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COLLEGE OF VETERINARY MEDICINE AND AGRICULTURE

DEPARTMENT OF ANIMAL PRODUCTION STUDIES

DETERMINING AN OPTIMUM COMBINATION OF METABOLIZEABLE ENERGY AND CRUDE PROTEIN LEVELS FOR DZ-WHITE CHICKENS

MSc Thesis

TEWODROS FEKADU GEBRU

June, 2021

Bishoftu, Ethiopia

DETERMINING AN OPTIMUM COMBINATION OF METABOLIZEABLE ENERGY AND CRUDE PROTEIN LEVELS FOR DZ-WHITE CHICKENS

A Thesis Submitted to the College of Veterinary Medicine and Agriculture
Addis Ababa University

In Partial Fulfillment of the Requirements for the Degree of
MASTER OF SCIENCE IN ANIMAL PRODUCTION

By

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APPROVAL SHEET

ADDIS ABABA UNIVERSITY

COLLEGE OF VETERINARY MEDICINE AND AGRICULTURE

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As MSc research advisors, we hereby certify that we have read and evaluated this Thesis prepared under our guidance by Tewodros Fekadu Gebru title: **Determining an Optimum Combination of Metabolizeable Energy and Crude Protein Levels for DZ-White Chickens**, we recommend that it can be submitted as fulfilling the MSc Thesis requirement.

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As members of the Examining Board of the final MSc open defense, we certify that we have read and evaluated the Thesis prepared by: **Tewodros Fekadu Gebru** Entitled "**Determining an Optimum Combination of Metabolizeable Energy and Crude Protein Levels for DZ-White Chickens**" and recommend that it can be accepted as fulfilling the Thesis requirement for the degree of Masters of Science in **Animal Production Studies**.

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DEDICATION

This Thesis is dedicated to my beloved families, my wife Mrs. Hana Tadesse for her love, encouragement and moral support throughout my life, my daughter Hasset Tewodros and my son Dagmawi Tewodros for their unreserved love.

STATEMENT OF THE AUTHOR

First, I declare that this Thesis is my own work and that all sources of materials used for this Thesis have been properly acknowledged. It has been submitted in partial fulfillment of the requirements for MSc degree at Addis Ababa University, college of Veterinary Medicine and Agriculture and is deposited at the University Library to be made available to borrowers under rules of the Library. I seriously declare that this Thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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BIOGRAPHICAL SKETCH

The author was born on July 03, 1988 E.C in Gondar, Ethiopia. He attended his elementary and secondary school educations in Ambagiorgis Higher and Junior Secondary School and his preparatory education in Fasiledes Preparatory School in Gondar. He completed his Bachelor of Science Degree in Animal, Rangeland and Wildlife Sciences from Mekelle University in 2008 E.C.

In April 2009, he joined Fogera District Agriculture and Rural Development Office and work as Extension Communication and Value Chain Officer and as Animal Feed and Nutrition Expert until February 2014. In June 2014 he joined Ethiopian Institute of Agricultural Research (EIAR), Debre Zeit Agricultural Research Center (DZARC) and served as an Assistant Researcher till now.

Subsequently, in September 2019 he joined Addis Ababa University, College of Veterinary Medicine and Agriculture, Department of Animal Production Studies for MSc Program in Animal Production.

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LIST OF ABBREVIATIONS

AA	Amino acid
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemist
BW	Body Weight Gain
CF	Crude Fiber
CBR	Cost Benefit Ratio
CP	Crude Protein
CSA	Central Statistics Agency
DM	Dry Matter
DMRT	Duncan Multiple Range Test
DZARC	Debre-Zeit Agricultural Research Center
EE	Ether Extract
EN	Egg Number
FAO	Food and Agriculture Organization of the United Nation
FCR	Feed Conversion Ratio
FI	Feed intake
GLM	General Linear Model
HDEP	Hen-Day Egg Production
HHEP	Hen-Housed Egg Production
HUS	Haugh Unit Score
Kcal	Kilo calorie
LW	Live Weight
ME	Metabolizeable energy
MOA	Ministry of Agriculture
NFE	Nitrogen Free Extract
NI	Net Income
NRC	National Research Council
SAS	Statistical Analysis System
SBM	Soybean Meal
SEM	Standard Error of Mean
TFC	Total Feed Cost

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ABSTRACT

*A feeding trial was conducted to determine an optimum combination of metabolizeable energy (ME, kcal/kg) and crude protein (% CP) levels for the DZ-White chicken strain at Debre-Zeit Agricultural Research Center (DZARC). The experiment had four phases: starter (0-8 wks), grower (9-14 wks), pullet (15-19 wks) and layer (20-35 wks). The experimental diets were formulated containing leveled proteins for starters (19, 18 or 17% CP), for growers (18, 17 or 16% CP), pullets (17, 16 or 15% CP) and layers (14.5, 15.5 or 16.5% CP). Metabolizeable energy (ME) was also leveled while formulating the above experimental diets for both starters and growers (2900, 2750 or 2600 kcal/kg DM), and for both pullets and layers (2850, 2750 or 2650 kcal/kg). A total of 1260 un-sexed one-day old DZ-white chicks were randomly allocated to the nine dietary treatments, with 3*3 factorial arrangements, in a Completely Randomized Design (CRD). Chemical compositions of feed ingredients were analyzed and body weight (BW), feed intake, egg production, hatchability, fertility and egg quality parameters were recorded. The results indicated that dietary treatments with varied levels of ME and CP showed a significant (P <0.05) effect on feed intake of chickens at the starter phase, but not at grower and pullet phases. The Feed conversion ratio (FCR) and body weight gain (BWG) of chickens were significantly (P <0.05) influenced by dietary proteins and energy in all experimental phases. FCR and BWG were increased in diets containing high levels of crude protein and ME. There was a significant (P <0.05) difference between birds on the total and percentage of hen-day egg production due to the leveled CP and ME in diets. No significant (P >0.05) effect was detected among the dietary treatments (CP, ME and their interaction) on hatchability, fertility and most egg quality parameters. From this study it can be concluded that for maximum growth and good FCR DZ-White chickens need a diet with higher levels of protein and energy (19% CP in starter and 18% CP in grower phases each with 2900 kcal/kg of ME). It is certainly suggested to economically feed the DZ-white chickens with a layer diet, containing 15.5% CP and 2750 kcal/kg of ME.*

Keywords: Crude Protein, DZ-White Chickens, Egg Production, Fertility, Growth, Hatchability, Metabolizeable Energy

1. INTRODUCTION

Poultry products consumption is recently outstripping the growth of all other animal-source foods in all regions of the world (Michael, 2017). However, average *per capita* poultry meat and egg consumption in Ethiopia are about 0.5 and 0.6 kg, respectively, which are the lowest among others in the world. For example, the *per capita,* in Sub-Saharan Africa is 2.3 kg (Robinson and Pozzi, 2011). Collectively, these all might be due to use of unimproved chicken breeds and traditional management systems. Pagani and Wossene (2008) also reported that the traditional poultry production continues to dominate domestic poultry production in Ethiopia. Most chicken productions in the country have been practicing on the backyard farming, using indigenous breeds (Halima *et al.,* 2007).

The poultry industry in Ethiopia is generally in its infancy stage, but still it holds a considerable potential for poverty alleviation, ensuring food security and economic growth (Robinson and Pozzi, 2011). Therefore, transformation of both traditional backyard poultry production and expansion of use of exotic layers are very important strategies to meet the future projected gap in total meat and egg consumption.

Different strategies have been implemented so far to improve production and productivity of the country's poultry sector. Different institutions have introduced exotic chicken breeds and distributed to the farmers across different parts of the country.

In parallel to the importation of improved chicken breeds, the National Poultry Research Program of the Debre-Zeit Agricultural Research Center (DZARC) has developed a synthetic dual purpose chicken strain known as DZ-white feather. A DZ-white feather chicken breed was developed from Lohman silver, Koekoek and Rhode Island White (RIW) chicken breeds. The main purpose of crossing the above different chicken breeds was to develop a strain, the so called DZ-white feather which is supposed to have better productivity and be able to fit to the semi-intensive production system that finally contributing to the improvement of living conditions of Ethiopian small holder farmers (Mulugeta *et al.,* 2020).

Moreover, the national poultry research program, in the DZARC has planned to multiply and distribute this dual purpose breed at larger scale. However, there are some limitations to prepare production package of this breed. One of the contents of this package is specific ration/diet formulation formula which satisfies the minimum nutrient requirements, at least for major nutrients (protein and energy) needs to be determined for this dual purpose chickens.

Currently, while formulating diet for this DZ-White chicken strain, the Research Center is using a common formula that basically uses to formulate diets for any commercial-layer chickens, which are completely different from this dual purpose chickens. The fact is that DZ-white chickens are a dual purpose and medium-egg-laying strain. Therefore, feeding these breeds with expensive diets that are prepared based on the requirements of commercial layers', may not be economical and cost effective.

So far, there is no or little information available on an optimum combination of dietary proteins and energy, as nutrient requirement levels for dual purpose chicken breeds, specifically DZ-white chickens. Therefore, it was expected that this study would help to find an optimum and cost effective combination of these major nutrients and thereby to prepare diets for this newly synthesized chicken breed.

Therefore, this study was carried out with the following objectives:

General Objective

- To determine an optimum combination of dietary energy and crude protein and least-cost diet for the newly developed DZ-white chicken breed.

Specific Objectives

- To evaluate the effects of different levels of dietary crude protein and metabolizeable energy on the growth performance of DZ-White chickens;
- To evaluate the effects of various combinations of metabolizeable energy and crude protein on egg production and egg quality; and
- To assess the effects of various levels of metabolizeable energy and crude protein on the cost-effectiveness of dual purpose chicken production.

2. LITERATURE REVIEW

Poultry production has important economic, social and cultural benefits and plays a significant role in family nutrition in the developing countries. In sub Saharan Africa, 85% of the rural households keep chickens and they are sources of affordable animal protein and household incomes (Aklilu *et al.*, 2007). It is also an employment opportunity for the youth, elders and women in the urban and peri-urban areas.

According to CSA (2020) the estimated chicken population in Ethiopia is about 57 million of which, 78.85%, 9.11% and 12.02% are indigenous, exotic and hybrid respectively. Even though chickens have a great importance to the lives of most rural people, their contribution is not proportional to the huge population. The low productivity of indigenous chickens; prevalence of diseases, lack of animal feed both in quantity and quality and poor extension service are among the major constraints affecting the chicken production in the country (Natnael, 2015).

The most important constraints that affecting the local chicken production are their low productivity, prevalence of diseases, poor quality of feeds and poor extension services (Natnael, 2015).

Many reports show that there has been shifting of production systems to the commercial production. However, the expansion of the commercial chicken production is limited by the shortage of local supply of improved chicken breeds (Dawud *et al.*, 2018). Efforts are currently being made to alleviate this problem by introducing high-performing exotic chicken strains that can adapt and perform in intensive and extensive management conditions in Ethiopia.

Literatures indicated that different strategies have been implemented so far to improve production and productivity of the poultry sector in Ethiopia. Among others, different institutions, such as Ministry of Agriculture (MOA), Research Institutions, Higher Learning Institutions, and NGOs, in Ethiopia have introduced and distributed exotic chicken breeds and the fertile eggs to the farmers almost across the country. Bovans Brown, Lohman Silver, koekoek, Sasoo, Rhode Island Red and White Leghorn were being the introduced chicken breeds into the country in different times by different organizations with the objective to fill this gap.

2.1. Dual Purpose Chickens in Ethiopia

Exotic chicken breeds require high nutritional and health management systems, in order to express their full genetic potentials (FAO, 2014). Those chickens are bred exclusively for meat or for egg production. However, dual purpose chickens have an advantage of both type i.e., hens lay eggs and males produce meat. A dual purpose chicken is a breed that lay eggs, but still grow fast (relatively) and large enough to be used as meat. The older hens (spent layers) are also heavy enough to be used as meat chickens.

Exotic chicken breeds have mostly been used to up-grade indigenous village chickens or used by commercial producers for egg and meat production. As it was mentioned in the background above, DZ-white is a strain-cross found by crossbreeding the Lohman Silver, Koekoek and Rhode Island White (RIW) chicken breeds.

Koekoek chickens are one of the South African dual purpose breeds introduced by Ethiopian Institute of Agricultural Research because of its good production traits (fast growth rate and good egg layers). Since it is a tropical breed it is suitable for the semi scavenging production system and good for overcoming the problem of environmental stress. This breed is a good scavenger and has an annual egg production potential of 180-240 eggs and an average egg weight of 55.7g under intensive management system (Globbelaar *et al.*, 2010). The average weight for male koekoek chickens was 1.33, 1.87 and 2.47 kg at 5, 8 and 12 months of age respectively, and for females were 1.2, 1.64 and 1.59 kg of the same age with the males. It has a broody behavior which makes it most preferred by the farmers who have no artificial incubators (Shumye *et al*, 2018). Similar egg weight and egg production performance were reported by Lemlem and Tesfay (2010) from Rhode Island Red (185 and 52g) and White leghorn (176 and 52g) chicken breeds respectively (Abraham and Yayneshe, 2010).

Rhode Island White, a parent of DZ-White chicken, is a medium-sized dual purpose breed originating in the Rhode Island state of USA. It is the white colored variety of one of the most popular American chicken breed the Rhode Island Red. These chickens are productive and outstanding for both eggs and meat production. It has an average annual egg production potential of 240-250.

The egg production of the local chicken ecotypes in Ethiopia is about 48 eggs per year under extensive production system (CSA, 2207). According to Wondmeneh *et al.* (2016) reports, egg production potential of un-improved Horro, a local chicken is 66 eggs per year and average egg weight is 52g. However, the improved Horro chicken can lay up to 171 and 149 eggs per year under improved management systems both on station and on farm respectively. They also added that average egg weight for improved Horro under on station performance is 52.3g (Wondmeneh *et al.,* 2016).

2.2. Major Nutrient Requirements of Layer Chickens

Chickens need a steady supply of energy, protein, essential amino acids, essential fatty acids, minerals, vitamins and water in their feeds. Nutrients that are required by birds could vary according to species, age and the purpose of production whether the birds are kept for meat or egg production. To meet these specific needs, different classes of chicken have to be fed differently (Grobas *et al*., 1999; Garba *et al*., 2012).

A nutrient requirement, published in Nutrient Requirements of chickens (NRC, 1994) is one of the available sources and then, when preparing for those newly developed ones, it should be better to view as minimal nutrient needs for chickens. These requirements are being set-out from an extensive review of the published data followed by conducting series of experiments. Main parameters used to determine the requirements for a given nutrient includes growth, feed efficiency, egg production and quality of products (Singh *et al.,* 2019).

Formulating a cost-effective and balanced diet is fundamental to an economical poultry production, and this process depends on knowledge of nutrient requirements of poultry and the nutritional attributes of nutrient sources.

Dietary energy and proteins are the major nutrients of the diets of laying hens. However, determination of the required amounts of ME and %CP levels; in the diets is the most important decision to be made when it comes to feed formulation for poultry (Etalem *et al*., 2017).

2.2.1. Dietary energy requirements of layers

Defining birds' need for energy is somewhat more complex than specifying needs for most other nutrients. Chickens have a remarkable ability to monitor their energy intake and adjust feed intake as energy concentration changes in diets. Managing variations of chickens can influence the need of energy and so it is important to relate all other nutrients to the energy levels (Leeson and Summers, 2005).

Energy is an essential component of poultry diets that must be supplied in adequate amounts to meet the birds' requirements for maintenance, optimum growth, egg production and reproduction (Harms *et al.*, 2000).

Metabolizeable energy (ME) is the conventional measure of the available energy contents of feed ingredients. Birds eat primarily to satisfy their energy needs, provided that the diet is adequate in all other essential nutrients. Therefore, the energy concentration in the diet is a major determinant of chickens' feed intake. When the dietary energy level in the diet changes, the feed intake also changes, and the specifications for other nutrients must be modified to maintain the required intake. For this reason, the dietary energy level is often used as the starting point in the formulation of practical diets for chickens (Rao *et al.,* 2011; Garba *et al*., 2012).

2.2.2. Dietary crude protein requirements of layers

Protein is one of those vital nutrients for chickens and all other classes of animals. Protein and amino acid plays a significant role in growth, egg production and in many other biological functions (Hassan *et al.,* 2013).

To provide the optimum protein, in diets of chickens, it requires a detailed understanding of the protein requirements of the chickens and then manipulation of protein supplies in order to improve their productivity and health. Failure to provide adequate protein in birds' diet will result in a number of structural and health problems for the flock, as well as reduction in egg production. However, it is important to remember that chickens' protein and amino acid requirements vary considerably depending on their growth rate and level of egg production (Almeida *et al*., 2012). However, depending on the rate of growth or level of egg production of the individual bird, it's important to remember that chickens' protein and amino acid requirements can vary considerably (Almeida *et al*., 2012).

Ten of these amino acids are considered as essential elements in the diet because they are synthesized too slowly or not synthesized at all to meet the metabolic requirement. These need to be supplied in the diets. The others referred as dietary non-essential elements can be synthesized from other amino acids and no need to be considered in feed formulations (Hassan *et al.*, 2013 and Lin, 2013).

2.3. Effects of Different Levels of Metabolizeable Energy on the Performance of Layer Chickens

The energy requirements of laying hens have been widely studied under a wide variety of conditions, and with several types of diets. Kumar *et al.* (2009) reported that the growth performance of chicks was significantly affected by the dietary energy levels. In their study the ration containing 2700 and 2900 Kcal ME/kg had better effect on body weight gain than 2500 Kcal ME/kg. The lower level of energy was found inadequate for optimum body weight gain.

Some of the experiments, conducted by Leeson and Summers (2005) showed that brown egg laying pullets seem more responsive to energy in diets than do the white egg laying pullets. As energy level increased from 2750 to 3030 kcal ME/kg, at a fixed protein level, a reduction in growth rate was sometimes seen because protein and amino acid intakes were limited. Brown egg laying pullets seem to change their feed intake very little under these conditions and consequently there was an improvement in growth rate.

It was reported by Perez-Bonilla *et al*. (2012) that increasing the level of ME in the diet from 2,650 to 2,750 kcal/kg decreased feed intake (FI) by 3.45%, which is consistent with previous studies by other scholars (Sohail *et al*., 2003; Wu *et al*., 2005, 2007). Contrary to these findings, Nahashon *et al*. (2007) reported that the FI of birds was not affected by the ME levels. These conflicting results may be attributed to the different experimental conditions or laying periods.

Although some reports indicated that there was no significant effects of low and high energy diets on egg production of layers (Singh *et al*., 2004; Valkonen *et al*., 2008), better feed efficiency was observed at high energy levels compared to low energy levels (Morris *et al.,* 2003; Yuan *et al.*, 2009). Some scholars observed also significant effects of different levels of energy on egg production, feed consumption and feed efficiency. For example, Kling and Hawes (2000) studied on the effects of different levels of energy (2650, 2750, 2850 and 2950 kcal of ME/kg) on the performance of the laying hens and then reported that significant differences were found in feed consumption, feed efficiency and egg production. From their study, egg production was decreased in diets containing higher level of energy and it was also concluded that 2850 kcal, ME/kg in diet is sufficient for optimum egg production.

2.4. Effects of Different Levels of Crude Proteins on the Performance of Layers

In recent years the protein intake requirements of laying hens have been studied under a wide variety of conditions and with several types of diets. Kumar *et al.* (2009) reported that the growth performance of chicks was significantly affected by the dietary protein levels. The same authors reported also that the ration containing 22% CP resulted in maximum growth whereas the lowest gain was observed in the dietary treatments having 16% CP in growers. The lower level of protein was found inadequate for optimum body weight gain.

Harms *et al.* (2000) found a reduced BWG and late point of first egg lay when feeding the diets containing 11 or 14%CP to the white leghorn chickens as compared to those fed on 17 or 20%CP. Byerly *et al*. (2008) reported also that higher protein levels (19% and 21%) had significant effects on BWG and FCR.

Almeida *et al.* (2012) reported that increasing CP concentration from 17% to 23% did not improve growth of chickens kept between 3-6 weeks of age under high temperature (32°C). Protein utilization is usually better in birds fed low CP diets. However, reduced levels of dietary protein may be detrimental if no consideration is given to crude protein quality and its amino acid profiles. Crude protein is possibly be reduced at 2-4% in diets when the protein sources have methionine and lysine in the required amount and proportions weight (Han & Thacker, 2011; Li *et al.*, 2013).

Bonila *et al.* (2019) has reported that the birds receiving iso-caloric diets, with 18% CP laid significantly more eggs of heavier weight than those receiving 15% CP. Similarly, other scholars (Kling and Hawes, 2000; Almeida *et al*., 2012) found that an increase in CP level improved the egg production and suggested that, for optimum egg production the hens require 18- 20% CP. Lower CP levels in the diets of laying hens may not support optimum egg production (Singh *et al*., 2004) and feed efficiency (Junqueira *et al*., 2006).

Most layer management guides suggest a 16% CP diet from 50% laying rate to reach maximum production (32 weeks) and from 32 to 44 weeks of age, except for Hy-line Brown and Lohmann who recommend an average of 18 % CP (Novak *et al*., 2006).

2.5. Dietary Energy and Crude Protein Combinations for Optimum Productivity of Layers

In a study by Kumar (2009) it was reported that higher energy levels (2700 and 2900 Kcal ME/kg) had a positive effect on BWG than the lower levels 2500 (kcal ME/kg). In his study maximum growth was achieved also in higher crude protein level (22% CP) than lower levels (16% CP). The lower level of protein and energy was found inadequate for optimum BWG.

Anitha *et al.* (2002) studied the effects of different levels of energy on the performance of commercial layers with different levels of protein and found that a combination of 16% protein with ME, 2600 kcal/kg diet appeared to be adequate for optimum egg production. Nahashon *et al.* (2007) suggested also that diets composed of 2,800 kcal/kg and 14% CP were utilized with more efficiency by the laying hens at 26 to 50 wk and 62 to 86 wk of age.

Junqueira *et al.* (2006) evaluated the layers by feeding diets, with leveled ME (2,850, 2,950 and 3,050 kcal/kg) and CP% (16, 18, and 20%), and then the result showed that diets with ME, 2,850 kcal/kg and 16% CP was adequate for satisfactory performance. In another study by Sakomura *et al.* (2005) White Leghorn layers were fed a diet containing 14, 16 and 18% protein and ME, 2500, 2700 and 2900 kcal/kg. The result of this experiment showed that 16% CP and 2700 kcal/kg, ME was the most favorable combination for optimum egg production. Same levels of energy as well as protein were also recommended by Jalaludeen and Ramakrishnan (2009). Reports about the requirements of ME and %CP were inconsistent, which may be due to the difference of experimental conditions, strains, bird age, lay period and evaluation index.

2.6. Effects of Varied Levels of Metabolizeable Energy and Crude Protein on Egg Quality Characteristics

Haugh unit and the albumen height are important indices concerning internal egg quality characteristics to measure the viscosity of the thick albumen. Similarly egg weight, eggshell strength and thickness are important indicators for reflecting external egg quality parameters. Eggshell strength ultimately affects the soundness of the shell, and weaker shelled eggs are more prone to have cracks and breakages followed by subsequent microbial contamination (Rao *et al*., 2011).

Scholars (Sehu *et al.,* 2005; Junqueira *et al.*, 2006 ; Almeida *et al*., 2012) studied on different levels of energy as well as protein in layers and reported that Haugh unit score, albumen index and shell thickness were not affected by either protein or energy variations. But, as reported by Yuan *et al.* (2009), decreased egg weight and shell thicknesses were found when feeding layers with highest energy levels (2950 kcal /kg).

Jalaludeen and Ramakrishnan (2009) found that shell thickness was superior in diets with 2600 kcal/kg ME than with 2500 kcal/kg ME, but differences in shell thickness among 2400, 2600, and 2700 kcal ME/kg were found to be statistically similar. Several other reports indicated that increasing levels of energy in the layer diets had no significant effects on egg weights (Keshavarez and Nakazima, 2000; Leeson and Summers, 2005).

Morris *et al.* (2003) recommended about 16-18% CP in layer diets for better egg weights. Kling and Hawes (2000) observed also that 16.8 % CP was sufficient for optimum egg weights. Novak *et al*. (2006) reported that egg weights were improved at 15% CP level than at 13% level and they also found that an increase in ME content from 2400 to 2750 kcal/kg had no effect on egg weights. Similarly, Singh *et al*. (2004) found an increased egg weights when increasing the CP levels (18-20%) in the diets of White Leghorn hens.

Tuan *et al.* (2010) reported that a diet containing 13% CP, supplemented with lysine and methionine to be as effective as diets with 17 or 18% CP for egg weights. Kling and Hawes (2000) reported also that layers fed on diet, with 10% CP and supplemented with methionine, lysine, tryptophan, and arginine produced 11% less egg mass compared to layers fed 17% CP diets.

Leeson and Summers (2005) concluded that body weight is the main factor controlling early egg size. Although there is some evidence indicating that nutrients, such as protein, methionine and linoleic acid can influence egg size throughout the laying cycle, these nutrients have only moderate effect on eggs size.

2.7. Effects of Dietary Energy and Crude Protein on Fertility and Hatchability

Fertility and hatchability are reproductive performance parameters which are affected by genetic and environment. Nutrition, breed, egg quality, egg storage durations and conditions are the main factors affecting fertility and hatchability of eggs. Diet mainly affects the egg number and egg size rather than their composition (Hassan et al., 2005; Kingori *et al.*, 2010).

Donald *et al.* (2002) reported that hatchability of fertile eggs may be related to the weight of the eggs. Chicks hatched from large eggs were heavier than those hatched from comparatively smaller eggs. It is possible that the decreased hatch weight of eggs produced by hens on low-protein can be a result of lower egg weights. Barker (2003) also reported that lower levels of dietary protein in the diet reduced egg production and consequently it has a negative effect on the hatchability of eggs.

In another study by Marie *et al.* (2009) it was found that high-energy diet fed hens significantly showed high percentage of fertility than those fed the lower energy levels.

2.8. Factors Affecting the Dietary Energy and Protein Requirements of Layers

Several factors influence the energy and protein requirements of chickens, such as breed and strain, sex, age, productive state of the bird, housing system, management, nutritional regimes, environmental temperature (Singh *et al*., 2004; Sakomura *et al*., 2005).

2.8.1. Temperature

The ambient temperature has a tremendous influence on energy consumption, because the layers try to maintain a homeostatic body temperature by adjusting the energy intake to the amount of heat the laying hen dissipates (Rao *et al*., 2011). In warmer houses, chickens need less energy in the diet because they are expending less energy to maintain their body temperature. Hens eat less feed with increasing temperatures and decrease feed consumption drastically at temperatures above 30°C (NRC, 1981).

The dietary requirements for protein and amino acids for layers should be based on specific environmental conditions, maintenance needs and product output. Protein and amino acid requirements listed above generally pertain to poultry kept in moderate temperatures (18° to 24°C). Ambient temperatures outside of this range cause an inverse response in feed consumption, the lower the temperature, the greater the feed intake and vice versa (NRC, 1981).

2.8.2. Genetics and body size

Layers and broilers have different genetic makeup, one selected for growth and the other for egg production. Body size, growth rate, and egg production of chicken are determined by their genetics. Amino acid requirements of chickens differ among types, breeds, and strains of chicken. Genetic differences in amino acid requirements may occur because of differences in efficiency of digestion, nutrient absorption, and metabolism of absorbed nutrients (NRC, 1994).

Different classes of chicken need different amounts of energy for metabolic purposes. For example, to sustain high productivity, modern chicken strains should be fed relatively high-energy diets (Chwalibog, 2005; Yuan *et al*., 2009). Nutrient deficiency will also affect the productivity of birds. If high-producing strains of birds fed on low energy diets, the consumption may be insufficient to sustain optimum egg output (Singh *et al.,* 2004).

Body size also affects the energy maintenance requirements. The energy needed to sustain normal body processes and activities other than growth and egg production is greater than that of basal metabolism. Layers of a light strain will normally consume less feed than a heavier strain (Hassan *et al.,* 2013). In normal temperatures, daily maintenance for hens is approximately 100 kcal/ kg per kg of body weight (Hassan *et al.,* 2013).

2.8.3. Production stage

Energy and protein requirements of birds vary considerably. The energy requirement for production is primarily determined by daily egg mass output, body mass increase between sexual maturity and mature weight and feathers (Hassan *et al.,* 2013). For example, a matured rooster has lower amino acid requirements than does the laying hen. High levels of egg output or feather growth require relatively high levels of methionine (Hassan *et al.,* 2013).

2.8.4. Housing system

Housing system influences both levels of activity of the birds and their energy requirements (Byerly *et al.,* 2008). Chickens raised in floor housing system requires higher nutrient than those raised on cage system.

The optimal nutrient composition of the diet will vary according to production aims, such as optimizing weight gain or carcass composition and egg production (Hassan *et al.,* 2013). Poultry that are raised for breeding purposes may need to have their energy intake restricted to ensure that they do not become obese.

2.9. Factor Affecting Egg Production and Quality

The major indices of measuring the profitability of raising layer chickens in a poultry enterprise are the total egg production and their quality. However, egg production and egg quality can be affected by different factors such as breed type, nutrition, bird age, disease, environmental temperature, day length and husbandry practices including feeding, watering and housing (Jacob *et al.*, 2014).

For the egg industry worldwide, the production of eggs which are of good egg shell quality and good internal quality is critical to the economic viability of the industry (Ahmadi and Rahimi, 2013). Currently problems with egg quality cost the industry many of millions of dollars per year. Therefore, it is of great importance to understand the factors that affects egg quality including the egg shell (Roberts and Ball, 2004).

2.9.1. Bird strain and age

Egg production performance of the laying hens is affected by breed and strain. Some chicken breeds have more capacity to lay eggs more than others. There are clear differences between improved commercial and indigenous chicken breeds (Hocking *et al.*, 2013).

Age of laying birds determine the sizes of eggs produced, early starter laid more eggs of small sizes. The sizes keep increasing as they are getting to more maturity in life. Egg production declines as the bird's age increased. Good layers can lay for about 50 to 60 eggs and then have a rest period called a molt. Poorer layers and older hens will molt more often and lay less consistently (Jacob *et al.*, 2014).

A number of studies have shown that egg shell quality decreases as birds grow older (Roberts and Chousalkar, 2013). As the birds age increases egg size increases. Older birds tend to lay bigger eggs and have a higher egg output, which impacts on shell strength. Since very young birds have immature shell glands, they may produce eggs with very thin shells or shell-less eggs (Butcher and Miles, 2003a).

2.9.2. Nutrition

Laying chickens require a well-balanced diet to sustain maximum egg production over time. Inadequate nutrition can cause hens to reduce or stop egg lay. Inadequate levels of energy, protein or calcium can cause a drop in egg production. When pullets begin egg lay, there is an increase in daily nutrient requirements such as protein, vitamin, and minerals due to deposition in the egg. If dietary protein is too low in the diet or the amino acid requirements are not met, low egg production and hatchability will occur (Jacob *et al.,* 2014). Therefore, it is so important to supply layer chickens nutritionally balanced ration constantly.

The provision of adequate dietary minerals and vitamins is essential for good eggshell quality (Jacob *et al.,* 2014). Inadequate dietary phosphorus may cause de mineralization of the skeleton in the laying hen. The ratio of calcium to phosphorus in the diet is important as high levels of phosphorus may interfere with the absorption of calcium from the gut, resulting in reduced shell quality (Boorman and Gunaratne, 2001). Inadequate calcium consumption will result in decreased egg production and lower eggshell quality (Jacob *et al.,* 2014).

Water is the most essential nutrient for hens as it is the greatest constituent of the body which represents about 70% of total body weight. Access to water is very important, and a lack of water for several hours will probably cause a decline in egg production. Hens are more sensitive to a lack of water than a lack of feed. Studies have shown that provision of cool drinking water can improve egg shell quality in heat-stressed hens (Glatz, 1993).

2.9.3. Disease

Diseases and parasites can cause losses in egg production. A number of diseases have been reported to affect egg production and egg quality particularly egg shell quality. Any disease that compromises the health of the bird may result in defective eggs and egg shells by indirect means. Any pathogenic agent that grows in the tissues of the reproductive tract can cause problems with egg shell formation. Infectious bronchitis has been reported to cause egg shells to be paler in color and sometimes wrinkled in appearance (Charlton *et al.,* 2000).

2.9.4. Production System

Different production systems are available in laying hens' husbandry such as conventional, cage, and free range systems. The type of production system may influence egg production and egg shell quality (Wall and Tauson, 2002). Some of the problems with egg shell quality reported from free range systems (Fraser and Bain, 1994) may result from an inability to ensure a balanced diet for the hens.

According to the report of Golden *et al.* (2012) hens in a cage system produced better egg production and had better egg quality characteristics compared to hens in free-range system.

In a study by Castellini *et al.* (2006) the layer chickens in conventional cages produced more eggs although the egg qualitaty properties (Haugh unit and yolk color) were poorer than the organic-plus eggs.

In another study by Krawczyk and Gornowicz (2010) it was suggested that, laying hens kept outdoors should be fed either with a complete feed or with a traditional feed enriched with protein and minerals in order to ensure good egg quality.

2.9.5. Temperature and Light

High environmental temperatures pose severe problems for all types of chickens. Egg production and egg size can be affected by environmental conditions. Stress or disturbance to a flock of layer chickens can de-synchronize the process of egg formation for several days, during which time, a number of different egg quality faults may be seen (Jacob *et al.*, 2014).

Daylight stimulates the reproductive cycle of egg layers, increasing production when exposed to more light. Generally, 14 to 16 hours of lighting for laying hens is required for better egg production. Shorter day length can cause a decline in egg production unless supplemental light is provided (Jacob *et al.,* 2014).

3. MATERIAL AND METHODS

3.1. Description of the Study Area

The experiment was conducted at DZARC which is located about 47 km east of Addis Ababa. It is located in the north east periphery of Bishoftu town at an altitude of 1920 m a.s.l and latitude of $8^{o}44'$ N and longitude of $38^{\circ}38'$E. It has a mean annual rainfall of 892 mm and mean temperature of 25^{o}C). The relative humidity ranges from 48% to 68% (DZARC GIS information).

3.2. Experimental Design and Diets

A Completely Randomized Design (CRD) with 3*3 factorial arrangements was employed in this study throughout all experimental phases. A total of 1260 un-sexed DZ-white day-old chicks were hatched in DZARC and randomly allocated to nine experimental diets. Each treatment was replicated four times, having 35 un-sexed chicks per replicate. Peak egg production period (35 wks) was the final target while planning to determine optimal major nutrient (ME and CP) requirements of this study. This trial had four phases, which included starter (0-8 wks), grower (9-14 wks), pullet (15-19 wks) and layer (20-35 wks). Whilst trying to satisfy the minimum nutrient requirements, each phase's experimental diets were formulated. Sufficient literature guidance including NRC (1994) was used at the time of setting the minimum and maximum nutrient levels of these experimental diets. Depending on the age and number of birds in each pen, a daily required diets were weighed and offered (twice a day) throughout the experimental period.

Feed ingredients used in the formulation of the experimental rations for this study were maize, wheat middling, soybean meal, nougseed cake, wheat bran, meat and bone meal, vitamin-mineral premix, salt, limestone, lysine and methionine. Compositions of feed ingredients used in the experimental diets are described in Table 5.

Since there is no cost-effective diet-formulation for the dual purpose chickens that to be used as a benchmark, levels of the test-nutrients (CP and ME) were firstly set-out ranging from 14.5-19 (%CP) and 2600-2900 (ME, kcal/kg). Accordingly, the starters, growers, pullets and layers experimental diets contained varied levels of protein (19, 18 or 17% CP), (18, 17 or 16% CP), (17, 16 or 15% CP) and (16.5, 15.5 or 14.5% CP), respectively. Varied levels of

ME (2900, 2750 or 2600 kcal/kg were used in diets of both starters and growers) and other levels of ME (2850, 2750 or 2650 kcal/kg) were also used for both pullets and layer diets too.

Starter diets (0 to 8 wks)

A 3 x 3 factorial arrangement, with 3 levels of ME-Kcal/kg (2900, 2750 or 2600) and 3 levels of CP% (19, 18 or17%) were used in this experimental phase.

Table 1: Composition of major nutrients and feed ingredients in starter diets

Ingredients (%)	Experimental diets								
	1	2	3	4	5	6	7	8	9
Maize	59	58.75	60.25	47.75	48.55	49.35	36	40	36.75
Nougseed Cake	5.5	7.25	6.8	9.55	9.05	9.15	7.25	9.7	9
Wheat Middling	4.5	6	8	9	9	10.14	16	13.5	19
Soybean Meal	15	12.5	9	12.25	12	8	13	10.5	8
Wheat bran	0	0.25	4	6.3	7	9.1	9	8	13
Meat and Bone Meal	10.5	8	6	8	7.15	7	9.5	7.8	5.5
Limestone	4	3.5	4.15	5.7	5.75	5.76	7.75	9	6.9
Salt	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
DL-Methionine	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
DL-Lysine	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Vitamin-mineral premix	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total (~)	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
CP (%)	19	18	17	19	18	17	19	18	17
ME (kcal/kg)	2900	2900	2900	2750	2750	2750	2600	2600	2600

Grower diets (9 to 14wks)

A 3 x 3 factorial arrangement, with 3 levels of ME-Kcal/kg (2900, 2750 or 2600) and 3 levels of CP% (18, 17 or 16%) were used in this experimental phase.

Table 2: Composition of major nutrients and feed ingredients in grower diets

Ingredients (%)	Experimental diets								
	1	2	3	4	5	6	7	8	9
Maize	59	59	60.35	48.8	51	50.7	39.25	42	38.5
Nougseed Cake	7	9	6	10	9.05	10	7	9.7	10
Wheat Middling	7	8	12.5	9	9	10.14	16	13	19
Soybean Meal	13	9	7.15	9.7	10	6.25	11.5	9.25	6
Wheat bran	0	2.5	3	8.73	7	10	10	9	13
Meat and Bone Meal	8.5	7.5	5.5	6.57	6	5.25	7.5	6.5	4.5
Limestone	4	3.5	4	5.7	6.45	5.76	7	9	6.9
Salt	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
DL-Methionine	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
DL-Lysine	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Vitamin-mineral premix	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total (~)	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
CP (%)	18	17	16	18	17	16	18	17	16
ME (kcal/kg)	2900	2900	2900	2750	2750	2750	2600	2600	2600

Pullet diets (15 to 19wks)

A 3 x 3 factorial arrangement, with 3 levels of ME-Kcal/kg (2850, 2750 or 2650) and 3 levels of CP% (17, 16 or 15%) were used in this experimental phase.

Table 3: Composition of major nutrients and feed ingredients in pullet diets

Ingredients (%)	Experimental diets								
	1	2	3	4	5	6	7	8	9
Maize	55.25	57.3	59.7	51	50.7	52	37.55	40.5	42.7
Nougseed Cake	9	9	8	9.05	10	9	11	9	8
Wheat Middling	8	8	8	9	10.14	10.14	19	19	19
Soybean Meal	9	8	6.75	10	6.25	5	7	6.5	5
Wheat bran	6.5	6.5	7	7	10	12	14	14	14
Meat and Bone Meal	6.55	5	4	6	5.25	4	4.5	3.5	3
Limestone	4.2	4.5	5.25	6.45	5.76	6	5.25	5.25	6
Salt	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
DL-Methionine	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
DL-Lysine	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Vitamin-mineral premix	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total (~)	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
CP (%)	17	16	15	17	16	15	17	16	15
ME (kcal/kg)	2850	2850	2850	2750	2750	2750	2650	2650	2650

Layer diets (starting from 20wks)

A 3 x 3, factorial, with 3 levels of ME, Kcal/kg (2800, 2700 or 2600) and 3 levels of CP% (16, 15 or 14%) were used in this experimental phase.

Table 4: Composition of major nutrients and feed ingredients in layer diets

Ingredients (%)	Experimental diets								
	1	2	3	4	5	6	7	8	9
Maize	56.5	58.2	59.7	50.75	52	51.25	39.15	43.5	47.5
Nougseed Cake	9	8.5	9	9	8	8.25	9	8	7
Wheat Middling	8	8.5	9.5	10.25	10	13	19	15.75	13.5
Soybean Meal	8.5	6.65	5	8	5.15	4	7	6	5.25
Wheat bran	6.5	7	7	8	11	13	14	14	14
Meat and Bone Meal	5.55	4.7	3	6	6	3	4.5	4	3
Limestone	4	5	5.3	6.5	6.25	6	6	6	7.25
Salt	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
DL-Methionine	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
DL-Lysine	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Vitamin-mineral premix	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total (~)	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
CP (%)	16.5	15.5	14.5	16.5	15.5	14.5	16.5	15.5	14.5
ME (kcal/kg)	2850	2850	2850	2750	2750	2750	2650	2650	2650

3.3. Management of Experimental Birds

The experimental house was prepared and partitioned into 36 pens with enough working space allowances. The house's wall, floor, door, windows, brooder, watering and feeding troughs were cleaned, washed and disinfected with savlon and dried before introduction of experimental birds in the house. The floor was covered with a dried and disinfected *Teff* straw bedding materials. Before the arrival of the birds, the experimental pens were ready with electric light, heater (cone shaped metal sheet as brooder with 250-watt lamp). The heaters in the brooders were switched on for 24 hours before the arrival of the chicks, to warm the rooms. Iso-management conditions like floor space, light, temperature, ventilation and relative humidity were provided to each of the groups.

The chicks were equally distributed, with initial BW (mean ± SD) of 39.14 ± 3.30 g to the respective experimental diets. The chicks were maintained under a partitioned deep litter housing system. Chicks were vaccinated with Marek's on the 1st day. New Castle Disease

(Lasota and HB1) on 7th, 21st, 49th, 98th days and in every three months. Gumboro was given on the 14th and 28th days for Infectious Bursal Disease. Fowl thypoid on 42nd and 84th days and Fowl pox on 56th day. Birds were administered with anti-stress vitamins and antibiotics in a solution form after each vaccination period.

Brooding temperature was kept at 32°c at the beginning of the first week and decreased gradually in subsequent weeks until it was adjusted to ambient temperature at around 21°C. Thirty-six 250 watt bulbs (one per each pen) were used. Artificial light was provided in the evening. Adjustments were done by raising the bulbs' height according to the temperature of the pens and also by observing the birds' behavior. Adequate ventilation and space was provided to make the chicks comfortable.

Clean drinking water was supplied at an *ad-libitum* throughout the experimental period. The feeders and water troughs were cleaned daily. To prevent any outbreak of diseases, strict bio-security measurements were maintained during the experimental period. Proper hygiene and sanitation program was also employed.

3.4. Laboratory Analysis

Representative samples of the feed ingredients and the treatment diets were taken and subjected to Proximate method of AOAC (2016) to determine dry matter (DM), crude protein (CP), crude fiber (CF), Ether extract (EE) and total ash content before the beginning of the experiment at laboratory of Bless Agri food laboratories P.l.c in Addis Ababa, Ethiopia. Besides, Kjeildhal procedure was employed to determine the nitrogen (N) content of each ingredient and the crude protein content was determined by multiplying the N content by 6.25 (Magomya *et al.,* 2014). The metabolize energy value was determined according to the method of Wiseman (1987) as follows: ME (Kcal/kg DM) = (3951 + 54.4 EE – 88.7 CF – 40.8 Ash).

3.5. Data Collection

The experiment was conducted starting from a day old age until the birds reached at peak egg production (35 wks). The following parameters were recorded for the experiment:

3.5.1. Feed intake and body weight gain

Measured amount of feed was offered twice a day in the morning and in the afternoon with *ad-libitum* water access throughout the experimental period. The feed offered and refused were recorded for each pen. Feed intake was calculated by subtracting amount of feed refused from amount of feed offered.

Initial body weights of the chickens were taken at the beginning of the experiment. The average body weight gain of the birds in each replication was calculated by subtracting the initial body weight from the final body weight at each experimental phase.

BWG (g) = Current BW – Initial BW (g)

3.5.2. Feed conversion ratio

Feed conversion ratio was calculated according to their developmental stage based on body weight gain of the chickens. It was calculated by using the following formula:

$$\text{FCR} = \frac{\text{Feed intake (g)}}{\text{Weight gain (g)}}$$

3.5.3. Egg production and sexual maturity

Egg production was recorded on daily basis starting from age at first egg-lay until to peak egg production. Eggs were collected three times a day from each pen. The sum of these 3 collections along with the numbers of hens were recorded and summarized. Average egg weight was computed by dividing the total egg weight to the number of eggs. Egg mass per bird was calculated as total egg mass divided by the number of birds. Hen-day egg production (HDEP) and hen-housed egg production (HHEP), as percentages were determined following the formula given below (Hunton, 1995).

$$\text{HDEP\% (Hen} - \text{day egg production)} = \frac{\text{Number of eggs collected per day}}{\text{number of hens present at that day}} \text{ x } 100$$

$$\text{HDEP\% (Hen} - \text{housed egg production)} = \frac{\text{sum of eggs counted}}{\text{number of hens originaly housed}} \text{ x } 100$$

Average egg mass per hen per day (g) = Percent of HDEP x average egg weight (g)

Age at first egg lay was fixed when at least 5% of the flock in each treatment started laying egg.

3.5.4. Egg quality parameters

A total of 108 eggs, 12 per treatment (3 eggs per pen) were randomly selected at one time at early laying stage (25 wks) and again repeated at peak egg production stage (35 wks) of the experimental period and then averages were computed for each of the following egg quality parameters.

The external egg quality parameters were assessed in terms of egg weight and egg shape index. After breaking the egg, near to the sharpen end, and carefully separating and dropping the contents, internal egg quality measuring parameters were measured, in terms of shell weight, shell thickness, yolk weight, yolk height and yolk color, albumen weight, albumin height and Haugh Unit Score (HUS). Shell thickness was measured by the digital caliper while removing the internal membranes. While measuring this thickness, the average value was taken from blunt, middle, and sharp points of the egg (Aberra, 2010). Height of the thick albumen was measured with the micrometer and the Haugh Unit Score was also calculated using the formula (Haugh, 1937):

$HU = 100 \log (AH - 1.7EW^{0.37} + 7.6)$ (Haugh, 1937)

Where, HU = Haugh unit,

AH = observed albumen height (mm) and

EW = weight of egg (g).

The yolk color determined by comparing the color of a properly mixed yolk sample placed on a colorless glass with the color strips of Roche color fan measurement, which consists of 1 to 15 strips ranging from pale to orange-yellow. Shape index was computed using the following formula (Panda, 1996):

Egg shape index = (Width of egg/Length of egg) x100

Average egg weight was determined by weighing eggs collected from 40 birds under each treatment. Sensitive balance of 0.000lg to 205g capacity was used.

3.5.5. Hatchability and fertility

A total of 180 eggs (20 eggs per treatment) were collected from each replicate, for seven consecutive days to determine fertility and hatchability. Temperature and relative humidity of artificial incubator were maintained at 37.6^{o}C and 55 – 60% during the first 18 days and 37.3^{o}C and 55 – 70% during the last 3 days, respectively. On the 10th day of incubation, all eggs were candled and the infertile eggs were counted and transferred to the hatching baskets. Percentage of fertility was calculated as:

$$\text{Fertility (\%)} = \frac{\text{Number of fertile eggs}}{\text{number of eggs set}} \text{ x } 100$$

Upon hatch, each day-old chick was weighed and counted. Hatchability parentage of set eggs per treatment was calculated as follows:

$$\text{Hatchability (\%)} = \frac{\text{Number of eggs hatched}}{\text{number of fertile eggs set}} \text{ x } 100$$

Dead chickens in different stages/phases (starter, grower, pullet and layers) were recorded as mortality and expressed as percent of mortality at the end of the experiment.

3.5.6. Partial economic analysis

The partial economic analysis was calculated as the difference between the feed costs incurred during the experimental period per bird for the eggs sales following the procedures of Miles and Jacob (2000), considering the other costs including labour, transportation and chick costs are similar among the treatments. Net income was assumed to be the difference between the total cost of feeds and total return from egg sale. The net income (NI) was calculated by subtracting total feed cost (TFC) from the total return (TR). Cost benefit ratio (CBR) was calculated as the ratio of returns over the total feed cost.

NI = TR−TFC

TFC = (TFI/b x feed cost per Kg ration)

Where, TFI = Total feed intake/ consumed/ (Kg)

TFC = Total feed cost

TR = Total return (returns from egg sale)

CBR = TR/TFC

3.6. Statistical Analysis

Data were statistically analyzed using General Linear Models Procedure of the Statistical Analysis System (SAS, 2008) version 9.1.3 computer software program subjected to the analysis of variance (ANOVA). Significance differences among the treatment means were determined by using Duncan Multiple Range Test (DMRT) as contained in the SAS package (Duncan, 1955). Differences between treatment groups were considered statistically significant at $P < 0.05$.

The model for the data analysis was: $Y_{ij} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ij}$

Where:

Y_{ij} = individual observation,

μ = the overall mean,

α_i = effect of CP level; i=(1,2 and 3),

β_j = effect of ME level; j=(1,2 and 3),

$(\alpha\beta)_{ij}$ = interaction effect between ME and CP; and

ε_{ij} = error component.

4. RESULTS

In this study, different parameters, such as feed intake, body weight gain, feed conversion ratio, egg production, egg quality, hatchability, fertility and partial economic analysis were evaluated.

4.1. Chemical Composition of Experimental Feed Ingredients

The laboratory chemical analysis of the feed ingredients used in this experiment is presented in Table 5.

Table 5: Chemical composition of the feed ingredients

	Parameters							
Ingredients (%)	DM	CP	EE	CF	ASH	Ca	P	ME (Kcal/kg)
Maize	89.7	9	4.07	3.54	1.51	0.182	0.3	3325
Nougseed cake	85.76	32	8.03	22.26	5.49	0.26	0.65	2650
Wheat middling	90.2	15.6	0.32	9.2	4.5	0.11	1.15	2515
Soybean Meal	91.48	42.29	1.92	3.79	4.42	6.22	0.7	2461
Wheat bran	93.34	15	4.23	43	5.2	0.094	0.92	2200
Meat and Bone Meal	95.78	43	15.6	3.54	32.64	7.8	64.2	2750

DM = Dry matter, CP = Crude protein, EE = Ether extract, CF = Crude fiber, TA = Total ash, Ca = Calcium, P = Phosphorus, ME = Metabolizeable energy kilo calorie per kilogram of Dry Matter.

4.2. Feed Intake, Body Weight Gain and Feed Conversion Ratio of DZ-White Chickens in Starter Phase

Mean values for parameters associated with feed intake (kg/b), initial body weight, final body weight at 8 weeks of age (g/b), body weight gain (g/b) and feed conversion ratio of DZ-White chickens in starter phase are shown in Table 6.

Table 6: Effects of different levels of CP and ME on the growth performance of DZ-White chickens in starter phase (0- 8 weeks of age).

Factors		Parameters				
CP (%)	ME(Kcal/kg)	FI (0-8 wks)	IBW	FBW (at 8 wks)	BWG (0-8 wks)	FCR (0-8 wks)
17	2600	1.33^{ab}	39.25	364.10^{de}	324.85^{e}	4.09^{a}
	2750	1.31^{b}	42.75	379.93^{de}	337.18^{de}	3.89^{a}
	2900	1.34^{ab}	35.75	380.07^{de}	344.32^{de}	3.89^{a}
18	2600	1.29^{c}	37.00	366.90^{e}	329.90^{e}	3.91^{a}
	2750	1.33^{ab}	40.00	390.08^{d}	350.08^{d}	3.80^{a}
	2900	1.33^{ab}	38.50	391.46^{d}	352.96^{d}	3.77^{a}
19	2600	1.32^{b}	37.75	407.39^{c}	369.64^{c}	3.57^{b}
	2750	1.33^{ab}	40.75	442.11^{b}	401.36^{b}	3.31^{c}
	2900	1.36^{a}	40.50	456.16^{a}	415.66^{a}	3.27^{c}
Pooled SEM		0.0072	8.25	19.74	14.95	0.016
Main effects						
17		1.32^{ab}	39.25	383.37^{b}	344.12^{b}	3.84^{a}
18		1.31^{b}	38.50	390.48^{b}	351.98^{b}	3.72^{b}
19		1.34^{a}	39.67	441.89^{a}	402.23^{a}	3.33^{c}
	2600	1.30^{c}	38.00	384.47^{b}	346.47^{b}	3.75^{a}
	2750	1.32^{ab}	41.18	415.37^{a}	374.19^{a}	3.53^{b}
	2900	1.34^{a}	38.25	415.90^{a}	377.65^{a}	3.51^{b}
P-values:						
CP%		0.0379	0.6076	<.0001	<.0001	<.0001
ME, kcal/kg		0.0059	0.0611	<.0001	<.0001	<.0009
CP x ME		0.1181	0.1374	<.0001	<.0001	<.0124

[a,b,c,d,e] Means in a column having no common superscripts differ significantly (P <0.05) whereas, within the same column, values with no or same superscripts differ not significantly (P >0.05), SEM = pooled standard error of mean. FI = cumulative feed intake of the birds up to 8 weeks age (kg/b), IBW = Initial body weight (g/b), FBW = Final body weight at 8 weeks age (g/b), BWG = Body weight gain (g/b), FCR = Feed conversion ratio (feed intake per weight gain), b = Bird, Kcal = Kilocalorie.

Different levels of dietary protein and energy showed significant (P <0.05) effects on the feed intake of the chickens at starter phase, but the interaction of energy and protein levels didn't show any significant (P >0.05) difference. DZ-White chickens fed a diet with 19% CP and 2900 kcal/kg-ME showed a higher feed intake than the lower levels.

The FCR was significantly (P <0.05) influenced by dietary treatments and the interaction of protein and energy levels. A diet containing 2900 kcal /kg- ME, with 19% CP had better FCR as compared to the diet containing 2600 kcal /kg- ME, with 17 and 18% CP. However, there were no significant (P >0.05) differences in FCR values between diets containing 17 and 18% CP with any ME levels at starter phase (shown in Table 6).

The effect of varied levels of dietary energy, protein and their interactions on the final body weight at 8 weeks age and body weight gain of the birds showed significant (P <0.05) effect among all treatment groups in this phase. A similar trend continued until the end of this experiment, where it was found that higher protein and energy levels had a positive effect on body weight. Birds fed on diet, containing 19% CP with 2900 kcal, ME/kg achieved highest body weight, but birds on diet, with 18% CP and 2600 kcal, ME/kg had the lowest BWG.

4.3. Feed Intake, Body Weight Gain and Feed Conversion Ratio in Grower Phase

Results of feed intake (kg/b), body (g/b), body weight gain (g/b), and feed conversion ratio of grower chicken from 9 to 14 weeks of age is presented in Table 7.

Table 7: Effects of different levels of CP and ME on the growth performance of DZ-White chickens in grower phase (9- 14 weeks).

Factors		Parameters				
CP (%)	ME (Kcal/kg)	FI (9-14wks)	BWG (9-14wks)	FCR (9-14wks)	FBW (at 14 wks of age) Females	Males
16	2600	2.42	486.33^{bcd}	4.98^{a}	850.43^{c}	883.28^{cd}
	2750	2.43	499.21^{bc}	4.87^{a}	879.14^{b}	915.05^{c}
	2900	2.45	502.09^{bc}	4.87^{a}	882.16^{b}	988.9^{bc}
17	2600	2.44	486.66^{bcd}	5.01^{a}	853.56^{c}	889.56^{c}
	2750	2.39	505.95^{bc}	4.72^{bc}	896.03^{b}	929.65^{c}
	2900	2.39	584.39^{a}	4.09^{e}	975.85^{a}	1060.06^{ab}
18	2600	2.42	488.07^{bcd}	4.96^{a}	895.86^{b}	963.68^{bc}
	2750	2.38	507.94^{bc}	4.69^{bc}	950.05^{a}	101.15^{b}
	2900	2.39	537.97^{b}	4.44^{d}	994.13^{a}	1152.65^{a}
Pooled SEM		0.32	9.99	0.09	8.76	5.30
			Main effect			
16		2.43	491.54^{b}	4.94^{a}	871.91^{b}	952.41^{b}
17		2.41	497.33^{b}	4.85^{b}	901.81^{a}	987.09^{b}
18		2.39	504.66^{a}	4.74^{b}	916.55^{a}	1068.49^{a}
	2600	2.43	483.35^{b}	5.01^{a}	869.82^{b}	952.51^{b}
	2750	2.41	488.03^{b}	4.94^{b}	878.40^{b}	972.29^{b}
	2900	2.40	529.15^{a}	4.54^{c}	945.05^{a}	1067.20^{a}
P-values:						
CP%		0.2537	<.0008	<.0012	<.0001	0.0261
ME, kcal/kg		0.5170	<.0001	<.0001	<.0001	0.0001
CP x ME		0.7152	<.0001	<.0001	<.0001	0.0267

[a,b,c,d,e] Means in a column having no common superscripts differ significantly (P <0.05) whereas, within the same column, values with no or same superscripts differ not significantly (P >0.05), SEM = pooled standard error of mean. FI = Feed intake (kg/b), FBW = Final body weight at 14 weeks age (g/b), BWG = Body weight gain (g/b), FCR = Feed conversion ratio (feed intake per weight gain), b = Bird, Kcal = Kilocalorie.

The effects of different dietary levels of protein, energy and their interactions did not show a significant (P >0.05) effect on the feed intake of DZ-White chickens at grower phase. Feed intake in this experimental phase ranging from 2.38 to 2.43 kg. Even though there was no significance difference found in feed intake, chickens fed on 16% CP and 2600 kcal, ME/kg showed higher feed intake compared to the others. There was significant (P <0.05) difference in FCR between birds fed a grower diets during this phase. Accordingly, birds fed on diets, with 17% CP with 2900 kcal /kg ME were significantly (P >0.05) efficient in feed utilization.

Significant difference (P <0.05) was observed on the final body weight at 14 weeks and body weight gain of the chickens in grower phase, due to varying levels of dietary energy, protein and their interactions. Growing chickens (both males and females) fed diets, containing 18% CP with 2900 kcal/kg ME showed higher body weight at 14 weeks and those fed 17% CP with the same level of energy achieved higher body weight gain than the lower level of CP and ME. Birds fed on diets, with 16% CP and 2600 kcal/kg ME showed lower body weight gain. It was observed that the final body weight of the birds at 14 weeks of age and body weight gains increased as the levels of energy and protein increased. The average body weight of DZ-White chickens at 14 weeks of age was 1.01 Kg and 0.89 Kg for both males and females respectively.

4.4. Feed Intake, Body Weight Gain and Feed Conversion Ratio in Pullet Phase

Mean values for FI (kg/b), BWG (g/b), FCR and Final BW at 19 wks age (g/b) of the dietary treatments are presented in Table 8.

Table 8: Effects of different levels of CP and ME on the growth performance of DZ-White chickens in pullet phase (15- 19 weeks).

Factors		Parameters			
CP (%)	ME (Kcal/kg)	FI (15-19 wks)	BWG (15-19 wks)	FCR (15-19 wks)	FBW at 19 wks
15	2650	2.67	459.26[bc]	5.73	1339.69[c]
	2750	2.77	474.62[bc]	5.74	1353.76[c]
	2850	2.68	488.76[bc]	5.78	1353.92[c]
16	2650	2.77	492.85[bc]	5.52	1346.69[c]
	2750	2.69	522.52[b]	5.59	1398.54[bc]
	2850	2.66	530.84[a]	5.99	1406.69[abc]
17	2650	2.79	514.61[b]	4.48	1390.07[bc]
	2750	2.65	585.87[a]	5.43	1465.92[ab]
	2850	2.74	590.14[a]	5.50	1484.27[a]
Pooled SEM		1.91	16.26	0.31	17.51
Main effect					
15		2.70	474.57[b]	5.62	1349.12[b]
16		2.71	480.37[b]	5.59	1383.88[b]
17		2.72	530.21[a]	5.42	1446.75[a]
	2650	2.70	488.91[b]	5.68[a]	1358.73[b]
	2750	2.67	527.67[a]	5.17[b]	1406.07[a]
	2850	2.66	527.81[a]	5.77[a]	1414.96[a]
P-values:					
CP%		0.8938	0.0068	0.4919	0.0003
ME, kcal/kg		0.5061	0.0087	0.0295	0.0262
CP x ME		0.4538	0.0649	0.0567	0.6066

[a,b,c,d,e] *Means in a column having no common superscripts differ significantly (P <0.05) whereas, within the same column, values with no or same superscripts differ not significantly (P >0.05), SEM = pooled standard error of mean. FI = Feed intake from 15 to 19 weeks (kg/b), FBW = Final body weight at 19 weeks age (g/b), BWG = Body weight gain (g/b), FCR = Feed conversion ratio (feed intake per weight gain), b = Bird, Kcal = Kilocalorie.*

The effect of different levels of dietary protein, energy and their interactions on the feed intake of DZ-White chickens from 14-19 weeks of age did not show a significant (P >0.05) differences. However, chickens fed 17% CP and 2650 kcal ME/kg tended to have higher FI compared to birds on other treatment diets. Even though, there was no significant difference among the treatment groups, it was observed that when the energy level in the diet increased the feed intake decreased in grower chickens at 14 to 19 weeks of age.

Feed conversion ratio was significantly (P <0.05) influenced by dietary energy in the diet. However, dietary protein and the interaction of CP and ME didn’t affect (P >0.05) the FCR of chickens in this experimental phase. Birds reared on 2750 kcal ME/kg showed highest FCR, compared to other energy levels. The lowest FCR was observed in treatment diet containing 2850 kcal /kg ME.

In this experimental phase dietary energy and protein had a significant (P <0.05) effects on the body weight gain and final body weight of chickens at 19 weeks of age. It was found that birds reared on a diet containing higher energy and protein levels (2850 kcal/kg of ME and 17%) attained highest body weight compared to the lower level diets. However, the interaction of dietary energy and protein didn’t show a significance (P >0.05) difference on the body weight gain, FCR and final body weight of DZ-White chickens in this experimental phase.

4.5. Egg Production

Effects of differently leveled energy and crude proteins on different egg production parameters of DZ-White chickens are presented in Table 9.

Table 9: Effects of different levels of CP and ME on egg number/bird, egg-weight, age at first egg lay, egg mass and other parameters (20-35 wks)

Factors		Parameters					
CP (%)	ME (Kcal/kg)	EN (20-35 wks)	%HDEP (20-35 wks)	%HHEP (20-35 wks)	AFL (days)	EW (g)	EM (g)
14.5	2650	50.67	46.77	33.99	148.50	51.32	25.5
	2750	52.33	48.90	31.86	148.00	52.93	24.5
	2850	51.07	46.02	34.46	147.50	51.95	25.0
15.5	2650	51.96	46.87	35.24	149.25	53.05	27.5
	2750	53.39	49.58	32.29	146.25	52.12	25.0
	2850	51.48	48.53	40.72	144.25	52.38	26.0
16.5	2650	46.15	41.17	39.33	146.25	51.55	23.5
	2750	49.61	43.85	31.87	145.75	52.44	21.5
	2850	48.21	43.19	34.05	142.75	51.43	25.5
Pooled SEM		10.62	11.16	7.53	0.26	2.59	7.24
Main effect							
14.5		51.02[a]	46.16[a]	33.43	147.00	52.07	25.00
15.5		51.43[a]	47.16[a]	36.08	146.58	52.52	26.17
16.5		45.67[b]	45.30[b]	35.08	144.92	51.81	23.17
	2650	51.72[b]	47.10[b]	36.18	147.00	51.97	25.5
	2750	53.43[a]	49.11[a]	36.01	146.67	52.50	23.33
	2850	50.77[b]	47.42[b]	36.11	144.83	51.92	25.5
P-values:							
CP (%)		0.0472	0.0197	0.3416	0.6489	0.5583	0.058
ME, kcal/kg		0.0310	0.0141	0.0552	0.6167	0.6306	0.115
CP x ME		0.6187	0.4939	0.1774	0.7657	0.6091	0.493

[a,b,c,d,e] Means in a column having no common superscripts differ significantly (P <0.05) whereas, within the same column, values with no or same superscripts differ not significantly (P >0.05), SEM = Pooled standard error of mean. AFL = Age at first egg lay, EN = Egg number/bird, %HDEP = Percentage of hen-day egg production, %HHEP = Percentage of hen-housed egg production, EM = Egg mass (g/b/d), Kcal = Kilocalorie, Kg = Kilogram.

Dietary energy and proteins had a significant (P <0.05) effects on egg production and HDEP of DZ-White chickens. The highest egg production and % of HDEP was recorded in birds fed a diet with 15.5% CP and 2750 kcal, ME/kg. However, differently leveled proteins, energy and their interactions didn’t show a significant (P >0.05) effects on AFL, egg mass and % of HHEP of DZ-White chickens.

4.6. Egg Quality Parameters

Data obtained on the egg quality traits as a sequent influence to dietary different levels of CP, ME and their interaction during the laying period are showed in Table 10.

Table 10: Effects of metabolizeable energy and protein levels on egg quality parameters.

Factors		Parameters							
CP (%)	ME (Kcal/kg)	EW (g)	AH (mm)	AW (gm)	YW (g)	ESI	ST (mm)	HUS	YI
14.5	2650	51.46^{ab}	6.29^{a}	27.88	17.03^{a}	78.73	0.30	81.75^{a}	0.45
	2750	55.53^{a}	6.42^{a}	30.33	16.57^{ab}	77.47	0.30	81.22^{ab}	0.46
	2850	52.43^{ab}	5.83^{abc}	30.52	16.33^{ab}	76.22	0.29	78.02^{ab}	0.47
15.5	2650	51.19^{ab}	6.08^{ab}	28.65	15.87^{ab}	77.50	0.31	80.49^{ab}	0.48
	2750	55.78^{a}	6.17^{ab}	30.13	16.83^{a}	78.87	0.32	79.17^{ab}	0.47
	2850	54.56^{a}	6.04^{ab}	30.14	16.19^{ab}	77.95	0.30	78.87^{ab}	0.46
16.5	2650	51.42^{ab}	6.33^{a}	27.50	16.73^{a}	76.49	0.32	81.66^{a}	0.47
	2750	54.63^{a}	5.88^{abc}	28.87	16.24^{ab}	77.09	0.31	77.78^{ab}	0.47
	2850	53.44^{ab}	5.67^{abc}	29.58	16.13^{ab}	77.66	0.31	76.61^{ab}	0.44
Pooled SEM		17.52	0.54	11.43	2.63	15.73	0.008	20.19	0.001
Main effect									
14.5		53.14	6.18	29.24	16.24	77.48	0.30	80.33	0.46
15.5		53.84	6.19	29.64	16.29	78.11	0.31	79.48	0.47
16.5		53.96	6.36	29.65	16.53	77.08	0.31	78.68	0.46
	2650	51.36^{b}	6.24^{a}	28.01	16.54	77.57	0.31	81.32^{a}	0.46
	2750	55.31^{a}	6.15^{a}	29.78	16.54	77.81	0.31	79.39^{ab}	0.46
	2850	53.48^{a}	6.05^{ab}	29.74	16.09	77.28	0.30	77.84^{b}	0.46
P-values:									
CP		0.720	0.432	0.4576	0.280	0.542	0.283	0.383	0.450
ME		0.006	0.065	0.0554	0.144	0.849	0.572	0.016	0.520
CP x ME		0.838	0.414	0.9490	0.250	0.502	0.508	0.630	0.092

[a,b,c] Means in a column having no common superscripts differ significantly (P <0.05) whereas, within the same column, values with no or same superscripts differ not significantly (P >0.05), SEM = Pooled standard error of mean, EW = Egg weight (g), ESI = Egg shape index, EST = Egg shell thickness (mm), HUS = Haugh unit scores, YI = Yolk index, AW = Albumin weight (g), AH = Albumin height (mm), YW = Yolk weight (g).

Variations in protein level between diets didn't show significant (P >0.05) effects on most egg quality parameters (shape index, albumin index and yolk index). A significant (P <0.05) difference were found on egg weight and HUS due to a dietary energy, but not due to protein or ME and CP interactions. The higher egg weight and HUS were found in diets with 2750 and 2650 kcal/kg of ME, respectively. The lower egg weight and HUS were found on diets with 2650 and 2850 kcal/kg of ME respectively.

4.7. Hatchability and Fertility

Table 11: Effects of diets, containing graded levels of energy and proteins on fertility and hatchability of eggs.

Factors		Parameters		
CP (%)	ME (Kcal/kg)	Fertility (%)	Hatchability(%) from fertile egg	Hatchability(%) from total egg set
14.5	2650	70.5	73.32	57.75
	2750	80.50	78.04	62.75
	2850	81.75	84.86	69.00
15.5	2650	71.25	74.90	58.75
	2750	72.00	75.50	59.25
	2850	73.50	81.81	60.25
16.5	2650	80.50	80.99	65.25
	2750	79.25	82.58	65.25
	2850	76.75	87.03	66.50
Pooled SEM		10.35	12.87	11.22
		Main effect		
14.5		76.92	78.07	61.83
15.5		77.08	79.74	65.67
16.5		79.83	83.53	66.08
	2650	72.75	79.10	59.92
	2750	74.92	80.37	62.42
	2850	77.17	84.57	65.25
P-values				
CP		0.1146	0.4790	0.1452
ME		0.3964	0.3092	0.0951
CP x ME		0.2784	0.6538	0.1012

^{a,b,c} *Means in a column having no common superscripts differ significantly (P < 0.05) whereas, within the same column, values with no or same superscripts differ not significantly (P > 0.05). SEM = Pooled standard error of mean.*

There were no significant (P > 0.05) differences observed between treatments in percentage of fertility and hatchability. In the present study, the highest percentage of fertility and hatchability was found in birds fed on diet, with 16.5% CP while the lowest was for 15% CP, but, there was no significant (P > 0.05) difference among the treatments. It was observed that fertility and hatchability generally increased with increasing protein and energy levels in the diet. The average percentages of fertility and hatchability from both fertile eggs and total egg set were 75.5%, 79.56% and 63.75% respectively.

4.8. Mortality

Varying level of ME and CP in the diet did not have significant impact (P >0.05) on the mortality of DZ-White chickens for the entire experimental period.

4.9. Partial Budget Analysis

The economic returns in terms of partial budget from layers reared under different diet having different levels of ME and CP are presented in Table 12.

The results of the partial budget analysis of different diets with varied levels of ME and CP based on 35 weeks of the experimental period are presented in Table 12. During the analysis, it was assumed that the cost of feed and the sale of eggs were the source of costs and profits respectively. The other costs such as purchasing of chick's labor and transportation costs were considered as similar among all treatments. Accordingly, there was a significant (P <0.05) difference among the treatments in economic analysis.

Generally, the highest feed cost per bird was recorded on concentrate diets with higher levels of CP (16.5 %) and ME (2850 kcal/kg) and the lowest feed cost was on low concentrated diets (14.5% CP and 2650 kcal/kg, ME). There was significant (P <0.05) difference in net income (NI) between treatments, and the highest net profit per bird was found on a layer diet with 15.5% CP with 2750 kcal/kg, of ME.

Table 12: Partial budget analysis of DZ-White chicken production

Items	Experimental Diets								
	T1	T2	T3	T4	T5	T6	T7	T8	T9
Feed cost/Kg ration (birr)									
Starter	15.08	14.68	14.02	14.38	14.27	13.73	14.07	13.79	13.23
Grower	14.78	14.28	13.85	13.96	13.95	13.41	13.80	13.57	12.97
Pullet	14.78	14.28	13.77	13.96	13.96	13.41	13.80	13.57	12.97
Layer	14.06	13.84	13.61	13.95	13.57	13.11	13.23	13.01	12.74
Feed consumed (Kg)									
Starter	1.36a	1.33^{ab}	1.34^{ab}	1.33^{ab}	1.33^{ab}	1.31^{b}	1.32^{b}	1.29^{c}	1.33^{ab}
Grower	2.39	2.39	2.45	2.38	2.39	2.45	2.42	2.44	2.42
Pullet	2.73	2.66	2.68	2.74	2.69	2.77	2.86	2.76	2.67
Layer	12.64	12.77	12.63	12.44	12.77	12.86	12.78	12.65	12.68
Total feed cost (b/bird)	332.36^{a}	325.71^{b}	317.15^{cd}	320.23^{bc}	320.07^{bc}	311.18^{de}	316.02^{cd}	307.46^{e}	298.49^{f}
Starter	20.55^{a}	19.52^{b}	18.72^{cd}	19.16^{bc}	18.90^{cd}	17.98^{e}	18.53^{d}	17.48^{e}	17.52^{e}
Grower	35.24^{a}	34.14^{ab}	33.89^{b}	33.16^{bc}	33.38^{bc}	32.55^{c}	33.36^{bc}	33.09^{bc}	31.37^{d}
Pullet	40.55^{a}	38.42^{ab}	36.21^{c}	35.77^{c}	37.54^{bc}	37.08^{bc}	39.43^{ab}	37.60^{bc}	34.58^{cd}
Layer	177.72^{a}	176.74^{a}	171.89^{ab}	173.54^{ab}	173.29^{ab}	168.60	169.08e	164.58^{f}	161.54^{g}
Egg produced (No./bird)	50.25^{bc}	50.98^{bc}	51.07^{bc}	50.61^{bc}	54.69^{a}	52.33^{a}	48.15^{bc}	49.96^{bc}	49.67^{bc}
Egg price (birr/egg)	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Return from egg sales	301.50^{bc}	305.88^{bc}	306.42^{bc}	303.66^{bc}	328.14^{a}	313.98^{ab}	294.90^{c}	302.76^{bc}	301.02^{bc}
NI (birr/bird)	27.60^{f}	37.50^{de}	44.90^{d}	39.52^{de}	64.98^{a}	57.40^{ab}	28.38^{f}	46.83^{d}	52.86^{bc}
CBR	1.10^{cd}	1.14^{bc}	1.17^{bc}	1.15^{bc}	1.25^{a}	1.22^{ab}	1.11^{cd}	1.19^{ab}	1.22^{ab}

^{b,c,d,e,f} *Means in a row having no common superscripts differ significantly (P <0.05) whereas, within the same column, values with no or same superscripts differ not significantly (P >0.05). SEM = Pooled standard error of mean. NI = Net income, CBR = Cost benefit ratio, LW = LW taken at 40 wks of age.*

Table 13: Partial budget analysis of DZ-White chicken production

5. DISCUSSION

5.1. Feed Intake, Body Weight Gain and Feed Conversion Ratio

Feed intake was significantly (P <0.05) increased with age advancement in all treatments. This increment in FI is to meet their protein and energy requirements for growth and development, which is consistent with the reports of (Nsoso *et al.*, 2008). In the present study, dietary treatments with varied levels of ME and CP had significant (P <0.05) effects on feed intake of chickens in a starter phase (0-8wks). The feed intake was higher among the chickens receiving diets with higher levels of CP (19 %) and ME (2900 kcal/kg). This result is in line with the report of Byerly *et al.* (2008) who reported that FI increased with increasing dietary protein levels in the diet.

Varying levels of CP, ME and their interactions had no effects (P >0.05) on feed intake of the birds in both grower and pullet phases. The present result is consistent with the work of Nahashon *et al.* (2007) who reported that ME and CP do not affect the FI of birds. However the current finding disagreed with the finding of other scholars (Sohail *et al.*, 2003; Wu *et al.*, 2005; Nahashon *et al.*, 2007; Perez -Bonilla *et al.*, 2012), who reported that increasing the ME levels in a diet decreases the FI of the birds. The present finding is contrary also with Etalem *et al.* (2019), who reported that chickens at the age of 10-22 wks consume more feed when supplied a feed with higher level of ME (3150 kcal/kg) and CP (23% CP) than lower levels (2650 ME in kcal/kg and 19% CP).

FCR was significantly (P <0.05) influenced by varied levels of dietary protein, energy and their interactions in starter and grower experimental phases. Chickens fed diets, with higher protein and energy levels (19% and 17% CP each with 2900 kcal/kg, ME) in starter and grower diets, respectively utilized feed more efficiently than those treatments with lower protein and energy levels. The present result is in agreement with Kumar *et al.* (2009), who reported that chicks fed on diets, with higher protein (22% CP) and energy (2900 kcal/kg ME) were more efficient in feed utilization. The present result is also consistent with Lotfi *et al.* (2018), who reported that feed efficiency was improved, with increasing dietary concentrations of energy in the diets. Contrary to this finding, Nsoso *et al.* (2012) reported that FCR was decreased with increasing ME from 2400 to 2700 kcal/kg. The differences in FCR values between the present and previous studies may be due to differences in diets, ages and management conditions. In pullet phase, it was observed that FCR was significantly (P <0.05) influenced by dietary energy. However, dietary protein or the interaction of CP and ME didn't affect (P >0.05) the FCR of chickens in this experimental phase. Birds reared on 2750 kcal ME/kg showed highest FCR, compared to other energy levels.

BWG and final BW at the end of starter, grower and pullet periods were significantly (P<0.05) increased and these increment were due to increasing levels of CP and ME. It was found that higher proteins and energy levels had a positive effects (P <0.05) on the final BW and BWG of DZ-White chickens in all experimental phases. As the levels of energy and protein increases, body weight increases in all experimental phases and the lower levels of protein and energy were found inadequate for optimum BWG. Chickens fed a diet containing 19% CP in starter and 18% CP in grower phases each with higher level of energy (2900 kcal/kg) and 17% with 2850 kcal/kg of ME in pullets phase gained maximum growth. This result is consistent with (Bamgboose, 1999; Tuan *et al.*, 2010), who reported that increasing dietary CP significantly increases the growth performance of chicks, where BW was closely related with protein contents in the diets. However, contrary to this finding other scholars (Hassan *et al.*,2000; Sohail et al., 2003 and Novak *et al.*, 2006) investigated and reported that increasing the levels of proteins in the diets did not influence the overall BWG and final live weight of chickens.

The present study is also in line with the findings of other previous studies (Kumar *et al.*, 2009; Hussein *et al.*, 2010) who reported that diets having higher levels of ME had better effects on BWG than lower levels.

5.2. Egg Production and Sexual Maturity

In this study it was observed egg production per hen and % of HDEP were influenced (P <0.05) by differently leveled experimental diets. These results are inline with the previous findings by Rao *et al.* (2011) and Perez-Bonilla *et al.* (2012) who observed significance (P <0.05) difference in egg production among dietary treatments range from 2350 to 2600 kcal/kg, ME in White Leghorn layers and from 2650 to 2850 kcal/kg, ME in Brown hens. However, contrary to this finding (Zeweil *et al.*, 2011; Etalem *et al.*, 2019) reported that levels of dietary energy and proteins didn't have significant (P >0.05) effects on the total egg production and percentage of HDEP.

From this study the highest egg production and % of HDEP was recorded in birds fed a diet with 15.5% CP and 2750 kcal, ME/kg. However, differently leveled proteins, energy and their interactions didn't show a significant (P >0.05) effects on AFL, egg mass and % of HHEP of DZ-White chickens. In the present study there was no ME and CP interaction effects on laying performance of DZ-White chickens, which are consistent with the previous studies (Wu *et al.*,2005; Byerly et al., 2008 and Novak *et al.*, 2008), who reported that interaction of CP and ME had no effects on egg production.

Even though there was no statistical difference observed in AFL, pullets received a diet containing 16.5% CP and 2850 kcal/kg ME reached to sexual maturity at earlier age (144 days) than those fed diet containing lower levels of CP (14.5 or 15.5 %) and ME (2650 or 2750 kcal/kg). In the previous study by Harms *et al.* (2000) late point of first egg lay was observed in diets with lower levels of CP (11 or 14% CP) as compared to the higher levels (17 or 20% CP) in white leghorn chickens.

5.3. Egg Quality Traits

Variation in crude protein and metabolizeable energy levels between diets didn't have a significant (P >0.05) effect on most egg quality parameters. Consistently Novak *et al*. (2008) found that the internal and external egg quality parameters did not influenced by low CP and ME diets.

Egg weight and HUS were significantly (P <0.05) influenced by the dietary energy levels. But, no significant (P > 0.05) differences were observed in the other egg quality traits as a

subsequent effect to the different levels of ME in the diet during the laying period. The present result on egg weight is consistent with Hassan *et al.* (2013) who found higher egg weight on diets with higher levels of ME (2800 kcal, ME/kg).

From the present study the HU values of eggs obtained from all experimental diets ranged between 76.61 to 81.66 and then these eggs can be classified as best quality eggs “AA” (72 to100). This classification is based on the United States Department of Agriculture (USDA). Similarly, Oluyemi and Robert (2000) reported also haugh unit score of 72 and above had been graded as the best quality. The higher the HU, the more desirable is the egg quality (Fayeye *et al.,* 2005). However, the present result on Haugh unit disagreed with other findings (Sehu *et al.*,2005; Junqueira *et al.,* 2006; Ding *et al*., 2016), who reported that the

Haugh unit were not affected by dietary ME and CP levels. Higher HUS was found in the diet containing 2650 kcal/kg ME and 14.5% CP. This result is disagreed with previous reports (Sehu *et al*., 2005) that varying levels of proteins, in the diet didn't affect the Haugh units.

Eggshell strength and eggshell thickness are the two important indicators for reflecting eggshell quality. In the present study the value of shape index was ranged between 76.22 and 78.87 mm, which indicate the quality of eggs. This study showed that eggshell thickness was not significantly (P >0.05) affected by dietary treatments with varied levels of CP, ME and their interactions, which is consistent with other reports (Sehu *et al.,* 2005; Junqueira *et al.,* 2006; Almeida *et al*., 2012) that shell thickness was not affected by either protein or energy variations in the diet. But contrary to this finding Lofti *et al.*, 2018 reported increasing ME and CP level in a diet resulted increment in egg shell thickness and egg shell strength.

Egg shape index, albumin index and yolk index were not significantly (P >0.05) influenced by the dietary treatments (CP, ME and their interaction). The present result on albumin and shape index of eggs disagreed with the previous finding by Lotfi *et al.* (2018) reported that albumin and shape index of eggs were increased with increasing the energy and protein levels in a diet.

5.4. Hatchability and Fertility

Statistical analysis indicated that there were no significant differences (P >0.05) observed between dietary treatments due to variations in ME, CP and their interaction, on the percentage of fertility and hatchability. The preset result on fertility and hatchability is consistent with Etalem *et al.* (2019) who reported dietary energy and protein didn't have a significance (P >0.05) effect on fertility and hatchability of eggs. However, contrary to the present finding Marie *et al.* (2009) and Lotfi *et al.* (2018) reported that the high-energy diet fed to hens, had significantly higher egg fertility than those fed with the lower energy levels. Although there were no significance differences in fertility and hatchability of eggs, linear increases in fertility and hatchability with increase in ME and CP levels were observed.

According to Hassan *et al.* (2000) and Kingori *et al.* (2010) fertility and hatchability of eggs are mainly affected by genetic and environmental conditions such as nutrition, breed, egg quality, storage conditions and durations rather than diets. Diet mainly affects the number and size of eggs rather than their composition (Hassan *et al.,* 2000; Kingori *et al.*, 2010).

5.5. Partial Economic Analysis

There was a significant (P <0.05) difference among the treatments with different levels of CP and ME in economic analysis. It is observed that as the level of protein and energy in the diets increased, the cost of experimental ration also increased. The result indicated that feeding of the experimental birds on layer diet containing 15.5% CP with 2650 kcal/kg of ME found to have comparatively lower production cost as compared to other diets. There was also significant (P <0.05) difference in net income (NI) among the treatments and the highest net profit per bird was found on a diet with 15.5% CP with 2650 kcal/kg, ME.

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

From this study it can be concluded that for maximum growth and good FCR DZ-White chickens need a diet with higher levels of protein and energy (19% CP in starter and 18% CP in grower phases each with 2900 kcal/kg of ME).

The current result revealed that egg production and % of HDEP was significantly ($P < 0.05$) influenced by dietary treatments with differently leveled proteins and energy. However, dietary energy, protein and their interaction didn't have a significant effect on the percentages of hatchability, fertility and most egg quality parameters.

It can be also concluded that DZ-White chickens can be reared economically on a layer ration containing 15.5% CP and 2750 kcal/kg of ME.

6.2. Recommendations

Based on this study it could be suggested /recommend to economically feed the DZ-White chickens with diets containing 19% CP in starter, 18% CP in grower phases each with 2900 kcal/kg of ME and also 15.5% CP with 2750 kcal/kg of ME in the layer phase.

Further investigation is recommended to assess the effects of further lower and upper levels of energy and protein on productive and reproductive performances of DZ-White chickens.

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8. APPENDECES

8.1. List of ANOVA tables

Appendix 1: Analysis of Variance of Feed Intake (kg) per Bird in Starter Phase

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	0.02168889	0.00197172	2.75	0.0187
Error	24	0.01723333	0.00071806		
Corrected total	35	0.03892222			

CV = 2.03

Appendix 2: Analysis of Variance of Initial Body Weight (g) in Starter Phase

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	182.4166667	16.5833333	2.01	0.0739
Error	24	197.8888889	8.245304		
Corrected total	35	380.3055556			

CV = 2.35

Appendix 3: Analysis of Variance of Body Weight (g) at 8 weeks age

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	38853.37	3532.124	38.93	0<.0001
Error	24	2177.653	90.735		
Corrected total	35	41031.019			

CV = 2.35

Appendix 4: Analysis of Variance of Body Weight Gain (g) for in Starter Phase

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	36742.320	3340.210	29.06	0<.0001
Error	24	2758.717	114.946		
Corrected total	35	39501.038			

CV = 2.93

Appendix 5: Analysis of Variance of FCR for Chicks in Starter Phase

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	2.27208611	0.20655328	12.59	0<.0001
Error	24	0.39387778	0.01641157		
Corrected total	35	2.66596389			

CV = 3.52

Appendix 6: Analysis of Variance of Feed Intake (kg) per Bird for Growers

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	0.05115278	0.00465025	1.43	0.2222

Error	24	0.07794444	0.00324769		
Corrected total	35	0.12909722			

CV = 2.36

Appendix 7: Analysis of Variance of Body Weight (g) for Females at 14 Weeks age

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	82029.127	7457.193	23.61	<0.0001
Error	24	7581.242	315.885		
Corrected total	35	89610.369			

CV = 1.98

Appendix 8: Analysis of Variance of Body Weight (g) for Males at 14 Weeks age

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	2352.829242	2138.93567	4.03	<0.0021
Error	24	1274.142997	530.8929		
Corrected total	35	3626.972239			

CV = 7.66

Appendix 9: Analysis of Variance of Body Weight Gain (g) for Growers

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	910.064	5074.206	12.35	0<.0001
Error	24	8086.595	411.010		
Corrected total	35	65680.501			

CV = 4.12

Appendix 10: Analysis of Variance of FCR for Growers

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	4.88516944	0.44410631	13.86	0<.0001
Error	24	0.76892778	0.03203866		
Corrected total	35	5.65409722			

CV = 3.63

Appendix 11: Analysis of Variance of Feed Intake (kg) per Bird for Pullets

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	0.26056389	0.02368763	0.62	0.7931
Error	24	0.91511111	0.03812963		
Corrected total	35	1.17567500			

CV = 7.21

Appendix 12: Analysis of Variance of Body Weight (kg) at 19 Weeks age

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	156171.9137	14197.4467	3.12	0.0095

Error	24	109144.7423	4547.6976
Corrected total	35	265316.6560	

CV = 4.85

Appendix 13: Analysis of Variance of Body Weight Gain (g) for Pullets

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	83452.3960	7586.5815	2.43	0.0335
Error	24	74944.6495	3122.6937		
Corrected total	35	158397.0455			

CV = 11.31

Appendix 14: Analysis of Variance of FCR for pullets

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	11.70803611	1.06436692	3.03	0.0112
Error	24	8.43226111	0.35134421		
Corrected total	35	20.14029722			

CV = 10.64

Appendix 15: Analysis of Variance for Egg Production

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	56356.2778	5123.2980	0.94	0.5254
Error	24	131502.6111	5479.2755		
Corrected total	35	187858.8889			

CV = 27.47

Appendix 16: Analysis of Variance for %HDEP

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	580.332672	52.757516	1.77	0.1182
Error	24	717.164617	29.881859		
Corrected total	35	1297.497289			

CV = 11.53

Appendix 17: Analysis of Variance for %HHEP

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	361.7962889	32.8905717	2.44	0.0582
Error	3	3695694111	15.3987255		
Corrected total	35	731.365700			

CV = 12.01

Appendix 18: Analysis of Variance for AFL (days)

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	128.1666667	11.6515152	0.35	0.9628

Error	3	794.8333333	33.1180556		
Corrected total	35	923.000000			

CV = 3.94

Appendix 19: Analysis of Variance for EW (g)

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	22.41777778	2.03797980	0.79	0.6513
Error	3	62.22222222	2.59259259		
Corrected total	35	84.64000000			

CV = 3.09

Appendix 20: Analysis of Variance for EM (g/b/d)

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	157.694444	14.3358586	1.40	0.2362
Error	3	245.944444	10.2476852		
Corrected total	35	403.6388889			

CV = 12.91

Appendix 21: Analysis of Variance for Hatchability

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	1094.942161	99.540196	0.80	0.6361
Error	24	2972.912661	123.871361		
Corrected total	35	4067.854822			

CV = 14.19

Appendix 22: Analysis of Variance for Fertility

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	1555.555556	141.414141	1.41	0.2317
Error	24	2408.333333	100.347222		
Corrected total	35	3963.888888			

CV = 13.92

Appendix 23: Analysis of Variance for Egg Shell Index

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	202.964506	18.451319	1.17	0.3159
Error	96	1509.981585	15.728975		
Corrected total	107	1712.946092			

CV = 5.11

Appendix 24: Analysis of Variance for Egg Shell Thickness

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	0.01596296	0.00145118	1.66	0.0933

Error	96	0.08370000	0.00087188		
Corrected total	107	0.09966296			

CV = 9.63

Appendix 25: Analysis of Variance for Yolk Weight

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	35.3790287	3.2162753	1.22	0.2816
Error	96	252.1609593	2.6266767		
Corrected total	107	287.5399880			

CV = 9.93

Appendix 26: Analysis of Variance for Yolk Index

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	0.01677315	0.00152483	1.29	0.2427
Error	96	0.11359259	0.00118326		
Corrected total	107	0.13036574			

CV = 7.45

Appendix 27: Analysis of Variance for Haugh Unit

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	403.599484	36.690862	1.46	0.1612
Error	96	2393.406781	25.193756		
Corrected total	107	2797.006265			

CV = 6.31

Appendix 28: Analysis of Variance for Albumin Weight

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	127.260888	11.569172	1.01	0.4419
Error	96	1097.444856	11.431717		
Corrected total	107	1224.705744			

CV = 11.59

Appendix 29: Analysis of Variance for Albumin Height

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	7.53009259	0.68455387	1.27	0.2507
Error	96	51.55092593	0.53698881		
Corrected total	107	59.08101852			

CV = 12.06

Appendix 30: Analysis of Variance for Partial Economic Analysis

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	11	7.53009259	0.68455387	1.27	0.2507

Error	96	51.55092593	0.53698881
Corrected total	107	59.08101852	

CV = 10.06