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CANARIUM (*Canarium indicum*) CAKE AS A SOURCE OF LYSINE IN FERMENTED CASSAVA-COPRA MEAL DIETS WITH CHALLENZYME FOR BROILERS IN SOLOMON ISLANDS

by

Desmond Sandakabatu

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

School of Agriculture and Food Technology
Faculty of Business and Economics
The University of the South Pacific

March, 2019

DECLARATION OF ORIGINALITY

Statement by Author

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ABSTRACT

High feed costs and scarcity of conventional feed ingredients in the Solomon Islands prompted studies into utilization of locally available nonconventional feed sources in broiler production. The effect of canarium cake as a source of lysine in fermented cassava-copra meal based diets with and without enzyme was investigated. Six cassava-copra meal based diets were formulated at starter (10-21 days) and finisher (22-42 days) phases. Two cassava-copra meal based diets contained HCL lysine with and without enzyme. In the other four diets, canarium cake replaced HCL lysine at 5 and 10% with and without enzyme. Commercial starter and finisher diets were used as controls. A total of 126 ten days old broilers were allotted to floor pens in groups of 6 and each diet fed to 3 replicates in a complete randomized design; for a total of 32 days. Higher feed intake and weight gain were observed on the control diet. ($P<0.05$). Feed intake was poor ($P<0.05$) in 10% canarium with and without enzyme in starter and finisher phases, yet the treatment recorded comparable daily weight gain to other cassava-copra meal based treatments in the starter phase ($P>0.05$). Diets containing 5% canarium without enzyme and HCL lysine with enzyme inclusions in both starter and finisher diets had similar feed intake ($P>0.05$). Feed conversion ratio (FCR) did not differ amongst groups fed 5% canarium without enzyme, 10% canarium with enzyme and the control diets in the starter phase ($P>0.05$), but FCR was improved on the control treatment in the finisher phase ($P<0.05$). Weight gain was improved on the control diet in both phases ($P<0.05$). Carcass and breast weights were similar among cassava-copra meal based diets ($P>0.05$), but increased in control treatment ($P<0.05$). No dietary effect was observed on relative weights of thighs ($P>0.05$), but heavier drumsticks were observed on 10% canarium without enzyme ($P<0.05$). Weights of gizzard and small intestine were lighter on control treatment ($P<0.05$). The caeca and pancreas also weighed lighter on the control compared to 10% canarium without enzyme ($P<0.05$). The weights of heart and abdominal fat followed the same pattern as pancreas. Liver weight was increased on cassava-copra meal with HCL lysine and reduced on 10% canarium with enzyme ($P<0.05$). It was concluded that there is a possibility of replacing HCL lysine with canarium cake in cassava copra meal based diets, however further researches to optimise the utilization of cassava-copra meal based diets in broiler nutrition is needed.

LIST OF ACRONYMS

ADF	Acid detergent fibre
AusAID	Australian Agency for International Development
CABI	Centre for Agriculture and Bioscience International
CIAT	The Spanish acronym for “The International Centre for Tropical Agriculture”
CTA	Technical Centre for Agricultural and Rural Cooperation
DM	Dry matter
FAO	Food and Agriculture Organisation
FCR	Feed conversion ratio
GIT	Gastrointestinal tract
HCL	Hydrochloride
HCN	Hydrogen cyanide
ICDF	International Cooperation and Development Fund
ME	Metabolisable energy
NARI	National Agriculture Research Institute
NDF	Neutral detergent fibre
NMI	National Measurement Institute
NPS	Non-starch polysaccharide
OECD	The Organisation for Economic Co-operation and Development
PARDI	Prime Partial Differential Ideal
PICs	Pacific Island countries
SBD	Currency of Solomon Islands
SPSS	Statistical Package for Social Sciences
USDA	United States Department of Agriculture
WHO	World Health Organisation

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CHAPTER ONE: INTRODUCTION

1.1 Background

As global human population continues to rise with increasing demand for protein in the world, chicken meat consumption has consistently increased (Bilgili, 2001; Chang, 2007; Shai, 2015). Since 1960s, global production of poultry meat increased at the fastest rate amongst all other meat sources (Chang, 2007). Between 2012 and 2013, world production of poultry, pork and beef were estimated to have increased by 2.0, 1.8 and 0.5% respectively (USDA, 2013). It was predicted that by 2020, the global broiler production will surpass pork production and all other meat sources in the world (The Poultry Site, 2014; Shai, 2015; OECD-FAO, 2016). The reasons for the remarkable increase in global poultry meat production are many and include among others, the increasing global human population, better purchasing power and high demand for healthier animal protein source (Thornton, 2010; Watt executive guide, 2011). Chicken meat is dense in nutrients, has very few religious restrictions and short growing periods, and can be produced at relatively low price (Bilgili, 2001; Shai, 2015). Over the past years, Oceania countries including Australia and New Zealand steadily increased their rates of chicken meat consumption to a total annual record at 35.7 kilograms per capita in 2009 (The Poultry Site, 2013).

Despite the high demand in the South Pacific region, domestic production of poultry meat is still low due to many constraints including high cost of feeding (Ravindran and Blair, 1991, Ochetim, 1998; Ayalew, 2011; Diarra, 2017). Most poultry products available in the South Pacific regional markets are imported. Between 2000 and 2011, the importation of poultry meat in the region increased more than triple (CTA Agritrade, 2014). According to Ochetim (1992) and Diarra (2017), unavailability or short supply of conventional feed ingredients such as maize, wheat and soybeans is the major reason for high feed cost in the South Pacific Island countries (PICs). Feed cost accounts for 60-75% of the total cost of commercially produced poultry products (Agah and Norollahi, 2008; Lee, 2009; African farming, 2017). This is likely to be much higher in the PICs as farmers depend solely on imported feed. Thus, the high cost of feed coupled with the flooding of regional markets with cheaper poultry products, make farmers unable to produce poultry meat at competitive prices.

1.2 Problem statement

In the Solomon Islands, there has been increased interest in raising broilers, but high feed cost is the major constraint of domestic commercial poultry production. In the periphery of Honiara (the capital city), household broiler production is a common practice. Most broiler farmers adopt semi-intensive and intensive production with 100-200 birds per unit (Nichol and Barnabas, 2004). In 2003, the total annual broiler production was estimated at 1,235 tonnes (Nichol and Barnabas, 2004). However, high cost of imported feeds is the major production constraint in the country (Nichol and Barnabas, 2004; Allen *et al.*, 2006). Broiler farmers depend entirely on imported feeds from Australia and Papua New Guinea, at relatively higher costs. On average, a 40kg bag of broiler feed costs US$17.60 in Honiara (Allen *et al.*, 2006), which may still be higher in distant provinces due to high freight from Honiara. According to Nichol and Barnabas (2004), many poultry units in remote provinces were forced to close down due to high feed cost. Consequently, an average annual chicken meat consumption per capita in the Solomon Islands is quite low with an average record of 2.3kg in 2009 (The Poultry Site, 2013).

As such, establishment of local feed mills in all provinces could be an approach to reduce cost and improve commercial poultry production in the Solomon Islands (Jansen *et al.,* 2006). However, conventional feed ingredients such as cereal grains and oilseed cakes are not available or in adequate amount to meet demands for animal feed in the country (Nichol and Barnabas, 2004; Allen *et al.*, 2006; Bourke *et al.*, 2006; Jansen *et al.*, 2006). A major challenge for nutritionists in the country is to formulate poultry diets based on local feed ingredients that could support performances and reduce cost of feeding.

There are several available feed resources in the South Pacific region, which could be efficiently utilized to replace all or part of the conventional feed ingredients for poultry feeding (Ravindran and Blair, 1991; Ochetim, 1998; FAO, 2012). Such feed resources include cassava, breadfruit, sweet potato and copra meal (Ravindran and Blair, 1991). There is information on the nutrient composition of many of such materials (Dignan *et al.*, 2004), but their use as major ingredients in poultry diets in the region is still limited possibly due to lack of knowledge and feed processing facilities.

Cassava (*Manihot esculenta*) is a tropical and sub-tropical starchy root crop that thrives in wide ranges of soils including poor soils (Chauynarong *et al.,* 2009). It can tolerate weeds, droughts and may yield as high as 60 tonnes of cassava root per hectare (Chauynarong *et al.,* 2009). World cassava production was reported to have increased by 4.6% between 2013 and 2014 (FAO, 2014) with Brazil, Thailand, Nigeria, Indonesia and the Congo Democratic Republic being the major producing countries (Adam, 2005; FAO, 2014). In the PICs, cassava is one of the most available locally grown root crops that has potential in poultry feeding (Ravindran and Blair, 1991; Ochetim, 1998; Willy, 2010). The annual cassava root production in Papua New Guinea, Fiji and Tonga was recorded at 148,213, 75,277 and 7,862 tonnes respectively (FAO, 2017). Like all other island countries in the region, cassava root production is mostly for human consumption. However, in global perspective, cassava root crop is also considered as a good source of energy for animal feeding. Several studies have shown that cassava roots could be used as major energy source in poultry nutrition. The main nutritional limitations of the root are very low protein content ranging between 1.7-2.6% (Heuzé *et al.*, 2016b), high fibre (especially when fed whole) and hydrocyanic acid content which is toxic to animals (Tewe and Egbunike, 1980; Chauynarong *et al.*, 2009). However, with appropriate post-harvest processing, supplementation of essential nutrients and exogenous enzyme and proper feed formulation, cassava root can totally replace maize in poultry feeds (Anaeto and Adighibe, 2011). In addition, fermentation has been reported to reduced cyanide content and improve the nutritive values of cassava root (Boonnop *et al.,* 2009; Ezekiel *et al.,* 2010; Gunawan *et al.,* 2015; Yuli *et al.,* 2015). Sugiharto *et al.* (2017) reported improved health and physiological response of broilers fed diets based on fermented cassava root.

Copra meal, the by-product of coconut oil (*Cocos nucifera*) processing, is the most common source of plant-protein ingredient available in the PICs (PARDI, 2011).

It is a moderate source of protein, but high in fiber and low in lysine and methionine (Nieuwkoop, 2004). General approaches to maximize the utilization of copra meal in poultry diets include supplementation of essential amino acids and exogenous enzymes and appropriate feed formulation (Sundu *et al*., 2009; Sundu and Dingle, 2011).

In addition to these commercial crops in the PICs, there are several wild growing native plants and trees, which yield high quantities of nutritious edible nuts and fruits that are readily available and could be used for animal feeding. Canarium (*Canarium indicum*) tree is native to Papua New Guinea, Vanuatu and Solomon Islands; some of which are domesticated, whilst many grow wild in the forest in the Melanesian countries (Nevenimo *et al.*, 2007). The total annual production of canarium nuts in the western Melanesian countries of the Pacific region was estimated at more than 100,000, tonnes (Stevens *et al.*, 1994). Islanders have used canarium nuts as food for thousands of years eating it either raw or roasted. The nuts are good sources of unsaturated fatty acids, including linoleic acid (Serge, 2004). Canarium is an average source of protein (14.4%) and the protein has good supply of lysine (1.91-2.73%) (Gregoria *et al.*, 2011). The lysine content of canarium meal is comparable to the 2.34% reported in soybean meal (Goldflus *et al.*, 2006). Hence, canarium nut products may have potential as poultry feedstuff in PICs where it is readily available.

Currently, the demand for canarium oil exceeds its supply in Papua New Guinea, Solomon Islands and Vanuatu (Barbara *et al.*, 2013). This makes the cake, readily available for livestock feeding. However, there is paucity of report on the use of canarium cake in poultry diets.

1.2 Hypotheses

1. Broilers will utilise fermented cassava-copra meal based diets with Challenzyme as well as the commercial feed.
2. Canarium cake can replace HCL lysine in cassava-copra meal based broiler diets.

1.4 Objectives

This research aims to investigate the effect of canarium meal as source of lysine in fermented cassava-copra meal based diets with exogenous enzyme on broiler performance in the Solomon Islands.

The specific objectives are to study the effects on:

i. Growth performance and feed utilization
ii. Carcass measurements; and
iii. Organ weights

CHAPTER TWO: LITERATURE REVIEW

2.1 Statistics of cassava and copra availability in the Solomon Islands

Recent official statistics of the production of cassava and copra meal in the Solomon Islands are not available as the bureau of statistics is currently updating its agriculture-census data (Mazini, 2018). However, surveys from various sources have shown positive outlook about the availability of these materials in the country. According to Jansen *et al.* (2006), cassava tubers are important sources of starch in all provinces of the Solomon Islands. In local markets, cassava tubers rank third starchy root crops after sweet potato, taro and yam. Since 1961, cassava root production in the Solomon Islands has increased by sixfold to an estimated 3,213 tonnes in 2016 (Knoema, 2017). This value is expected to rise in coming years as many subsistence farmers, about 84% of the national human population (FAO, 2010), are gradually adopting new cropping techniques with the assistance of Taiwan Technical Corporation and the Ministry of Agriculture to improve staple-food security, and combat current effects of climate change in the country (ICDF, 2018). However, according to Bourke *et al.* (2006) and Knoema (2017), cassava root as a staple food source, is not comparable to sweet potato, taro and yam by means of starchy-food preferences and production in the Solomon Islands. The production of sweet potatoes, taro and yam in the country has increased rapidly over the years to annual production records of 103,447, 46,064 and 44,075 tonnes respectively in 2016 (Knoema, 2017). Therefore, the availability of cassava root in all provinces coupled with relatively low demand in human diets justify its use as animal feed in the Solomon Islands.

Copra meal on the other hand is readily available from coconut oil companies in the country. Copra products are the major export commodities in the Solomon Islands with a total export value of SBD $110 million in 2014 (David and Moses, 2015). According to Indexmundi (2017), copra oil production in the country was 12,000 metric tonnes in 2016. In Honiara, there are three well-established copra industries which produce the meal as by-product of coconut oil for soap production. It was estimated that a total of 60-70 tonnes of copra meal is produced monthly from the three companies (AusAID, 2011). Thus, this by-product could be a cheaper ingredient for poultry feeding in the Solomon Islands.

2.2 Composition of cassava root and copra meal

2.2.1 Cassava root

Cassava root is relatively low in nutrient content and quality compared with conventional feed ingredients such as corn and wheat, but has potential in broiler diets. According to Heuzé *et al.* (2016b), the protein content of the cassava root ranges from 1.7-2.9% compared to 7-12.4% in corn (Shaver and Hoffman, 2011; Heuzé *et al.*, 2017) and 8.9-19.2% in wheat grain (Heuzé *et al*., 2015). Similarly, cassava root is generally low in minerals and vitamins as the crop is usually cultivated on poor soils (Montagnac *et al.,* 2009; Nnadi *et al.,* 2010). Minerals and vitamins are essential nutrients required in relatively less quantities, but play vital roles for health and normal growth of birds. According to Montagnac *et al.* (2009) and Nnadi *et al.* (2010), cassava roots are low in vitamin A, iron and zinc. Vitamin A is very important nutrient needed for eyes, health and growth of birds. Deficiency of such elements would result in body weaknesses, poor growth and decline egg production (Pal, 2017). On the other hand, iron and zinc are essential micro-nutrients. Available zinc in digested diets activates several body enzymes and enhances growth and feathering of birds. Whilst, iron is needed to prevent anemia and enhances blood pigment formation (Pal, 2017). Therefore, with such elemental deficiencies in cassava roots, chickens fed with cassava root diets may be prone to poor growth performances and anemia unless appropriate inclusion of minerals and vitamin premix is provided to compensate the essential nutrients.

Cassava root is high in fiber which can negatively influence growth of broilers. In plants there are two types of fiber, namely soluble and insoluble fibers (CABI, 2010). The insoluble fibers may lock nutrients within its cell walls and prevent efficient utilization of nutrients by the birds during digestion. Soluble fibers normally form viscous gels and reduce rate of flow in the digestive track, which reduces feed intake of broilers (CABI, 2010). Hence, with reduced feed intake and inefficient nutrient utilization, birds are susceptible to nutrient hunger that consequently affects feed conversion ratio and body weight gain.

On the other hand, higher levels of hydrocyanic acid in fresh cassava root is considered harmful to health of broilers due to its toxicity. This chemical compound is a natural constituent of the crop. Its concentration ranges from 75-1000mg/kg and varies amongst cassava varieties (Ngiki *et al.,* 2014). Bitter cassava varieties have more hydrocynic acid than sweet varieties (Panda, 2004; Lucas, 2012). In addition, according to Tan (1995) and Dolodolotawake and Aalbersberg (2011), prolonged drought periods during cassava cultivation increased cyanide levels in cassava roots. However, several detoxification methods have been used to improve its safely in animal feeding.

Cassava peel which accounts for 10-13% of the cassava root (Oladunjoye *et al.,* 2010) and considered traditionally as a waste, has received much attention in poultry nutrition in recent years. Dry cassava peel is relatively high in fiber (7.6-38.4%), protein (2.9-8.4%) and gross energy (19.1-19.8 MJ/kg) (Heuzé *et al.,* 2016a) in relative to cassava root meal, but not comparable to corn. Besides, the hydrocyanic acid is about 5 to 10 times higher in the peel than in the root parenchyma (Bokanga, 1999). However, it contains large quantities of enzymes linamarase, which is vital for detoxification processes of cassava roots (Bokanga, 1999).

The composition of cassava root is influenced by several factors such as environmental conditions, soil type, crop variety, age of plant and post-harvest processing methods (Julie *et al.,* 2009; Morgan and Choct, 2016; Unigwe *et al.,* 2017). The proximate composition and gross energy content of corn, cassava root and peel are summarized in Table 1.

Table 1: Proximate composition (% DM) and gross energy (MJ/kg) of cassava tuber, peels and maize grain Values in brackets are ranges NDF: Neutral detergent fibre; ADF: Acid detergent fibre

Proximate composition	Cassava tuber (peeled)	Dry cassava peels	Maize grain
Dry matter (DM)	28.5 (28.5-30)	87.4 (79.7-94.2)	86.3 (81.8-90.5)
Crude protein	2.2 (1.7-2.6)	5.2 (2.9-8.2)	9.4 (7.2-12.4)
Crude fibre	1.0 (0.4-1.6)	14 (7.6-38.4)	2.5 (1.6-3.8)
NDF	3.7	51.4	12.2 (9.6-15.3)
ADF	1.6	37.4	3.0 (2.3-3.7)
Lignin	0	-	0.6 (0.2-1.2)
Ether extract	0.6 (0.5-0.7)	1.4 (0.7-3.0)	4.3 (3.1-5.7)
Ash	3.8 (2.4-5.2)	5.8 (4.7-7.5)	1.4 (1.1-2.1)
Gross energy	16.7	19.5 (19.1-19.8)	18.7 (18.6-19.1)

Sources: Heuzé *et al*. (2016a; 2016b); Heuzé *et al*. (2017).

2.2.2 Copra meal

Copra meal, the by-product of coconut oil processing is expelled either by solvent or mechanical extraction methods (Sundu *et al.*, 2009). According to Heuzé *et al.* (2015), copra meal processed by mechanical means is relatively common with higher residual oil of about 5-15% and slightly less protein compared with solvent extracted meals. The protein of copra meal is inferior in nutritive values compared to that of traditional protein sources in poultry diets such as groundnut and soybeans meals (Heuzé *et al.,* 2015). Essential amino acids, especially lysine and methionine, are limiting in copra meals (Heuzé *et al.,* 2015). Unlike cassava root, copra meal is much higher in fibre (10-19.7%) most of which is in the form of non-starch polysaccharide (NPS) (Heuzé *et al.,* 2015). The proximate composition, gross energy content and amino acid profile of copra meal are summarized in Tables 2 and 3.

Table 2: Proximate composition (% DM) and gross energy (MJ/kg) of copra meal and soybean meal Values in brackets are ranges NDF: Neutral detergent fibre; ADF: Acid detergent fibre

Proximate composition	Copra meal	Soybean meal
Dry matter (DM)	91.5 (88.5-94.0)	87.9 (85.0-92.1)
Crude protein	22.4 (19.6-24.9)	51.8 (45.2-56.1)
Crude fibre	14.2 (10.1-19.7)	6.7 (3.5-10.1)
NDF	54.7 (43.9-61.7)	13.7 (10.7-18.1)
ADF	28.7 (22.3-36.5)	8.3 (6.0-13.5)
Lignin	6.7 (4.5-12.8)	0.8 (0.2-1.8)
Ether extract	9.8 (5.2-18.4)	2.0 (0.6-4.4)
Ash	6.8 (5.7-8.0)	7.1 (6.1-9.4)
Total sugars	11.4 (7.8-15.8)	9.4 (7.9-11.6)
Gross energy	20.1 (18.8-23.8)	19.7 (18.8-20)

Sources: Heuzé *et al*. (2015); Heuzé *et al*. (2017).

Table 3: Amino acid composition (% protein) of copra meal and soybean Values in brackets are ranges

Amino acid	Copra meal	Soybean meal
Alanine	4.0 (3.9-4.2)	4.4 (3.8-4.6)
Arginine	10.7 (9.4-11.3)	7.4 (6.6-7.9)
Aspartic acid	7.7 (7.4-8.1)	11.3 (10.1-11.9)
Crystine	1.2 (0.9-1.4)	1.5 (1.3-1.9)
Glutamic	17.8 (16.6-20.2)	17.7 (16.9-18.7)
Glycine	4.1 (4.0-4.3)	4.2 (4.0-4.5)
Histidine	1.9 (1.8-2.1)	2.6 (2.3-3.1)
Isoleucine	3.0 (2.9-3.2)	4.6 (4.2-4.8)
Leucine	5.9 (5.7-6.2)	7.5 (7.1-7.9)
Lysine	2.6 (2.3-2.9)	6.1 (5.7-6.7)
Methionine	1.3 (1.0-1.8)	1.4 (1.2-1.7)
Phenylalanine	4.1 (3.8-4.5)	5.0 (4.7-5.3)
Proline	3.4	4.9 (4.5-5.6)
Serine	4.4 (4.1-4.6)	5.0 (4.5-5.4)
Threonine	3.0 (2.8-3.2)	3.9 (3.6-4.4)
Tryptophan	1.3	1.3 (1.2-1.4)
Tyrosine	2.1 (1.9-2.2)	3.5 (3.3-3.8)
Valine	4.7 (4.3-5.1)	4.8 (4.4-5.2)

Sources: Heuzé *et al*. (2017); Heuzé *et al*. (2015).

2.3 Recommendations of cassava root and copra meal in broiler diets

2.3.1 Cassava roots products

Recommendations of cassava root in broiler diets have been variable depending on the source of cassava product, form and processing method. Cassava root meal inclusion up to 50% as replacement of dietary maize and enzyme supplementation, have shown positive effects on growth performances of broilers (Enriquez and Ross, 1967; Stevenson and Jackson, 1983; George and Sese, 2012; Bhuiyan and Iji, 2015). However, increased levels of cassava flour in broiler diets subsequently reduced weight of broilers (Tada *et al.*, 2004) due to dustiness, which reduces feed consumption. Inclusion of up to 25% cassava flour in broiler diets did not have detrimental effect on birds' growth performance (CIAT, 2007; Zanu *et al.*, 2016). Cassava root meal has been found to have positive effects on weight gain and feed conversion ratio of broilers when included at levels between 11.88 and 20% in finisher diets (Ferreira *et al.,* 2012). Brum *et al.* (1990), observed that replacing 66.7% maize with cassava root in broiler diets did not affected growth performance of the birds. Dried cassava peels, a by-product of cassava flour processing, has also been found to have potential as replacement for maize with improved nutrient digestibility (Aguihe *et al.*, 2015, Dayal *et al.,* 2018), and replacements of maize with cassava peel meal at 40% (Dayal *et al.,* 2018) and 50% (Aguihe *et al.*, 2015). Pellet was reported to increase the utilization of cassava based broiler diets (CIAT, 2007). Therefore, these recommendations of the cassava root, must be taken into account when formulating poultry diets based on this ingredient.

2.3.2 Copra meal in broiler nutrition

Like cassava root, the recommendations of copra meal in broiler diets are variable. Copra meal is a moderate source of protein (15-25%) (Thomas and Scott, 1962; Ayasan, 2016), but its inclusion is limited due to poor protein quality, high fiber and low bulk density, which impedes digestion and nutrient absorption in birds (Sundu *et al.,* 2004, 2009). Several factors including enzyme supplementation, diet composition and the age of the bird affect utilization of copra by poultry. Bastos *et al.* (2007) found that 5% copra meal deteriorated weight gain of young broilers. According to Sundu *et al.* (2009), 20% dietary copra meal is recommended for acceptable growth performances of broilers. However, with enzyme supplementation, dietary inclusion of 25% copra meal gave better growth results in broilers (Sundu *et al.,* 2009). Devi (2017), observed that broilers can utilize copra meal better when fed with animal protein than plant protein sources.

2.4 Strategies to improve utilization of cassava root and copra meal by poultry

2.4.1 Sun-drying

Cassava tubers are fast perishable due to two deteriorative stages known as primary and secondary deterioration (Bokanga, 1999). Primary deterioration occurs 24 hours after harvest depending on cassava variety and is triggered by mechanical damage on roots. Secondary deterioration is initiated by micro-organism such as fungi species mainly from *Bacillus* family (Bokanga, 1999). As such, cassava roots can easily lose its value and becomes unfit for consumption. Thus, post-harvesting methods have been developed to basically reduce the root moisture content from 60-70% (Morgan and Choct, 2016) to 8-12% (Bokango, 1999) and extend shelf-life of cassava products. Processing methods such as peeling, grating and sun drying have been reported to improve the keeping quality and nutrient value of cassava root meal (Bokanga, 1999).

2.4.2 Soaking

Due to the presence of cyanide in cassava roots, several detoxification methods have also been developed over the years by cassava growers to make cassava safe for animal and human consumption. According to Nebiyu and Getachew (2011), soaking of cassava root chips in water for 24 hours and sun-drying for 3-4 days are the most effective methods of reducing cyanide in cassava root. This procedure has been shown to reduce cyanide content from 108.37 to 10.83ppm (Nebiyu and Getachew**,** 2011). According to FAO/WHO (2013), fresh and processed sweet cassava varieties are considered safe as food/feed sources at cyanide concentrates of <50mg/kg and 10mg/kg respectively.

2.4.3 Fermentation

Fermentation is a metabolic process by which micro-organisms breakdown complex compounds into simpler substances as they perform metabolic activities in growth. Attempts to improve the nutritive quality of cassava roots and peels by fermentation have shown positive effects. Fermentation of cassava roots and peels by yeasts species such as *Bacillus mycoides, Saccharomyces cerevisiae, Bacillus megaterium and Aspergillus tamari* increased crude protein and reduced hydrocyanic acid contents (Boonnop *et al.,* 2009; Ezekiel *et al.,* 2010; Gunawan *et al.,* 2015; Yuli *et al.,* 2015). According to Gunawan *et al.* (2015), submerged fermentation of cassava roots by *S. cerevisae, R. oryzae* and *L. platarum*, improved the protein content from 1.92% to 2.29%, 4.7% and 8.58%, and reduced cyanide contents from 17.5mg/kg to 3.2, 3.17 and 1.8mg/kg respectively.

Similarly, fermentation was reported to improve the nutritive value of copra meal with regard the protein content (Haryati, 2006; Hatta and Sundu, 2009). Hatta and Sundu (2009) reported higher body weight gain of broilers fed 1% copra meal fermented by *Aspergillus niger* compared to birds fed diets containing unfermented copra meal diets.

2.4.4 Supplementation of amino acids

Supplementation of synthetic essential amino acids in poultry diets to fortify protein quality in formulated diets is common nowadays (Khattak *et al.*, 2006)**.** Such inclusions are more nutritious and readily available for absorption compared with protein ingredients because the quality of proteins mainly depends on the availability of amino acids (Bryden and Li, 2010). Thus, amino acid supplementation is very important in diets containing poor quality proteins, high fiber and anti-nutritional factors. Furthermore, supplementation of sufficient non-essential amino acids can be applied to avoid conversion of essential to non-essential amino acids (Todd, 2008). This is common when protein supply is low causing poor feed efficiency results. Hence, it is vital to acquire knowledge about nutrient composition of any available feed stuffs before adding supplements. For example, in corn-soybean diets, methionine is the most limiting amino acid (Garcia and Batal, 2005) and its supplementation becomes necessary.

According to CABI (2003), methionine, lysine and threonine are the most important amino acids in broilers. Methionine has four primary functions including protein synthesis, synthesis of polyamines, glutathione precursor and methyl donation (Rubin *et al.*, 2007). Lysine supports growth and feather pigmentation; and threonine contributes to maintenance and digestion (Paul and William, 2013).

2.4.5 Exogenous enzyme supplementation

Enzymes are biological catalysts that increase chemical reactions without being used. In poultry digestion, specific enzymes are naturally secreted by salivary glands, proventriculus, pancreas and small intestine to act on particular substrates in feedstuffs. However, poultry do not produce enzymes that hydrolysis non-starch polysaccharides (insoluble and soluble polysaccharides); therefore, these are not well digested by chickens (Khattak *et al.*, 2006).

Inclusion of exogenous enzymes in poultry nutrition is rapidly expanding these days as farmers intended to reduce cost of production by utilizing cheaper nonconventional feed sources. Such feed ingredients are commonly high in non-starch polysaccharides. Thus, enzymes are incorporated in feeds purposely to enhance utilization of proteins and energy in feedstuffs by improving their digestibility (Khattak *et al.*, 2006). Hence, enzymes are becoming important to improve bioavailability and feed efficiency of poultry feeds. Some enzyme products that have been used in cassava-copra meal diets are summarized in Table 4.

Table 4: Some enzyme products used in cassava and copra meal based diets for chickens

Enzyme product	Active enzymes	Recommendations	References
Avizyme 1502	Xylanase, protease, amylase, phyzyme XP and phytase	0.1g/kg feed (cassava root)	Bhuiyan and Iji, (2015)
Roxazyme G2G	β-glucanase and β-xylanase	0.1g/kg feed (cassava root)	Ogunsipe *et al.,* (2015)
Challenzyme	ß-glucanase, xylanase, ß-mannanase, α-galactosidase, protease, amylase, pectinase and cellulase	0.35g/kg (cassava peel and copra meal)	Dayal *et al.,* (2018)
Allzyme SSF$^{(R3)}$	Cellulase, pentosanase, protease, phytase, β-glucanase, amylase and pectinase	0.2g/kg feed (copra meal)	Sundu *et al.,* (2004)
Hemicell Mannanase$^{(R1)}$	β–mannanase	0.5g/kg (copra meal)	

The types and concentrations of enzymes required for inclusion in feedstuffs depend on the type, properties and concentration of substrates. According to Khattak *et al*. (2006), the rate of reactions caused by enzymes increases with increasing substrate concentrations until enzymes become saturated. Thus, matching quantity and type of enzymes with substrate types and concentrations is important. However, concentrations and types of substrate vary in different feed sources, thus acquiring such information is vital for effective utilization of enzymes in poultry nutrition.

2.4.6 Fat addition

Cassava roots and solvent extracted copra meals are low in residual fat (Heuzé *et al.*, 2015). In poultry nutrition, addition of fat helps to increase metabolisable energy level of feeds and allow birds to acquire more calories in lesser quantity of feed (Murugesan, 2012). It improves the palatability, absorption of fat-soluble vitamins and diminishes pulverulence in feed rations (Baião and Lara, 2005). Supplementation of diets with fats rich in essential fatty acids such as linoleic acid, has also been reported to enhance growth and carcass composition of broilers (Suksombat *et al.,* 2007). It was suggested that 1-1.25% of linoleic acid is required in broiler diets (Aviagen, 2014). Furthermore, vegetable oils containing a minimum of 80% unsaturated fatty acids and 50% linoleic acids are best to increase feed efficiency of poultry (Murugesan, 2012) . According to Gunstone (1996), vegetable oils from safflower, canola, soybeans and peanut have higher concentrations of linoleic acid and total unsaturated fatty acids compared with coconut oil. Coconut oils have only 2% linoleic acid and a total of 9% unsaturated fatty acids (Gunstone 1996).

2.4.7 Feed dilution

Dilution of expensive commercial feed with cheaper feed ingredients such as copra meal and cassava root meal have been studied with the aim to improve profitability of village broiler productions without significant effect on birds' performance. According to Pandi (2005), commercial broiler finisher diets can be diluted with 20-40% copra meals without detrimental effects on village broilers. A study by Glatz (2012) found that dilution of commercial diets with cassava root significantly reduced cost of production of village broilers in Papua New Guinea.

2.4.8 Pelleting

The effect of pelleting on feed intake and weight gain of broilers is well documented. Thomas and Van der Poel (1996), McCracken (2002) and Sundu *et al.* (2005b) observed that birds are able to obtain their feed requirements with ease from pelleted diets compared to mash feeding. The beneficial effect of pelleting on the utilization copra meal diets has been reported. Sundu *et al.* (2005b) and Adeyemi *et al*. (2008) showed improvements in weight gains of broilers fed pelleted copra meal (as 30% of a mash diet) and cassava root meal. According to Aviagen (2014), broiler diets should be in crumble forms at starter and pelleted at 3.5mm diameter at grower and finisher phases. However, in most PICs, pelleting diets may be limited by the lack of pelleting machines, scanty animal nutrition studies and the absences of most conventional feed ingredients.

2.5 Availability of canarium cake in the Solomon Islands

Canarium cake is the by-product of canarium oil. Currently, there are no statistics on the availability of canarium cakes and nuts in the Solomon Islands probably because the government has not yet recognised its potentials. However, the nut has been well utilized as traditional food in all provinces of the country. In local markets, raw nuts are commonly sold as snacks and oven dried nuts are stored in shield containers and sold in bulks. Prices of oven dried nut fluctuates depending on the supply.

Nowadays, processing of canarium nut to produce cooking oil and skin care ointments is at its early stages in Solomon Islands and the demand for canarium oil is increasing (Wallace, 2016). A canarium oil plant (Maraghoto Holdings) situated in Guadalcanal province, closer to Honiara city is producing reasonable quantities of canarium oil and the cakes from these extractions are available. Due to better nutritive quality of the oil, it was expected that the demand for canarium oil will continue to rise in the near future (Wallace, 2016). Thus, with increase production of canarium oil, the quantity of by-product expelled would also increase and this may pose disposal problems in the near future. Thus, seeking ways to improve the value of canarium by-products would avoid environmental degradation and support canarium industry in the Solomon Islands. Studies on supplementation of canarium cake in broiler diets in the Solomon Islands is a concern to fully utilize the potential of the nut species in the country.

2.6 Nutrient composition of canarium cake

The chemical composition of the canarium cake is rarely reported. However, as mentioned earlier, dried canarium nut kernel has 14.4 % protein with satisfactory lysine (1.91-2.73%) content (Gregoria *et al.*, 2011). Since lysine is one of the most limiting amino acid in broiler diets (Farkhoy *et al.,* 2012), dietary canarium cake could enhance growth performance in broilers. It is expected that protein and lysine content in canarium cake would increase due to oil extraction and suitable feed source for broilers. Other nutrients in canarium kernel include 5.5% carbohydrate, 3.2% fibre and crude fat of 74.9% (Nevenimo *et al.*, 2007), with 13% linoleic acid (Serge, 2004).

Canarium kernel or oil is considered non-toxic and edible. According to Rahman *et al.* (2015), canarium is high in linoleic, oleic and palmitic acids. Hence, the oil is mostly of monounsaturated fatty acids, polyunsaturated and saturated fatty acids. Based on the physicochemical properties of the oil, the author commended the edibility of the nut and possibilities to use as raw material for medical applications.

CHARPTER THREE: RESEARCH METHODOLOGY

3.1 Experimental site

The study was conducted at Lunga area (Latitude = 09.42687˚ S and Longitude = 160.03125˚ E), approximately 7 km east of Honiara, the capital city of Solomon Islands. Solomon Islands is a developing country in the Pacific Ocean covering a land mass of 28400 km^2 with a population of about 550,000 (Oishimaya, 2017). The climate is tropical with average temperature of 27°C, and 83% humidity that changes very little all year around (Tomahawk, 2018). Cassava, copra meal and canarium cake are readily available in the area.

3.2 Fermentation of cassava root

Saccharomyces cerevisiae (yeast) was cultured in a sterilized cylinder vessel containing 20% sucrose (w/v), 4% urea (w/v) and 10g/ℓ yeast extract. It was incubated at room temperature for 60 hours (Boonnop *et al.*, 2009) prior to inoculation time.

Cassava roots from a seven-month old sweet variety was purchased from local cassava growers at Lunga villages and thoroughly washed under tap water. Cassava roots with peel were sliced to increase their surface area and loaded in a large fermentation vessel (200ℓ capacity) at 50% (w/v) with 12.5% inoculum. About 37.5% water was added to keep the roots submerged. The vessel was then covered with loosen lid to allow dispersion of carbon dioxide during subsequent 60 hours of fermentation. After fermentation, the whole cassava root was pounded to fine particles and subjected to 3-4 days of sun-drying to further reduce cyanide content and microbial activity. It was then stored in well shielded containers at room temperature.

3.3 Experimental diets

Six diets based on fermented cassava and copra meal were formulated at starter and finisher phases to have similar nutrient content to the commercial broiler feed (control) from Riverina broiler feed company (Riverina, 2015a; 2015b). The commercial diets contained metabolisable energy 12MJ/kg, crude protein 22.5%, fat 2.5%, fibre 4.5% and lysine 1% in the starter and 12.5MJ/kg, 20, 2.5, 4.5 and 0.8% respectively in the finisher. The composition of the experimental diets (% as fed) is presented in Tables 5 and 6. Canarium cake was included in the diets at 5 and 10% with and without challenzyme. The complex enzyme used was Challengyme 1309A manufactured by Beijing Challenge Bio-Technology Co. Ltd. It has eight active enzymes namely: ß-glucanase, xylanase, ß-mannanase, α-galactosidase, protease, amylase, pectinase and cellulose. HCL lysine was removed with the inclusion of canarium in some diets.

Table 5: Ingredient composition of experimental starter diets (% as fed basis)

Ingredients	Cassava-copra meal based diets					
	HCL lysine	HCL lysine + enzyme	5% canarium	10% canarium	5% canarium + enzyme	10% canarium + enzyme
Fermented cassava	58	57.96	58.45	58.45	58.41	58.41
Copra meal	27.1	27.1	21.8	16.8	21.80	16.80
Canarium meal	0.00	0.00	5.00	10.00	5.00	10.00
Fishmeal	12.00	12.00	12.00	12.00	12.00	12.00
Challenzyme	0.00	0.04	0.00	0.00	0.04	0.04
Peanut oil	0.50	0.50	0.50	0.50	0.50	0.50
Limestone	1.50	1.50	1.50	1.50	1.50	1.50
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Lysine	0.15	0.15	0.00	0.00	0.00	0.00
Methionine	0.10	0.10	0.10	0.10	0.10	0.10
Premix	0.30	0.30	0.30	0.30	0.30	0.30
Calculated analyses						
Metabolisable Energy (MJ/kg)	12.82	12.81	12.89	12.96	12.89	12.96
Crude Protein (%)	22.63	22.62	22.72	22.96	22.71	22.95
Crude Fibre (%)	5.40	5.40	5.15	4.92	5.15	4.92
Lysine (%)	1.43	1.43	1.29	1.30	1.29	1.29
Methionine (%)	0.46	0.46	0.46	0.46	0.46	0.46

Table 6: Ingredient composition of experimental finisher diets (% as fed basis)

Ingredients	Cassava-copra meal based diets					
	HCL lysine	HCL lysine + enzyme	5% canarium	10% canarium	5% canarium + enzyme	10% canarium + enzyme
Fermented cassava	59.2	59.16	59.5	59.5	59.46	59.46
Copra meal	29.35	29.35	24.20	19.20	24.20	19.20
Canarium meal	0.00	0.00	5.00	10.00	5.00	10.00
Fishmeal	7.00	7.00	7.00	7.00	7.00	7.00
Challenzyme	0.00	0.04	0.00	0.00	0.04	0.04
Peanut oil	2.00	2.00	2.00	2.00	2.00	2.00
Limestone	1.50	1.50	1.50	1.50	1.50	1.50
Salt	0.40	0.40	0.40	0.40	0.40	0.40
Lysine	0.15	0.15	0.00	0.00	0.00	0.00
Methionine	0.10	0.10	0.10	0.10	0.10	0.10
Premix	0.30	0.30	0.30	0.30	0.30	0.30
Calculated analyses						
Metabolisable Energy (MJ/kg)	13.12	13.11	13.24	13.27	13.19	13.26
Crude Protein (%)	19.91	19.90	20.02	20.25	20.01	20.25
Crude Fibre (%)	5.70	5.70	5.46	5.22	5.46	5.22
Lysine (%)	1.21	1.21	1.06	1.07	1.06	1.07
Methionine (%)	0.39	0.39	0.39	0.38	0.38	0.38

3.4 Experimental birds and managements

One hundred and twenty-six 10-day old Cobb broiler chicks were weighed and assigned to the seven dietary treatments with 3 replicates of 6 birds each in a completely randomized design. Birds were fed the starter from day 10 to 21 and the finisher diets from 22rd day to the end of the experiment (day 42). Birds were housed in open-sided floor pens (1x1.5m) with wood shaver as litter material. The lighting programme consisted of 20 hours light. Feed and clean drinking water were provided *ad-libitum* throughout the duration of the experiment (Diarra *et al.,* 2014).

3.5 Data collection

3.5.1 Growth data

Weighed quantities of feed were fed and leftover weighed on daily basis. Feed intake was calculated by difference between the quantities fed and leftover (Diarra *et al.,* 2014). Weight gain was monitored by weekly weighing and feed conversion ratio was calculated by dividing the feed intake by the weight gain in each pen (Diarra *et al.,* 2014).

3.5.2 Carcass data

At the end of the 42nd day of the experiment, one bird having the closest weight to the pen mean was selected from each pen and fasted overnight and euthanised by decapitation (Diarra *et al.,* 2014). Slaughtered birds were scaled in hot water ($55^{o}C$) for 2 minutes, plucked and eviscerated (Diarra *et al.,* 2014). The weight of carcass and cuts (breast, thigh and drumsticks) were expressed as relative weights of the live chicken. Abdominal fats and organs (caeca, small intestine, pancreas, liver, gizzard and heart) were also weighed and expressed as relative weights.

3.6 Chemical Analysis

Cassava root, copra, fish and canarium meals were analysed for proximate composition, and amino acid profile and cassava for cyanide content at the National Measurement Institute (NMI) in Australia. However, due to the commercial-in-confidence basis of the analytical procedures, detailed steps of the chemical analysis could not be provided.

3.7 Statistical Analysis

Data collected on growth, carcass measurements and organs weights were subjected to one-way analysis of variance (ANOVA) (Steel and Torrie, 1980) using SPSS (2007) software and significant differences reported as 5% level of probability.

CHAPTER FOUR: RESULTS

4.1 Chemical analysis

Results of proximate analysis and amino acid composition of fermented cassava root, copra meal, fish and canarium cake are presented in Tables 7 and 8. Canarium cake contained more metabolisable energy, crude protein and fat compared to copra and fermented whole cassava root meals. The fibre content is higher in copra meal and canarium compared to cassava meal. Canarium cake was higher in all analysed amino acids than copra meal.

Table 7: Proximate composition (% as dry matter) and metabolisable energy of ermented whole cassava root meal, copra, fishmeal and canarium cake

	Fermented whole cassava root meal	Copra meal	Canarium cake	Fishmeal
Moisture	15.70	12.50	3.70	7.70
Crude Protein	1.80	18.20	29.60	57.80
Crude fibre	2.10	11.80	11.20	<0.10
Crude fat	0.40	11.50	43.60	16.00
Ash	1.10	5.00	7.40	20.60
Total cyanide	<0.00005	NT	NT	NT
Metabolisable Energy (Kcal/kg)	2,860	3,070	4,900	3,310

NT: Not tested.

Table 8: Amino acid composition (as % basis) of fermented whole cassava root meal, copra, fishmeal and canarium cake

Amino acid	Canarium cake	Copra meal	Fishmeal	Fermented cassava
Aspartic Acid	3.20	1.50	6.10	0.13
Serine	<0.01	<0.01	0.20	<0.01
Glutamic Acid	5.80	3.20	7.60	0.17
Glycine	1.60	0.79	4.80	0.08
Histidine	0.64	0.32	1.80	0.03
Arginine	1.20	0.70	2.50	0.06
Threonine	1.10	0.58	3.00	0.06
Alanine	1.20	0.78	4.30	0.11
Proline	1.20	0.59	0.30	0.05
Tyrosine	0.94	0.33	1.60	0.03
Valine	1.90	0.98	3.50	0.08
Lysine	0.95	0.60	4.70	0.09
Isoleucine	1.20	0.57	2.60	0.06
Leucine	2.40	1.20	5.10	0.10
Phenylalanine	1.60	0.73	2.60	0.06
Methionine	0.71	0.27	1.70	0.01
Hydroxyproline	0.03	0.029	0.93	0.02
Taurine	<0.01	<0.01	0.19	<0.01
Tryptophan	0.45	0.14	0.55	0.02

4.2 Growth performance

The growth performance results of the broilers are presented in Tables 9, 10, and 11. During the starter phase (Table 9), broilers fed diets containing 10% canarium with or without enzyme consumed less feed ($P<0.05$). Feed intake was similar between the groups fed 5% canarium and HCL lysine with enzyme ($P>0.05$). Similarly, there was no difference in feed intake between the groups fed the commercial feed and cassava-copra based diet with HCL lysine ($P>0.05$). Weight gain did not differ among the cassava-copra based diets ($P>0.05$), but was depressed on these diets compared to the control ($P<0.05$). Feed conversion ratio (FCR) was comparable amongst groups fed cassava-copra diets containing HCL lysine with or without enzyme, 10% canarium without enzyme and 5% canarium with enzyme ($P>0.05$); but was poor on these diets compared to the control ($P<0.05$). Broiler starter fed 10% and 5% canarium with and without enzyme respectively were similar to control in terms of FCR (P>0.05).

During the finisher phase (Table 10), feed intake was significantly reduced in broilers fed 10% canarium with or without enzyme (P<0.05). Feed intake did not differ between broilers fed 5% canarium with and without enzyme (P>0.05) and the diet supplemented with HCL lysine and enzyme (P>0.05). Birds fed the control diet gained more weight than the cassava-copra meal fed groups (P<0.05). Weight gain was poor on the 5% canarium supplemented with enzyme compared to the 5% canarium with enzyme and the HCL lysine groups (P<0.05). The poorest FCR was observed on 5% canarium with enzyme and the best on the control (P<0.05). Feed conversion ratio did not differ among the lysine supplemented groups and 10% canarium with and without enzyme (P<0.05). Similarly, there was no significant difference in FCR between the 5% canarium without enzyme and 10% with enzyme (P>0.05). Feed conversion ratio of birds fed 5% canarium without enzyme was improved during the finisher compared to the starter phase.

The results of the overall growth performance of the broilers (day 10-42) are presented in Table 12. Birds fed the control diet consumed more feed, gain more weight and converted their feed into weight better than the cassava-copra meal based diets (P<0.05). Birds fed 10% canarium with or without enzyme consumed significantly less feed compared to those fed the control and HCL lysine supplemented group (P<0.05). Feed intake did not differ between the groups fed 5% canarium with and without enzyme and HCL lysine supplemented with enzyme (P>0.05). Among the cassava-copra fed groups, feed conversion ratio was poorer on HCL lysine without enzyme and 5% canarium with enzyme compared to 10% canarium with enzyme (P<0.05).

Table 9: Growth performance of starter broilers (10-21d) fed canarium meal as source of lysine in fermented cassava-copra diets a, b, c, d: Means in the same column with different superscripts are significantly different (P=0.05); SEM: Standard error of the mean; FCR: Feed conversion ratio.

Diets	Parameter		
	Daily feed intake (g)	Daily weight gain (g)	FCR
HCL lysine	76.04^{ab}	12.60^{b}	6.07^{a}
HCL lysine + enzyme	70.37^{bc}	13.99^{b}	4.99^{a}
5% canarium	66.43^{bcd}	14.58^{b}	4.59^{ab}
10% canarium	56.28^{d}	11.43^{b}	5.31^{a}
5% canarium + enzyme	63.45^{cd}	13.18^{b}	5.70^{a}
10% canarium + enzyme	55.56^{d}	14.28^{b}	3.89^{ab}
Commercial starter (control)	82.92^{a}	38.06^{a}	2.18^{b}
SEM	3.974	1.725	0.830
P value	0.002	0.000	0.074

Table 10: Growth performance of finisher broilers (22-42 d) fed canarium meal as source of lysine in fermented cassava-copra diets a, b, c, d: Means in the same column with different superscripts are significantly different (P=0.05); SEM: Standard error of the mean; FCR: Feed conversion ratio.

Diets	Parameter		
	Daily feed intake (g)	Daily weight gain (g)	FCR
HCL lysine	103.47^{b}	31.28^{b}	3.31^{ab}
HCL lysine + enzyme	97.99^{bc}	30.95^{b}	3.17^{b}
5% canarium	92.36^{bcd}	31.28^{b}	2.95^{c}
10% canarium	86.55^{d}	27.74^{bc}	3.12^{b}
5% canarium + enzyme	87.46^{cd}	25.08^{c}	3.50^{a}
10% canarium + enzyme	86.53^{d}	27.78^{bc}	3.12^{bc}
Commercial finisher (control)	141.22^{a}	72.79^{a}	1.95^{d}
SEM	3.686	1.671	0.093
P value	0.000	0.000	0.000

Table 11: Effect of canarium meal as source of lysine in fermented cassava-copra diets on growth performance of broiler (10-42days) a, b, c, d: Means in the same column with different superscripts are significantly different (P=0.05); SEM: Standard error of the mean; FCR: Feed conversion ratio.

Diets	Parameter		
	Daily feed intake (g)	Daily weight gain (g)	FCR
HCL lysine	93.17^{b}	23.81^{bc}	3.92^{a}
HCL lysine + enzyme	87.63^{bc}	24.17^{bc}	3.62^{ab}
5% canarium	82.67^{cd}	24.60^{b}	3.36^{ab}
10% canarium	75.20^{d}	21.21^{bc}	3.56^{ab}
5% canarium + enzyme	78.47^{cd}	20.32^{c}	3.93^{a}
10% canarium + enzyme	74.93^{d}	22.38^{bc}	3.35^{b}
Commercial feed (control)	119.37^{a}	58.90^{a}	2.04^{c}
SEM	3.33	1.416	0.187
P value	0.000	0.000	0.000

4.3 Carcass measurements

Results of carcass measurements of the broilers are presented in Table 12. The relative weights of carcass and breast were increased on the control diet compared to the cassava-copra based diets (P<0.05). Carcass weight did not differ among the cassava-copra meal fed groups (P>0.05). Breast weight was reduced on the 10% canarium with enzyme compared to the HCL lysine supplementation diets (P<0.05). There was no dietary effect on the relative weights of thighs (P>0.05). A heavier drumstick was recorded on the 10% canarium without enzyme compared to the control, 5% canarium with enzyme and HCL lysine supplemented groups (P<0.05).

Table 12: Effect of canarium meal as source of lysine in cassava-copra diets on the relative weight of carcass and major cuts of broiler (% live weight) a, b, c: Means in the same column with different superscripts are significantly different (P=0.05); SEM: Standard error of the mean.

Diets	Parameter			
	Carcass	Breast	Thighs	Drumsticks
HCL lysine	73.03^{b}	15.92^{b}	12.28	10.55^{bc}
HCL lysine + enzyme	72.32^{b}	16.41^{b}	11.73	10.55^{bc}
5% canarium	72.00^{b}	14.64^{bc}	12.18	11.22^{ab}
10% canarium	71.86^{b}	13.03^{c}	11.95	11.88^{a}
5% canarium + enzyme	70.69^{b}	14.40^{bc}	11.97	9.86^{c}
10% canarium + enzyme	72.12^{b}	14.19^{bc}	12.02	11.30^{bc}
Commercial feed (control)	78.14^{a}	23.77^{a}	12.09	10.05^{c}
SEM	0.93	0.934	0.514	0.307
P value	0.002	0.000	0.992	0.004

4.4 Organ weights

From Table 13, the relative weights of small intestine and gizzard were markedly reduced on the control diet compared to the cassava-copra meal based diets (P<0.05), but did not differ among birds fed the test diets (P>0.05). The weight of caeca was significantly increased on the 10% canarium without enzyme compared to the control (P<0.05), but was not different among the cassava-copra based diets (P>0.05). Liver weight was increased on cassava-copra meal with HCL lysine and reduced on 10% canarium with enzyme (P<0.05). A lighter pancreas was observed on the control commercial diet compared to 10% canarium without enzyme and 5% canarium with enzyme (P<0.05). Pancreas weight was not different among birds fed cassava-copra meal based diets (P>0.05). The weights of abdominal fat and heart followed a pattern similar to that of pancreas.

Table 13: Effect of canarium meal as source of lysine in cassava-copra diets on organ weights of broiler (% live weight) a, b, c: Means in the same column with different superscripts are significantly different (P=0.05); SEM: Standard error of the mean.

Diets	**Parameter**						
	Small intestine	Caeca	Gizzard	Liver	Pancreas	Abdominal fat	Heart
HCL lysine	3.20^{a}	0.37^{ab}	2.30^{ab}	1.97^{ab}	0.16^{ab}	1.94^{ab}	0.55^{ab}
HCL lysine + enzyme	3.80^{a}	0.57^{ab}	2.09^{ab}	2.21^{a}	0.16^{ab}	2.01^{ab}	0.54^{ab}
5% canarium	3.59^{a}	0.49^{ab}	2.29^{ab}	1.85^{c}	0.15^{ab}	2.06^{ab}	0.59^{a}
10% canarium	3.32^{a}	0.65^{a}	2.98^{a}	1.56^{b}	0.18^{a}	1.62^{ab}	0.60^{a}
5% canarium + enzyme	3.26^{a}	0.44^{ab}	2.78^{ab}	1.64^{bc}	0.17^{a}	2.52^{a}	0.54^{ab}
10% canarium + enzyme	3.22^{a}	0.59^{ab}	2.07^{b}	1.59^{c}	0.14^{ab}	1.70^{ab}	0.53^{ab}
Commercial feed (control)	1.85^{b}	0.31^{b}	1.11^{c}	1.71^{bc}	0.11^{b}	1.10^{b}	0.48^{b}
SEM	0.263	0.102	0.296	0.115	0.018	0.338	0.035
P value	0.004	0.026	0.013	0.013	0.018	0.019	0.032

CHAPTER FIVE: DISCUSSION

5.1 Chemical analysis

Moderate crude protein (8-14%) and amino-acid profile have been reported in canarium kernel by several authors (Thomson and Evans, 2006; Nevenimo *et al.*, 2007; Gregoria *et al.,* 2011), but there are limited reports on the proximate composition of canarium cake. The canarium cake used in this study contained higher crude protein (29.6%) than the values reported in the kernel. This could be mainly due to the inverse association between fat and protein as more oil was extracted to produce this by-product.

The lysine content (0.95%) in canarium cake (Table 9) is lower than the range (1.91- 2.73%) observed by Gregoria *et al.* (2011). In the Solomon Islands, the cake is produced from nuts subjected to 5 days solar-drying (below 40°C), and oven drying (100-120°C) to reduce moisture content and improve its self-life (Wallace, 2012). This processing might have influenced amino acid denaturing due to the prolonged heat exposure of nuts during drying. According to Parsons *et al.* (1992), excess heat reduced amino acid availability and protein quality. Similar observations were made by several studies when working with other plant feed ingredients. Studies by Taira *et al.* (1965), Fernandez and Parsons (1996), and Lokuruka (2011) showed reduced amino acid contents, including lysine, in heat processed soybeans. Under high temperatures, lysine has been found to form a complex with oligosaccharides in Maillard reaction, which depresses protein quality in feed ingredients and bioavailability of lysine during digestion (Williams *et al.,* 2006; Almeidia, 2013). Other factors such as origin of nuts, age of canarium trees and analytical procedures may have also contributed to the variation in amino acid composition of the cake.

The metabolisable energy (ME) content of canarium cake used in this study is lower than that of canarium kernel (7,278 Kcal/kg) reported by NARI (2007). This was attributed to the reduced fat content of the by-product during canarium oil processing. According to Murugesan (2012), fats are concentrated sources of energy, which boosts ME in poultry feeds. The fibre content of the experimental canarium cake (11.2%) is higher than the value (3.2%) reported in the kernel by Nevenimo *et al.* (2007). The higher fibre content in the cake might attributed to oil extraction.

The copra meal used in this experiment had a protein, fat and fibre content comparable to the values (19.6, 5-15, and 10-19.7% respectively) reported by Heuzé *et al*. (2015). The lower amino acid profile of copra meal is also in agreement with the observation of Heuzé *et al.,* (2015; 2017).

In contrast, the fermented whole cassava root meal is relatively low in fat (0.4%) than values reported in literature. Boonnop *et al.* (2009) reported an increase fat content in cassava root meal following fermentation from 2.3 to 3%. The low fibre (2.1%) content of fermented whole cassava root despite the higher fibre (7.6-38.4%) reported in cassava peel (Heuze *et al.,* 2016a) may be attributed to possible breaking down of complex structures during fermentation. Adeleke *et al.* (2017) also reported reduced fibre in fermented cassava roots and attributed this to the ability of fermenting microorganisms to secrete oxidizing and hydrolysing enzymes, produce abundant organic acids and degrade crude fibre.

Boonnop *et al*. (2009) reported up to 21% protein in cassava root meal fermented with *Saccharomyces cerevisiae* against the 1.8% observed in this study. This wide difference could not be thoroughly explained, but the cultivar of cassava, age of maturity and agronomic factors, which have been reported to affect the composition of cassava products (Corbishley and Miller, 1984; Manano, *et al.,* 2017) may be possible sources of variations.

In this study, fermentation reduced the HCN content of cassava root below the recommended safe cyanide concentration (10mg/kg) in processed cassava root for animal feeds (FAO/WHO, 2013). Study by Boonnop *et al.* (2009), also found significant reduction in cyanide concentration from 3.4 to 0.5mg/kg cassava chips fermented by *Saccharomyces cerevisiae*. Thus, this may indicate that the fermentation process used in this study is capable of hydrolysing cyanogenic glucosides in cassava roots.

5.2 Growth performance

Despite the reduction in cyanide content, supplementation of amino acids and exogenous enzymes in fermented cassava-copra meal based diets, feed intake was suppressed on the test diets compared to the control. According to Peter and Abel (2006), feed intake is mainly influenced by metabolisable energy, feed particle size and anti-nutritional factors. Our findings showed that diets with relatively higher ME level significantly reduced feed intake in broilers as birds may have acquired required daily energy with less feed consumed. The higher fat (43.6%) content of canarium cake might have boosted the ME level in cassava copra meal based diets. This might explain the lower feed intake in broilers fed 10% canarium with or without enzyme in both starter and finisher phases. With slightly reduced ME in cassava copra meal based diets, feed intake was marginally improved and comparable amongst birds fed 5% canarium and HCL lysine with enzyme supplementation in both starter and finisher phases. Thus, increased canarium cake inclusion numerically reduced feed intake in broilers.

The fine feed particle size in mashed cassava-copra meal based diets in this study may have also contributed to the relatively lower intake of the test diets. Many studies have shown increased feed intake in broilers fed pelleted diets due to improved palatability, selective feeding and decreased feed wastage (McKinney and Teeter, 2004; Amerah *et al.,* 2008; Chewning *et al.,* 2012). In this study, the cassava root was reduced to powder form after subsequent processes including fermentation, pounding and 3-4 days of sun-drying. Although peanut oil and canarium cake were included to improve feed texture by preventing dustiness in the test diets, the feed particle sizes varied between the mashed cassava-copra meal based diets and pelleted control diets. This difference in particle size could be a possible reason for reduced intake of the cassava root meal based diets.

In addition, the high fibre content in copra meal, mostly non-starch polysaccharides (Heuzé *et al.,* 2015), which associate with low bulk density and high water holding capacity (Sundu *et al.,* 2009) probably contributed to the lower feed intake in broilers fed the test diets. As such, copra meal used in this study might have occupied more space in the digestive track due to the low bulk density and high water holding capacity.

Moreover, studies by Knudsen (1997) have shown that the non-starch polysaccharides (NSP) in copra meal impede nutrient digestion in the digestive track of broilers by enclosing intra-cellular proteins and other essential nutrients and subsequently suppress availability and absorption of nutrients. Inclusion of fibre degrading and complex exogenous enzymes countered the negative effects the NSP in copra meal and improved feed intake, weight gains and feed conversion ratios of broilers fed copra meal based diets (Sundu *et al.,* 2005a; 2006). However, the findings in this experiment showed no significant improvements in daily feed intake as well as weight gains of birds fed diets with enzyme inclusion. It is possible that the level of enzyme inclusion in this study was probably low to cause sufficient hydrolysis of dietary fibre in the test diets and improve absorption of essential nutrients in both starter and finisher test diets. Therefore, the lower feed intake on the experimental cassava-copra meal diets, probably due to feed form (mash), complex structure and enzyme level, was the main reason for reduced weight gain on these diets compared to the control.

Amongst fermented cassava-copra meal based diets, daily weight gain was comparable during the starter phase although feed intake was slightly reduced at a linear trend with increasing canarium inclusions. This occurrence might be attributed to the increased utilization of canarium cake despite the high dietary fibre content of the ingredient. This suggests that canarium cake can replace HCL lysine in broiler starter diets without adverse effects on weight gain and feed utilization. Thus, enhanced weight gains in canarium cake diets could reduce feed cost of production on these diets.

However, a controversial outcome was observed in the finisher phase as birds fed 5% canarium with enzyme inclusion recorded the least weight gain, whilst birds fed the low level of canarium without enzyme gained the best weight amongst cassava-copra meal treatments. The reason for this is not clear, but it is possible that enzyme addition must have increased feed transit time in the GIT at this low level of dietary canarium. A possible longer digesta retention and better utilization of the diet without enzyme may explain the improvement in weight gain on this diet.

The groups fed 5% canarium without enzyme recorded the best feed conversion ratio (FCR) amongst the cassava copra meal based diets while poor FCR was observed in 5% canarium with enzyme inclusion during the finisher phase. As earlier mentioned this might be due to faster digesta transit with enzyme supplementation. The FCR values in birds fed 5 and 10% canarium with enzyme in starter phase were similar to the value for control treatment probably due to lower requirement of starter broilers.

Despite the improved FCR in canarium cake diets, the values are much higher than the 1.2 and 1.6 FCR reported for broilers at 3 and 4 weeks respectively (Cobb-vantress, 2015). Relatively reduced palatability and inappropriate enzyme concentration in the fermented cassava-copra meal based diets discussed previously might have probably contributed to higher FCR values in this study.

Conversely, all cassava-copra meal based treatments showed improved FCR at the finisher phase. This trend shows that broilers would gradually adapt to cassava-copra meal based diets; suggesting that performances could improve on cassava-copra to acceptable values if the feeding period was extended beyond 42 days in this experiment.

5.3 Carcass measurements

The findings of this study revealed that birds fed cassava-copra meal based diets have comparable dressing percentage (70.7-73%). These values are similar to the minimum (71.9%) dressing percentage reported in Cobb-vantress (2015). However, breast and thighs weights of broilers fed the test diets fall below the reported values of 21.25% and 14.4% for breast and thighs respectively in Cobb-vantress (2015). Breast weight was lowest in birds fed the 10% canarium without enzyme, but did not differ among other canarium and HCL lysine treated diets. These finding further confirm the possibilities of replacing HCL lysine with canarium cake in broiler diets. Similarly, heavier drumsticks were observed on 10% canarium without enzyme. The values of drumstick values in this experiment were above the 9.52 % reported in Cobb-vantress (2015). However, birds fed the control diet recorded the highest percentage in carcass (78.14%) and breast weights (23.77%). These could have been attributed to the better growth performance in the control treatment.

5.4 Organ weights

According to Peter and Abel (2006), high dietary fibre increases feed viscosity in the gut, thus reduces feed intake as more time and energy were spent on digestion. Increased gizzard and small intestine weights in diets of high insoluble fibres was reported by Mateos *et al.* (2012). Similarly, Diarra *et al.* (2014) observed heavier weights of pancreas in cassava-copra meal based diets and attributed this to increased secretion of pancreatic juices for hydrolysis of dietary fibre in cassava-copra meal diets. The complex structure of canarium and copra meal could influence the relatively high weights of caeca, in groups fed 10% canarium without enzyme. Svhus (2014) reported that caeca, the fermentation organ for undigested nutrients, enlarges as a consequence of fibre-rich and fermentable diets. In this study, fermentation of feed ingredients was not applied to copra meal and canarium cake. Hence, possible fermentation of these ingredients in the caeca probably increased the weight of this organ on cassava-copra meal based diets. The fine particle size of cassava meal and canarium cake could also be possible reasons for the patterns of caeca weight observed. Svhus (2014) also reported the ease entry of fine feed materials through the tiny opening into caeca.

As the liver plays important function in detoxification, comparable liver weights observed among treatments containing canarium and commercial diets may indicate the positive effects of fermentation of cassava root and non-toxicity of canarium cake. According to Rahman *et al.* (2013), canarium nut is non-toxic and was recommended as a raw material for medical products due to its high nutritional quality. Similarly, Summit (2013) also reported remedial properties of canarium nuts and oil on human health. However, in-depth study of canarium products in relation to poultry health is limited. The patterns of heart and abdominal fat weights could not be explained despite the reduced intake of the test diets compared to the control.

CHAPTER SIX: SUMMARY, CONCLUSION AND RECOMMENDATIONS

A preliminary investigation on the utilization of canarium cake as a source of lysine in fermented cassava-copra meal based diets by broilers was conducted. Six cassava-copra meal based and control commercial diets were fed. Two treatments contained HCL lysine supplements with and without enzyme inclusion. In the other four dietary treatments, HCL lysine was replaced with canarium cake at 5 and 10% with and without enzyme. Each dietary treatment was fed to 3 replicates of 6 broilers for a period of 32 days in a completely randomized design. Broiler performance was significantly depressed on the cassava-copra meal based diets compared to the commercial diet (control). Canarium cake inclusion gave performances comparable to the HCL lysine supplementation.

It is concluded that cassava-copra meal based diets fed as mash would not produce performance comparable to the commercial broiler feed. However, canarium cake can replace HCL lysine in cassava-copra meal based diets with satisfactory broiler performances.

Based on these findings, the following recommendations are made:

1. Further studies with different levels of canarium meal inclusions in conventional feed ingredients is needed to isolate canarium utilization capacity and to better understand the optimum inclusion levels of canarium cake as a substitute for HCL lysine in broiler diets.

2. More researches into feed processing (particle size and pelleting) to improve the utilization of cassava-copra meal based diets by broilers is needed

3. There is a need for research into enzyme sources and concentrates that will improve utilization of diets based on cassava-copra meal by broilers.

4. As the feed ingredients are readily available in the Solomon Islands, feed cost analysis is also important to justify economic viability of experimental diets.

6.1 Limitations of the study

The limitations of the study include the following:

1. Digestibility studies could help understand the trend of the results better, but this could not be carried out due to lack of facilities in the study area.

2. Serum biochemistry, gut morphology and histology would have also help understand the results better, but could not be done.

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APPENDICES

Appendix 1: ANOVA for daily feed intake in starter phase

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1813.822[a]	6	302.304	6.380	.002
Intercept	95093.555	1	95093.555	2006.755	.000
Treatment	1813.822	6	302.304	6.380	.002
Error	663.414	14	47.387		
Total	97570.792	21			
Corrected Total	2477.237	20			

a. R Squared = .732 (Adjusted R Squared = .617)

Appendix 2: ANOVA for daily weight gain in starter phase

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1591.835[a]	6	265.306	29.720	.000
Intercept	5978.897	1	5978.897	669.771	.000
Treatment	1591.835	6	265.306	29.720	.000
Error	124.975	14	8.927		
Total	7695.706	21			
Corrected Total	1716.809	20			

a. R Squared = .927 (Adjusted R Squared = .896)

Appendix 3: ANOVA for feed conversion ratio in starter phase

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	31.012[a]	6	5.169	2.502	.074
Intercept	459.389	1	459.389	222.417	.000
Treatment	31.012	6	5.169	2.502	.074
Error	28.916	14	2.065		
Total	519.317	21			
Corrected Total	59.928	20			

a. R Squared = .517 (Adjusted R Squared = .311)

Appendix 4: ANOVA for daily feed intake in finisher phase

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6871.634[a]	6	1145.272	28.098	.000
Intercept	207352.398	1	207352.398	5087.080	.000
Treatment	6871.634	6	1145.272	28.098	.000
Error	570.648	14	40.761		
Total	214794.680	21			
Corrected Total	7442.282	20			

a. R Squared = .923 (Adjusted R Squared = .890)

Appendix 5: ANOVA for daily weight gain in finisher phase

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5024.424[a]	6	837.404	99.972	.000
Intercept	26127.663	1	26127.663	3119.210	.000
Treatment	5024.424	6	837.404	99.972	.000
Error	117.269	14	8.376		
Total	31269.357	21			
Corrected Total	5141.693	20			

a. R Squared = .977 (Adjusted R Squared = .967)

Appendix 6: ANOVA for feed conversion ratio in finisher phase

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4.509[a]	6	.752	29.093	.000
Intercept	191.166	1	191.166	7399.981	.000
Treatment	4.509	6	.752	29.093	.000
Error	.362	14	.026		
Total	196.037	21			
Corrected Total	4.871	20			

a. R Squared = .926 (Adjusted R Squared = .894)

Appendix 7: ANOVA for mean feed intake (10-42 days)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4384.872[a]	6	730.812	21.924	.000
Intercept	160221.738	1	160221.738	4806.515	.000
Treatment	4384.872	6	730.812	21.924	.000
Error	466.680	14	33.334		
Total	165073.290	21			
Corrected Total	4851.552	20			

a. R Squared = .904 (Adjusted R Squared = .863)

Appendix 8: ANOVA for mean weight gain (10-42 days)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3404.985[a]	6	567.498	95.678	.000
Intercept	16361.490	1	16361.490	2758.498	.000
Treatment	3404.985	6	567.498	95.678	.000
Error	83.038	14	5.931		
Total	19849.513	21			
Corrected Total	3488.024	20			

a. R Squared = .976 (Adjusted R Squared = .966)

Appendix 9: ANOVA for mean feed conversion ratio gain (10-42 days)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	7.462[a]	6	1.244	11.817	.000
Intercept	242.352	1	242.352	2302.790	.000
Treatment	7.462	6	1.244	11.817	.000
Error	1.473	14	.105		
Total	251.287	21			
Corrected Total	8.935	20			

a. R Squared = .835 (Adjusted R Squared = .764)

Appendix 10: ANOVA for carcass weight

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	105.658[a]	6	17.610	6.786	.002
Intercept	111544.298	1	111544.298	42982.895	.000
Treatment	105.658	6	17.610	6.786	.002
Error	36.331	14	2.595		
Total	111686.286	21			
Corrected Total	141.989	20			

a. R Squared = .744 (Adjusted R Squared = .634)

Appendix 11: ANOVA for breast weight

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	231.167[a]	6	38.528	14.721	.000
Intercept	5410.937	1	5410.937	2067.422	.000
Treatment	231.167	6	38.528	14.721	.000
Error	36.641	14	2.617		
Total	5678.745	21			
Corrected Total	267.809	20			

a. R Squared = .863 (Adjusted R Squared = .805)

Appendix 12: ANOVA for weight of thighs

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.563[a]	6	.094	.118	.992
Intercept	3040.101	1	3040.101	3828.797	.000
Treatment	.563	6	.094	.118	.992
Error	11.116	14	.794		
Total	3051.780	21			
Corrected Total	11.679	20			

a. R Squared = .048 (Adjusted R Squared = -.360)

Appendix 13: ANOVA for weight of drumsticks

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	9.446[a]	6	1.574	5.565	.004
Intercept	2439.299	1	2439.299	8623.202	.000
Treatment	9.446	6	1.574	5.565	.004
Error	3.960	14	.283		
Total	2452.705	21			
Corrected Total	13.406	20			

a. R Squared = .705 (Adjusted R Squared = .578)

Appendix 14: ANOVA for weight of small intestine

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	7.050[a]	6	1.175	5.671	.004
Intercept	211.979	1	211.979	1023.112	.000
Treatment	7.050	6	1.175	5.671	.004
Error	2.901	14	.207		
Total	221.930	21			
Corrected Total	9.951	20			

a. R Squared = .708 (Adjusted R Squared = .584)

Appendix 15: ANOVA for weight of caeca

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.272[a]	6	.045	1.453	.264
Intercept	5.013	1	5.013	160.910	.000
Treatment	.272	6	.045	1.453	.264
Error	.436	14	.031		
Total	5.720	21			
Corrected Total	.708	20			

a. R Squared = .384 (Adjusted R Squared = .120)

Appendix 16: ANOVA for weight of gizzard

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6.526[a]	6	1.088	4.135	.013
Intercept	104.431	1	104.431	397.011	.000
Treatment	6.526	6	1.088	4.135	.013
Error	3.683	14	.263		
Total	114.639	21			
Corrected Total	10.208	20			

a. R Squared = .639 (Adjusted R Squared = .485)

Appendix 17: ANOVA for liver weight

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.985[a]	6	.164	4.163	.013
Intercept	67.286	1	67.286	1706.944	.000
Treatment	.985	6	.164	4.163	.013
Error	.552	14	.039		
Total	68.822	21			
Corrected Total	1.536	20			

a. R Squared = .641 (Adjusted R Squared = .487)

Appendix 18: ANOVA for weight of pancreas

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.010[a]	6	.002	1.732	.186
Intercept	.491	1	.491	515.205	.000
Treatment	.010	6	.002	1.732	.186
Error	.013	14	.001		
Total	.514	21			
Corrected Total	.023	20			

a. R Squared = .426 (Adjusted R Squared = .180)

Appendix 19: ANOVA for weight of abdominal fat

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.479[a]	6	.580	1.691	.196
Intercept	71.947	1	71.947	209.748	.000
Treatment	3.479	6	.580	1.691	.196
Error	4.802	14	.343		
Total	80.228	21			
Corrected Total	8.282	20			

a. R Squared = .420 (Adjusted R Squared = .172)

Appendix 20: ANOVA for weight of heart

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.028[a]	6	.005	1.291	.323
Intercept	6.254	1	6.254	1719.000	.000
Treatment	.028	6	.005	1.291	.323
Error	.051	14	.004		
Total	6.333	21			
Corrected Total	.079	20			

a. R Squared = .356 (Adjusted R Squared = .080)