EFFECT OF FEEDING WHOLE OR GROUND PEARL MILLET (P*ENNISETUM GLAUCUM*) WITH OR WITHOUT ENZYME SUPPLEMENTATION ON THE PERFORMANCE OF JAPANESE QUAILS (*COTURNIX COTURNIX JAPONICA*)

BY

Mustapha Nalado SABO, B. AGRIC (ZARIA) 2010
M.Sc/AGRIC/13994/2010-2011

A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTERS DEGREE IN ANIMAL SCIENCE

DEPARTMENT OF ANIMAL
SCIENCE FACULTY OF AGRICULTURE
AHMADU BELLO UNIVERSITY, ZARIA

OCTOBER, 2014

DECLARATION

I declare that the work in this thesis entitled 'Effect of feeding whole or ground pearl millet (*Pennisetum glaucum*) with or without enzyme supplementation on the performance of Japanese quails (*Coturnix coturnix japonica*)' has been carried out by me in the Department of Animal Science. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other Institution.

Mustapha Nalado SABO

Name of Student	Signature	Date

CERTIFICATION

This thesis entitled 'EFFECT OF FEEDING WHOLE OR GROUND PEARL MILLET (*PENNISETUM GLAUCUM*) WITH OR WITHOUT ENZYME SUPPLEMENTATION ON THE PERFORMANCE OF JAPANESE QUAILS (*COTURNIX COTURNIX JAPONICA*)' by Mustapha Nalado, SABO meets the regulations governing the award of the degree of Masters in Animal Science of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

Signature…… Date……..
Dr. S. Duru
Chairman, Supervisory Committee

Signature…… Date……..
Dr. S. B. Afolayan
Member, Supervisory Committee

Signature…… Date……..
Dr. S. Duru
Head of Department, Animal Science
Ahmadu Bello University, Zaria

Signature…… Date……..
Prof. A. Z. Hassan
Dean, School of Postgraduate Studies
Ahmadu Bello University, Zaria

ACKNOWLEGDEMENT

All thanks are to Allaah (S.W.T.), the Creator of all, Who has made it possible for me to complete this work. May His peace and blessings be upon His noble Prophet, Muhammad (S.A.W.), his household and his companions and those who follow their footstep till the last day.

My sincere appreciation goes to my thesis supervisors, Dr S Duru and Dr S B Afolayan who have given an immeasurable support to ensure that this work becomes a success. Your thoughtful, timely and constructive criticisms, corrections and recommendations towards improving the quality of this research work will never be forgotten.

My everlasting gratitude goes to my parents; Alhaji Sabo Nalado and Malama Saratu Usman for making my educational bliss a success and for their help financially and morally in the course of this study.

I am also indebted to my siblings, numerous friends, course mates, senior and junior colleagues who have in one way or the other assisted me during the course of this study.

My acknowledgement would be incomplete without recognizing the ability of all the academic and non academic staff of Department of Animal Science for their contributions and constructive criticisms toward improving this work.

Table of Contents

Page

Title Page ---------- i
Declaration ----------ii
Certification ---------- iii
Acknowledgement ---------- iv
Table of Contents ---------- v
List of Tables ---------- viii
Abstract ---------- x

CHAPTER ONE ---------- 1
1.0 INTRODUCTION ---------- 1
1.1 Justification ----------2
1.2 Objectives ---------- 4
1.3 Hypotheses ---------- 4

CHAPTER TWO ---------- 6
2.0 LITERATURE REVIEW ---------- 6
2.1 Whole Grains Feeding in Poultry Nutrition ---------- 6
2.2 Cereals Fed as Whole Grains to Poultry ---------- 7
2.3 Whole Grains Feeding: Implications on the Digestion and Performance of Poultry ---------- 9
2.4 Implications of Feeding Whole Grains to Gastrointestinal Tract Morphology and Physiology and Health of Poultry ---------- 11
2.5 Cost Implications of Feeding Whole Grains to Poultry ---------- 13
2.6 Exogenous Enzymes in Poultry Nutrition ---------- 14
2.7 Whole Grain Feeding and Exogenous Enzyme Efficiency ---------- 17
2.8 Pearl Millet in Poultry Nutrition ---------- 18

CHAPTER THREE ---------- 20
3.0 MATERIALS AND METHODS ---------- 20
3.1 Experimental Site ---------- 20
3.2 Experiments ---------- 20

3.3.1 Experiment 1: Influence of pearl millet inclusion level, form and enzyme supplementation on performance and carcass characteristics of Growing Japanese quails ---------- 20
3.3.2 Experiment 2: Influence of pearl millet inclusion level, form and enzyme supplementation on performance and nutrients digestibility of laying Japanese quails ---------- 23
3.3 Statistical Analysis ---------- 27

CHAPTER FOUR ---------- 30
4.0 RESULTS AND DISCUSSION ---------- 30
4.1 Proximate Composition of the Experimental Diets ---------- 30
4.2.1 Effect of pearl millet inclusion level on the performance of growing Japanese quails (2-6 weeks) ---------- 35
4.2.2 Effect of pearl millet form on the performance of growing Japanese quails (2-6 weeks) ---------- 38
4.2.3 Effect of enzyme supplementation of pearl millet based diets on the performance of growing Japanese quails (2-6 weeks) ---------- 39
4.2.4 Effect of the interaction between pearl millet inclusion level, pearl millet form and enzyme supplementation of pearl millet diets on the performance of growing Japanese quails (2-6 weeks) ---------- 42
4.2.5 Effect of pearl millet inclusion level on the carcass characteristics of growing Japanese quails (2-6 weeks) ---------- 43
4.2.6 Effect of pearl millet form on the carcass characteristics of growing Japanese quails (2-6 weeks) ---------- 45
4.2.7 Effect of enzyme supplementation of pearl millet based diets on the carcass characteristics of growing Japanese quails (2-6 weeks) ---------- 45
4. 2.8 Effect of pearl millet inclusion level on the performance of laying Japanese quails (7-20 weeks) ---------- 49
4.2.9 Effect of pearl millet form on the performance of laying Japanese quails --------- 52
4.2.10 Effect of enzyme supplementation of pearl millet based diets on the performance of laying Japanese quails (7-20 weeks) ---------- 55
4. 2.11 Effect of the interaction between pearl millet inclusion level, pearl millet form and enzyme supplementation on the performance of laying Japanese quails (7-20 weeks) ---------- 58

4. 2.12 Effect of pearl millet inclusion level on the external and internal egg quality characteristics of laying Japanese quails (7-20 weeks) ---------- 58
4. 2.13 Effect of millet form on the external and internal egg quality characteristics of laying Japanese quails (7-20 weeks) ---------- 61
4. 2.14 Effect of enzyme supplementation of pearl millet based diets on the external and internal egg quality characteristics of laying Japanese quails (7-20 weeks) ---------- 66
4. 2.15 Effect of pearl millet inclusion level on the nutrient digestibility of laying Japanese quails (7-20 weeks) ---------- 68
4. 2.16 Effect of pearl millet form on the nutrient digestibility of laying Japanese quails (7-20 weeks) ---------- 70
4. 2.17 Effect of enzyme supplementation of pearl millet diets on the nutrient digestibility of laying Japanese quails (7-20 weeks) ---------- 72

CHAPTER FIVE ---------- 72
5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS ---------- 72
5.1 Summary ---------- 72
5.2 Conclusions ---------- 74
5.3 Recommendations ---------- 74
REFERENCES ---------- 75

LIST OF TABLES

Table 2.1: Proximate composition of millet, maize and sorghum ----------18

Table 3.1: Composition (%) of experimental diets (Experiment 1) ---------- 28

Table 3.2: Composition (%) of Experimental diets (Experiment 2) ---------- 29

Table 4.1: Proximate Chemical Composition of Millet ---------- 31

Table 4.2: Mineral Composition of Millet ---------- 32

Table 4.3: Proximate composition of feed samples (Experiment 1) ---------- 33

Table 4.4: Proximate composition of feed samples (Experiment 2) ---------- 34

Table 4.5: Main effect of Pearl Millet inclusion levels on the performance of growing Japanese quails---------- 37

Table 4.6: Main effect of Millet Form on the performance of growing Japanese quails ---------- 40

Table 4.7: Main effect of Enzyme supplementation of pearl millet diets on the performance of growing Japanese quails ---------- 41

Table 4.8: Main effect of Pearl Millet inclusion level on the carcass characteristics of growing Japanese quails ---------- 44

Table 4.9: Main effect of Pearl Millet form on the carcass characteristics of growing Japanese quails ---------- 47

Table 4.10: Main effect of Enzyme supplementation of pearl millet diets on the carcass characteristics of growing Japanese quails ---------- 48

Table 4.11: Main effect of Pearl Millet inclusion level on the performance of laying Japanese quails ---------- 50

Table 4.12: Main effect of Millet Form on the performance of
laying Japanese quails ---------- 53
Table 4.13: Main effect of Enzyme supplementation of pearl millet diets
on the performance of laying Japanese quails ---------- 56
Table 4.14: Main effect of Pearl Millet inclusion level on the External and
Internal egg quality characteristics of laying Japanese quails ---------- 59
Table 4.15: Main effect of Millet Form on the External and Internal egg quality
characteristics of laying Japanese quails---------- 62
Table 4.16: Main effect of Enzyme supplementation of pearl millet diets on the
External and Internal egg quality characteristics of laying Japanese quails-------- 65
Table 4.17: Main effect of Pearl Millet inclusion level on the Nutrient Digestibility (%)
of Laying Japanese quails ---------- 67
Table 4.18: Main effect of Pearl millet form on the Nutrient Digestibility (%)
of Laying Japanese quails---------- 69
Table 4.19: Main effect of Enzyme supplementation of pearl millet diets on the
Nutrient Digestibility (%) of Laying Japanese quails---------- 71

ABSTRACT

Two experiments were conducted to evaluate the effect of dietary inclusion level (50% or 100%), form (whole or ground), and enzyme supplementation (with or without) of pearl millet at the expense of maize on the performance of Japanese quails. In the first experiment (growing phase), 378 two weeks old unsexed Japanese quails were used in a 2 x 2 x 2 factorial arrangement in a completely randomized design with eight treatments and a control all replicated thrice with 14 quails per replicate in a four-week feeding trial. Feed intake and weight gain were measured weekly. Three quails per treatment were used for carcass evaluation. The second experiment (laying phase) evaluated the effect of pearl millet inclusion (50% or 100%), pearl millet form (whole or ground), and enzyme supplementation of pearl millet diets (with or without) as replacement for maize on the laying performance, egg quality parameters and nutrient's digestibility of laying Japanese quails using 162 seven weeks old female Japanese quails in the same arrangement as in the first experiment with 6 quails per replicate. Egg production, feed intake and body weight were measured and recorded. Egg quality analysis was also carried out. At the end, digestibility study was conducted. In experiment 1, weight gain, age at first lay, weight at first lay and weight of first egg were similar ($P>0.05$) among the treatments. Feed intake, feed conversion ratio, total feed cost and feed cost/kg gain were significantly affected ($P\leq0.05$) by pearl millet inclusion with the control group doing better than either of the pearl millet inclusion levels of 50% or 100%. Dressing percentage, gizzard weight and liver weight were not affected by dietary inclusion level, form or enzyme supplementation of pearl millet diets. Pearl millet inclusion regardless of form or enzyme supplementation led to increased intestinal weight relative to the control. Quails fed pearl millet without enzyme had heavier proventriculus than those fed maize (control). In experiment 2, inclusion level, form (whole or ground) and enzyme supplementation in pearl millet based diets increased feed intake and feed cost/dozen eggs of quails as compared to the control. Feeding pearl millet increased the egg weight, albumen percentage and shell thickness but decreased the egg yolk percentage of laying Japanese quails. Feeding whole pearl millet increased the digestibility of crude protein, ether extract and ash by laying Japanese quails. Pearl millet inclusion increased crude protein digestibility. Enzyme supplementation in pearl millet based diets did not improve their nutrient's digestibility. The results of this study showed that where the price of pearl millet is less than that of maize, whole pearl

millet can conveniently replace maize in the diet of Japanese quails without any adverse effects.

CHAPTER ONE

INTRODUCTION

Feed is the most expensive portion (70-80%) of the cost of raising poultry and this expense is magnified by the fact that most farmers feed ground mash or pelleted diet (Schivera, 2003). In an attempt to reduce this cost, feeding whole grains to poultry is now becoming a common management practice used frequently in Europe, Australia, and Canada (Bennett *et al.*, 2002). This practice reduces feed costs and wastage due to handling, processing, transportation and storage (Bennett *et al.*, 2002; Schivera, 2003; Hidalgo *et al*., 2004; Garcia and Dale, 2006; Biggs and Parsons, 2009; Svihus, 2010). Apart from saving costs, many benefits attributed to feeding whole grains include increased gizzard activity (Bennett *et al*.,2002; Engberg *et al*., 2004; Svihus and Hetland, 2004; Garcia and Dale, 2006; Biggs and Parsons, 2009; Svihus, 2010), increased pancreatic enzyme secretion (Svihus and Hetland, 2004; Svihus, 2010), increased efficiency of exogenous enzymes (Svihus, 2010), increased starch and amino acid digestibility (Engberg *et al*., 2004; Garcia and Dale, 2006; Biggs and Parysons, 2009; Svihus, 2010), greater apparent metabolizable energy (Biggs and Parsons, 2009), improvement in feed conversion ratio (Bennett *et al.*,2002; Engberg *et al*., 2004; Garcia and Dale, 2006) and an indirect effect on reducing many enteric diseases and skeletal problems in poultry (Svihus, 2001; Bennett *et al.*,2002; Engberg *et al*., 2004; Svihus and Hetland, 2004; Biggs and Parsons, 2009).

Pearl millet (P*ennisetum glaucum*) is native to the western edges of the Sahara Desert (Hidalgo *et al*., 2004). Pearl millet grows under difficult ecological conditions, tolerates poor soils better than other cereal crops and it appears to be tolerant of acidic soils with low fertility (Dozier *et al*., 2005; Sade, 2009). From nutritional stand point, pearl millet is an attractive feed grain for non ruminant animals as it combines a high level of

metabolizable energy with up to 50% increase in protein compared to maize. Most strikingly, is the level of the critical amino acids lysine and methionine, in which pearl millet is 40% richer than maize (Abubakar *et al.,* 2006; Dale, 2006). When compared to maize or sorghum, pearl millet is reported to have equal or higher nutritive value (Heuze and Tran, 2012). Pearl millet is free of condensed polyphenils such as tannins in sorghum that can interfere or slow down digestibility (Abubakar *et al.*, 2006).

Japanese quails (*Coturnix coturnix japonica*) are small-bodied birds of the Galliforme family. They were introduced into the Nigerian poultry in 1992 and they have gained tremendous interest among Nigerian populace especially because of their medicinal value, short generation interval, fast growth rate and less susceptibility to common poultry diseases (Bawa, 2006; Olatoye, 2011). They mature in about 6 weeks and are usually in full egg production by 50 days of age, with female quails laying 200-300 eggs in their first year of age.

1.1 Justification

Feed remains the most expensive input in poultry production with cereal grains constituting about 40% of the feed cost (Ijaiya *et al*., 2012). The reduction of feed particle size is the largest user of energy in layer industry where feeds are fed as mash. Hence, any reduction in energy consumption from grinding could significantly lower feed cost (Amerah, 2008). Energy required for grinding comprises between 25 and 30% of feed manufacturing (Umar Faruk *et al.*, 2010a). Blair (2008) pointed out that the poultry digestive system is capable of processing whole grain and it therefore seems unnecessary to feed it a ground diet. Therefore, it is logical to think that the cost incurred in grinding and handling of cereals will be significantly reduced if birds are fed whole grains (Umar Faruk *et al.*, 2010a). In addition, it allows the use of locally grown cereals in the farm

(Umar Faruk *et al.*, 2010a). This is why in northern Europe, the feeding of whole wheat with concentrate to broilers is practiced, as it enables the use of wheat grown on site and this reduces feed costs (Engberg *et al*., 2004).This also reduces the amount of gas emissions due to grinding and transportation and the cost of transport and diet mixing as it may be more economical to transport only a protein concentrate.

Maize is the major source of energy in poultry production accounting for 45 – 65% of poultry feeds (Ijaiya *et al*., 2012). However, with the current trend of global warming, erratic fertilizer supply and increased transport costs, the availability and affordability of maize especially in the semi arid regions is likely to become difficult. Hence the search for viable alternatives and way of improving their utilization becomes imperative. Millet is one of such alternatives, as it is draught tolerant, with acceptable grain yields even on acidic soils with low fertility (Dozier *et al*., 2005).

The high fibre levels of pearl millet could be a limiting factor to its use in poultry diets. The utilization of this fibre could be improved with the use of exogenous enzymes (Singh and Perez-Maldonado, 1999). Svihus (2010) hypothesized that a more developed gizzard as a consequence of structural components may improve efficacy of exogenous enzymes. This could be due to increased retention time in the gizzard and the favourable pH there. Particle size influences retention time in the digestive tract. The larger the particle size, the longer feed is retained, the greater its exposure to endogenous and exogenous enzymes and subsequently the greater the nutrients utilization (Patrick, 2004).

1.2 Objectives

The objectives of this study were to determine;

1. The effect of pearl millet inclusion level as replacement for maize on performance of Japanese quails.
2. The effect of pearl millet form as replacement for maize on performance of Japanese quails.
3. The effect of enzyme supplementation of pearl millet diets as replacement for maize on performance of Japanese quails.
4. The interaction between pearl millet form and enzyme supplementation on performance of Japanese quails.

1.3 Hypotheses

The null hypotheses are:

1. The inclusion of pearl millet as replacement for maize gives similar performance of Japanese quails
2. Feeding whole or ground pearl millet as replacement for maize gives similar performance of Japanese quails
3. Enzyme supplementation of pearl millet diets as replacement for maize gives similar performance of Japanese quails.
4. There is no interaction between form and enzyme supplementation of pearl millet diets on performance of Japanese quails.

The alternate hypotheses are:

1. The inclusion of pearl millet as replacement for maize affects the performance of Japanese quails

2. Feeding whole or ground pearl millet as replacement for maize affects the performance of Japanese quails
3. Enzyme supplementation of pearl millet diets as replacement for maize affects the performance of Japanese quails.
4. There is interaction between form and enzyme supplementation of pearl millet diets on performance of Japanese quails.

CHAPTER TWO

LITERATURE REVIEW

2.1 Whole Grains Feeding in Poultry Nutrition

2.1.1 Introduction

The use of whole grains in feeding poultry is not new. Feeding whole cereal grains as supplements to local poultry has been a practice of rural households in Africa (Kondombo *et al.,* 2005). Free choice-feeding of poultry was used commonly in the past in many countries before commercial poultry production became intensified, the chickens were being allowed to range free in the fields and fed mainly on scratch grains (Blair, 2008). Adult pigeons are often fed mixtures of whole or cracked grains and protein feeds (Leeson and Summers, 2005). Most pet birds are fed diets based on whole seeds rather than complete feeds as pellets (Leeson and Summers, 2005). Chickens can successfully consume 70% of their diet as whole grain when it is choice-fed (Blair, 2008). Laying hens are able to maintain their feed intake for satisfactory egg production regardless of cereal particle size (Blair, 2008). Chickens will readily consume whole wheat, whole oats or whole barley, but they have difficulty with whole maize, which needs to be reduced in particle size (Blair, 2008).

However, for intensive production involving automated feeding systems and high producing stock the earlier feeding system of using whole grains was largely abandoned in favour of the all-mash (complete) or pelleted diet (Blair, 2008). The use of whole grains in commercial poultry feeding began two decades ago in Europe, Australia, and Canada (Bennett *et al.,* 2002). Whole grains feeding is recommended for feeding organic poultry as it approaches the natural feeding system much more closely than other feeding systems (Blair, 2008).

Numerous studies have been published on the effects of whole grains on bird growth performance and cost of production. However, most of these studies were conducted with chickens with a few conducted with Japanese quails and other poultry species.

2.2 Cereals Fed as Whole Grains to Poultry

2.2.1 Wheat

Wheat has received the greatest attention with regards to whole grain feeding in commercial poultry production. Feeding whole wheat is a common practice in many countries where there is high production of wheat (Amerah, 2008). Offering whole wheat and a balancer feed with adequate minerals and vitamins provides a very economical way for farmers to utilize home-grown wheat (Leeson and Summers, 2005). Male broilers voluntarily consumed 15% - 41% of their ration as wheat from 7-49 days of age when offered a choice between whole wheat and crumbled broiler starter and finisher diet (Leeson and Summers, 2005). Maize can be replaced with wheat up to 75 per cent level as an alternative source of energy in the ration of laying quails depending on the cost and availability of these ingredients (Seema *et al.*,2007)**.**

2.2.2 Barley

Barley can be used in choice-feeding studies but due to the physical structure of the kernel however,with its sharp spinets, birds are often reluctant to consume whole barley grain (Leeson and Summers, 2005). Ernst *et al.* (1994) found that whole barley could substitute for up to 40% of the dietary corn without a deleterious effect on weight gain of broilers. Turkeys at least seem to readily eat whole barley in a choice-feeding situation after 50 days of age (Leeson and Summers, 2005). Feeding whole barley to chicks increased gizzard weights when compared with chicks fed the ground maize-soyabean diet as observed by Biggs and Parsons (2009). They also observed that at 21 days, chicks fed part of their diet as whole barley had a significant improvement in

Nitrogen – corrected Metabolizable energy (MEn) when compared with chicks fed the maize-soyabean diet.

2.2.3 Pearl Millet

Pearl millet is relatively small (2 to 3mm) in size. This makes it suitable to be incorporated into broiler diets in whole form (Hidalgo *et al.*, 2004). Production performance of laying quails was not affected by the use of increasing levels of pearl millet grain and pearl millet is a good maize substitute for Japanese quail, but a yolk pigment should be used in the ration (Leandro *et al.*,1999). Hidalgo *et al*. (2004) found that whole pearl millet seeds can be readily broken down by young broilers and thus be incorporated into their diets. They also observed that the digestion of the whole pearl millet, as measured by the presence of whole pearl millet seed in the excreta was 95.3 - 98.5% for diets containing 5 - 20% whole pearl millet with no differences in digestibility values between the dietary treatments. Similarly, they reported that feeding whole pearl millet seeds to broilers from 1 to 15 days of age resulted in performance equivalent to that of broilers fed standard corn-soybean diet. Seema *et al.*(2007) observed that maize can be replaced with millet up to 75% level as an alternative source of energy in the ration of laying quails depending on the cost and availability of these ingredients. Whole pearl millet seeds can be incorporated at 10% level in broiler diets without adversely affecting broiler performance (U. K. C. A. G., 2012). Laying hens can be fed up to 15 % dietary level for unground pearl millet as a replacement for maize in soybean-maize based diets (Heuzé and Tran, 2012).

2.2.4 Sorghum

Sorghum whole seeds can be used for feeding geese with less breast development compared with maize (Arroyo *et al.*, 2012). Biggs and Parsons, (2009) reported that chicks fed 10 and 20% whole sorghum had consistently lower weight gains and feed

efficiencies than chicks fed the maize-soyabean diet from 0 to 21days age. In contrast they found that feeding whole sorghum to the chicks increased gizzard weights when compared with chicks fed the maize-soyabean diet. They also reported that whole sorghum had little positive effect on amino acids digestibility (Biggs and Parsons, 2009).

2.2.5 Oats and Triticale

Oats are difficult to grind. Ernst *et al.* (1994) used whole oats after 15 wk and sprinkled grit over the feed every second day. Whole oats could substitute for up to 40% of the dietary corn without a deleterious effect on weight gain of broilers (Ernst *et al.*, 1994). Jones and Taylor (2001) showed that whole triticale could be utilized successfully in pelleted diets with broilers, giving production results similar to (or better than) those with pelleted diets containing ground triticale.

2.3 Whole Grains Feeding: Implications on the Digestion and Performance of Poultry

Numerous studies have been published on the effects of whole grain diets on bird growth performance. Differences in diet composition, feed form (pelleted with or without the whole grain or in mash form), age of birds when exposed to whole grains, and the amount of whole grain provided make comparisons among experimental results difficult (Biggs and Parsons, 2009).

Most studies reported that the early growth of chickens is unaffected by the inclusion of a whole grain (Biggs and Parsons, 2009). Hidalgo *et al.* (2004) reported that digestion of the whole pearl millet, as measured by the presence of whole pearl millet seed in the excreta was 95.3 - 98.5% for diets containing 5 - 20% whole pearl millet with no differences in digestibility values between the dietary treatments. Their results indicate that whole pearl

millet seeds can be readily broken down by young broilers and thus be incorporated into their diets. Similarly, after incorporating the whole pearl millet seeds into broiler diets from 1 to 15 days of age, Hidalgo *et al*. (2004) observed that their performance was equivalent to broilers fed a standard maize-soybean diet. Enberg *et al*. (2004) reported that the inclusion of whole grains improves broiler performance, in particular the feed gain ratio which may be related to an increased starch digestibility. Leeson and Summers, (2005) reported that feeding whole grains can improve starch digestibility and is not detrimental to feed utilization, when the whole grains are incorporated into broiler diets at low levels. Male broilers voluntarily consumed15% - 41% of their ration as wheat from 7-49 days when offered a choice between whole wheat and crumbled broiler starter and finisher diet with slight depressions in body weight, reduced carcass weight and breast yield by about 10% (Leeson and Summers, 2005). Svihus *et al.* (2004) found that replacement of ground wheat with whole wheat increased apparent metabolizable energy (AME) and starch digestibility measured at ileal as well as faecal level. Also jejunal chyme showed increased amylase activity and bile salt concentration (Svihus *et al.*, 2004). Svihus *et al.* (2004) found that replacement of ground wheat with whole wheat increased dry matter content as well as bile content of gizzard, and stimulated an increase in gizzard as well as pancreas weight. They posited that results from this experiment indicate that the improved feed value sometimes observed with whole wheat may be associated with modulation of digestive processes resulting in increased pancreas and liver secretions. Whole grain feeding has significant effect on gizzard development and have unchanged or improved egg production and feed efficiency equal to that of birds fed on all mash diets where the grain has been pre-ground prior to feeding (Evans *et al.*, 2005). In the same vein, Biggs and Parsons, (2009) observed that at 7 days and 21 days chicks fed 10% whole barley had an improved digestibility of most amino acids when compared with chicks fed

the maize-soyabean meal diet and that at 21 days, whole sorghum had little positive effect on amino acids digestibility. Robinson (1985) reported that diet consisting of unground wheat, unground sorghum, limestone grit and protein concentrate resulted in a higher egg number and egg mass than a fully ground diet.

However, generally speaking, digestibility and performance benefits attributed to feeding whole grains include increased gizzard activity (Bennett *et al.*,2002; Svihus and Hetland, 2004; Garcia and Dale, 2006; Biggs and Parsons, 2009; Svihus, 2010), increased pancreatic enzyme secretion (Svihus and Hetland, 2004; Svihus, 2010), increased efficiency of exogenous enzymes (Svihus, 2010), increased starch and amino acid digestibility (Garcia and Dale, 2006; Biggs and Parsons, 2009; Svihus, 2010), greater apparent metabolizable energy (Biggs and Parsons, 2009;), improvement in feed conversion ratio (Garcia and Dale, 2006; Bennett *et al.*,2002).

2.4 Implications of Feeding Whole Grains to Gastrointestinal Tract Morphology and Physiology and Health of Poultry

The particle size of feed (e.g., coarsely ground mash vs. whole grains) has been shown to have a strong effect on the morphological and physiological function of the poultry gastrointestinal tract (Matthias and Hasan, 2003; Enberg *et al*., 2004).

In his review Blair (2008) informed that several research findings have demonstrated that whole grain feeding has beneficial effects on the overall health of poultry. They revealed that a better-developed gizzard has an important function as a barrier organ in preventing pathogenic bacteria from entering the distal digestive tract. Hence, some researchers have suggested that whole grain could be considered as an effective alternative to antibiotic growth promoters.

Enberg *et al*. (2004) reported that the inclusion of whole grains prevents proventricular dilatation and mortality related to ascites. Feeding whole grain limits microbial growth by stimulating gizzard activity and manipulating digesta pH (Leeson and Summers, 2005). This reduces many enteric diseases and skeletal problems in poultry (Svihus, 2001; Bennett *et al.,* 2002; Svihus and Hetland, 2004; Biggs and Parsons, 2009).

Taylor and Jones (2004) reported that the incidence of proventricular dilatation and mortality from ascites was reduced in broilers when whole grain was incorporated into pelleted diets at 200 g/kg. Evans *et al*. (2005) studied the effects of feeding laying hens on diets containing wheat in whole or ground form on coccidial oocyst output after being challenged with coccidiosis. They found that birds fed on the diet with whole wheat had a significantly lower (2.5 times) oocyst output than birds fed on the diet with ground wheat, suggesting that an active functioning gizzard can play a role in resistance to coccidiosis. Whole wheat feeding stimulates gizzard and gastric motility and the enhanced activity within this acidic environment is thought to reduce oocyte viability and coccidiosis (Leeson and Summers, 2005). Chickens fed free-choice on a high (420g/kg CP) protein concentrate and whole wheat were more resistant to coccidiosis than those on complete high-fibre diets (Blair, 2008). In male broiler chickens, oocyst output has been shown to be negatively correlated with relative gizzard size, both with a conventional complete diet or free choice-feeding (Blair, 2008).

Engberg *et al*. (2004) reported an increase in intestinal counts of some beneficial Lactobacillus species, decrease in *E. coli* counts, *Salmonella* spp. and *Clostridium perfringens* (responsible for necrotic enteritis) as a result of whole grain feeding. Bjerrum *et al*. (2005) reported lower numbers of rifampicin-resistant *Salmonella typhimurium* strain

in the gizzard and ileum of broiler birds receiving whole wheat compared with pellet-fed birds.

2.5 Cost Implications of Feeding Whole Grains to Poultry

Feed remains the most expensive input in poultry production with cereal grains costing about 40% of the feed cost (Ijaiya *et al*., 2012). Feed processing represents a significant portion of feed costs and likely gives the greatest opportunity for influencing animal performance beyond nutritional adequacy (Koster, 2003). Feed processing and the costs associated with processing include a wide range of unit operations including receiving, grinding, proportioning, mixing, pelleting, load out, and delivery (Koster, 2003). The cost of feed processing (grinding, mixing, pelleting, handling and transportation) increases the original price of whole cereals by over a fifth in most compounding operations (Kermanshahi and Classen, 2001).

Grinding is a major function of feed manufacturing and is by far the most common method of feed processing (Koster, 2003). The process of grinding requires about 20 kW/h/t of grain (Henuk and Dingle, 2002). The reduction of feed particle size is the largest user of energy in layer industry where feeds are fed as mash. Hence, any reduction in energy consumption from grinding could significantly lower feed cost (Amerah, 2008).

Feeding whole grains reduces feed costs and wastage due to handling, processing, transport and storage (Bennett *et al.,* 2002; Schivera, 2003; Hidalgo *et al*., 2004; Garcia and Dale, 2006; Biggs and Parsons, 2009; Svihus, 2010).

Blair (2008) pointed out that since the bird has a digestive system capable of processing whole grain it seems unnecessary to feed it a pre-ground diet. The bird's gizzard is capable of grinding whole grains, provided that hard grit is available. In this way the grinding cost is eliminated by feeding whole grains (Kermanshahi and Classen, 2001).

Feeding whole grain diets provide an opportunity to reduce cost through not having to process the grain prior to feeding (Evans *et al.*, 2005). The use of whole grains, especially wheat and barley, in poultry production has gained favor in many European countries as a way to reduce feed costs. Typically the whole grains are not incorporated into the pellet but simply mixed with the pellets prior to being delivered to the flock (Hidalgo *et al.*, 2004). In northern Europe, the feeding of whole wheat as a supplement to a concentrated compound feed for broilers is currently a common practice. This feeding strategy enables the broiler producer to use wheat grown on site, which reduces feed costs (Enberg *et al*., 2004).

Seema *et al.*(2007) found that **t**here was reduction in feeding cost by 4.73 and 7.24% when 50 and 70% of maize was replaced with millet respectively in the diet of laying quails. Robinson (1985) reported that laying hens' diet consisting of unground wheat, unground sorghum, limestone grit and protein concentrate resulted in a higher financial return than a fully ground diet. Another work with laying hens resulted in feed cost saving of 7.4 to 17.6% when whole wheat was used (Kermanshahi and Classen, 2001). Leeson and Summers (2005) reported a saving of 10% in feed cost per kg live weight gain of male broilers when fed 15% - 41% of their ration as whole wheat. Feeding whole grains also presents energy savings in feed preparation.

2.6 Exogenous enzymes in poultry nutrition

Scientific studies describing the use of exogenous enzymes date back to 1920s (Bedford and Partridge, 2001). However, the first commercial use of feed enzymes dates back to 1984 in Finland, where opportunities existed to improve significantly the nutritional quality of barley based rations by inclusions of enzymes derived from the brewing industry (Bedford and Partridge, 2001). The principal rationale for the use of enzymes is to improve the nutritive value of feedstuffs (Sheppy, 2001). The supplementation of animal feeds with

enzymes also increases the efficiency of digestion and is an extension of the animal's own digestive process (Sheppy, 2001).

The four main reasons for using enzymes in animal feed as outlined by Munir and Maqsood (2013) are:

i. To breakdown anti-nutritional factors that are present in many feed ingredients. These substances, many of which are not susceptible to digestion by the animal's endogenous digestive enzymes, can interfere with the normal digestion, causing poor performance and digestive upsets.
ii. To increase the availability of the starches, proteins, and minerals that are either enclosed within the fibre-rich cell wall and, therefore, not accessible to the animal's own digestive enzymes, or bound up in a chemical form that the animal is unable to digest (e,g, phosphorus as phytic acid).
iii. To break down specific chemical bonds in raw materials that are not usually broken down by animal's own enzymes, thus releasing more nutrients.
iv. To supplement the enzymes produced by young animals where, because of the immaturity of their own digestive system, endogenous enzyme production may be inadequate.

The improvements obtained by adding enzymes to the diet of poultry depend on many factors, including the type and amount of cereal in the diet; the level of anti-nutritive factor in the cereal, which can vary within a given cereal; the spectrum and concentration of enzymes used; the type of bird and their age (young bird tend to respond better to enzymes than older birds) (Munir and Maqsood, 2013). Improvement in feed conversion ratio (FCR) that may be expected to be achieved via the use of currently available enzymes for wheat- or barley-based diets (especially for carbohydrases) is higher, or at least more consistent,

than may be anticipated via the use of enzymes for diets based on maize (Cowieson *et al*., 2006).

Response to enzyme supplementation in diets of poultry depends on the type of the cereal, with laying performance improved more in barley-based diets than for wheat and maize based diets. Feed conversion ratio was also improved for wheat, barley and maize diets in the same order. Enzymes allow for the use of poor quality raw materials such as wheat bran or rye in rates of up to 45% without adverse effects on performance. Feed can therefore be saved using enzyme (Geraert and Dalibard, 2003). To benefit from the use of exogenous enzymes, reformulation of diets is often recommended. Decreasing the energy value of sorghum or maize-soyabean meal based diets by 25, 50 or 75 kcal/kg could be totally compensated by enzyme supplementation with even further improvement of feed conversion ratio and egg mass on the sorghum based diet. Improvement in "on-top" of the feed addition of exogenous enzyme is usually slight and might only be observed when all the parameters are precisely recorded. Improvement in energy digestibility is not always accompanied by reduced feed intake in layers.

Several studies have reported that the inclusion of degradative enzymes in animal feedstuffs can increase the availability of nutrients (Kermanshahi and Classen, 2001). Exogenic enzymes such as xylanases are currently added to commercial wheat-based compound feed for broilers in order to improve growth and feed conversion ratio (Enberg *et al.*, 2004). Udeybir *et al.* (2009) observed no significant differences in feed intake and feed conversion ratio in the diets they fed to broilers with or without enzyme. On the contrary, Manwar and Mandal (2009) reported that the addition of enzymes to raw pearl-millet based diet improved the body weight gain of broiler chickens. and hence supplementation of the feed enzymes in pearl millet based diet may improve the utilization of pearl millet in broiler chickens. Also Alam *et al.* (2003) reported that growth rate, feed

intake, feed conversion were increased by addition of exogenous enzymes. Body weights of birds supplemented with xylanase were higher than those of nonsupplemented birds (Engberg *et al.*, 2004).

Benefits linked to NSP-enzyme supplementation of layer feeds have been shown in several trials: from energy digestibility determinations to laying performance and egg quality measurements. Enzyme addition does not appear to affect egg quality in terms of yolk colour, egg composition or eggshell characteristics (Geraert and Dalibard, 2003). An improvement in yolk colour has been reported due to improved lipid digestibility by enzyme supplementation. Such an improvement will save carotenoid supplementation. No significant effect of enzyme supplementation was observed on egg characteristics. Addition of enzyme in layer feeds containing either wheat barley or even maize improve the nutritive value of the feeds and thus their efficacy (Geraert and Dalibard, 2003).

2.7 Whole Grain Feeding and Exogenous Enzyme Efficiency

Particle size influences retention time particularly in the upper digestive tract. The longer feed is retained, the greater its exposure to phytase and phosphatase enzymes and the greater the Phosphorus utilization (Patrick, 2004). Svihus (2010) opined that increased retention time in the gizzard may also potentially improve efficacy of exogenous enzymes added to the diet, especially as it is often believed that an exogenous enzyme such as phytase exerts its main function in the gizzard due to the favourable pH there. Thus, it is a reasonable hypothesis that a more developed gizzard as a consequence of structural components may improve efficacy of this particular enzyme. Engberg *et al.* (2004) observed an interaction between the effects of wheat form and enzyme addition.

2.8 Pearl Millet in poultry nutrition

Literature on the use of millet as energy source for poultry (especially Japanese quails) appears to be limited (Medugu *et al*., 2011). Millet is reported to have lower metabolizable energy, higher crude protein, crude fibre and ash than maize and sorghum (Medugu *et al*., 2010; Medugu *et al*., 2011; Ijaiya *et al*., 2012,) (Table 2.1). Many researchers have suggested that millet can replace maize without adverse effects on performance in both broiler and layer diets (Hidalgo *et al*., 2004; Garcia and Dale, 2006; Umar Faruk *et al*., 2010b; Medugu *et al*., 2011; Ibitoye *et al*., 2012).

Table 2.1: Proximate composition of millet, maize and sorghum

Composition	Millet (Aduku, 1993)	Maize (Medugu *et al*., 2010)	Sorghum (Low tannin) (Medugu *et al*., 2010)
Energy (ME kcal/kg)	2984	3318.98	3308.08
Protein (%)	11.5	10.10	11.55
Ether extract (%)	3.6	3.25	4.25
Crude fibre (%)	6.5	5..50	5.75
Ash (%)	3.2	1.00	2.25

Experiments with broiler and layer hens have showed that pearl millet could be incorporated in their diets without any adverse effect on their performance (Singh and Perez-Maldonado, 1999; Faruk, 2010; Heuzé and Tran, 2012). Collins *et al.* (1997) replaced maize with pearl millet in Leghorn laying hen diets during the second production cycle and observed that dietary treatment had no effect on feed intake, body weight gain,

egg production, feed conversion (feed per dozen eggs or feed per gram of egg), mortality, egg weight, yolk weight, and percentage yolk but reduced yolk pigmentation. Feeding pearl millet also produces eggs significantly enriched in n-3 fatty acids. (Collins *et al.*, 1997). Kumar *et al.* (1991) evaluated levels of 0, 30 and 60% of corn replacement by pearl millet in laying hen diets and reported no negative effects in egg production, feed intake, feed conversion and body weight. A later study has also shown that the inclusion of pearl millet in broiler chicken diets at levels up to 50% resulted in performance and carcass quality similar to or better than corn-based diets (Davis *et al.* , 2003). There was a linear reduction in feed intake, egg production, egg weight and yolk pigmentation index with increasing inclusion levels of pearl millet as observed by (Filardi *et al.*, 2005). The increase of pearl millet inclusion up till 51% only improved egg shell percentage and did not result in lower production costs, but should be more viable in regions where it is less expensive than corn (Filardi *et al.*, 2005).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experimental Site

The study was conducted at the Poultry Unit of the Research and Training Farm of the Department of Animal Science, Ahmadu Bello University Zaria, located within Northern Guinea Savannah Zone of Nigeria at latitude 11˚ 09' 06″N longitude 7˚ 3' 8″E with an altitude of 706m above sea level (GPS) and having a tropical continental climate with marked periods of rainfall ranging from 1102 mm to 1904 mm. The mean temperature fluctuates from 31^{o}C maximum in dry season to 18^{o}C minimum in wet season (as reported by Hassan *et al.*, 2013).

3.2 Experiments

Two experiments were carried out to determine the influence of whole millet inclusion and enzyme supplementation on performance, carcass characteristics and nutrient digestibility of Japanese quails.

3.2.1 Experiment 1: Influence of millet inclusion level, form and enzyme supplementation on performance and carcass characteristics of Growing Japanese quails (2-6weeks).

3.2.1.1 Experimental birds and their management

Two weeks old Japanese quails were sourced from a private farm in Jos, Plateau state. The birds were reared in constructed cages and all routine management practices were strictly adhered to. Feed and water were provided *ad libitum*. The birds were given the experimental diets from the end of the second week until 42 days of age (growing period).

3.2.1.2 Experimental design

378 two weeks old unsexed Japanese quails were used in 2 x 2 x 2 factorial arrangement in a completely randomized design with two levels of millet inclusion (50 and 100%) as replacement for maize, two forms of millet (whole or ground) and enzyme supplementation (with or without). The birds were allocated to nine dietary treatments with each treatment having three replicates and 14 birds per replicate.

3.2.1.3 Experimental diets

Ingredients for the experimental diets were obtained from local markets and feed millers within Zaria. A maize based layer diet was formulated according to the NRC (1994) recommendation (24% CP and 2900MEkcal/kg) as the control. Pearl millet replaced maize on a weight to weight basis for the different inclusion levels and forms and each with or without enzyme supplementation as shown in table 3.1.

Treatment 1 (control) ----------0% pearl millet

Treatment 2 ----------50% whole pearl millet

Treatment 3 ----------50% whole pearl millet with enzyme

Treatment 4 ----------100% whole pearl millet

Treatment 5 ----------100% whole pearl millet with enzyme

Treatment 6 ----------50% pearl ground millet

Treatment 7 ----------50% ground pearl millet with enzyme

Treatment 8 ----------100% pearl ground millet

Treatment 9 ----------100% ground pearl millet with enzyme

The exogenous enzyme used in this study was Maxigrain®. Maxigrain® enzyme is a multi-enzyme compound of β-glucanase, xylanase, phytase, arabinoxylanase and a mixture of yeast and minerals produced by the Bio-Organics Ltd.

3.2.1.4 Measurements

i. Proximate analysis

Proximate analyses of pearl millet and that of representative samples of the experimental diets were carried out according to methods described by AOAC (2003) at the Animal Science Biochemical Laboratory of Ahmadu Bello University, Zaria.

ii. Mineral analysis

Mineral analysis of the millet was carried out using an Atomic Absorption Spectrophotometer at Multi-user Scientific Research Laboratory, Faculty of Science and a Spectrophotometer at Soil Chemistry Laboratory at the Department of Soil Science, Ahmadu Bello University, Zaria.

iii. Feed intake and live weight gain

A given quantity of feed was measured and fed to the birds on a weekly basis. From which weekly feed intake was measured. Daily feed intake and total feed intake were determined. The birds were weighed in the early morning before receiving any feed and water using a weighing balance at weekly intervals during the experimental period. Initial and final body weights of the Japanese quails were measured at the beginning and end of the experiment respectively. Average daily weight gain and feed conversion ratio were determined.

$$\text{Feed conversion ratio} = \frac{\text{Feed intake (g)}}{\text{Weight gain (g)}} \times 100$$

iv. Mortality

Mortality was recorded as it occured.

v. Point of lay

Age at first lay, weight at first lay and weight of first egg were measured and recorded immediately the first egg was laid for each treatment.

vi. Carcass evaluation

At the end of the growing period (42 days), carcass evaluation was carried out using three quails around the average live body weight of each treatment. The quails were fasted, then individually weighed to the nearest gram, and slaughtered by severing the jugular vein. Few minutes after bleeding, each bird was dipped into a hot water bath for two minutes, and feathers were removed by hand. After the removal of head, the carcasses were eviscerated manually, they were then weighed to obtain carcass weight. Dressing percentage was determined. Weights of different parts of the gut were measured using a digital scale and recorded.

$$\text{Dressing percentage (\%)} = \frac{\text{Carcass weight (g)}}{\text{Live weight (g)}} \times 100$$

3.2.2 Experiment 2: Influence of millet inclusion level, form and enzyme supplementation on performance, egg quality and nutrients' digestibility of laying Japanese quails (8-20 weeks).

3.2.2.1 Experimental birds and their management

Female Japanese quails from experiment 1 above were used for this experiment. The birds were reared in constructed cages and all routine management practices were strictly adhered to. Feed and water were provided *ad libitum*. The birds were given the

experimental diets from the 8th week until when they were 20 weeks of age (laying period).

3.2.2.2 Experimental design

162 seven weeks old female Japanese quails were used in 2 x 2 x 2 factorial arrangement in a completely randomized design with two levels of millet inclusion (50 and 100) as replacement for maize, two forms of millet (whole or mash) and enzyme supplementation (with or without). The birds were allocated to 9 dietary treatments with each treatment having three replicates and 6 birds per replicate.

3.2.2.3 Experimental diets

Ingredients for the experimental diets were obtained from local markets and feed millers within Zaria. A maize based layer diet was formulated according to the NRC (1994) recommendation (20% CP and 2900MEkcal/kg) as the control. Pearl millet replaced maize on a weight to weight basis for the different inclusion levels and forms and each with or without enzyme supplementation as mentioned in experiment 1 and shown in table 3.2.

The exogenous enzyme used in this study was Maxigrain®.

3.2.2.4 Measurements

i. Feed intake and live weight gain

The Japanese quails were weighed to the nearest gram in the early morning before receiving any feed and water at weekly intervals during the experimental period. Total feed intake, Initial body weight and final body weight were measured. Average daily feed intake, weight change and feed conversion ratio were determined.

$$\text{weight change (\%)} = \frac{\text{Current body weight – previous body weight}}{\text{Previous body weight}} \times 100$$

$$\text{Feed conversion ratio} = \frac{\text{Feed intake (g)}}{\text{Number of dozen eggs produced}} \times 100$$

ii. Mortality

Mortality was recorded as it occured.

iii. Egg Production

Age and weight at first lay were recorded. Egg production and egg weight were recorded daily and pooled weekly to calculate hen day production (HDP) and hen housed production (HHP) using the formulae below:

$$\text{Hen day production (\%)} = \frac{\text{No. of eggs laid a day}}{\text{No. of birds available that day}} \times 100$$

$$\text{Hen housed production (\%)} = \frac{\text{Total no. of eggs laid}}{\text{Total no. of birds housed}} \times 100$$

iv. Determination of egg quality parameters

Three fresh eggs were randomly picked from each replicate fortnightly starting from the 10^{th} week to determine the egg quality parameters. The parameters determined were:

- Egg weight

  The eggs were weighed using a sensitive electronic scale to the nearest 0.01g. The values were used to calculate the average weight of an egg per replicate.

- Albumen weight, yolk weight and shell weight

  Albumen weight and yolk weight were measured for individual egg to the nearest 0.01g using a sensitive electronic scale. Shell weight was also measured after sun drying to remove moisture.

- Shell thickness

  Shell thickness was measured for individual sun dried egg shells to the nearest 0.01mm using a micrometer screw gauge.

- Egg Haugh Unit

  Each egg was broken around the middle; care was taken to keep the yolk intact. The albumen height was measured with the aid of Vernier calipers and values obtained were used to calculate the haugh unit values for each replicate, using the formula outlined by Haugh (1937).

  $$HU = 100\log_{10} (H - 1.7W^{0.37} + 7.6)$$

  Where HU = Haugh unit

  H = observed height of the albumen in (mm)

  W = weight of eggs in gram

3.2.2.5 Digestibility Trial

At the end of the experiment, 3 quails per treatment (1 bird per replicate) were randomly picked and housed in individual cages. They were then fasted for 24hrs. After the 24hrs of fasting, feeding for fecal collection was started immediately. A known quantity of each diet was weighed per bird for the period of the study. The birds were fed *ad libitum.* All faeces voided were collected by placing a polythene sheet on the floor of the cages. The faeces were cleaned of wasted feed, feathers and other foreign materials to avoid contamination. The faeces collected from each bird were labelled according to treatment and sun dried. After four days of faecal collection, faecal samples collected were dried in the oven at 70^{o}C for 24hrs. The dried faecal samples were allowed to equilibrate with atmosphere and then weighed. The faecal samples were bulked and samples were collected

for proximate analysis. The dried samples were assayed for their proximate composition (Dry matter, Crude Protein, Ether extract, Crude fibre and Ash) in the Animal Science Laboratory, Ahmadu Bello University, Zaria. The percentage digestibility was calculated using the formular below;

$$\text{Nutrients Digestibility (\%)} = \frac{\text{Nutrients in diet} - \text{Nutrients in feaces}}{\text{Nutrients in diet}} \times 100\%$$

3.3 Statistical Analysis

Data from both experiments were analyzed using the general linear models (GLM) procedure of SAS software (SAS, 1994). Data were subjected to analysis of variance. Where the analysis of variance was significant, Duncan's multiple range test was used to separate treatment means other than control (0%PM) (Steel and Torrie, 1980). The control was contrasted from each of the treatments using Dunnett test at 5%.

The model for the experiment is:

$Y_{ijkl} = \mu + F_i + L_j + Z_k + (FZ)_{ik} + E_{ijkl}$

where:

Y_{ijkl} = observation l in level i of factor F, level j of factor L and k of factor Z

μ = the overall mean

F_i = the effect of level i of factor F (form of millet; whole or ground millet)

L_j = the effect of level j of factor L (inclusion level; 50 or 100)

Z_k = the effect of level k of factor Z (enzyme supplementation; with or without enzyme)

$(FZ)_{ik}$ = the effect of the interaction of level i of factor F with level k of factor Z

E_{ijkl} = random error with mean 0 and variance σ^2

Table 3.1: Composition (%) of Experimental Diets (Experiment 1)

Ingredients	0%PM	50%WPM	50%WPM+EN	100%WPM	100%WPM + EN	50%GPM	50%GPM +EN	100%GPM	100%GPM+EN
Maize	46.0	23.0	23.0	-	-	23.0	23.0	-	-
Pearl millet	-	23.0	23.0	46.0	46.0	23.0	23.0	46.0	46.0
Soyabean meal	20	20	20	20	20	20	20	20	20
Groundnut cake	25	25	25	25	25	25	25	25	25
Maize offal	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25
Palm oil	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Limestone	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Bone meal	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vit. Premix*	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Lysine	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Methionine	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Maxigrain	-	-	0.01	-	0.01	-	0.01	-	0.01
Total	100	100	100	100	100	100	100	100	100
Calculated analysis									
Crude protein (%)	24.8	25.4	25.4	25.9	25.9	25.4	25.4	25.9	25.9
ME (kcal/kg)	2896	2696	2696	2495	2495	2696	2696	2495	2495
Ether extract (%)	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Crude fibre (%)	3.14	4.4	4.4	5.6	5.6	4.4	4.4	5.6	5.6
Calcium (%)	1.2	1.2	1.2	1.4	1.4	1.2	1.2	1.4	1.4
Phosphorus (%)	0.7	0.7	0.7	0.6	0.6	0.7	0.7	0.6	0.6
Lysine (%)	1.3	1.3	1.3	1.4	1.4	1.3	1.3	1.4	1.4
Methionine (%)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Feed cost(₦/kg)	95.82	97.53	98.13	101.44	102.04	99.73	100.33	103.64	104.24

PM- pearl millet, WPM- whole pearl millet, GPM – ground pearl millet, EN – enzyme

*Biomix premix supplied the following per kg diet: vit. A, 10000 I.U; vit. D, 2000 I.I; vit. E, 25 mg; vit. K, 2 mg; Thiamine B1, 1.8 mg; Riboflavin B2, 5 mg; Pyridoxine B6, 3.5 mg; Niacin, 28 mg; vit. B12 0.015 mg; Pantothenic acid, 7.5 mg; Folic acid, 0.75 mg; Biotin, 0.06 mg; chlorine chloride, 300 mg; Manganese, 40 mg; Zinc, 30 mg; Iron, 20 mg; Copper, 3 mg; Iodine, 1 mg; Selenium, 0.2 mg; Cobalt, 0.2 mg

Table 3.2: Composition (%) of Experimental Diets (Experiment 2)

Ingredients	0%PM	50%WPM	50%WPM +EN	100%WPM	100%WPM + EN	50%GPM	50%GPM +EN	100%GPM	100%GPM+EN
Maize	56.0	28.0	28.0	-	-	28.0	28.0	-	-
Pearl millet	-	28.0	28.0	56.0	56.0	28.0	28.0	56.0	56.0
Soyabean meal	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
Groundnut cake	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Maize offal	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Palm oil	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Limestone	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Bone meal	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vit. Premix*	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Lysine	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Methionine	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Maxigrain	-	-	0.01	-	0.01	-	0.01	-	0.01
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated analysis									
Crude protein (%)	19.6	20.3	20.3	21.0	21.0	20.3	20.3	21.0	21.0
ME (kcal/kg)	2889	2645	2645	2401	2401	2645	2645	2401	2401
Ether extract (%)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Crude fibre (%)	2.9	4.4	4.4	5.9	5.9	4.4	4.4	5.9	5.9
Calcium (%)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Phosphorus (%)	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Lysine (%)	1.1	1.1	1.1	1.2	1.2	1.1	1.1	1.2	1.2
Methionine (%)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Feed cost(₦/kg)	92.90	95.46	96.06	100.22	100.82	97.66	98.26	102.42	103.02

PM- pearl millet, WPM- whole pearl millet, GPM – ground pearl millet, EN – enzyme

*Biomix Layers premix supplied the following per kg diet; Vit.A, 100000iu; Vit.D3; 20000iu;Vit.E, 100iu; Vit.K, 20mg; ThiamineB1, 15mg; RiboflavinB2, 40mg; PyridoxineB6, 15mg; Niacine, 150mg; Vit.B12, 0.01mg; Pantothenic acid, 50mg; Folic acid, 5mg; Biotin, 0.2mg; Choline chloride, 2mg; Anti oxidant, 1.25g; Manganese, 0.8g; Zinc, 0.5g; Iron, 0.2g; Copper, 0.05g; Iodine, 0.12g;Selenium, 2mg; Cobalt, 2mg.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Proximate Composition of the Experimental Diets

Tables 4.1, 4.2, 4.3 and 4.4 show the proximate composition of millet, mineral composition of millet, proximate composition of the starter diet and proximate composition of the layer diet respectively.

The proximate composition of the three samples of millet analyzed (table 4.1) revealed that it has an average dry matter of 89.67% which is lower than the 96.25% reported by Medugu *et al.*(2010) and 91% reported by NRC (1994). Its crude protein value (9.21%) is lower than 11.5% reported by Aduku (1993), 14% reported by NRC (1994) and 12-14% reported by Garcia and Dale (2006) and Hidalgo *et al.* (2004). Its ether extract value (2.89%) less than 3.6%, 5.50% and 4% reported by Aduku (19933), Medugu *et al.*(2010) and NRC (1994) respectively. Its nitrogen free extract content (79.95%) was higher than 68.40% reported by Medugu *et al.*(2010). Its ash content (1.83%) is very much lower than the 3.2% reported by Aduku (2003) and relatively close to the 2.25% reported by Medugu *et al.*(2010).

Table 4.1: Proximate Chemical Compsition of Millet

Parameter	Percentage			
	Sample 1*	Sample 2*	Sample 3*	Average
Dry Matter	89.67	89.67	89.67	89.67
Crude Protein	9.19	8.98	9.46	9.21
Crude Fibre	6.29	6.13	5.96	6.13
Ether Extract	3.41	2.39	2.87	2.89
Ash	1.78	2.01	1.69	1.83
Nitrogen Free Extract	79.33	80.49	80.02	79.95

* Three different samples of pearl millet were analyzed

Table 4.2: Mineral Composition of Millet

Mineral	Percentage
Calcium	0.072
Phosphorus	0.33
Potassium	0.32
Magnesium	0.095
Sodium	0.13
Manganese	0.0071
Zinc	0.016

Table 4.3: Proximate composition (%) of feed samples (Experiment 1)

Parameter	0%PM	50%WPM 50%M	50%WPM 50%M+EN	100%WPM	100%WPM + EN	50%GPM 50%M	50%GPM 50%M+EN	100%GPM	100%GPM+EN
Dry Matter	92.21	92.56	92.56	92.80	92.80	92.56	92.56	92.80	92.80
Crude Protein	25.04	26.25	26.25	27.45	27.45	26.25	26.25	27.45	27.45
Crude Fibre	8.65	8.94	8.94	9.75	9.75	8.94	8.94	9.75	9.75
Ether extract	5.32	5.22	5.22	5.01	5.01	5.22	5.22	5.01	5.01
Ash	9.44	11.1	11.1	11.15	11.15	11.1	11.1	11.15	11.15
Nitrogen free extract	51.55	48.49	48.49	46.64	46.64	48.49	48.49	46.64	46.64

PM- pearl millet, WPM- whole pearl millet, GPM – ground pearl millet, EN – enzyme

Table 4.4: Proximate composition (%) of feed samples (Experiment 2)

Parameter	0%PM	50%WPM 50%M	50%WPM 50%M+EN	100%WPM	100%WPM + EN	50%GPM 50%M	50%GPM 50%M+EN	100%GPM	100%GPM+EN
Dry Matter	92.56	91.17	91.17	92.70	92.70	91.17	91.17	92.70	92.70
Crude Protein	21.56	22.06	22.06	22.81	22.81	22.06	22.06	22.81	22.81
Crude Fibre	4.39	6.22	6.22	7.51	7.51	6.22	6.22	7.51	7.51
Ether extract	6.02	5.68	5.68	5.39	5.39	5.68	5.68	5.39	5.39
Ash	5.39	6.04	6.04	6.34	6.34	6.04	6.04	6.34	6.34
Nitrogen free extract	62.64	60.00	60.00	57.95	57.95	60.00	60.00	57.95	57.95

PM- pearl millet, WPM- whole pearl millet, GPM – ground pearl millet, EN – enzyme

4.2.1 Effect of pearl millet inclusion level on the performance of growing Japanese quails (2-6 weeks)

Growing Japanese quails fed 50 and 100% pearl millet had similar (P>0.05) final body weight, weight gain, average daily weight gain, age at first lay, weight at first lay and weight of first egg compared to the control (0% pearl millet) as shown in table 4.5. This agrees with the findings of Davis *et al.* (2003) who observed that completely replacing maize with pearl millet from 1 to 16 days and replacing 50% of maize with pearl millet from 0 to 42 days in the diets of broilers did not had any adverse effect on their performance. The above results also agreed with the findings of Reddy *et al.* (2006) who showed that when pearl millet replaced maize part per part or isocalorically and isoproteinically the performance of chicks was either comparable or better than that of chicks fed maize. In contrast, Hafeni (2013) observed that broiler chickens fed pearl millet based diets gained significantly more weight than those fed maize based diets. Tornekar *et al*. (2009) also reported that up to 50% replacement of maize with pearl millet resulted in increased body weights of broilers. The similarity of the above mean values obtained in the assessed parameters in this study could likely be due to the level of metabolizable energy in the pearl millet which is close to that of maize and its higher protein content compared to maize (Abubakar *et al.*, 2006; Dale, 2006).

Total feed intake, average daily feed intake, feed conversion ratio, total feed cost and feed cost/kg gain, were significantly affected (P<0.05) by varying levels of pearl millet inclusion. Total feed intake and average daily feed intake were higher (P<0.05) for birds fed either of the two levels of pearl millet (50 and 100%) when compared with that of the control group. However, the two pearl millet inclusion levels were similar (P>0.05) with regard to these performance parameters. The increase in total feed intake and average daily feed intake observed in this study agrees with the findings of Tornekar *et al*. (2009), who observed that broilers fed pearl millet as replacement for maize consumed more feed than those fed maize.

The results of this study disagree with the of findings of Hafeni (2013) who observed that replacement of maize with pearl millet had no significant effect on feed intake of broiler chickens from 21 to 49 days of age. In the same vein, it was also observed in this study that the feed conversion ratio of growing Japanese quails fed maize was superior ($P<0.05$) to that of those fed the either levels (50% or 100%) of pearl millet. The two millet inclusion levels had similar ($P>0.05$) feed conversion ratio. This agrees with the observation of Tornekar *et al*. (2009) that broilers fed maize had lower feed conversion ratio than those fed pearl millet. In contrast, Udeybir *et al.* (2009) reported similar feed conversion ratio both in 50% pearl millet diet and 100% maize as fed to broilers. Hafeni (2013) also observed that replacement of maize with pearl millet had no significant effect on feed conversion ratio of broiler chickens from 21 to 49 days of age. The higher feed intake and feed conversion ratio with increasing levels of pearl millet recorded in this study may be attributed to reduced energy with increasing levels pearl millet inclusion (Tables 3.1 and 4.3). Under normal circumstances, birds would eat to satisfy their energy needs and birds fed with low energy diets compensate for the lower energy concentration by increasing feed intake (Akinola and Sese, 2012). Also the results of proximate analysis of the experimental diets as showed increase in crude fibre content with increase in pearl millet inclusion (table 4.3). Increase in feed intake with increased levels of fibre in the diet has been reported by many researchers (Mateos *et al.,* 2012; Michard, 2011). Fibre usually dilutes the energy content (and other nutrients) of diets and this increases feed intake (Michard, 2011). Apart from that, increased dietary fibe generates physical distension of the walls of the gastro-intestinal tract, increasing gastro-intestinal capacity and gut fill and these results in increased feed intake (Mateos *et al.*, 2012; Matthias and Hasan, 2003).

Table 4.5: Main effect of Pearl Millet inclusion levels on the performance of growing Japanese quails

	PEARL MILLET INCLUSION LEVEL			
	Control	50%	100%	SEM*
PARAMETER				
Initial weight (g/bird)	35.47	35.63	35.26	1.11
Final weight (g/bird)	129.49	135.66	137.54	2.86
Total weight gain (g/bird)	94.02	100.03	102.28	2.48
Average daily weight gain (g/bird)	3.36	3.57	3.65	0.09
Total feed Intake (g/bird)	307.30^{b}	367.78^{a}	372.53^{a}	5.98
Average daily feed intake (g/bird)	10.97^{b}	13.14^{a}	13.30^{a}	0.21
Feed conversion ratio	3.27^{a}	3.68^{b}	3.66^{b}	0.06
Total feed cost (₦/bird)	29.45^{a}	36.38^{b}	38.31^{b}	0.65
Feed cost/kg gain (₦)	313.31^{a}	364.25^{b}	376.39^{b}	6.38
Age at first lay (days)	42.33	41.08	40.67	0.50
Weight at first lay (g/bird)	128.85	131.56	134.15	2.98
Weight of first egg (g)	7.33	7.75	7.50	0.23

$^{a, b, c}$ means in a row with no common superscript(s) differ significantly ($P<0.05$) SEM – standard error of mean

* The SEM is for comparison between the 2 pearl millet inclusion levels. Comparison with the control was done using Dunnet's test

Total feed cost and feed cost/kg gain were higher (P<0.05) for birds fed either of the two levels of pearl millet (50 and 100%) when compared with that of the control group. The two millet inclusion levels had similar (P>0.05) total feed cost and feed cost/kg gain. The higher total feed cost and feed cost/kg gain in the pearl millet fed groups is due to the price (as at that time in the experimental location) of pearl millet which was higher than that of maize (₦96/kg vs. ₦70/kg) as well as the higher feed intake observed in the pearl millet fed groups.

4.2.2 Effect of pearl millet form on the performance of growing Japanese quails (2-6 weeks)

Results of the effect of pearl millet form on the performance of growing Japanese quails are shown in table 4.6. Growing Japanese quails fed either ground or whole pearl millet (unground) had similar (P>0.05) performance parameters. Hence, grinding of pearl millet had no effect on the performance of growing Japanese quails. These results confirm the observations of Dale (2006) which show that high levels of pearl millet can be fed in unground form. It also agrees with the assertion of Biggs and Parsons (2009), that most studies reported that the early growth of chickens is unaffected by the inclusion of a whole grain.

Feeding either unground or ground pearl millet to growing Japanese quails as replacement for maize significantly affected (P<0.05) total feed intake, average daily feed intake, feed conversion ratio, total feed cost and feed cost/kg gain. Quails fed either unground or ground pearl millet based diets have higher (P<0.05) total feed intake, average daily feed intake, feed conversion ratio, total feed cost and feed cost/kg gain compared to those fed the control (0% pearl millet). Since the two pearl millet forms (whole and ground) recorded similar (P>0.05) performance parameters, the higher feed intake and feed conversion ratio of the pearl millet fed groups compared to the control may as well be attributed to the reduced energy and

higher fibre content of the pearl millet based diets which resulted in increased feed intake as discussed earlier. These results however disagree with the findings of Hidalgo *et al*. (2004) and U. K. C. A. G. (2012), who reported that feeding whole pearl millet seeds to broilers resulted in feed conversion and weight gain equivalent to that of broilers fed standard maize-soybean diet at the end of the starter, grower and finisher periods of age.

The higher ($P<0.05$) total feed cost and feed cost/kg gain is due to the higher feed intake as well as the price of pearl millet which was higher than that of maize (₦96/kg vs ₦70/kg).

4.2.3 Effect of enzyme supplementation of pearl millet based diets on the performance of growing Japanese quails (2-6 weeks)

The result of the effect of enzyme supplementation on the performance of growing Japanese quails is shown in table 4.7. Feeding pearl millet based diets with or without enzyme supplementation to growing Japanese quails as replacement for maize affected ($P<0.05$) total feed intake or average daily feed intake, feed conversion ratio, total feed cost and feed cost/kg gain. Quails fed pearl millet based diets with or without enzyme supplementation have higher ($P<0.05$) total feed intake, average daily feed intake, feed conversion ratio, total feed cost and feed cost/kg gain compared to those fed the control (0% pearl millet). Growing Japanese quails fed pearl millet based diets with enzyme have similar ($P>0.05$) performance parameters with those fed the same diets without enzyme. Enzyme supplementation did not improve any of the performance parameters of growing Japanese quails fed pearl millet based diets. The results of this study show that enzyme supplementation in pearl millet based diets may not be necessary. This agrees with the findings of Arumbackam *et al.* (2004) that addition of feed enzymes to diets of growing Japanese quails did not improve growth performance, feed intake and feed efficiency.

Table 4.6: Main effect of Millet Form on the performance of growing Japanese quails

	PEARL MILLET FORM			
	Control	WPM	GPM	SEM*
PARAMETER				
Initial weight (g/bird)	35.47	35.98	34.91	1.11
Final Weight (g/bird)	129.49	138.64	134.56	2.86
Total weight gain (g/bird)	94.02	102.65	99.65	2.48
Average daily Weight gain (g/bird)	3.36	3.67	3.56	0.09
Total feed Intake (g/bird)	307.30^{b}	377.24^{a}	363.07^{a}	5.98
Average Daily feed intake (g/bird)	10.97^{b}	13.47^{a}	12.97^{a}	0.21
Feed Conversion ratio	3.27^{a}	3.69^{b}	3.65^{b}	0.06
Total Feed Cost (₦/bird)	29.45^{a}	37.65^{b}	37.04^{b}	0.65
Feed cost/kg gain (₦)	313.31^{a}	368.36^{b}	372.28^{b}	6.38
Age at first lay (days)	42.33	40.83	40.92	0.50
Weight at first lay (g/bird)	128.85	136.20	129.51	2.98
Weight of first egg (g)	7.33	7.67	7.58	0.23

$^{a, b, c}$ means in a row with no common superscript(s) differ significantly ($P<0.05$) SEM – standard error of mean
WPM: whole pearl millet GPM: ground pearl millet

* The SEM is for comparison between the 2 pearl millet forms. Comparison with the control was done using Dunnet's test

Table 4.7: Main effect of Enzyme supplementation of pearl millet diets on the performance of growing Japanese quails

	ENZYME			
	Control	PM-EN	PM+EN	SEM*
PARAMETER				
Initial weight (g/bird)	35.47	35.69	35.20	1.11
Final weight (g/bird)	129.49	136.12	137.02	2.86
Total weight gain (g/bird)	94.02	100.48	101.82	2.48
Average daily weight gain (g/bird)	3.36	3.59	3.64	0.09
Total feed Intake (g/bird)	307.30[b]	367.09[a]	373.22[a]	5.98
Average daily feed intake (g/bird)	10.97[b]	13.11[a]	13.33[a]	0.21
Feed conversion ratio	3.27[a]	3.66[b]	3.68[b]	0.06
Total feed cost (₦/bird)	29.45[a]	36.92[b]	37.76[b]	0.65
Feed cost/kg gain (₦)	313.31[a]	368.47[b]	372.17[b]	6.38
Age at firdt lay (days)	42.33	40.67	41.08	0.50
Weight at first lay (g/bird)	128.85	133.83	131.88	2.98
Weight of first egg (g)	7.33	7.50	7.75	0.23

[a, b, c] means in a row with no common superscript(s) differ significantly (P<0.05) SEM – standard error of mean
PM-EN: pearl millet without enzyme PM+EN: pearl millet with enzyme

* The SEM is for comparison between the 2 pearl millet based diets. Comparison with the control was done using Dunnet's test

Generally, improvements obtained by the supplementation of enzymes in poultry feeds are hinged on many factors, including the type and amount of cereal in the diet; the level of anti-nutritional factors in the cereal (Munir and Maqsood, 2013). Hence, improvement expected and usually achieved with the use of currently available enzymes for wheat- or barley-based diets is higher, or at least more consistent, than may be obtained with the use of same enzymes for diets based on maize (Cowieson *et al*., 2006). Therefore, the pearl millet used in this study did not respond significantly to enzyme supplementation.

Since enzyme supplementation did not affect any of the performance parameters, the higher feed intake and feed conversion ratio of the pearl millet fed groups compared to the control may as well be attributed to the reduced energy and higher fibre content of the pearl millet based diets which resulted in increased feed intake as discussed earlier. The results of this study are in conformity with the observation of Udeybir *et al.* (2009) who observed no significant differences in feed intake and feed conversion ratio in the diets they fed PM to broilers with or without enzyme. On the contrary, Manwar and Mandal (2009) reported that the addition of enzymes to pearl-millet based diet improved the body weight gain of broiler chickens. Also Alam *et al.* (2003) reported that growth rate, feed intake, feed conversion were increased by addition of exogenous enzymes. Engberg *et al.* (2004) observed increased body weights of birds fed diets supplemented with xylanase compared with birds fed non-supplemented diets. There was no effect in body weight gain in male and female Japanese quail due to different dietary treatments and enzyme supplementation (Attia *et al.*, 2008).

4.2.4 Effect of the interaction between pearl millet form and enzyme supplementation on the performance of growing Japanese quails (2-6 weeks)

There was no interaction between the forms (whole or ground) of pearl millet and enzyme supplementation with respect to their influence on performance of growing Japanese quails.

This finding was contrary to the observation of Engberg *et al.* (2004) who discovered a significant interaction between wheat form and enzyme supplementation when whole wheat was fed to broilers.

4.2.5 Effect of pearl millet inclusion level on the carcass characteristics of growing Japanese quails (2-6 weeks)

Growing Japanese quails fed the two pearl millet inclusion levels had similar ($P>0.05$) carcass weight, dressing percentage, gizzard weight, weight of proventriculus and liver weight with the control (Table 4.8). However, growing Japanese quails fed 100% millet had a heavier ($P<0.05$) intestine than that of quails fed maize. Both 50 and 100% millet fed groups had similar ($P>0.05$) intestinal weights. The intestinal weights of quails fed 50% millet and maize were also similar ($P>0.05$). Almost similar to these results is the observation of Davis *et al.* (2003) who found that up to 50% pearl millet grain as replacement for maize in broiler diets did not adversely affect carcass yields. Substituting yellow maize with pearl millet resulted in similar dressing percentage, gizzard weights and intestinal weight but higher liver weight (Rao *et al.*, 2004). The higher intestinal proportion observed in this study in quails fed the 100% pearl millet diet compared to the control (0% pearl millet) may be due to higher fibre content of the pearl millet. Higher levels of fibre might have increased the physical activity of digestive organs in an effort to grind and digest them resulting in hypertrophy or hyperplacia of these organs (Rao *et al.*, 2004). Matthias and Hasan (2003) explained that switching from a standard diet to a high-fibre diet, increases the sizes of gizzard muscle and small intestine of Japanese quails. In the small intestine, decreasing quality of the food may be compensated by increasing intestinal length, circumference and surface magnification. With increasing digestive load to the intestine we also expected the muscle layer to thicken.

Table 4.8: Main effect of Pearl Millet inclusion level on the carcass characteristics of growing Japanese quails

	PEARL MILLET INCLUSION LEVEL			
	Control	50%	100%	SEM*
PARAMETER				
Live weight (g/bird)	111.67	110.75	111.50	1.90
Carcass weight (g/bird)	78.00	76.67	75.83	1.33
Dressing percentage (%)	69.85	69.24	68.05	0.65
Weight of organs expressed as a percentage (%) of carcass weight				
Gizzard	2.64	2.53	2.56	0.10
Proventriculus	0.35	0.41	0.40	0.014
Intestine	3.23^{b}	3.68^{ab}	3.85^{a}	0.15
Liver	1.39	1.35	1.37	0.10

$^{a, b, c}$ means in a row with no common superscript(s) differ significantly ($P<0.05$) SEM – standard error of mean

* The SEM is for comparison between the 2 pearl millet inclusion levels. Comparison with the control was done using Dunnet's test

4.2.6 Effect of pearl millet form on the carcass characteristics of growing Japanese quails (2-6 weeks)

Growing Japanese quails fed either whole or ground pearl millet as replacement for maize had similar carcass weight, dressing percentage, gizzard weight, weight of proventriculus and liver weight but different intestinal weights (Table 4.9). Quails fed ground pearl millet as replacement for maize recorded significantly higher ($P<0.05$) intestinal weight than quails fed maize or whole pearl millet based diets. The intestinal weights of quails fed whole millet and maize were statistically similar. Similar to these results, Umar Faruk *et al.* (2010a) reported similar weights of duodenum and ileum, gizzard, liver pancreas and proventriculus when whole pearl millet was fed to laying hens compared to the feeding of ground pearl millet. In contrast to these results, Engberg *et al.* (2004) found that the relative weights of gizzard and pancreas were influenced by the form of the wheat and was higher in birds fed whole wheat compared with pellet-fed birds. Also gut development was higher when whole sorghum was offered as a mash (loose mix) compared with a complete pelleted diet (Arroyo *et al.*, 2012). Dietary particle size is known to influence the avian digestive tract such that the gizzard weight increases with increasing particle size (Garcia, 2006; Umar Faruk *et al.*¸2010a).

4.2.7 Effect of enzyme supplementation of pearl millet based diets on the carcass characteristics of growing Japanese quails (2-6 weeks)

Growing Japanese quails fed pearl millet with or without enzyme supplementation as replacement for maize had similar carcass weight, dressing percentage and weights of gizzard and liver. Enzyme supplementation affected the weights of proventriculus and intestine of growing Japanese quails fed pearl millet as replacement for maize (Table 4.10). Quails fed pearl millet without enzyme supplementation recorded proventricular weight higher ($P<0.05$) than that of quails fed maize but similar to that of quails fed millet with enzyme

supplementation. Quails fed either maize or millet with enzyme supplementation or maize had similar proventricular weights. Quails fed millet with enzyme supplementation recorded intestinal weight higher ($P<0.05$) than that of quails fed maize but similar to that of quails fed millet without enzyme supplementation. Quails fed either maize or millet without enzyme supplementation or maize had similar intestinal weights. Almost similar with the results of this study, Rao *et al.* (2004) observed that enzyme supplementation of pearl millet diets as replacement for maize did not affect the dressing percentage, gizzard, liver and intestinal weights of broilers. Arumbackam *et al.* (2004) also observed no difference in carcass characteristics as a result of enzyme supplementation. Attia *et al.* (2008) observed similar percentages of dressed carcass, liver, gizzard, heart and pancreas of Japanese quails with or without enzyme supplementation. In contrast, Engberg *et al*. (2004) observed that the addition of xylanase resulted in a reduction of the weight of jejunum and ileum. Alam *et al.* (2003) reported increased dressing percentage with addition of exogenous enzymes. The higher percentages of the intestine observed in this study in quails fed the pearl millet without enzyme supplementation compared to the control (0% pearl millet) may be due to higher fibre content of the pearl millet based diets. Higher levels of fibre might have increased the physical activity of digestive organs in an effort to grind and digest them resulting in hypertrophy or hyperplacia of these organs (Rao *et al.*, 2004). Enzyme supplementation hence did reduce the load of increased fibre in pearl millet diets on the digestive organs as quails fed that diet had similar gizzard, proventricular and intestinal weights. This was earlier opined by Sheppy (2001) that the supplementation of animal feeds with enzymes is to increase the efficiency of digestion and is an extension of the animal's own digestive process. Munir and Maqsood (2013) advanced that one of the reasons of enzyme supplementation of poultry diets is to increase the availability of nutrients that are enclosed within the fibre-rich cell wall.

Table 4.9: Main effect of Pearl Millet form on the carcass characteristics of growing Japanese quails

	PEARL MILLET FORM			
	Control	WPM	GPM	SEM*
PARAMETER				
Live weight (g/bird)	111.67	110.17	112.08	1.90
Carcass weight (g/bird)	78.00	75.00	77.50	1.33
Dressing Percentage (%)	69.85	68.09	69.19	0.65
Weight of organs expressed as a percentage (%) of carcass weight				
Gizzard	2.64	2.52	2.57	0.10
Proventriculus	0.35	0.40	0.41	0.014
Intestine	3.23^{b}	3.55^{ab}	3.97^{a}	0.15
Liver	1.39	1.21	1.50	0.10

$^{a, b, c}$ means in a row with no common superscript(s) differ significantly ($P<0.05$) SEM – standard error of mean
WPM: whole pearl millet GPM: ground pearl millet

* The SEM is for comparison between the 2 pearl millet forms. Comparison with the control was done using Dunnet's test

Table 4.10: Main effect of Enzyme supplementation of pearl millet diets on the carcass characteristics of growing Japanese quails

	ENZYME			
	Control	PM-EN	PM+EN	SEM*
PARAMETER				
Live weight (g/bird)	111.67	110.50	111.75	1.90
Carcass weight (g/bird)	78.00	76.42	76.08	1.33
Dressing Percentage (%)	69.85	69.17	68.12	0.65
Weight of organs expressed as a percentage (%) of carcass weight				
Gizzard	2.64	2.58	2.51	0.10
Proventriculus	0.35^{b}	0.42^{a}	0.39^{ab}	0.014
Intestine	3.23^{b}	3.87^{a}	3.65^{ab}	0.15
Liver	1.39	1.44	1.27	0.10

$^{a, b, c}$ means in a row with no common superscript(s) differ significantly (P<0.05) SEM – standard error of mean
PM-EN: pearl millet without enzyme PM+EN: pearl millet with enzyme

* The SEM is for comparison between the 2 pearl millet based diets. Comparison with the control was done using Dunnet's test

4.2.8 Effect of pearl millet inclusion level on the performance of laying Japanese quails (8-20 weeks)

The results of the effect of millet inclusion level on the performance of laying Japanese quails are shown in table 4.11. Laying Japanese quails fed either 50% or 100% pearl millet had similar ($P>0.05$) final weight, weight change, hen day egg production, hen housed egg production and feed conversion ratio compared to the control (0% pearl millet). This agrees with the observation of Seema *et al.* (2007) who reported that there was no significant effect on egg production and feed conversion ratio (kg of feed/dozen eggs) in quails by replacing maize with pearl millet. Collins *et al.* (1997), also found that dietary treatment had no effect on body weight gain, egg production, feed conversion (feed per dozen eggs or feed per gram of egg) and mortality of laying hens at different levels of maize substitution (0, 50 or 100%) by pearl millet. Similarly, inclusion of pearl millet in the diet at the expense of maize did not significantly influence hen-day egg production, feed efficiency and body weight of laying hens as observed by Kumar *et al.* (1991). Abd-ElRazig, (1997) found that egg production, feed consumption and feed conversion ratio were not affected by replacing maize with pearl millet in the diets of laying hens. Faruk (2010) observed no difference in body weight with reduced egg production and improved feed efficiency when laying hens were fed millet-based diet in place of the maize-based diet. Also contrary to the results of this study Filardi *et al.* (2005) observed linear decrease in egg production with increasing levels of pearl millet as replacement for millet. Umar Faruk *et al.* (2010b) observed similar body weight gain with increased egg production and feed efficiency when maize was replace with pearl millet in the diet of laying hens. Diets containing up to 60% pearl millet had no effect on egg production, feed conversion and final body weight (Singh and Perez-Maldonado, 1999).

Table 4.11: Main effect of pearl millet inclusion level on the performance of laying Japanese quails

	PEARL MILLET INCLUSION LEVEL			
	Control	50%	100%	SEM*
PARAMETER				
Initial weight (g/bird)	169.44	168.75	171.53	1.40
Final weight (g/bird)	172.22	171.53	175.69	1.62
Weight change (%)	1.47	1.35	1.62	0.49
Total Feed Intake (g/bird)	1996.67[b]	2144.44[a]	2220.14[a]	26.37
Daily feed intake (g/bird)	25.93[b]	27.85[a]	28.83[a]	0.35
Hen day egg production (%)	81.53	83.21	84.69	2.24
Hen housed egg production (%)	81.53	82.97	84.46	2.25
Feed cost/dozen eggs (₦)	35.69[b]	39.29[ab]	41.58[a]	1.21
Feed Conversion ratio g/dozen eggs	384.21	405.77	409.34	12.39
Mortality	0.00	1.39	2.78	1.50

[a, b, c] means in a row with no common superscript(s) differ significantly (P<0.05) SEM – standard error of mean

* The SEM is for comparison between the 2 pearl millet inclusion levels. Comparison with the control was done using Dunnet's test

The similarity of the above mean values obtained in the assessed parameters in this study could likely be due to the level of metabolizable energy in the pearl millet which is close to that of maize and its higher protein content compared to maize (Abubakar *et al.*, 2006; Dale, 2006).

Total feed intake, average daily feed intake and feed cost/dozen eggs were significantly affected ($P<0.05$) by pearl millet inclusion in the diet of laying Japanese quails. Laying Japanese quails fed 100% pearl millet recorded the highest ($P<0.05$) total feed intake and average daily feed intake than quails fed 50% pearl millet which were also higher than the control (0% pearl millet). In line with this result, Singh and Perez-Maldonado (1999) observed that laying hens consuming pearl millet (400 g/kg) had significantly higher feed intake ($P<0.05$) than birds fed control diets. Contrary to these, Faruk (2010) observed that average daily feed intake was not significantly different between the treatments fed maize-based and those fed millet-based complete diet. Filardi *et al.* (2005) reported conflicting result with regards to feed intake. They observed reduced feed intake when pearl millet replaces maize until a replacement level of 64.18% and increased feed intake afterwards. However, when pearl millet was not added (0%) or when maize was completely replaced by pearl millet (100%), there were no effects on feed intake. On the contrary, Kumar *et al.* (1991) and Umar Faruk *et al.* (2010b) observed no difference in feed intake with the inclusion of pearl millet at the expense of maize in the diet of laying hens. Collins *et al.* (1997), also found that dietary treatment had no effect on feed intake of laying hens at different levels of maize substitution (0, 50 or 100%) by pearl millet. The higher feed intake with increasing levels of pearl millet recorded in this study may be attributed to reduced energy with increasing levels pearl millet inclusion (Tables 3.1 and 4.3). Under normal circumstances, birds would eat to satisfy their energy needs and birds fed with low energy diets compensate for the lower energy concentration by increasing feed intake (Akinola and

Sese, 2012). Also the results of proximate analysis of the experimental diets showed increase in crude fibre content with increase in pearl millet inclusion (table 4.4). Increase in feed intake with increased levels of fibre in the diet has been reported by many researchers (Michard, 2011; Mateos *et al.*, 2012). High fibre content in the diet is usually correlated with dietary energy depression Fibre usually dilutes the energy content and birds need to increase intake in order to obtain enough energy to maintain production (Singh and Perez-Maldonado, 1999; Michard, 2011). Apart from that, increased dietary fibre generates physical distension of the walls of the gastro-intestinal tract, increasing gastro-intestinal capacity and gut fill and these results in increased feed intake (Matthias and Hasan, 2003;Mateos *et al.*, 2012).

Laying Japanese quails fed 100% pearl millet had higher ($P<0.05$) feed cost/dozen eggs compared to the control (0% pearl millet). Laying Japanese quails fed 50% pearl millet had similar ($P>0.05$) feed cost/dozen eggs compared to that of both the 100% pearl millet fed groups and the control group (0% pearl millet). This result is contrary to the observation of Filardi *et al.* (2005) that pearl millet levels had no significant effect on production costs per egg mass (kg) or per dozen eggs. Kumar *et al.* (1991) had a different observation that profits from egg sales over feed cost being directly proportional to the inclusion of pearl millet in the diet.

4.2.9 Effect of pearl millet form on the performance of laying Japanese quails

The result of the effect of pearl millet form on the performance of laying Japanese quails is shown in table 4.12. Pearl millet form did not influence ($P>0.05$) final weight, weight change, hen day egg production, hen housed egg production and feed conversion ratio of laying Japanese quails fed either whole or ground pearl millet as replacement for maize. This conforms to the observations of Garcia and Dale (2006) who reported that laying hens can utilize whole pearl millet when used at moderate levels of inclusion without apparent effect on egg production.

Table 4.12: Main effect of pearl millet form on the performance of laying Japanese quails

	PEARL MILLET FORM			
	Control	WPM	GPM	SEM*
PARAMETER				
Initial weight (g/bird)	169.44	171.11	170.14	1.40
Final weight (g/bird)	172.22	170.83	176.39	1.62
Weight change (%)	1.47	0.91	2.90	0.49
Total Feed Intake (g/bird)	1996.67^{c}	2245.14^{a}	2119.44^{b}	26.37
Daily feed intake (g/bird)	25.93^{c}	29.16^{a}	27.53^{b}	0.35
Hen day egg production (%)	81.53	83.35	84.55	2.24
Hen housed egg production (%)	81.53	83.26	84.17	2.25
Feed cost/dozen eggs (₦)	35.69^{b}	41.37^{a}	39.50^{ab}	1.21
Feed Conversion ratio g/dozen eggs	384.21	421.41	393.70	12.39
Mortality	0.00	2.78	1.39	1.50

$^{a, b, c}$ means in a row with no common superscript(s) differ significantly (P<0.05) SEM – standard error of mean
WPM: whole pearl millet GPM: ground pearl millet

* The SEM is for comparison between the 2 pearl millet forms. Comparison with the control was done using Dunnet's test

Faruk (2010) also observed similar hen day egg production and feed efficiency between laying hens fed whole pearl millet and ground millet based diets. He however on the contrary observed lower body weight gain for laying hens fed whole pearl millet than those fed the ground pearl millet diet. Bennett and Classen (2003) observed that feeding 60% whole barley with a mash concentrate reduced egg production and feed efficiency and increased body weight gain. Similar egg production, feed conversion ratio and body weight were observed by Umar Faruk *et al.* (2010a) when they fed a whole wheat (loose-mix) diet in place of maize based diet to laying hens.

However, total feed intake and average daily feed intake were significantly affected ($P<0.05$) by pearl millet form. All the treatments have statistically different feed intakes. Laying Japanese quails fed whole pearl millet had the highest feed intake followed by that of quails fed ground pearl millet. Those receiving the control (0% pearl millet) had the least feed intake. Higher pearl millet intake in whole pearl millet fed groups may be attributed to the feed particle selection compared to ground pearl millet fed groups. Increasing particle size increases feed intake (Umar Faruk *et al.*, 2010a). Reduced energy and increased fibre content of the pearl millet based diets (Tables 3.2 and 4.4) is likely the cause of their increased intake relative to the control as explained earlier. This is contrary to the report of Faruk (2010) that feed intake was not significantly affected when ground pearl millet was replaced by whole pearl millet in feeding laying hens. Garcia and Dale (2006) observed no effect on feed intake when they fed either whole or ground pearl millet to laying hens. However, they fed only 10% pearl millet as opposed to the 50% or 100% fed in this study. With respect to whole grain feeding, Umar Faruk *et al.* (2010a) observed similar average total feed intake when they fed whole wheat (loose mix) and conventional maize based diet. On the other hand, Bennett and Classen (2003) observed that feeding 60% whole barley increased feed intake of laying hen compared to the feeding of ground barley.

Feed cost per dozen eggs was significantly (P<0.05) affected by pearl millet form. Laying Japanese quails fed whole pearl millet had higher (P<0.05) feed cost per dozen eggs than that of quails fed the control (0% pearl millet). Quails fed ground pearl millet had similar feed cost per dozen eggs with those fed either whole pearl or the control. This is as a result of the feed intake of whole pearl millet as well as the cost of pearl millet which were higher than those of the control. Also the increased intake, while maintaining similar egg production and feed conversion ratio, resulted in an increased cost of feed per dozen eggs compared to the feeding of whole pearl millet and maize (control). This contradicts the suggestion of Garcia and Dale (2006) that laying hen producers should use pearl millet as an alternative grain as a strategy to reduce feed cost. It also contradicts the suggestion of Summers (1996) that the use of larger particle size for the grain component of a diet would result in a significant saving in the energy cost of grinding.

4.2.10 Effect of enzyme supplementation of pearl millet based diets on the performance of laying Japanese quails (8-20 weeks)

The result of the effect of enzyme supplementation on the performance of laying Japanese quails is shown in table 4.13. Laying Japanese quails fed pearl millet with or without enzyme supplementation as replacement for maize had similar (P>0.05) final weight, weight change, hen day egg production, hen housed egg production, feed cost per dozen eggs and feed conversion ratio compared to those fed the control. Arumbackam *et al.* (2004) observed that egg production did not differ because of enzyme supplementation and hence concluded that addition of feed enzymes to conventional diets containing varying levels of maize, soyabean meal may not be beneficial to improve growth and egg production performance of Japanese quails. Attia *et al.* (2008) also observed similar feed conversion ratio with or without enzyme supplementation in the diet of laying Japanese quails.

Table 4.13: Main effect of enzyme supplementation of pearl millet diets on the performance of laying Japanese quails

	ENZYME			
	Control	PM-EN	PM+EN	SEM*
PARAMETER				
Initial weight (g/bird)	169.44	168.75	171.53	1.40
Final weight (g/bird)	172.22	173.61	173.61	1.62
Weight change (%)	1.47	1.84	1.13	0.49
Total Feed Intake (g/bird)	1996.67[b]	2157.64[a]	2206.9[a]	26.37
Average daily feed intake (g/bird)	25.93[b]	28.02[a]	28.66[a]	0.35
Hen day egg production (%)	81.53	82.74	85.16	2.24
Hen housed egg production (%)	81.53	82.59	84.84	2.25
Feed cost/dozen eggs (₦)	35.69[b]	40.51[a]	40.36[a]	1.21
Feed Conversion ratio g/dozen eggs	384.21	409.68	405.43	12.39
Mortality	0.00	1.39	2.78	1.50

[a, b, c] means in a row with no common superscript(s) differ significantly (P<0.05) SEM – standard error of mean
PM-EN: pearl millet without enzyme PM+EN: pearl millet with enzyme

* The SEM is for comparison between the 2 pearl millet based diets. Comparison with the control was done using Dunnet's test

A significant (P<0.05) increase in total feed intake and average daily feed intake of laying Japanese quails fed pearl millet based diets with or without enzyme supplementation as replacement for maize was observed in this study. Laying Japanese quails fed either pearl millet with or without enzyme supplementation recorded higher (P<0.05) total feed intake and average daily feed intake compared to the control (0% pearl millet).

Feed cost per dozen eggs was significantly higher (P<0.05) when laying Japanese quails were fed pearl millet with or without enzyme supplementation compared to the feeding of the control (0% pearl millet). This is because the feed intake of pearl millet based diets with or without enzyme supplementation and the cost of pearl millet which were higher than those of maize. The increased feed intake and cost, while maintaining similar egg production and feed conversion ratio, resulted in an increased cost of feed per dozen eggs of the pearl millet (with or without enzyme supplementation) fed groups compared the control fed groups.

Laying Japanese quails fed pearl millet based diets with enzyme have similar (P>0.05) performance parameters with those fed the same diets without enzyme. Enzyme supplementation did not improve any of the performance parameters of laying Japanese quails fed pearl millet based diets. As stated earlier, the improvements obtained by adding enzymes to the diet of poultry depends on many factors, including the type and amount of cereal in the diet and the level of anti-nutritive factor in the cereal, which can vary within a given cereal (Munir and Maqsood, 2013). Response to enzyme supplementation in diets of poultry depends on the type of the cereal. With laying performance more improved in barley based diets than for wheat and maize based diets. Feed conversion ratio was also improved for wheat, barley and maize diets in the same order. Feed cost can therefore be saved using enzyme (Geraert and Dalibard, 2003; Cowieson *et al*., 2006). The results of this study show that enzyme supplementation in pearl millet based diets may not be necessary. Since enzyme supplementation did not affect any of the performance parameters, the higher feed intake of

the pearl millet fed groups compared to the control may be attributed to the higher fibre content of the pearl millet which resulted in increased feed intake as discussed earlier.

4.2.11 Effect of the interaction between pearl millet form and enzyme supplementation on the performance of laying Japanese quails (8-20 weeks)

There was no interaction between the form (whole or ground) of pearl millet and enzyme supplementation with respect to their influence on performance of laying Japanese quails.

4.2.12 Effect of pearl millet inclusion level on the external and internal egg quality characteristics of laying Japanese quails (8-20 weeks)

The effect of pearl millet inclusion level on external and internal egg quality characteristics of laying Japanese quails is shown in table 4.14. Laying Japanese quails fed 50 and 100% pearl millet had similar ($P>0.05$) egg shape index, shell weight, shell percentage, albumen weight and yolk weight when compared to the control (0% pearl millet).

Egg weight of laying quails fed 100% pearl millet was significantly ($P<0.05$) higher than that of the control group (0% pearl millet) but similar to the 50% pearl millet fed group. Quails fed the control diet (0% pearl millet) and 50% pearl millet produced eggs with similar ($P>0.05$) weights.

Albumen percentage was higher ($P<0.05$) for quails fed 50% pearl millet compared with the 100% pearl millet group. Quails fed either 50% or 100% pearl millet had similar ($P>0.05$) albumen percentage with the control. Yolk percentage was also affected ($P<0.05$) by the varying pearl millet inclusion levels. The control (0% pearl millet) diet has higher yolk percentage than the 100% pearl millet diet. Quails fed 50% pearl millet had similar ($P>0.05$) yolk percentage with either the 100% pearl millet diet or the control. Shell thickness was lower ($P<0.05$) for the control diet than either of the two pearl millet inclusion levels (50% or 100%).

Table 4.14: Main effect of Pearl Millet inclusion level on the External and Internal egg quality characteristics of laying Japanese quails

	INCLUSION LEVEL			
	Control	50%	100%	SEM*
PARAMETER				
Egg weight (g)	9.16[b]	9.50[ab]	9.67[a]	0.08
Egg shape index	77.56	77.98	78.74	0.50
Shell weight (g)	1.20	1.35	1.23	0.60
Shell percentage	13.08	14.18	12.78	0.50
Albumen weight (g)	4.35	4.62	4.30	0.20
Albumen percentage	47.49[ab]	48.63[a]	44.45[b]	1.14
Yolk weight (g)	2.91	2.78	2.75	0.07
Yolk percentage	31.81[a]	29.31[ab]	28.46[b]	0.70
Shell thickness (mm)	0.103[b]	0.126[a]	0.130[a]	0.004
Haugh unit	61.99[a]	61.01[b]	60.84[b]	0.17

[a, b, c] means in a row with no common superscript(s) differ significantly (P<0.05) SEM – standard error of mean

* The SEM is for comparison between the 2 pearl millet inclusion levels. Comparison with the control was done using Dunnet's test

The two pearl millet inclusion levels (50% or 100%) have similar (P>0.05) shell thickness. Haugh unit was higher (P<0.05) for the control diet than either of the two pearl millet inclusion levels (50% or 100%). The two pearl millet inclusion levels (50% or 100%) have similar (P>0.05) Haugh unit. Earlier works on the replacement of maize with pearl millet reported a variety of effects on egg quality parameters. Similar to these results, increase in egg weight of laying hens was observed by Faruk (2010) when maize was replaced completely with pearl millet. On the contrary, Faruk (2010) observed no statistical difference between the egg yolk, egg albumen and eggshell of pearl millet and maize based diets. Also replacing 50% or more of maize with pearl millet in the diet of laying hens increased their eggshell percentage, decreased their egg weight and did not alter their shell thickness and Haugh unit as observed by Filardi *et al.* (2005). Egg weight, yolk weight, and percentage yolk of laying hens were unaffected by diet when maize was replaced with pearl millet (Collins *et al.,* 1997). Egg weight showed a tendency to improve with diets providing pearl millet compared to maize (Kumar *et al.,* 1991). Umar Faruk *et al.* (2010b) observed increased egg weight and egg mass when maize was replaced with pearl millet in the diet of laying hens. Diets containing up to 60% pearl millet had no effect on egg weight and egg mass (Singh and Perez-Maldonado, 1999). Similar egg weights with increased shell thickness and reduced albumen height was observed in eggs laid by hens fed pearl millet as replacement for maize by Abd-ElRazig (1997). Lower egg weight was observed when maize was completely (Amini and Ruiz-Feria, 2008) or partially (Mehran *et al.,* 2010) replaced with pearl millet. However in this study, it might be assumed that higher egg weight might be related to the additional supply of protein in the pearl millet-based diet. Leeson and Summers (2005) explained an obvious linear relationship between increased egg size and increased protein intake. The Haugh unit of Japanese quails obtained in this study has met the minimum requirement of Haugh unit for eggs reaching the consumer which is 60 (Roberts, 2010). The

decrease in Haugh unit with pearl millet inclusion might be as a result of the increase in protein content in the pearl millet based diets. This agrees with the report of Roberts (2010) who reported that albumen quality decreases with increasing dietary protein and amino acid content.

4.2.13 Effect of millet form on the external and internal egg quality characteristics of laying Japanese quails (8-20 weeks)

The effect of pearl millet form on external and internal egg quality characteristics of laying Japanese quails is shown in table 4.15. Laying Japanese quails fed either whole, ground pearl millet or the control had similar ($P>0.05$) egg shape index, shell weight, shell percentage, albumen weight, albumen percentage and yolk weight. Egg weight of quails fed either whole or ground pearl millet was significantly ($P<0.05$) higher than that of the control. The egg weights of quails fed whole or ground pearl millet were similar ($P>0.05$). Laying Japanese quails fed the control had higher yolk percentage ($P<0.05$) than those fed ground pearl millet. The yolk percentage of the quails fed whole pearl millet was similar ($P>0.05$) to that of control and ground pearl millet group. Feeding of whole pearl millet resulted in higher ($P<0.05$) shell thickness compared to feeding ground pearl millet or the control. Quails fed ground pearl millet or the control have similar ($P>0.05$) shell thickness. Haugh unit was higher ($P<0.05$) for the control diet than either of the two pearl millet forms (whole or ground). The two pearl millet forms (whole or ground) have similar ($P>0.05$) Haugh unit.

From the above results it can be seen that there were no significant differences in egg quality parameters considered in these study between quails fed whole pearl millet and the quails fed ground pearl millet, except for shell thickness.

Table 4.15: Main effect of Millet Form on the External and Internal egg quality characteristics of laying Japanese quails

	PEARL MILLET FORM			
	Control	WPM	GPM	SEM*
PARAMETER				
Egg weight (g)	9.16[b]	9.62[a]	9.55[a]	0.08
Egg shape index	77.56	77.86	78.86	0.50
Shell weight (g)	1.20	1.30	1.28	0.60
Shell percentage	13.08	13.52	13.44	0.50
Albumen weight (g)	4.35	4.62	4.29	0.20
Albumen percentage	47.49	48.11	44.97	1.14
Yolk weight (g)	2.91	2.79	2.74	0.07
Yolk percentage	31.81[a]	29.07[ab]	28.69[b]	0.70
Shell thickness (mm)	0.103[b]	0.143[a]	0.113[b]	0.004
Haugh unit	61.99[a]	61.01[b]	60.83[b]	0.17

[a, b, c] means in a row with no common superscript(s) differ significantly (P<0.05) SEM – standard error of mean

WPM: whole pearl millet GPM: ground pearl millet

* The SEM is for comparison between the 2 pearl millet forms. Comparison with the control was done using Dunnet's test

When comparing whole or ground pearl millet as fed to laying hens, Faruk (2010) observed similar egg and albumen weights, but heavier yolk and eggshell for whole millet fed hens compared to ground pearl millet. Similarly, the average egg mass, egg weight, eggshell weight (g and %), albumen weight (both in g and %) and yolk weight of loose-mix and control were not statistically different (Umar Faruk *et al.,* 2010a). With reference to feeding whole grains, Bennett and Classen (2003) found that feeding 60% whole barley increased egg weight. Increased shell thickness in whole pearl millet compared to feeding ground pearl millet or the control obtained in this study might be due to prolonged retention time in the whole pearl millet fed groups. It has been ascertained that larger particles are retained in gizzard for a prolonged period of time. This retention allows calcium to dissolve slowly and enter the intestine at a slow rate and make calcium available during the period of shell formation (Pavlovski *et al.*, 2000).

4.2.14 Effect of enzyme supplementation of pearl millet based diets on the external and internal egg quality characteristics of laying Japanese quails (8-20 weeks)

The result of the effect of enzyme supplementation on the external and internal egg quality characteristics of laying Japanese quails is shown in table 4.16.

Laying Japanese quails fed pearl millet with or without enzyme supplementation had similar ($P>0.05$) egg shape index, shell weight, shell percentage, albumen weight, albumen percentage and yolk weight with those fed the control. Quails fed pearl millet with enzyme had heavier ($P<0.05$) eggs than quails fed the control. While quails fed pearl millet without have egg weight similar ($P>0.05$) to those fed either pearl millet with enzyme or the control. Laying Japanese quails fed the control had higher yolk percentage ($P<0.05$) than those fed pearl millet without enzyme. The yolk percentage of the quails fed pearl millet with enzyme was similar ($P>0.05$) to that of quails fed control and quails fed pearl millet without enzyme.

The shell thickness of laying Japanese quails fed pearl millet with or without enzyme supplementation was higher ($P<0.05$) than that quails fed the control. Quails fed pearl millet with enzyme and those fed pearl millet without enzyme have similar ($P>0.05$) shell thickness. Haugh unit of quails fed the control was higher ($P<0.05$) than that of quails fed either pearl millet with enzyme or without enzyme supplementation. Quails fed pearl millet with or without enzyme supplementation had similar ($P>0.05$) Haugh unit.

From the above results, laying Japanese quails fed pearl millet with enzyme or without enzyme supplementation had similar egg quality parameters. Hence the addition of enzymes in pearl millet diet as replacement for maize might not be necessary as most of the improvements were not significant. The improvements obtained by adding enzymes to the diet of poultry depends on many factors, including the type and amount of cereal in the diet and the level of anti-nutritive factor in the cereal, which can vary within a given cereal (Geraert and Dalibard, 2003; Munir and Maqsood, 2013). Barley and wheat based diets show more improvement than wheat and maize based diets (Geraert and Dalibard, 2003). Improvement expected and usually achieved via the use of currently available enzymes for wheat- or barley-based diets is higher, or at least more consistent, than may be anticipated via the use of same enzymes for diets based on maize (Cowieson *et al*., 2006). Contrary to the findings of this study, no significant effect of enzyme supplementation was observed on egg characteristics by Geraert and Dalibard (2003). Similar to the results of this study, Shehab *et al.* (2012) reported increased egg weight, yolk weight and shell thickness of laying Japanese quails with enzyme supplementation. Albumen weight, shell weight and egg shape index were not affected by enzyme supplementation (Shehab *et al.*, 2012). Attia *et al.* (2008) reported that egg shape index, yolk percentage, albumen percentage, Haugh unit score and other shell quality criteria were not significantly affected by enzyme supplementation. However, they observed that enzyme supplementation improved shell thickness.

Table 4.16: Main effect of Enzyme supplementation of pearl millet diets on the External and Internal egg quality characteristics of laying Japanese quails

	ENZYME SUPPLEMENTATION			
	Control	PM-EN	PM+EN	SEM*
PARAMETER				
Egg weight (g)	9.16[b]	9.47[ab]	9.70[a]	0.08
Egg shape index	77.56	78.00	78.71	0.50
Shell weight (g)	1.20	1.27	1.31	0.60
Shell percentage	13.08	13.40	13.55	0.50
Albumen weight (g)	4.35	4.35	4.57	0.20
Albumen percentage	47.49	45.90	47.19	1.14
Yolk weight (g)	2.91	2.67	2.86	0.07
Yolk percentage	31.81[a]	28.22[b]	29.54[ab]	0.70
Shell thickness (mm)	0.103[b]	0.129[a]	0.126[a]	0.004
Haugh unit	61.99[a]	61.07[b]	60.78[b]	0.17

[a, b, c] means in a row with no common superscript(s) differ significantly (P<0.05) SEM – standard error of mean

PM-EN: pearl millet without enzyme PM+EN: pearl millet with enzyme

* The SEM is for comparison between the 2 pearl millet based diets. Comparison with the control was done using Dunnet's test

The improvement in shell thickness of enzyme supplemented diet could be due to the improvement in the utilization of mineral complexes in the cell wall (Attia *et al.*, 2008). In this study, addition of enzymes to pearl millet based diets did not improve shell thickness. This was contrary to the effect of enzyme on shell thickness in wheat and barley based diets. Addition of enzymes improved shell quality for wheat and barley based diets (Roberts, 2010). Also a reduction in Haugh unit was not observed with the addition of enzyme as quails fed pearl millet with or without enzyme supplementation had similar Haugh unit. However, there were reports of reduction in Haugh unit with enzymes supplementation of wheat and barley based diets (Roberts, 2010).

4.2.15 Effect of pearl millet inclusion level on the nutrient digestibility of laying Japanese quails (8-20 weeks)

The effect of pearl millet inclusion level on the nutrient digestibility of laying Japanese quails is shown in table 4.17. The crude protein digestibility of laying Japanese quails fed 50% pearl millet was significantly higher ($P<0.05$) than that of the control (0% pearl millet). Quails fed 100% pearl millet had similar ($P>0.05$) crude protein digestibility with both the 50% pearl millet fed group and those fed the control. Laying Japanese quails fed 50 and 100% pearl millet had similar ($P>0.05$) crude fibre digestibility, ether extract digestibility, ash digestibility and nitrogen free extract digestibility compared to the control (0% pearl millet). As found in this study, Baurhoo *et al.* (2010) observed crude protein digestibility between broilers fed pearl millet and maize. Also similar with the ash digestibility obtained in this study, Chiripasi *et al.* (2013) observed that pearl millet can replace maize in guinea fowl diets without negatively affecting mineral retention.

Table 4.17: Main effect of Pearl Millet inclusion level on the Nutrient Digestibility (%) of Laying Japanese quails

	INCLUSION LEVEL			
	Control	50%	100%	SEM*
PARAMETER				
Crude Protein (%)	79.94[b]	84.45[a]	83.38[ab]	1.31
Crude Fibre (%)	62.90	55.92	52.39	3.73
Ether extract (%)	91.50	92.99	91.65	0.61
Ash (%)	79.73	82.04	78.64	1.76
Nitrogen free extract (%)	70.29	73.80	71.51	2.11

[a, b, c] means in a row with no common superscript(s) differ significantly (P<0.05) SEM – standard error of mean

* The SEM is for comparison between the 2 pearl millet inclusion levels. Comparison with the control was done using Dunnet's test

4.2.16 Effect of pearl millet form on the nutrient digestibility of laying Japanese quails (8-20 weeks)

The effect of pearl millet form on the nutrient digestibility of laying Japanese quails is shown in table 4.18. The crude protein digestibility of laying Japanese quails fed whole pearl millet was higher ($P<0.05$) than that of the control. Quails fed ground pearl millet had similar ($P>0.05$) crude protein digestibility with both the whole pearl millet and the control fed groups. Quails fed the control digest crude fibre better ($P<0.05$) than those fed ground pearl millet. While those fed whole pearl millet have similar ($P>0.05$) crude fibre digestibility to those of the ground pearl millet or the control. Ether extract digestibility was highest ($P<0.05$) for the whole pearl millet fed quails followed by those fed the control and the least was for those fed ground pearl millet. Ash digestibility was higher ($P<0.05$) in the whole pearl millet based diet compared to the ground pearl millet based diet. The control has similar ($P>0.05$) ash digestibility with both the whole pearl millet and ground pearl millet diets.

Laying Japanese quails fed whole pearl millet and ground pearl millet had similar ($P>0.05$) nitrogen free extract digestibility compared to the control. This is contrary to the report of Garcia (2006) who observed that digestibility of starch was slightly, but significantly, improved when whole millet was incorporated into the diet. Leeson and Summers, (2005), Enberg *et al*. (2004) and Svihus *et al.* (2004) reported increased starch digestibility in birds fed with whole grains. Biggs and Parsons, (2009) also observed that at 7d and 21d chicks fed 10% whole barley had an improved digestibility of most amino acids when compared with chicks fed the maize-soyabean meal diet and that at 21d, whole sorghum had little positive effect on amino acids digestibility. The improvement in nutrients' digestibility was hinged to increased gizzard size and function as reported by these authors. This stimulation might not have occurred or was not significant in this study as feeding whole pearl millet did not affect gizzard weight (table 4.9).

Table 4.18: Main effect of Pearl millet form on the Nutrient Digestibility (%) of Laying Japanese quails

	PEARL MILLET FORM			
	Control	WPM	GPM	SEM*
PARAMETER				
Crude Protein (%)	79.94[b]	85.81[a]	82.01[ab]	1.31
Crude Fibre (%)	62.90[a]	59.37[ab]	48.94[b]	3.73
Ether extract (%)	91.50[b]	93.81[a]	90.84[c]	0.61
Ash (%)	79.73[ab]	84.65[a]	76.04[b]	1.76
Nitrogen free extract (%)	70.29	75.09	70.22	2.11

[a, b, c] means in a row with no common superscript(s) differ significantly (P<0.05) SEM – standard error of mean

WPM: whole pearl millet GPM: ground pearl millet

* The SEM is for comparison between the 2 pearl millet forms. Comparison with the control was done using Dunnet's test

4.2.17 Effect of enzyme supplementation of pearl millet diets on the nutrient digestibility (%) of laying Japanese quails (8-20 weeks)

The effect of enzyme supplementation of pearl millet diets on the nutrient digestibility (%) of laying Japanese quails is shown in table 4.19. Laying Japanese quails fed pearl millet without enzyme, pearl millet with enzyme or the control (0% pearl millet) had similar ($P>0.05$) crude protein digestibility, crude fibre digestibility, ether extract digestibility, ash digestibility and nitrogen free extract digestibility. In accordance with this result, Arumbackam *et al.* (2004) observed that enzyme supplementation did not influence crude protein digestibility and energy metabolizability. Contratry to the findings of this study, Baurhoo *et al.* (2011) discovered supplemention of pearl millet diets with enzyme increased crude protein digestibility in broilers chickens. Manwar and Mandal (2009) also found that enzymes supplementation may improve the utilization of pearl millet by broiler chickens.

Table 4.19: Main effect of Enzyme supplementation of pearl millet diets on the Nutrient Digestibility (%) of Laying Japanese quails

	ENZYME			
	Control	PM-EN	PM+EN	SEM*
PARAMETER				
Crude Protein (%)	79.94	84.45	83.38	1.68
Crude Fibre (%)	62.90	55.92	52.39	4.68
Ether extract (%)	91.50	93.00	91.65	0.98
Ash (%)	79.73	82.03	78.64	2.89
Nitrogen free extract (%)	70.29	73.80	71.51	2.45

[a, b, c] means in a row with no common superscript(s) differ significantly (P<0.05) SEM – standard error of mean

PM-EN: pearl millet without enzyme PM+EN: pearl millet with enzyme

* The SEM is for comparison between the 2 pearl millet based diets. Comparison with the control was done using Dunnet's test

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

This study was conducted with a view to reduce feed cost through feeding whole grains to Japanese quails, increase the feed ingredient base of Japanese quails and also literature on the use of pearl millet as energy source for Japanese quails. The aim of the study was to determine the effect of pearl millet inclusion level, pearl millet form and enzyme supplementation of pearl millet diets on the performance of Japanese quails.

Proximate analyses of pearl millet and that of different samples of the experimental diets were carried out. Two separate experiments were conducted. In the first experiment, 378 two weeks old unsexed Japanese quails were used in a 2 x 2 x 2 factorial arrangement in a completely randomized design with nine treatments replicated thrice with 14 quails per replicate in a four-week feeding trial. Feed intake and weight gain were measured weekly. Three quails per treatment were used for carcass evaluation. The second experiment evaluated the effect of pearl millet inclusion (50% or 100%), pearl millet form (whole or ground), and enzyme supplementation of pearl millet diets (with or without) as replacement for maize on the performance, egg quality parameters and nutrient's digestibility of laying Japanese quails using 162 seven weeks old female Japanese quails in the same arrangement as above but 6 quails per replicate. Egg production, feed intake and weight gain were measured and recorded. Egg quality analysis was also carried out. At the end, digestibility study was conducted.

The results of the study show that:

i. Pearl millet inclusion increased the total feed intake, average daily feed intake, feed conversion ratio, total feed cost and feed cost/kg gain of growing Japanese quails.

Performance parameters of growing Japanese quails were not affected by either pearl millet form or enzyme supplementation.

ii. Completely replacing maize with ground pearl millet without enzyme supplementation increased the intestinal weight while enzyme supplementation increased the proventricular weight of growing Japanese quails. Carcass yield, gizzard weight and liver weight were not affected by dietary inclusion level, form or enzyme supplementation of pearl millet diets.

iii. Pearl millet inclusion level, form (whole or ground) and enzyme supplementation in the diets increased feed intake and feed cost/dozen eggs of the laying Japanese quails compared to those of quails fed maize.

iv. Completely replacing maize with whole or ground pearl millet with or without enzyme supplementation increased the egg weight and reduced the Haugh unit of laying Japanese quails. Albumen and yolk percentages increased when 50% pearl millet was fed and decreased at 100% level. Feeding ground pearl millet and feeding pearl millet without enzyme supplementation decreased yolk percentage. The feeding whole pearl millet witrh or without enzyme supplementation increased shell thickness. Egg shape index, shell weight, shell percentage, albumen weight and yolk weight were not affected by these factors.

v. Feeding whole pearl millet increased the digestibility of crude protein, ether extract and ash while decreasing digestibility of crude fibre in laying Japanese quails compared to feeding maize. Pearl millet inclusion increased only the crude protein digestibility of laying Japanese quails compared to maize. Enzyme supplementation of pearl millet based diets did not improve their nutrient's digestibility.

5.2 Conclusions

From the results of this study, it can be concluded that;

i. Pearl millet is a satisfactory cereal grain for the feeding both growing and laying Japanese quails. However, it increased feed cost.
ii. Grinding and enzyme supplementation of pearl millet based diets were not beneficial in the feeding of growing and laying Japanese quails.

5.3 Recommendations

i. Where the price of millet of pearl millet is lower than that of maize, pearl millet can replace maize in the diets of growing and laying Japanese quails.
ii. Whole pearl millet can be fed to Japanese quails.
iii. Enzyme supplementation might not be necessary when feeding pearl millet based diets.
iv. Further studies should be carried out to look at the effects of the feed particle sizes and systems of whole pearl millet feeding on the performance of Japanese quails.

REFERENCES

Abd-ElRazig, S. M. (1997). Nutritional Value of Pearl Millet in Laying Hen Diets. A Master's Thesis in Poultry Production submitted to the University of Khartoum, Sudan.

Abubakar, A., Bashar, Y. A. and Eguke B. O. C. (2006). Pearl millet as substitute for maize in the diets of broiler chickens in Sokoto, Nigeria. *Tropical Journal of Animal Science 9*(2) 53-61.

Aduku, A. O. (1999). Tropical Feedstuff Analysis Table. Deepartment of Animal Science, Ahmadu Bello University, Zaria, Nigeria.

Akinola, L. A. F. and Sese, B. T. (2012). Performance and Body Composition of Japanese quail (*Coturnix Coturnix Japonica*) Fed Different Dietary Nutrients in Nigerian Humid Tropical Environment. *Journal of Animal Sciences Advances, 2*(11): 907-913.

Alam, M. J., Howlider, M. A. R., Pramanik, M. A. H. and Haque, M. A. (2003) Effect of Exogenous Enzyme in Diet on Broiler Performance. *International Journal of Poultry Science, 2* (2): 168-173, 2003

Amerah, A. M. (2008). Feed Particle Size, Whole Wheat Inclusion and Xylanase Supplementation in Broiler Diets: Influence of Performance, Digesta Characteristics and Digestive Tract Development. Ph.D. Thesis. Massey University, Palmerston North, New Zealand.

Amini, K. and Ruiz-Feria, C. A. (2008). Production of Omega-3 Fatty Acid Enriched Eggs Using Pearl Millet Grain, Low Levels of Flaxseed and Natural Pigments. *International Journal of Poultry Science, 7: 765-772.* Retrieved 30th July, 2013, from http://scialert.net/abstract/?doi=ijps.2008.765.772 DOI: 10.3923/ijps.2008.765.772

AOAC (2003). Official methods of analysis of the Association of official analytical chemist, 17th edition. Association of official analytical chemist, Arlington, Virginia, U.S.A.

Arroyo J., Auvergne, A., Dubois, J. P., Lavigne, F., Bijja, M., Bannelier, C. and FortunLamothe, L. (2012). Effects of presentation and type of cereals (corn or sorghum) on performance of geese. *Poultry Science*, 91(8):2063-2071. Retrieved 7th June, 2013, from http://www.thepoultrysite.com/poultrynews/26592/whole-sorghum-shows-promise-for-feeding-geese

Arumbackam, V. E., Asit, B. M., Pramod, K T., Praveen, K. T., Saroj, T. and Tripurari, S. J. (2004). Effects of enzymes in diets with varying energy levels on growth and egg production performance of Japanese quail. *Journal of the Science of Food and Agriculture, 84*(15), 2028–2034. doi: 10.1002/jsfa.1910

Attia, Y. A., Tag El-Din, A. E., Zeweil, H. S., Hussein, A. S., Qota, E. M. and Arafat, M. A. (2008). The effect of supplementation of enzyme on laying and reproductive performance in Japanese quail hens fed Nigella seed meal. *The Journal of Poultry Science, 45*:110-115. doi:10214/jpsa.45.110

Baurhoo, N., Baurhoo, B., Mustafa, A. F. and Zhao, X. (2010). Comparison of corn-based and Canadian pearl millet-based diets on performance, digestibility, villus morphology, and digestive microbial populations in broiler chickens. *Poultry Science, 90*(3), 579-586.

Baurhoo, N., Baurhoo, B. and Zhao, X. (2011). Effects of exogenous enzymes in corn-based and Canadian pearl millet-based diets with reduced soybean meal on growth performance, intestinal nutrient digestibility, villus development, and selected microbial populations in broiler chickens. *Journal of Animal Science, 89*:4100-4108

Bawa, G. S. (2006). Practical feed formulation and mixing for quails. A paper presented at a workshop on quails production for sustainable household protein intake at NAERLS on 11 – 14 September, 2006.

Bedford, M. R. and Partridge, G. G. (2001). *Enzyme in Farm Animal Nutrition*, Finnfeeds Malborough, Wiltshire, UK. CABI Publishing, UK, pp. 1-9.

Bennett, C. D. , Classen, H. L. and Riddell, C. (2002). Feeding broiler chickens wheat and barley diets containing whole, ground and pelleted Grain. *Poultry Science, 81*:995–1003

Bennett, C. D. and Classen, H. L. (2003). Performance of Two Strains of Laying Hens Fed Ground and Whole Barley with and Without Access to Insoluble Grit. *Poultry Science, 82*:147–149

Biggs, P. and Parsons, C. M. (2009). The effects of whole grains on nutrient digestibilities, growth performance, and cecal short-chain fatty acid concentrations in young chicks fed ground corn-soybean meal diets. *Poultry Science, 88* :1893–1905.

Bjerrum, L., Pedersen, A.K. and Engberg, R.M. (2005). The influence of whole wheat feeding on Salmonella infection and gut flora composition in broilers. *Avian Diseases, 49*(9):9–15. Retrieved 7th June, 2013, from http://www.jstor.org/stable/15934

Blair, R. (2008). *Nutrition and feeding of organic poultry*. Wallingford, UK: CABI Publishing, UK, pp. 6-207.

Chiripasi, S. C., Moreki, J. C., Nsoso, S. J. and Letso, M. (2013). Effect of feeding yellow maize, white sorghum and pearl millet as energy sources on mineral intake, retention and utilisation by guinea fowl under intensive management system. *ARPN Journal of Science and Technology, 3*(1):124 – 137.

Collins, V. P., Cantor, A. H., Pescatore, A. J., Straw, M. I. and Ford, M. J. (1997). Pearl millet in layer diets enhances egg yolk n-3 fatty acids. *Poultry Science, 76*:326-330.

Cowieson, A. J., Hruby, M. and Pierson, E. E. M. (2006). Evolving enzyme technology: impact on commercial poultry nutrition. *Nutrition Research Reviews, 19*:90-103. doi:10.1079/NRR2006121.

Dale, N. M. (2006). *Pearl millet for layers: A new opportunity*. *Commercial Egg Tip*. (Factsheet) The University of Georgia, Cooperative Extension Service College of Agricultural and Environmental Sciences, Athens, Georgia.

Davis, A. J., Dale, N. M. and Ferreira, F. J. (2003). Pearl millet as an alternative feed ingredient in broiler diets. *Journal of Applied Poultry Research, 12*:137–144.

Dozier, W. A., Hanna, W. and Behnke, K. (2005). Grinding and pelleting responses of pearl millet-based diets. *Journal of Applied Poultry Research, 14*:269–274.

Engberg, R. M., Hedemann, M. S., Steenfeldt, S., and Jensen, B. B. (2004). Influence of whole wheat and xylanase on broiler performance and microbial composition and activity in the digestive tract. *Poultry Science, 83*:925–938.

Ernst, R. A., Pran, V., Kratzer, E. H. and Ibanga, O. (1994). A comparison of feeding corn, oats and barley on the growth of White Leghorn chickens, gastrointestinal weights of males, and sexual maturity of females. *Journal of Applied Poultry Research, 3*:253–260.

Evans, M., Singh, D.N., Trappet, P. and Nagle, T. (2005) Investigations into the effect of feeding laying hens complete diets with wheat in whole or ground form and zeolite presented in powdered or grit form, on performance and oocyst output after being challenged with coccidiosis. In: Scott, T.A. (ed.) *Proceedings of the 17th Australian Poultry Science Symposium*. Sydney, New South Wales, Australia, 7–9 February 2005, pp. 187–190. Retrieved 7th June, 2013, from http://sydney.edu.au/vetscience/apss/documents/2005/APSS2005-evans-pp187-190.pdf

Faruk, M. U. (2010). *Evaluation of the impact of Loose-mix and Sequential feeding using locally available feed ingredients on performance in layer hen*. Doctoral dissertation, Universite Francois - Rabelais de Tours Ecole Doctorale Sst Dynamiques Nutritionnelles Unité de Recherches Avicoles – INRA Centre de Tours, Nouzilly, France.

Filardi, R. S., Junqueira, O. M., Casartelli, E. M., Laurentiz, A. C., Duarte, K. F. and Assuena, V. (2005). Pearl millet utilization in commercial laying hen diets formulated on a total or digestible amino acid basis. *Revista Brasileira de Ciência Avícola, 7*(2):99-105. Retrieved 7th June, 2013, from http://dx.doi.org/10.1590/S1516-635X2005000200006

Garcia, A. R. (2006). *Evaluating Feed Components for Formulation of Pre-Starter Diets for Broiler Chickens*. A Doctoral dissertation, University of Georgia. Athens, Georgia

Garcia, A. F. Q. M., Murakami, A. E., Massuda, E. M., Urgnani, F. J., Potença, A., Duarte, C. R. do A. and Eyng, C. (2012). Pearl millet in the diet of Japanese quails.(Milheto na alimentação de codornas japonesas). *Revista Brasileira de Saude e Producao Animal, 13*(1):150-159. Retrieved 27th August, 2013 from http://www.cabdirect.org/abstracts/20123130831Html

Garcia, A. R. and Dale, N. M. (2006). Feeding of unground pearl millet to laying hens. *Journal of Applied Poultry Research, 15*:574–578. Retrieved 27th August, 2013 from http://japr.fass.org/content/15/4/574.full.pdf+html

Geraert, P. A. and Dalibard, P. (2003). Enzymes in layer diets: an opportunity. World Poultry Volume 19 number 4. http://www.worldpoultry.net/PageFiles/23766/001_boerderij-download-WP6111D01.pdf

Hafeni, S. (2013). Performance of Broiler Chickens Fed Pearl Millet as an Energy Source and *Acacia Karroo* Leaf Meal as an Additive. A Thesis Submitted in Fulfillment of the Requirements for the Degree of Master of Science in Agriculture in the Department of Animal Science, Faculty of Agriculture and Natural Resources, The University of Namibia.

Hassan, M. R., Amodu, J. T., Abdu, S. B., Adamu, H. Y., Enaohwo, A., Adedibu, I. I., Tamburawa, M. S. and Abia, E. (2013). Dry Leaves of African Black Plum (*Vitex doniana L. Sweet*) as Option for Smallholder Goat Keepers in Nigeria. *Advances in Agriculture, Sciences and Engineering Research*, Vol 3, No 8.

Hemid, A. E. A., Abd El-Gawad, A. H., El-Wardany, E., El-Daly, E. F. and Abd El- Azeem, N. A. (2010). Alleviating the Effect of Some Environmental Stress Factors on. Productive Performance in Japanese Quail 2. Laying Performance. *World Journal of Agricultural Sciences* 6(5). 517-524.

Henuk, Y.L. and Dingle, J.D. (2002). Practical and economic advantages of choice feeding systems for laying poultry. *World's Poultry Science Journal* 58, 199–208.

Heuzé V. and Tran G., (2013). *Maize grain*. A programme by INRA, CIRAD, AFZ and FAO. Retrieved 31st July, 2013 from http://www.feedipedia.org/node/556

Heuzé V. and Tran G., (2012). *Pearl millet (Pennisetum glaucum), grain*. A programme by INRA, CIRAD, AFZ and FAO. Retrieved 31st July, 2013 from http://www.feedipedia.org/node/724

Hidalgo, M. A., Davis, A. J., Dale, 1 N. M. and Dozier, W. A. (2004). Use of whole pearl millet in broiler diets. *Journal of Applied Poultry Research, 13*:229-234.

Ibitoye, E. B., Olorede, B. R., Egbewande, O. O., Jimoh, A. A., Suleiman, N., Kolawole, N. Y. and Abdullahi, H. (2012). Replacement value of sorghum and millet for maize in the diets of broiler chickens. In Bitto, I. I., Kaankuka, F. G. and Attah, S. (Eds.) *Proceedings of the 37th Annual Conference of Nigerian Society for Animal Production*, 18 – 21 March, 2012. University of Agriculture Makurdi, Benue state, Nigeria. Pp 226-228.

Ijaiya, A. T., Aremu, A., Egena, S. S. A., Akinwale, M. O., Alao, R. O. and Mamman, H. (2012). Growth, performance and nutrient digestibility of Japanese quails (*Coturnix coturnix japonica*) fed graded levels of fermented cassava peel meal. In Bitto, I. I., Kaankuka, F. G. and Attah, S. (Eds.) *Proceedings of the 37th Annual Conference of Nigerian Society for Animal Production*, 18 – 21 March, 2012. University of Agriculture Makurdi, Benue state, Nigeria. Pp 391-394.

Jones, G. P. D. and Taylor, R. D. (2001). The incorporation of whole grain into pelleted broiler chicken diets: production and physiological responses. *British Poultry Science, 42*, 477–483.

Kasim, A.B. and Edwards Jr. H.M. (2000) Effect of sources of maize and maize particle sizes on the utilization of phytate phosphorus in broiler chicks. *Animal Feed Science and Technology, 86*:15 - 26.

Kermanshahi, H. and Classen, H.L. (2001). Feeding Whole Wheat With or Without a Dietary Enzyme or Grit to Laying Hens. *Journal of Agricultural Science and Technology 3*:193-198. Retrieved 8th July, 2013, from http://jast.journals.modares.ac.ir/jufile

Kilburn, J. and H.M. Edwards, Jr., (2001). The response of broilers to the feeding of mash or pelleted diets containing maize of varying particle sizes. *British Poultry Science, 42*:484- 492.

Kondombo, S.R., Slingerland, M.A., Kwakkel, R.P., Nianogo, A.J. and Verstegen, M.W.A. (2005). Village chicken production systems. In Kondombo, S.R. (2005). *Improvement of village chicken production in a mixed (chicken-ram) farming system inBurkina Faso.*PhD Thesis, Wageningen Institute of Animal Sciences, Animal Nutrition Group, Wageningen University, AH Wageningen, The Netherlands.

Koster, H. (2003) Improved animal performance through feed processing technology Paper presented at AFMA's annual symposium on 22 August 2003.

Kumar, A. M., Reddy, V. R., Reddy, P. V. and Reddy, R. S. (1991). Utilization of pearl millet (*Pennisetum typhoides*) for egg production. *British Poultry Science* 32:463-469.

Leandro, N. S. M., Stringhini, J.H., Café, M. B., França, A.F.S. and Freitas, S. A. (1999). Milheto (*Pennisetum glaucum* (L.) R.Br.) como substituto do milho em rações para codornas-japonesas em postura (*Coturnix coturnix japonica*) (Pearl millet grain as corn substitute in laying japanese quail(*Coturnix coturnix japonica*) rations). Arquivo Brasileiro de Medicina Veterinária e Zootecnia vol. 51 no.2. Retrieved 7th June, 2013, from http://www.scielo.br/scielo.php?script=sci_arttext&pid=S010209351999000200010&lng=en&nrm=iso&tlng=pt

Ledvinka, Z., Zita, L. and Klesalov L. (2012). Egg quality and some factors influencing it: a review. *Scientia agriculturae bohemica, 43* (1): 46–52.

Leeson, S. and Summers, J.D. (2005). *Commercial Poultry Nutrition*, Third Edition. Nottingham University Press, Nottingham, England, pp. 9-229.

Manwar, S. J. and Mandal, A. B. (2009). Effect of high moisture storage of pearl millet (Pennisetum typhoides) with or without feed enzymes on growth and nutrient utilization in broiler chickens. *Animal Science Journal*, *80*(4): 438-445.

Mateos, G. G., Jiménez-Moreno, E., Serrano, M. P. and Lázaro, R. P. (2012). Poultry response to high levels of dietary fiber sources varying in physical and chemical characteristics. *Journal of Applied Poultry Research.* 21:156–174. Retrieved 4th April, 2012, from http://dx.doi.org/10.3382/japr.2011-00477

Matthias, S. J. and Hasan, G. A. (2003). Phenotypic flexibility of structure and function of the digestive system of Japanese quail. *The Journal of Experimental Biology, 206*: 1887-1897.

Medugu, C. I., Kwari, I. D., Igwebuike, J., Nkama, I., Mohammed, I. D., and Hamaker, B. (2010). Performance and economics of production of broiler chickens fed sorghum or millet as replacement for maize in the semi-arid zone of Nigeria. *Agriculture and Biology Journal of North America, 1*(3): 321-325. Retrieved 17th March, 2014, from http://scihub.org/ABJNA/PDF/2010/3/1-3-321-325.pdf

Medugu, C. I., Raji, A. O., Igwebuike, J. U. and Barwa, E. (2011). Alternative cereal grains and cereal by-products as sources of energy in poultry diets – A review. *Research Opinions in Animal and Veterinary Sciences.* Pp 530- 542

Mehran, M., Pourreza, J. and Sadeghi, G. (2010). Replacing maize with pearl millet in laying hens*'* diets. *Tropical Animal Health and Production, 42*: 439-444 doi:10.1007/s11250-009-9440-6.

Michard, J. (2011) *Dietary fibre, the forgotten nutrient*. Hubbard Technical Bulletin. Retrieved 24th August, 2013, from http://www.hubbardbreeders.com/bulletins/

Munir K. and Maqsood S. (2013). A review on role of exogenous enzyme supplementation in poultry production. *Emirates Journal of Food Agriculture, 25* (1): 66-80.

Muramatsu, K., Stringhini, J. H., Café, M. B., Jardim Filho, R. de M., Andrade, L., and Godoi, F. (2005). Pearl millet and corn based rations supplemented with different levels of soybean oil on performance and egg quality of laying hens. *Acta Scientiarum - Animal Sciences, 27*(1):43-48. Retrieved 24th August, 2013, from http://www.cabdirect.org/abstracts/20053179322.html

National Research Council, (1994). *Nutrient requirement of poultry*. 9th revised edition. National Academy of Sciences, Washington DC. 45pp

Olatoye, O. (2011). Healing power of Japanese quail egg. Nigerian Tribune, Oct. 4. Retrieved 7th June, 2012, from http://tribune.com.ng/index.php/wealth-creation-through-agric/29101-healing-power-of-japanese-quail-eggs

Patrick, D. J. (2004). Performance and Bone Quality of the Modern Broiler Chicken as Influenced by Dietary Calcium, Phosphorus, Phytase and 1−Alpha−Hydroxycholecalciferol. A thesis submitted to the Graduate Faculty o The University of Georgia in partial fulfillment of the requirements for the Degree Doctor of Philosophy. Athens, Georgia.Pearl Millet Grains In Poultry Feeds – An Indian Perspective. In: The 8th Asian Pacific Poultry Conference 2007, 5-6 March 2007, Bangkok, Thailand.

Pavlovski, Z., Vitorovic, D., Skrbic, Z. and Vracar, S. (2000). Influence of limestone particle size in diets for hens and oviposition time on eggshell quality. *Acta Veterinaria (Beograd), 50*(1): 37-42.

Rao, R. S. V., Raju, M. V. L. N., Reddy, M. R. and Panda, A. K. (2004). Replacement of Yellow maize with Pearl millet (*Pennisetum typhoides*), Foxtail millet (*Setaria italica*) or Finger millet (*Eleusine coracana*) in broiler chicken diets containing supplemental enzymes. *Asian-Australian Journal of Animal Science, 17*:836-842

Reddy, A. R., Gowda, C. L. L., Reddy, B. V. S., Rai, K. N., Waliyar, F., Alur, A. S. and Ravinder Reddy, Ch (2006). Enhanced Utilization of Sorghum and Pearl Millet Grains in Poultry Feeds – An Indian Perspective. In: The 8th Asian Pacific Poultry Conference 2007, 5-6 March 2007, Bangkok, Thailand.

Roberts, J. R. (2010). Factors affecting egg shell and internal egg quality. 18th Annual ASAIM SE Asian Feed Technology and Nutrition Workshop May 24-27, 2010. Le Meridien Siem Reap. Cambodia. University of New England, Australia.

Robinson, D. (1985). Performance of Laying Hens as Affected by Split Time and Split Composition Dietary Regimens Using Ground and Unground Cereals. *British Poultry Science, 26*: 299-309.

Sade, F. O. (2009). Proximate, antinutritional and functional properties of processed pearl millet. *Journal of Food Technology, 7*(3): 92-97.

Statistical Analysis System, (1994). Statistical users guide. SAS institute Inc. Cary, North Carolina, U.S.A.

Schivera, D. (2003). Feeding whole grains to chickens. A publication of Maine Organic Farmers and Gardeners Association. Retrieved 4th April, 2012, from www.mofga.org/Publications

Seema, A., Gupta, S.C. and Chopra, S.K. (2007) Effect of replacement of maize with wheat or bajra on the egg production of Japanese Quails Department of Livestock Production and Management CCS Haryana Agril. University, Hisar – 125004. Retrieved 31st July, 2013, from http://www.poulvet.com/poultry/articles/avian_species/egg_production_quails.php

Shehab, A. E., Khedr, N. E., Zahran, K. M., Ahmed, T. E. and Esmaeil, F. A. (2012). Effect of Dietary Enzyme supplementation on Egg Laying Performance and Nutrient Digestibility of Japanese Quails. *International Journal for Agro Veterinary and Medical Sciences, 6*(5):377-384 doi:10.5455/ijavms.165

Sheppy, C. (2001). The current feed enzyme market and likely trends. In Bedford, M. R. and Partridge, G. G. (eds) (2001). *Enzyme in Farm AnimalNutrition*, CABI Publishing, UK

Singh, D. N. and Perez-Maldonado, R. (1999). Nutritional value of pearl millet as poultry feed. A report for the Rural Industries Research and Development Corporation. RIRDC Project No DAQ-243A

Statistical Analysis System, (1994). Statistical users guide. SAS institute Inc. Cary, North Carolina, U.S.A.

Steel, R.O.G. and Torrie, J.H. (1980). Principles and Procedures of Statistics. A biometrical approach. Students edition. McGraw-Hill Int. Books Co. London.

Summers, J. (1996). *Effect of cereal particle size on energy costs of grinding and broiler performance*. Factsheet-93 Retrieved 7th June, 2013, from http://www.poultryindustrycouncil.ca/pdfs/factsheets/fs_93.pdf

Svihus, B. (2001). Norwegian poultry industry converts to whole grain pellets. *Feed Technology, 5*(10):22–23.

Svihus, B. (2010). Challenging current poultry feeding dogmas by feed intake restriction and the use of coarse feed ingredients. In P. Selle (Ed) 21st Annual Australian Poultry Science Symposium Sydney, New South Wales, 1 – 3 February, 2010.

Svihus, B. and Hetland, H. (2004). *Feed particle size and dietary fibre affect nutrient utilization*. Agricultural University of Norway, As. Norway.

Svihus, B., Juvik, E., Hetland, H. and Krogdahl, A. (2004). Causes for improvement in nutritive value of broiler chicken diets with whole wheat instead of ground wheat. *British Poultry Science, 45*(1):55-60. Retrieved 7th June, 2013, from http://www.ncbi.nlm.nih.gov/pubmed/15115201

Taylor, R.D. and Jones, G.P.D. (2004). The influence of whole grain inclusion in pelleted broiler diets on proventricular dilatation and ascites mortality. *British Poultry Science*, 45: 247–254.

Tornekar, A.P., Munde, V.K. and Kokane, S.S. (2009). Effect of Replacing Maize with Bajra (Pearl Millet) on the Performance of Broilers. *Veterinary World*, *2*(8):310-312.

U. K. C. A. G. (2012). *Common grains in poultry diets*. Department of Animal and Food Sciences, College of Agriculture, Food and Environment. University of Kentucky. Retrieved 7th June, 2013, from www2.ca.uky.edu/smallflocks/Feed_ingredients/ Grains.html

Udeybir, Niranjan, P. S., and Yadav, K. R. (2009). Effect of pearl millet based diet with or without enzyme supplementation on broilers. *Journal Indian Veterinary Journal*, *86*(2): 210-211

Umar Faruk, M., Bouvarel, I., Meme, N., Rideau, N., Roffidal, L., Tukur, H.M., Bastianelli, D., Nys, Y., Lescoat, P. (2010a) Sequential feeding using whole wheat and a separate protein-mineral concentrate improved efficiency in laying hens. *Poultry Science, 80*:785-796.

Umar Faruk, M., Lescoat, P., Bouvarel, I., Nys, Y. and Tukur, H. M. (2010b). Use of whole millet (*Pennisetum glaucum*) and protein-mineral concentrate in poultry feeding is an efficient method in feed management in Nigeria. *Proceedings of the XIIIth European Poultry Conference*, 23 – 27 August, 2010. Tours, France, pp. 211-215.