not significantly different (P=0.05)

D1: Control diet with no CM, D2: CM fed with FM + MBM, D3: CM fed with FM + SBM, D4: CM fed with FM + SBM + MBM, D5: CM fed with SBM + MBM.

4.5 Feed cost of broiler meat production

The results of feed cost of meat production (Table 10) showed significant dietary effects on feed cost per kilogram (kg) live weight and carcass weight ($P<0.05$). Feed cost per kg live weight was significantly reduced ($P<0.05$) on diet 2 compared to diets 1, 3 and 5. There was no statistical difference in feed cost per kg live weight among birds fed diets 1, 3, 4 and 5 as well as between diets 2 and 4. Feed cost per kg carcass was reduced ($P<0.05$) on diet 2.

Table 10: Feed cost of meat production of broilers fed copra meal with different combinations of traditional protein sources

parameters	Diets					
	D_1	D_2	D_3	D_4	D_5	SEM
Final weight (g)	1,866.25[a]	1,970.97[a]	1,646.95[b]	1,821.56[ab]	1,943.03[a]	65.091
Cost of feed (ST$/kg)	2.88	2.49	2.54	2.58	2.71	NA
Carcass (%)	68.49[a]	69.56[a]	66.90[a]	66.27[b]	66.95[ab]	0.944
Feed Cost per kg live weight (ST$)	7.48[a]	5.41[b]	7.77[a]	6.60[ab]	7.31[a]	0.459
Feed cost per kg carcass (ST$)	10.94[a]	7.78[b]	11.65[a]	9.96[a]	10.89[a]	0.694

SEM: standard error of the mean; NA: not analyzed.

Values in the same row with the same superscript are not significantly different ($P=0.05$)

D1: Control diet with no CM, D2: CM fed with FM + MBM, D3: CM fed with FM + SBM, D4: CM fed with FM + SBM + MBM, D5: CM fed with SBM + MBM.

CHAPTER FIVE: DISCUSSION

5.1 Chemical analysis

The crude protein content of the experimental copra meal (21.1%, Table 3) is within the range (20 -22%) reported in literature (Sundu *et al.,* 2006; Sulabo *et al.,* 2013). The NSP content of the experimental copra meal (Table 3) is also in agreement with earlier reports**.** Balasubramaniam *et al*. (1976) and Sundu et al. (2006) all reported the presence of both soluble and insoluble NSPs in copra meal.

The amino acid composition of the feed ingredients (Table 4) showed a lower profile in all essential amino acids. This corroborates earlier findings that copra meal is characterized by low essential amino acids especially lysine and methionine (Son *et al*., 2012; Sulabo *et al*., 2013).

5.2 Growth performance

Poor palatability (Göhl, 1982) mainly due to rancidity of stored copra meal (Ehrlich *et al.,* 1990) is known to affect its feeding value for poultry. The similarity in feed intake among the control and copra meal-based diets in this study suggests that there was no palatability problem. Copra meal for this experiment was collected fresh on the day of oil extraction and used for the formulation to minimize the risk of oxidation. A higher ME value was recorded on diet 3 compared to the other diets on account of the high inclusion rates of full fat soybean (18.7% fat) and fish meal (12.4%). This higher ME and ME/protein ratio was probably the main reason for lower feed intake on diet 3 as birds feed to meet their energy requirement. This low feed consumption with the resultant lower intake of individual essential nutrients is probably the main reason for the poor growth performance observed on this diet. The traditional protein sources used in diet 2 (fish meal and meat and bone meal) are known to have higher protein digestibility than soybean meal (Zhou *et al.*, 2004). In addition they had higher essential nutrient density than soybean meal (Tables 3 and 4). Higher digestibility and availability of essential nutrients may explain the lower feed intake by birds fed diet 2 compared to diet 5. Despite this lower daily feed intake however, birds on diet 2 achieved a daily body weight gain similar to the value (65g) reported for 42 day-old Cobb broilers (Cobb Broiler Management Guide,

2012) further suggesting ready availability of nutrients on this diet based on fish and meat and bone meals. The superiority of animal proteins over plant protein sources in broiler diets is well-documented (Vieira and Lima, 2005; Ojewola *et al.*, 2005; Bhuiyan *et al.*, 2012a; Hossain *et al.,* 2012a; 2013a). These differences in the utilization of animal compared to plant protein sources maybe used to explain the improved performance of birds on diets 1, and 2. Hossain *et al.* (2012a; 2013a) observed better growth performance of broiler chickens fed diets containing fish meal compared to those fed vegetable protein diets. The poor performance of birds fed the copra meal-based diets containing soybean meal is in agreement with earlier report by Sundu *et al.* (2006) who observed reduced growth performance of broilers fed 10% dietary copra meal in corn-soybean diets. Growth performance differences observed in this study suggest that differences in digestibility between plant and animal protein sources is the major factor affecting the utilization of copra meal by the broilers. The reduced growth performance of birds fed diet 4 maybe due to the lower inclusion level of the animal protein sources (fish meal and meat and bone meal) and the inclusion of two plant protein sources (soybean and copra meal). The calculated composition of the experimental diets (Table 5) showed a higher total, insoluble and soluble NSPs in diets 3, 4 and 5 (based on copra and soybean meals). The anti-nutritional effect of NSPs in monogastric animals is well known (Ikegami *et al.,* 1990; Choct, 1997; Amerah *et al.,* 2008; Stef *et al.,* 2010). Dietary NSP acts by encapsulation of starch and protein in the cell wall NSP, digesta viscosity which reduces the diffusion of digestive enzymes (Amerah *et al.,* 2008; Angkanaporn *et al.,* 1994), formation of complexes with digestive enzymes and endogenous losses of amino acids (Angkanaporn *et al.,* 1994). Poor digestibility of soybean carbohydrates have also been reported (Kerley and Allee, 2003) probably due to the deleterious effect of NSPs. Addition of soluble NSP to the diet has also been reported to increase production of volatile fatty acids (VFAs) in the ileum (Choct *et al.,* 1996). All these deleterious effects might have contributed to the poor performance of birds fed copra meal in soybean-based diets due to the additive effect of NSP from the two plant protein sources. Contrary to the observation of Thomas and Scott (1962) who attributed poor performance of birds fed copra meal-based diets to nutrient imbalance, it appears from these results that nutrient availability rather than imbalance is the major factor affecting the utilization of copra meal by broilers. The findings of this study however, corroborate the observation of Sundu *et al.,* (2006)

that copra meal exerts anti-nutritional properties. These authors fed copra meal-based diets with similar nutrient profile and observed adverse effect on growth from 10% inclusion of copra meal in the diets. The increased feed intake on diet 5 coupled with the higher essential amino acid profile of meat and bone meal (Table 4) might have helped overcome the deleterious effect of dietary fibre in these birds. Low (1993) also observed that diet composition affects the utilization of fibre by monogastric animals.

5. 3 Nutrient digestibility

The improved nutrient digestibility on diet 2 (without soybean) compared to the other copra meal-based diets may be attributable to the NSP level on one hand and its source on the other. The amount of dietary NSP is known to affect their digestibility in poultry (Carré *et al.,* 1990; Choct and Annison, 1990; Carré *et al.*, 1995). Carré *et al.,* (1990) observed that inclusion of 6.9% soybean NSP lowered digestibility to as low as 13% in cockerels. Carré *et al.*, (1995) reported that NSP digestibility of corn-soybean diets is still lower in adult broilers than cockerels. In the present study nutrient digestibility was depressed on diets containing copra and soybean meals suggesting that poor solubility of soybean NSP is a major factor responsible for the poor performance of birds fed these diets. Knudsen (1997) observed low fat digestibility with increasing dietary fibre and attributed this to the blocking of enzyme access to the cell content. The reason for lower fat digestibility on the control diet despite its lower crude fibre and NSP (total, insoluble and soluble) was not understood. This pattern of nutrient digestibility explains the improved performance of birds fed diet 2 in the present study.

5.4 Dressing percentage and some carcass cut up parts

Upon digestion, a part of the nutrients absorbed are used for tissue synthesis. The higher nutrient digestibility observed on diet 2 was the reason for higher dressing percentage on this diet. This result is congruent with the finding of Dogo (2001) who reported a higher dressing percentage on a fish meal-based diet compared to palm kernel based diet. Dressing percentages recorded in this study, were lower than the 72.5% reported in Cobb Broiler Management Guide (2012) for birds of similar live weight (1800g) but percent breast, thigh and drumstick

compared well with 21.25, 13.94 and 8.79% reported respectively for Cobb broilers of this live weight (Cobb broiler Management Guide, 2012). Differences in diet composition significantly affect dressing percentage in broilers. The increase gastro-intestinal weight as a result of the high fibre content of the diets may explain the lower dressing percentage in the present study.

5.5 Organ weights

The ready digestibility of diet 2 as suggested earlier, may be the reason for higher liver weight of birds fed this diet as a response to increase secretion during digestion and absorption. The pattern of the weight of gut segments and their digesta content was not clear but probably due to the level of fibre fractions in the diet. The effect of elevated levels of both soluble and insoluble NSP on gut morphology has been reported. Shortening of digesta transit time as a result of feeding high levels of insoluble NSP (Choct, 1997) and increase transit time on high levels of soluble NSP (Choct *et al.,* 1996) have been reported. As the emptying of the crop is dependent on the rate of digestion in the lower segments of the gut, the lighter weight of the crop and its digesta in birds fed diet 2 is an indication of faster breakdown of feed in these segments of the gut. The lower digesta weight observed in most other segments of the gut on diet 2 suggests a better utilization of this diet as earlier suggested. This finding further confirms the superiority of animal over plant protein sources in broiler diets.

5.6 Feed cost of broiler meat production

The cost of a kilogram diet was reduced on the experimental diets compared to the control diet on account of the lower market price of copra meal. At the time of the experiment a kg of copra meal sold for ST$0.7/kg against 3.80, 3.20, and 5.60 for fish meal, meat and bone meal and soybean meal respectively. The higher market price of soybean compared to other protein sources was the reason for reduced cost of diet 2 which contained no soybean. The reduced feed cost coupled with the higher final body weight and dressing percentage resulted in a reduced cost of meat production on diet 2.

CHAPTER SIX: SUMMARY, CONCLUSION AND RECOMMENDATIONS

A preliminary investigation on the effect of dietary protein source on the utilization of 15% expeller copra meal in the diet by broiler chickens was conducted. A control diet based on traditional protein sources (fish meal, meat and bone meal and soybean meal) and 4 other diets containing 15% copra meal with different combinations of these protein sources were formulated to contain 20% crude protein, and about 1 and 0.4% lysine and methionine respectively. The diets were fed each to 4 replicates of 5 broilers in a completely randomized design for a period of 21 days. Broiler performance was adversely reduced when copra meal was fed in combination with soybean meal but this adverse effect was overcome when copra meal was fed with animal protein sources (fish meal and meat and bone meal).

Based on these results it is concluded that copra meal exerts anti-nutritional properties in broilers mainly through reduced nutrient availability. Feeding 15% copra meal with soybean meal has deleterious effect on broiler performance but when fed with animal proteins (fish meal and meat and bone meal), this level of copra meal will reduce cost of meat production with no adverse effects on broiler growth and nutrient utilization.

In the light of these findings, the following recommendations are made:

1. In order to further reduce feed cost, investigation into feeding higher levels of copra meal with fish and meat and bone meals singly or in combination is recommended;

2. In view of ready availability of copra meal in most countries of the region research into its feeding value with other available animal protein sources is warranted;

3. The variability in the composition of copra meal, calls for the need to conduct more research into the value of copra meal from different processing methods in the study area.

LIMITATIONS OF THE STUDY

The study had the following limitations:

1. Inadequate space and equipment on the research farm did not give room to test different levels of copra meal. This could form the topic of another research.

2. Gut morphology and histology would have given a better picture of the pattern of the results. This was not possible due to inadequate laboratory equipment.

3. Serum biochemistry is an important tool in nutritional investigations. This was proposed but could not be done due to lack of laboratory/equipment in the study area.

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APPENDICES

Appendix 1: ANOVA for Daily Feed Intake in week 1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	631.561[a]	4	157.890	5.554	.006
Intercept	205349.298	1	205349.298	7223.371	.000
treat	631.561	4	157.890	5.554	.006
Error	426.427	15	28.428		
Total	206407.286	20			
Corrected Total	1057.988	19			

a. R Squared = .597 (Adjusted R Squared = .489)

Appendix 2: ANOVA for Daily Weight Gain in week 1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	627.282[a]	4	156.820	7.650	.001
Intercept	26634.051	1	26634.051	1299.236	.000
treat	627.282	4	156.820	7.650	.001
Error	307.497	15	20.500		
Total	27568.830	20			
Corrected Total	934.778	19			

a. R Squared = .671 (Adjusted R Squared = .583)

Appendix 3: ANOVA for feed conversion ratio in week 1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.928[a]	4	.732	6.924	.002
Intercept	160.291	1	160.291	1515.947	.000
treat	2.928	4	.732	6.924	.002
Error	1.586	15	.106		
Total	164.806	20			
Corrected Total	4.514	19			

a. R Squared = .649 (Adjusted R Squared = .555)

Appendix 4: ANOVA for final body weight in week 1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	35706.800[a]	4	8926.700	7.404	.002
Intercept	21327320.450	1	21327320.450	17688.501	.000
treat	35706.800	4	8926.700	7.404	.002
Error	18085.750	15	1205.717		
Total	21381113.000	20			
Corrected Total	53792.550	19			

a. R Squared = .664 (Adjusted R Squared = .574)

Appendix 5: ANOVA for Daily Feed Intake week 2

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1000.103[a]	4	250.026	3.318	.039
Intercept	467962.765	1	467962.765	6209.856	.000
treat	1000.103	4	250.026	3.318	.039
Error	1130.371	15	75.358		
Total	470093.239	20			
Corrected Total	2130.474	19			

a. R Squared = .469 (Adjusted R Squared = .328)

Appendix 6: ANOVA for Daily weight gain week 2

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	550.541[a]	4	137.635	3.492	.033
Intercept	76896.121	1	76896.121	1950.744	.000
treat	550.541	4	137.635	3.492	.033
Error	591.283	15	39.419		
Total	78037.945	20			
Corrected Total	1141.824	19			

a. R Squared = .482 (Adjusted R Squared = .344)

Appendix 7: ANOVA for feed conversion ratio week 2

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.238[a]	4	.060	.949	.463
Intercept	124.151	1	124.151	1976.042	.000
treat	.238	4	.060	.949	.463
Error	.942	15	.063		
Total	125.332	20			
Corrected Total	1.181	19			

a. R Squared = .202 (Adjusted R Squared = -.011)

Appendix 8: ANOVA for final body weight week 2

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	250901.200[a]	4	62725.300	1.119	.384
Intercept	40140777.800	1	40140777.800	716.406	.000
treat	250901.200	4	62725.300	1.119	.384
Error	840461.000	15	56030.733		
Total	41232140.000	20			
Corrected Total	1091362.200	19			

a. R Squared = .230 (Adjusted R Squared = .025)

Appendix 9: ANOVA for Daily Feed Intake week 3

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2008.509[a]	4	502.127	1.252	.332
Intercept	597625.421	1	597625.421	1489.618	.000
treat	2008.509	4	502.127	1.252	.332
Error	6017.908	15	401.194		
Total	605651.838	20			
Corrected Total	8026.417	19			

a. R Squared = .250 (Adjusted R Squared = .050)

Appendix 10: ANOVA for Daily weight gain week 3

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3006.064[a]	4	751.516	1.535	.242
Intercept	118144.580	1	118144.580	241.385	.000
treat	3006.064	4	751.516	1.535	.242
Error	7341.656	15	489.444		
Total	128492.300	20			
Corrected Total	10347.720	19			

a. R Squared = .291 (Adjusted R Squared = .101)

Appendix 11: ANOVA for feed conversion ratio week 3

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6.247[a]	4	1.562	1.576	.232
Intercept	127.866	1	127.866	129.012	.000
treat	6.247	4	1.562	1.576	.232
Error	14.867	15	.991		
Total	148.980	20			
Corrected Total	21.114	19			

a. R Squared = .296 (Adjusted R Squared = .108)

Appendix 12: ANOVA for final body weight week 3

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	59162114.178[a]	4	14790528.545	.972	.452
Intercept	147411305.395	1	147411305.395	9.686	.007
treat	59162114.178	4	14790528.545	.972	.452
Error	228279534.137	15	15218635.609		
Total	434852953.710	20			
Corrected Total	287441648.315	19			

a. R Squared = .206 (Adjusted R Squared = -.006)

Appendix 13: ANOVA for mean daily feed intake

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1051.614[a]	4	262.903	3.468	.034
Intercept	405185.044	1	405185.044	5345.524	.000
treat	1051.614	4	262.903	3.468	.034
Error	1136.984	15	75.799		
Total	407373.642	20			
Corrected Total	2188.598	19			

a. R Squared = .480 (Adjusted R Squared = .342)

Appendix 14: ANOVA for mean Daily weight gain

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	771.040[a]	4	192.760	2.909	.058
Intercept	68335.064	1	68335.064	1031.433	.000
treat	771.040	4	192.760	2.909	.058
Error	993.788	15	66.253		
Total	70099.892	20			
Corrected Total	1764.828	19			

a. R Squared = .437 (Adjusted R Squared = .287)

Appendix 15: ANOVA for mean feed conversion ratio

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.617[a]	4	.404	3.293	.040
Intercept	136.974	1	136.974	1115.967	.000
treat	1.617	4	.404	3.293	.040
Error	1.841	15	.123		
Total	140.432	20			
Corrected Total	3.458	19			

a. R Squared = .468 (Adjusted R Squared = .326)

Appendix 16: ANOVA for dressing percentage

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	29.259[a]	4	7.315	2.052	.138
Intercept	91487.159	1	91487.159	25665.501	.000
treat	29.259	4	7.315	2.052	.138
Error	53.469	15	3.565		
Total	91569.887	20			
Corrected Total	82.728	19			

a. R Squared = .354 (Adjusted R Squared = .181)

Appendix 17: ANOVA for breast muscle weight

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	85.640[a]	4	21.410	3.273	.041
Intercept	6667.822	1	6667.822	1019.199	.000
treat	85.640	4	21.410	3.273	.041
Error	98.133	15	6.542		
Total	6851.595	20			
Corrected Total	183.773	19			

a. R Squared = .466 (Adjusted R Squared = .324)

Appendix 18: ANOVA for thigh weight

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5.672[a]	4	1.418	1.284	.320
Intercept	3178.225	1	3178.225	2878.862	.000
treat	5.672	4	1.418	1.284	.320
Error	16.560	15	1.104		
Total	3200.456	20			
Corrected Total	22.231	19			

a. R Squared = .255 (Adjusted R Squared = .056)

Appendix 19: ANOVA for drumstick weight

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	11.590[a]	4	2.898	.633	.647
Intercept	1564.504	1	1564.504	341.616	.000
treat	11.590	4	2.898	.633	.647
Error	68.696	15	4.580		
Total	1644.789	20			
Corrected Total	80.286	19			

a. R Squared = .144 (Adjusted R Squared = -.084)

Appendix 20: ANOVA for liver weight

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.425[a]	4	.106	2.137	.126
Intercept	82.987	1	82.987	1669.654	.000
treat	.425	4	.106	2.137	.126
Error	.746	15	.050		
Total	84.158	20			
Corrected Total	1.170	19			

a. R Squared = .363 (Adjusted R Squared = .193)

Appendix 21: ANOVA for empty crop weight

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.044[a]	4	.011	4.306	.016
Intercept	.780	1	.780	302.961	.000
treat	.044	4	.011	4.306	.016
Error	.039	15	.003		
Total	.863	20			
Corrected Total	.083	19			

a. R Squared = .534 (Adjusted R Squared = .410)

Appendix 22: ANOVA for digesta weight in the crop

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.000[a]	4	4.250E-5	1.821	.177
Intercept	.003	1	.003	123.429	.000
treat	.000	4	4.250E-5	1.821	.177
Error	.000	15	2.333E-5		
Total	.003	20			
Corrected Total	.001	19			

a. R Squared = .327 (Adjusted R Squared = .147)

Appendix 23: ANOVA for empty proventriculus weight

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.013[a]	4	.003	.933	.471
Intercept	4.343	1	4.343	1216.560	.000
treat	.013	4	.003	.933	.471
Error	.054	15	.004		
Total	4.410	20			
Corrected Total	.067	19			

a. R Squared = .199 (Adjusted R Squared = -.014)

Appendix 24: ANOVA for weight of digesta in proventriculus

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.010[a]	4	.002	1.862	.170
Intercept	.052	1	.052	39.211	.000
treat	.010	4	.002	1.862	.170
Error	.020	15	.001		
Total	.082	20			
Corrected Total	.030	19			

a. R Squared = .332 (Adjusted R Squared = .154)

Appendix 25: ANOVA for weight of empty gizzard

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.240[a]	4	.060	.641	.641
Intercept	116.644	1	116.644	1245.005	.000
treat	.240	4	.060	.641	.641
Error	1.405	15	.094		
Total	118.290	20			
Corrected Total	1.646	19			

a. R Squared = .146 (Adjusted R Squared = -.082)

Appendix 26: ANOVA for weight of digesta in gizzard

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.082[a]	4	.021	1.211	.347
Intercept	4.861	1	4.861	286.727	.000
treat	.082	4	.021	1.211	.347
Error	.254	15	.017		
Total	5.197	20			
Corrected Total	.336	19			

a. R Squared = .244 (Adjusted R Squared = .043)

Appendix 27: ANOVA for weight of pancreas

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.033[a]	4	.008	3.350	.038
Intercept	1.285	1	1.285	515.128	.000
treat	.033	4	.008	3.350	.038
Error	.037	15	.002		
Total	1.356	20			
Corrected Total	.071	19			

a. R Squared = .472 (Adjusted R Squared = .331)

Appendix 28: ANOVA for weight of empty small intestine

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.919[a]	4	.480	4.993	.009
Intercept	130.356	1	130.356	1356.323	.000
treat	1.919	4	.480	4.993	.009
Error	1.442	15	.096		
Total	133.717	20			
Corrected Total	3.361	19			

a. R Squared = .571 (Adjusted R Squared = .457)

Appendix 29: ANOVA for weight of digesta in small intestine

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.008[a]	4	.002	4.206	.018
Intercept	.438	1	.438	973.511	.000
treat	.008	4	.002	4.206	.018
Error	.007	15	.000		
Total	.452	20			
Corrected Total	.014	19			

a. R Squared = .529 (Adjusted R Squared = .403)

Appendix 30: ANOVA for weight of empty caeca

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.003[a]	4	.001	.139	.965
Intercept	2.911	1	2.911	470.376	.000
treat	.003	4	.001	.139	.965
Error	.093	15	.006		
Total	3.007	20			
Corrected Total	.096	19			

a. R Squared = .036 (Adjusted R Squared = -.222)

Appendix 31: ANOVA for weight of digesta in caeca

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.011[a]	4	.003	.347	.842
Intercept	.890	1	.890	111.395	.000
treat	.011	4	.003	.347	.842
Error	.120	15	.008		
Total	1.021	20			
Corrected Total	.131	19			

a. R Squared = .085 (Adjusted R Squared = -.160)

Appendix 32: ANOVA for cost per kilogram live weight

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	14.337[a]	4	3.584	4.255	.017
Intercept	956.206	1	956.206	1135.006	.000
treat	14.337	4	3.584	4.255	.017
Error	12.637	15	.842		
Total	983.181	20			
Corrected Total	26.974	19			

a. R Squared = .532 (Adjusted R Squared = .407)

Appendix 33: ANOVA for cost per kilogram carcass

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	36.176[a]	4	9.044	4.696	.012
Intercept	2098.381	1	2098.381	1089.491	.000
treat	36.176	4	9.044	4.696	.012
Error	28.890	15	1.926		
Total	2163.447	20			
Corrected Total	65.066	19			

a. R Squared = .556 (Adjusted R Squared = .438)

Appendix 34 ANOVA for dry matter digestibility

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	77.697[a]	4	19.424	2.402	.096
Intercept	130120.712	1	130120.712	16089.393	.000
treat	77.697	4	19.424	2.402	.096
Error	121.310	15	8.087		
Total	130319.719	20			
Corrected Total	199.007	19			

a. R Squared = .390 (Adjusted R Squared = .228)

Appendix 35 ANOVA for crude protein digestibility

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	192.203[a]	4	48.051	6.065	.004
Intercept	127194.870	1	127194.870	16054.580	.000
treat	192.203	4	48.051	6.065	.004
Error	118.840	15	7.923		
Total	127505.913	20			
Corrected Total	311.043	19			

a. R Squared = .618 (Adjusted R Squared = .516)

Appendix 36 ANOVA for crude fibre digestibility

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1129.378[a]	4	282.345	5.742	.005
Intercept	89863.099	1	89863.099	1827.576	.000
treat	1129.378	4	282.345	5.742	.005
Error	737.560	15	49.171		
Total	91730.037	20			
Corrected Total	1866.938	19			

a. R Squared = .605 (Adjusted R Squared = .500)