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NUTRITIONAL EVALUATION AND FEEDING VALUE OF SORGHUM (*Sorghumbicolor* (L). Moench) VARIETIES ON THE PERFORMANCE OF LAYER CHICKEN

MSc Thesis

BY

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ADDIS ABABA UNIVERSITYCOLLEGE OF VETERINARY MEDICINE AND AGRICULTUREDEPARTMENT OF ANIMAL PRODUCTON STUDIES

JUNE, 2020

BISHOFTU, ETHIOPIA

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MSC THESIS SUBMITTED TO COLLEGE OF VETERINARY MEDICINE AND AGRICULTURE DEPARTMENT OF ANIMAL PRODUCTON STUDIES
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IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR DEGREE OF MASTERS OF SCIENCE IN ANIMAL PRODUCTION STUDIES

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BIZUNESH FIKRE BEZU

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APPROVAL SHEET

ADDIS ABABA UNIVERSITY

COLLEGE OF VETERINARY MEDICINE AND AGRICULTURE

DEPARTMENT OF ANIMAL PRODUCTION STUDIES

As MSc research advisors, we hereby certify that we have read and evaluated this Thesis prepared under our guidance by **Bizunesh Fikre Bezu** title: **Nutritional Evaluation and Feeding Value of Sorghum (*Sorghum bicolor* (L). Moench) Varieties on the Performance of Layer Chicken**, we recommend that itcan be submitted as fulfilling the MSc thesis requirement.

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DEDICATION

This thesis is dedicated to my beloved family, my father Fikre Bezu, my mother Birkinesh Chamisa and my brother Kinfe fikire their unreserved financial and moral support for my academic success is highly memorable.

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 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

Bizunesh Fikre was born on Sep 02/01/1985 E.C, in Southern Ethiopia. She attended her Elementary Education in Mezwor, Secondary Education in Cheza Sefere and College Education in Mizan Tepi ATVET College. After completion of her College Education, She joined Dilla University, College of Agriculture and Natural Resource in 2005 E.C and Graduated with BSc degree in Animal and Range science in 2007 E.C.

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LIST OF ABBREVIATIONS

AEP	Average Egg Production
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemist
ATVET	Agricultural and Technical Vocational Education Training
BSc	Bachelor of Science
BW	Body Weight
BWC	Body Weight Change
CF	Crude Fiber
CP	Crude Protein
CSA	central statistics agency
CT	Condensed Tannin
DM	Dry Matter
DZARC	Debre Zeit Agricultural Research Centers
EE	Ether Extract
FAO	Food and Agricultural Organization
FBW	Final Body Weight
FCR	Food Conversion Ratio
HDEP	Hen Day Egg Production

HHEP	Hen House Egg Production
HU	Haugh Unit
ICRISA	International Crops Research Institute for the Semi-Arid
INTSORMIL	International Sorghum and Millets
MARC	Melkasa Agricultural Research Centers
ME	Metabolize Energy
SAS	Statistical Analysis System
SGS	School of Graduate Studies
SVD	Sorghum Variety *Degalit* yellow
SVM	Sorghum Variety *Melekam*
TEP	Total Egg Production
USDA	United States Department of Agriculture

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ABSTRACT

A study was conducted to evaluate nutritional and feeding value of the two newly released (sorghum bicolor (L). Moench) varieties, melkam and degalit yellow on the performance of layer chicken mainly on egg laying performance and egg quality parameters. Two hundred ten Bovan's Brown hens, aging 22-33 weeks were used and equally divided into seven dietary treatments with three replications. Treatment rations contained control [i.e., T1 (0% Sorghum varities), T2 (20% Sorghum variety melkam, SVM), T3 (30% Sorghum variety melkam, SVM), T4 (40% Sorghum variety melkam, SVM), T5 (20% Sorghum variety degalit, SVD), T6 (30% Sorghum variety degalit, SVD), T7 (40% Sorghum variety degalit, SVD). Data on feed intake, hen-day egg production (HDEP), hen-housed egg production(HHEP) and egg weight were recorded and feed conversion ratio(FCR) calculated from gram(g) egg mass to gram(g) feed consumed. The results showed that highest and lowest body weight change were recorded in T6 (209.83 g) and in T2 (76.33 g), respectively. In terms of sorghum levels, the highest and lowest body weight change of209.83 and 76.33 were recorded at 30% sorghum variety degalit and 20% Sorghum variety melkam, respectively. Regarding variety type, in the present study, a higher (P<0.05) BW change was record observed in hens that fed on sorghum variety degalit (160.52g) than sorghum variety melkam (86.28g). Feed conversion ratio was not affected (P>0.05) in hens fed across all treatments, levels of sorghum varieties and in between the two sorghum varieties. The highest and lowest egg production per hen was produced in T7 (40%SVD) and T3 (30SVM) respectively. Hen housed egg production was highestin T7 (40% SVD) than the rest of the treatments. In terms of varieties, Hen housed egg production was higher (P<0.05) in degalit (SVD) than melkam (SVM). However, hen day egg production was not different (P>0.05) among the treatments and levels except T3 (30% level of SVM) while considering the type of variety it showed a non-significant (P>0.05) difference between the two sorghum varieties. Both albumin weight and Haugh unit were significantly different in hens fed on across treatments, sorghum varieties and levels of sorghum varieties. On the other side; egg shape index, shell thickness, yolk weight and yolk color were not significantly different (P>0.05) in hens fed on all treatments, both sorghum varieties (Sorghum variety melkam and Sorghum variety degalit) and across all levels of the sorghum varieties. Better net income was earned *from hens fed on T7 (40%SVD) than other treatments and levels but in terms of sorghum varieties, Sorghum variety degalit was contributed for earning better net income. Generally, from the inclusion of both sorghum varieties (Sorghum variety melkam and Sorghum variety degalit) in layer diet, hens fed on Sorghum variety degalit resulted in higher net income than hens fed on Sorghum variety melkam and control group. Although there were no difference (P>0.05) in the net income 219.02 (birr/hen) was gained from the hens fed on T7 (40% of Sorghum variety degalit) than other treatments and levels, and 205.33 (birr/hen) was earned from hens fed on degalit (SVD) than melkam. As aresult, Sorghum Varity degalit production level should be increase and needs further researches that can give evidence about the nutritional value of Sorghum variety degalit in different levels in layer per performance.*

Keywords: *Body weight change, Egg production, Egg quality, Feeding value, Sorghum varieties*

1. INTRODUCTION

Poultry production is the most common for meat and eggs sources of the human being. Poultry meat and eggs are among food consumed at the global level, through a wide diversity of cultures, traditions and religions, making them key to food security and nutrition. Within the livestock sector, poultry emerges as the most efficient sub-sector in its use of natural resources and providing protein to supply a global growing demand. It is important for small holders and poor rural and urban communities and mainly produced in large scale and intensive operations, making it one of the fastest growing agricultural sub-sectors (Mottet *et al*., 2017). Poultry production in Ethiopia is a livelihoods activity mainly undertaken by women and children of the household to meet their immediate cash expenditure needs. These shows, the importance of poultry in intra-household gender equality, and for development outcomes where incomes managed by women have been found to result in improved outcomes for family, particularly for children, for example in terms of health, nutrition and education (Hailu, 2019).

The poultry industry has suffered more than any other livestock industry as a result of inadequate supply and high cost of feed (Leplaideur, 2004). Feed cost is expected to continue in the upward swing (Conolly, 2012). The ever-rising prices of feed ingredients remained to be the greatest single item determining the profit margins in poultry farming, especially in developing countries. The energy level of the feed is also the major factor influencing feed intake, as birds under normal circumstances eat to satisfy their energy needs. The most appropriate strategy for this challenge is to develop diets, which allow locally available ingredients that can meet the energy requirement of the birds used. Such an approach would reduce feed costs as well as the dependency on imported and conventional feed materials. Cereal grains constitute the major sources of energy in poultry diets in the tropics (Etuk *et al*., 2012).

Maize is the main energy source in poultry diets, and there is high competition among human beings, livestock and the industry (Atteh, 2002; Mabelebele *et al.,* 2015). The grain is increasingly being used to produce ethanol, and many areas in the world are not self-sufficient in grain production to meet human and animal needs. Because of its multiple uses and relatively higher moisture requirement for growth, use of maize in drier areas in most part of the country may be limited in the future. In comparison to maize, sorghum is drought tolerant and grows successfully on relatively poor soils with lower moisture condition (Medugu *et al*., 2010; Hadebe *et al.*, 2017). It is abundant in most parts of Africa and Asia, and it is among the main cereal crops that are used as food and feed. The adaptive agronomic characteristics of sorghum make it suitable for cultivation in different environmental conditions.

Sorghum (*Sorghum bicolor* (L). Moench) is an important food crop particularly in arid and semi-arid tropics. Many people in Africa and Asia depend on sorghum as the stuff of life. Being a drought tolerant crop, it can give dependable and stable yield in both raining and post raining seasons. It thrives with less rainfall than needed for rice and maize and can be grown where no other major cereal can be cultivated. It is not only drought resistant but can also withstand periods of water logging. Sorghum is an important cereal crop that can plays a key role in the animal feeds and nutrition (Sedghi *et al*., 2011; Kaufman *et al*., 2013). Though sorghum is similar in chemical composition to maize, it has been associated with sub-optimal and inconsistent poultry performance (Black *et al*., 2005; Bryden *et al*., 2009; Ravindran, 2014 ;) due to the anti-nutritional factor tannin in it that hinders the protein digestibility. Studies by Kumar *et al*. (2007) revealed that feeding reconstituted red sorghum-based diet with a tannin content of 16 g/kg to broiler chicken did not exert any appreciable influence on nutrient utilization, blood biochemical's, enzymes and gross pathological changes even at 100% replacement of maize. However, raw red sorghum-based diet with 23 g/kg tannin fed to broiler chickens caused higher immuno-responsiveness in comparison to their reconstituted counterpart. It is possible that the development of low tannin sorghum could raise its value to comparable levels with maize in poultry diet (Smithhard, 2002).

The present study designed with a general objective to evaluate the nutritional and feeding value of low tannin content sorghum varieties (*melkam* and *degalityellow*) released by National Sorghum Research Program, Ethiopian Institute of Agricultural Research, Ethiopia on the performance of layer chicken. The following points are the specific objectives of this study:

1. To evaluate effect of feeding sorghum variety *melkam* and sorghum variety *degalit* yellow in the laying performance and egg quality characteristics of Bovan Brown hen,

2. To determine the optimum level of inclusion of sorghum variety *melkam* or sorghum variety *degalit* yellow in the diet of layers,
3. To compare sorghum varieties *melkam* and *degalit* yellow in the production performances of Bovan Brown hen; and,
4. To evaluate the partial budgeting analysis of inclusion of sorghum varieties in the layer chicken diet

2. LITERATURE REVIEW

2.1. Origin, Description and Agro-Ecology ofSorghum

The crop sorghum originated in northeastern Africa, where large variability in wild and cultivated forms remains (Shewale and Pandit, 2011). It is a self-pollinating summer plant classified under the family Poaceae (grass family), tribe and Aropogoneae, species, *Sorghum bicolor* (L.) Moench. It is the fifth most important cereal crop in the world, after wheat, maize, rice and barley (FAO, 2012) and the second major crop (after maize) across all agro-ecologies in Africa (Taylor, 2003; Zhao *et al.*, 2019). Domesticated in North Africa, possibly in the Nile or Ethiopian regions around 1000 BC. Its cultivation likely spread from Ethiopia, where it is believed domestication occurred, to Africa, the Middle East, and India along trade and shipping routes over 3,000 years ago (Dahlberg *et al*. 2011; Shewale and Pandit, 2011).

Sorghum used as a source of food, feed, fiber and fuel and is one of the most important cereal crops grown in arid and semi-arid areas of the world, receiving 400 to 800 mm of rainfall annually (Truayinet, 2018). Sorghum known under a variety of names: great millet and guinea corn in West Africa, kaffir corn in South Africa, durra in Sudan, Mtama in East Africa, johaalacholam in India and kaoliang in China. Cultivated sorghum divided into five groups namely bicolor, guinea, caudatum, kafir and dura. Sorghum varieties have used for many years for poultry and human consumption, especially in Africa and Asia, and have been shown to vary in physical and chemical characteristics (Sedghi *et al*., 2011). Sorghum is cultivated as a major food crop in several countries in South Asia, Africa, and Central America. The crop is mainly grows in tropical and subtropical areas that are marginal and stress prone. Sorghum known as guinea-corn, dawa, or sorgho in West Africa, durra in the Sudan, Mashelia in Ethiopia and Eritrea, Mtama in East Africa, Kaffircorn, Mabele, or Amabele in southern Africa, and as jowar, jonna, cholam or jola in the Indian subcontinent (Bantilan *et al*., 2004). Sorghum is a major cereal crop in arid and semi-arid areas of the world. It is a staple crop of semiarid sub-Saharan Africa. Sorghum is a major food and nutritional security crop to more than 100 million people in Eastern horn of Africa, owing to its resilience to drought and other production constraints (Gudu *et al.*, 2013*)*.Sorghum is indigenous to

Africa and accounts for 43% of all major food staples produced in sub-Saharan Africa considered sorghum as a traditional crop in much of Africa and Asia and an introduced and hybridized crop in the Western hemisphere (Maunder, 2002).

Sorghum (Sorghum bicolor) is one of the most widely grown cereal crops in Ethiopia. It is a main food crop on which the lives of millions of poor Ethiopians depend. It has tremendous uses for the Ethiopian farmer and no part of this plant is ignored. Sorghum grows in a wide range of agro-ecologies most importantly in the moisture stressed parts where other crops can least survive and food insecurity is rampant. The primary and most important source of sorghum germplasm introduction for Ethiopia has been the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). From the very beginning of sorghum research in Ethiopia, a significant number of sorghum germplasm lines have been introduced from ICRISAT and evaluated annually for various desirable traits. The second most important source has been the International Sorghum and Millets (INTSORMIL) collaborative research support program (Asfaw, 2007).

Sorghum used in various ways in our country; the grain is used for human foods such as injera, bread, porridge, Nifro, infant food, syrup, and local beverage known as "Tella" and "Arekie." In addition, the leaf and stalk used for animal feed, and further, the stalks used for the construction of houses and fences and as fuel wood (Masresha *et al*, 2020).

2.2. Nutrient Composition of Sorghum

Sorghum grain is similar to maize with respect to chemical composition. Sorghum contains about 10.4 % crude proteins, 3.4 % Ether Extract, 2.5 % Crude Fibre, and 3264.02 kcal/kg metabolize energy (Tamburawa *et al.*, 2012). According to Mohammed *et al* (2013), sorghum has about % 94.3 DM, 13.03 % crude protein, 2.94 % Ether Extract, 3.59 % Crude Fibre. On the other hand, the low-tannin sorghum (1.23% tannin) contains 3214.00 kcal/kg and protein contents of sorghum is 10.83 to 12.79%, ether extract 3.52 to 4.23% and crude fibre 2.16 to 3.02% as reported by Medugu *et al*. (2014). Climatic, soil conditions, fertilizers are factors responsible for the variation in chemical composition of sorghum varieties (Etuk *et al*., 2012; Patricia *et al*., 2012). The CP content of sorghum is higher than that of maize but similar to wheat. In terms of energy value, sorghum rated as high as 90 – 100% of maize depending on the livestock specie (Etuk*etal.*, 2012). However, sorghum is lower than maize but higher than wheat in fat content (Atteh, 2002). Sorghum contains low levels of lysine but high tryptophan content relative to maize. Sorghum proximate composition varies significantly due to genetics and environment; for example, high nitrogen fertilizer level increases grains protein content and decreases the amount of starch in the grain (Ralph *et al*., 2000).

Maize and sorghum have the main limiting indispensable amino acids, argentine, lysine, methionine, cystine and tryptophan. Sorghum has lower starch digestibility relative to other grains such as maize, rice, wheat and barley, although the degree of digestibility depends on the method of processing. The nutritional quality of sorghum proteins is diminished because they are more resistant to digestion and have low levels of essential amino acids such as lysine, tryptophan and threonine. In contrast, there are high levels of leucine (McDonald *et al.*, 2000).

Sorghum is a source of B-complex vitamins such as thiamin, riboflavin, vitamin B_6, biotin, and niacin that are diminished with grain refining processes including decortications. The mineral composition in sorghum is similar to millet, higher compared to maize, lower than wheat and is predominantly composed of potassium and phosphorus. Sorghum-based foods are a good source of both iron and zinc, although anti-nutrients such as phytates may diminish bioavailability (Hurrell *et al*., 2003).

2.2.1. Proteins

Protein is the second largest constituent of sorghum grain after starch (Taylor*et al*., 2011). Sorghum proteins are classified as albumins, globulins, kafirins, cross-linked kafirins and glutelins (De Mesa *et al*., 2010). Kafirins, the main protein, comprising 50-70% of total protein content (Belton *et al*., 2006). The kafirins are prolamin storage proteins with limiting levels of some amino acids, in particular lysine, a disadvantage not unique among cereal grains. The kafirins differ in structure from the gliadin and glutenin storage proteins in wheat (Duodu *et al*., 2003). Sorghum kafirins are poorly digested due to the formation of cross-linking especially when moist cooked, resulting in protease resistance. *In vitro* and animal studies have also shown that sorghum protein digestibility may be reduced by other protein, protein-phenol and carbohydrate-phenol complexes (Taylor, 2002).

2.2.2. Starches

Sorghum grain is a good source of starch, containing approximately 71% of dry whole grain weight. The starch is encapsulated in granules that are located predominantly in the endosperm (storage tissue), though uniquely some are present in the pericarp (outer layer of grain). Sorghum starch is comprised of both amylose and amylopectin polysaccharides (branched polymers of glucose) with very low percentages of amylose present in the starch of waxy sorghum varieties compared to 24-33% in non-waxy sorghum starch(Taylor,2010).

The lower starch digestibility reported for sorghum foods is not an intrinsic property of the sorghum starch granules themselves, but appears mainly to be a consequence of the interactions of the starch with the endosperm protein matrix, as well as with cell wall material and polyphenolic compounds, such as condensed tannins and flavonoids. These interactions inhibit carbohydrate-hydrolyzing enzymes, such as α-glucosidase and α-amylase, thereby lowering starch digestibility (Kim *et al.*, 2011*).*Grain sorghum contains high levels of phytate or phytic acid, in addition to minerals, phytate binds with protein through binary and ternary complexes and binds with starch directly or indirectly through starch granule-associated protein (Baldwin, 2001; Oatway *et al*., 2001). Due to this relationship, the enzymatic degradation of phytate increases availability of starch and protein in the sorghum. The use of phytase in poultry feed has also increased in response to increasing concerns over phosphorus (P) pollution in the environment.

2.2.3. Phytochemicals

Most sorghum varieties, except white sorghums, have a high concentration of photochemical, particularly phenolic compounds, which exhibit high antioxidant activity and are linked to health benefits (Rooney *et al*., 2005). In fact, bran of some sorghum grain varieties reportedly has the highest antioxidant activity of all cereal crop fractions, even higher than many fruits and vegetables. Specifically, sorghum bran has up to two orders of magnitude higher antioxidant activity than oat bran and wheat cereal, and an order of magnitude higher than rice bran although the precise amount is highly dependent on the variety of sorghum (Awika *et al*., 2004).

2.3. Nutritional and Feeding Value of Sorghum

The nutritional properties of sorghum are unique and variety dependent. Some varieties are rich in polyphenols, especially condensed tannins as natural antioxidants (Dykes and Rooney, 2006). Other important nutrients of sorghum include dietary fiber, fat soluble and B vitamins, and minerals (Waniska *et al*., 2004). All nutritional properties make sorghum gain a spotlight for better production and utilization as human food and also an important feed for ruminants, pigs, and poultry. Various strategies have been suggested to improve feed values by increasing the digestibility of both protein and starch. Much of the sorghum utilization and product quality is to a large extent related to the quality of sorghum starch. Sorghum contains some anti-nutritional factors especially tannin which inhibit the use of important nutrients like protein, energy and minerals (phosphorus, calcium, zinc and magnesium) in diets (Liu *et al*., 2013).

According to Jimoh and Abdullahi (2017), nutritionally, sorghum has high carbohydrate content in form of starch. The protein content is significant and comparable to that of wheat and maize but its digestion is an obstacle to its nutritive value. It has a high fat content than wheat or rice, but, it is lower than that of maize.

2.3.1. Feeding value of sorghum in poultry diets

Considering the nutritive value, cost and availability, sorghum grain is the next alternative to maize in poultry feeding (Maunder, 2002). Sorghum grain is as ideal as maize for poultry (Subramanian and Metta, 2000; Ravindran, 2014). According to Rajasekher *et al*. (2005) maize be replaced by sorghum in poultry feed rations without affecting body weight and egg production performance of layer birds. Maize, wheat and sorghum may be used effectively in poultry diets when fed on the basis of their nutrient composition in properly balanced poultry feeds. Although sorghum has been used in poultry feed, farmers in India are reported to be apprehensive regarding the use of sorghum in poultry feed (Subramanian and Metta, 2000). Farmers have the notion that sorghum has tannin and has low energy compared to maize grain. Studies by Kumar *et al*. (2007) revealed that feeding reconstituted red sorghum-based diet with a tannin content of 16 g/kg to broiler chicken did not exert any appreciable influence on nutrient utilization, blood biochemical's, enzymes and gross pathological changes even at 100% replacement of maize. However, raw red sorghum-based diet with 23 g/kg tannin fed to broiler chickens caused higher immuno-responsiveness in comparison to their reconstituted counterpart. It is possible that the development of low tannin sorghum could raise its value to comparable levels with maize in poultry diet (Smithhard, 2002).

Sorghum based brewers' dried grains have found effective use in poultry diet (Uchegbu*et al*., 2004). Sorghum dust, an extracted residue from the use of sorghum in beer production led to a decrease in weight gain of birds, maize and sorghum dust however, supported similar hematological development in chicks (Ajaja *et al*., 2002).

2.3.1.1. Sorghum feeding value in broilers

Broilers chickens play a significant role in the provision of animal protein required by man to meet his daily protein intake (Maidala and Istifanus, 2012). Broilers have high growth rate, high feed conversion ratio and also short generation interval (Atteh, 2003). The chicken meat is superior to that of other livestock species because of its associated relatively lower calorie and sodium intake while containing high protein content (Atteh, 2003). Poultry meat is nutritious, tender, juicy, tasty and generally appealing and accepted when processed (Omole *et al*., 2006). The primary reason for including sorghum in diets for broiler chickens is for the provision of energy, which mainly derived from its starch component. However, the utilization of starch/energy in sorghum by poultry is suboptimal. Moreover, the digestibility of sorghum starch is inferior to that of maize because of both *in vitro* (Giuberti *et al*., 2012) and *in vivo* (Liu *et al*., 2014, Truong *et al*., 2016).

Quality of sorghum as a feed grain for chicken-meat production is somewhat better than the perceived value; nevertheless, the performance of broiler chickens offered sorghum-based diets is open to improvement. Two prime targets in this respect are reductions in concentrations of kafirin and 'non-tannin' phenolic compounds. Kafirin, as a proportion of protein, is positively correlated with sorghum protein concentrations. Consequently, as protein contents of grain sorghum increase, kafirin concentrations will also increase in both relative and absolute terms. Therefore, it follows that 'low-protein' sorghums are more likely to support better broiler performance than 'high-protein' varieties by virtue of lesser kafirin contents as demonstrated by Truong *et al*. (2015).

2.3.1.2. Nutritional value of sorghum in layers diets

When evaluating the potential of a feed ingredient for use in layer diets several factors need to be considered. These include not only rate of egg production and feed efficiency, but also egg weight, shell thickness, Haugh units and yolk mottling. Accordingly (Ligeiro *et al*., 2009), indicating that sorghum may completely replace corn in the feed with no detrimental effects on performance on chiken. In addition a study conducted by Usman and Garba (2012) reported that when Isa Brown chickens were fed with a maize and sorghum based diet formulation there was no significant differences in the egg weight, yolk weight, albumen weight, Haugh unit percentage and shell thickness.

Sorghum can replace all the maize in poultry diets provided xanthophylls are added for skin and egg yolk pigmentation. When competitively priced, grain sorghum can be used at up to 70% in a broiler and layer rations and 55% in turkey rations replacing all of the corn (Scott, 2010). Whole sorghum used as 45% of the total feed composition and source of energy showed that there was no statistical difference in the feed consumed by the birds and the percentage of egg production (Subramanian and Metta, 2000). Egg production and feed intake tended to be greater ($P<0.1$) in layers fed sorghum-based diets, however there were no differences in average egg weight ($P>0.05$) and feed conversion ($P>0.05$) among birds fed corn and the sorghums (Issa, 2009). Substitution of corn with different grain sorghum had no any negative effect on laying performance, except reduction for egg shell quality when inclusion rate is high (Ebadi *et al.*, 2005).

2.4. Digestibility and Energy Value of Sorghum Grain and Sorghum By-Products

The digestibility of cereals varies tremendously based on genetic background. Sorghum has the lowest starch digestibility due to the resistance to digestive enzymes of the hard peripheral endosperm layer. Similarly, a study with growing pigs showed that digestibility was highest for cassava, followed by maize, sorghum and barley *(*Dowling *et al*., 2002). Variations exist among sorghum cultivars, especially those low in tannin which appears to have the same digestibility as maize. There are also large differences between animal species in their capacity to digest cereal starch. The digestibility of sorghum starch across the whole digestive tract of poultry is 99% compared with 87% for cattle, even though with in specie, age differences also affect digestibility of feedstuff (Rowe *et al*., 1999).

The overall total digestible nutrients in sorghum are roughly 95% of those in dry rolled yellow dent maize; this is due to lower starch availability because sorghum starch content varies and is bound in a thicker protein matrix. The actual dietary energy content of any feedstuff therefore will depend on its chemical composition since all organic components have an energy yielding value. Chemical composition gives only the potential value of feed though the quantity of carbohydrate, fat and protein does help in measuring the usefulness of feed (Ranjhan, 2001).

2.4.1. Starch and protein digestibility

Sorghum grain has the lowest raw starch digestibility due to restrictions in accessibility to starch caused by endosperm proteins. The digestibility of the starch, dependent on hydrolysis by pancreatic enzymes, determines the available energy content of cereal grain. The chemical nature of the starch, particularly the amylase and amylopectin content, is yet another factor that affects its digestibility. Lower starch digestibility has reported in case of cooked sorghum flours than normal maize flour; irrespective of the endosperm type (Elkhalil *et al*., 2001). Both *in vitro* and *in vivo* studies have wide variability in protein digestibility of sorghum varieties.

In certain sorghum varieties, the presence of condensed tannins in the grains is another factor that adversely affects protein digestibility and amino acid availability. A decrease in the protein digestibility of sorghum on cooking was attributed to reduced solubility of prolamin and its reduced digestibility by pepsin. Protein digestibility of sorghum could also be improved by malting (germinating) the grain. Malt pretreatment also resulted in a reduction in phytic acid content, which is a significant anti-nutritional factor.

2.5. Anti-Nutritional Factors in Sorghum

Sorghum contains anti-nutrient compounds, such as tannins and phytic acid (Suarni and Singgih, 2002). It contains some anti-nutritional factors that makes it less digestible than maize (Etuk *et al*., 2012). These anti-nutritional factors include the presence of tannin and phytic acids which lowers the palatability, protein utilization and activity of digestive enzymes by non-ruminants (Medugu *et al*., 2010). Tannins also affect carbohydrate utilization by forming complex compound which are difficult to digest. Phytic acid, oxalic acids, gluccosinolates and gossypol and Substances in activating or increasing the requirements of certain vitamins, Anti-vitamins A, D, E and K, anti-thiamine, nicotinic acid, pyridoxine and cyanocobalamin. Most parts of the sorghum plant are used as animal feed. Growing sorghum be grazed, or the aerial parts of the plant may be ensiled or dried and fed as stover or silage for ruminant animals. Whole sorghum grain is cracked, ground, or steam flaked and fed to poultry, swine, dairy and beef cattle as a source of energy. Although not common, by-products of sorghum starch extraction such as hominy and gluten feed or gluten may feed to livestock (Akande *et al*., 2010; Maidala *et al*., 2013).

Tannin is the major anti-nutrient of concern in sorghum grain products, particularly bran, in varieties that contain tannins. There is diversity in chemical composition and anti-nutritional factors mainly tannin in the different varieties of sorghum resulting in variability in digestibility (Patricia *et al*., 2012).

Tannins are well known as anti-nutritive factors that hinder the utilization of feeds by monogastrics animals especially poultry. Tannins depressed growth rate, reduced palatability and feed utilization by forming complexes with proteins and carbohydrates or inhibition of digestive enzymes. Unlike ruminant animals, poultry do not have microbes in their gastrointestinal tract to detoxify or reduce the effect of tannins, but several methods have been used to reduce the tannin content of poultry feeds for better utilization. These methods are mainly physical and chemical in nature. Tannins exert inhibitory effect on a broad spectrum of digestive enzymes at several sites in the digestive tracts of poultry. Feed conversion efficiency increased with increasing level of tannin up to 15g/kg diet while pancreatic and jejenal enzymes activities were not affected. This suggests that a wider range of factors may be involved in regulating the effect of tannins on poultry (Iji *et al*., 2004; Ola *et al*., 2005).

Kumar *et al.* (2007) showed that tannin content of 16 g/kg in red sorghum had no effect on nitrogen, calcium and phosphorus preservation in broiler chickens. Similarly plasma albumin, globulin, protein, glucose, calcium, phosphorus, and uric acid levels were not affected even at 100% replacement of maize with red sorghum. The tannin sorghum varieties had low amino acid digestibility and metabolizable energy compared with the non-tannin varieties, which suggests the anti-nutritional activity of the tannins. On the other hand, the tannin varieties had higher levels of antioxidants than the non-tannin varieties. White sorghum varieties are considered to be superior to red sorghum varieties by both pig and poultry nutritionists. While speculative, the superiority of white sorghums as a feed grain for poultry may simply be attributed to lesser concentrations of phenolic compounds.

Ambula *et al*. (2003) reported that varying tannin level from 0 to 3.1% of the diet by graded inclusion of high-tannin sorghum did not affect egg production (69 to 71%), egg weight (57 to 61 g), and egg specific gravity (1.083 *vs* 1.090 mg/mL). In a 42-d experiment, corn, low-tannin sorghum (0.6%), high tannin sorghum (3.7%), and bentonite (2.5 or 5%) tested in layers. Birds fed low- tannin sorghum performed better than birds fed corn or high- tannin sorghum. Bentonite treatment did not improve the nutritive value of the high-tannin sorghum (Ambula *et al*., 2003). Similarly, in an 18-month experiment, Issa *et al.* (2007) reported 57% egg production for layers fed low-tannin (0.3%) sorghum *vs* 47% for birds fed a corn-based diet.

2.5.1. Cyanogenic glycosides

Cyanogenic glycosides are mainly present in germinating seeds, sprouts and the leaves of immature sorghum plants. Traore *et al*. (2004) showed that malted red sorghum that had been dried contained on average 320 ppm cyanogens. The most abundant of cyanogen is dhurrin, which may comprise three to four percent of the leaves of germinating seeds (Waniska and Rooney, 2000). Stressors such as drought, frost, heavy insect infestation, or overgrazing can result in increased levels of these compounds, which, along with tannins, are part of the plants' defense mechanisms. The use of potassium nitrate fertilizer was also increase cyanogens production in sorghum (Busk and Moller, 2002).

In the stomach of livestock, cyanogenic glycosides may be converted into hydrogen cyanide, which is very toxic, and at low level chronic exposure may result in poor growth or reduced milk production. Processing of germinating seeds for feed may result in the release of cyanide. It is generally recommended not to graze animals on young plants or cut them for green chop until they are at least 18 to 51 cm tall. However, traditional curing processes such as drying for hay, and malting processes of sprouts such as heating and drying, reduces the concentration of this toxin below a level of concern (Waniska and Rooney, 2000).

Phytate is an anti-nutritive factor in poultry diets is established and sorghum contains phytate at relative and absolute concentrations that are usually higher than other cereal grains (Waniska and Rooney, 2000).

The inclusion of phytate-degrading feed enzymes in poultry diets is routine but responses generated in sorghum-based diets appear to be soft. While speculative, the likelihood is that broiler chickens offered diets based on sorghums with low or modified kafirin levels coupled with low phenolic compound contents would respond more robustly to exogenous phytases. The premise for this contention is that phytase simply cannot attenuate the anti-nutritive properties of these sorghum components. Another tangible benefit is that such sorghums could result in better pellet quality stemming from lower starch gelatinisation temperatures in sorghums with lesser concentrations of kafirin and phenolic compounds (Selle *et al*., 2003).

2.5.2. Phenolic compounds

Polyphenols and phenolic acids are important negative factors integral in grain sorghum. It is doubtful that other phenolic compounds are innocuous and devoid of anti-nutritive properties. Grain sorghum cultivars contain higher levels of phenolic compounds than other cereals and red (non-tannin) sorghums are highly pigmented with polyphenols (anthocyanins and anthocyanidins) and, importantly, these phenols bind strongly to starch. Condensed tannin is only partially responsible for variations in the nutrient quality of grain sorghum (Barros *et al.*, 2012).

Total phenolic compounds tended to be negatively correlated weight gain and N retention and positively correlated with feed conversion ratio (FCR). The negative correlations with starch disappearance rates are noteworthy as the clear implication is that phenolic compounds in sorghum are impeding starch digestion, glucose absorption and consequently energy utilization in poultry. Phenol compounds are believed to form complexes readily with starch and are probably more likely to form starch–phenol complexes with amylase than amyl pectin. It appears that phenol compounds may interact with starch through hydrogen bonds, covalent bonds or chelation *via* their carboxyl and hydroxyl groups Non-covalent interactions between starch and phenol compounds can influence the nutritional properties of feedstuffs (Kandil *et al.*, 2012).

2.5.3. Tannins

Sorghums classified based on their tannin content: type I, no detectable tannin; type II, tannins in pigmented testa; type III, tannins in pigmented testa and pericarp (Waniska and Rooney, 2000). Digestibility and utilization of absorbed nutrients may be reduced 3-15% by tannins. Tannins act as a plant defense against consumption by birds, and also provide some resistance to mold. In livestock production, tannins reduce the availability of key nutrients such as protein, energy, vitamins and minerals. Tannins are associated with the outer layers of the pericarp and testa of the sorghum kernel. White sorghum varieties without a pigmented testa are free of tannins. Red, brown, or black varieties may contain significant amounts of tannins, but only if they have a pigmented testa. The old varieties of sorghum grain contained relatively high amount of an anti-nutritional compound called tannin (Hancock, 2000; Ravindran *et al*., 2005; Sell *et al*., 2010).

Tannins are found in many different families of the higher plants and their content may be high in many foods of vegetable origin, including cereals, legumes, fruits, nuts and beverages, such as tea, wine and cocoa. As a consequence, they are an integral part of daily diet. Tannins have different biological effects in human and animal nutrition because of their ability to chelate metal ions, form complexes with macromolecules and to act as antioxidants. They are able to form complexes with numerous types of molecules, including proteins, carbohydrates and enzymes involved in their digestion, polysaccharides and bacterial cell membranes; besides substances present in foods, tannins can bind endogenous proteins, such as digestive enzymes, inhibiting their activities. As a consequence, tannins reduce the digestibility of proteins, with a subsequent increase in fecal nitrogen excretion, affect the glycaemic and insulinemic responses and increase the fecal fat excretion. Tannins also affect the absorption of trace minerals by forming insoluble complexes in the gastrointestinal tract. Minerals chelated by tannins are not bioavailable for the organism, thus a diet based on consumption of large quantities of tannin-rich food, such as sorghum, is associated with minerals deficiency diseases, such as iron-deficiency anemia (Mamiro *et al.,* 2005).

2.6. Treatment and Processing of Sorghum to Enhance its Nutritional Value

Early Sorghum processing methods consisted essentially of chemical and mechanical detoxification. However, during the last two decades processing sorghum grain by grinding, crumbling, pelleting, expanding, extruding, and steam flaking has become popular.

2.6.1. Grinding and hydro-thermal processing

Grinding grains before mixing into diets is thought to improve feed homogeneity, increase surface area for enzymatic degradation, and reduces selective feeding/sorting. In the U.S. broiler industry, cereal grains are usually ground through a hammer mill equipped with screens having openings of 4 to 5 mm (Behnke, 2009).

Pelleted diets improved weight gain and feed efficiency in broilers by 13 and 7%, respectively, compared to a mash diet. Fed broilers mash and crumbled sorghum-based diets pelleted or expanded at 85 ºC (Cramer *et al*. 2003). Growth performance is similar for birds fed mash or crumbles. Starch gelatinization usually does not exceed 200 g/kg following steam conditioning and pelleting (Bryden *et al*., 2009). The temperature at which sorghum starch gelatinizes (68 to 78ºC) exceeds that of corn (62 to 72ºC) and wheat (58 to 64ºC), implying that sorghum-based diets require a greater temperature during pelleting. However, pelleting sorghum-based diets at higher temperatures (82 to 90ºC) may induce the honey comb protein matrix to collapse. This collapse inhibits starch expansion, denies amylases access to their substrates, and reduces starch digestibility in cooked sorghum meal .Thus, there is little consensus about the need to pellet sorghum-based diets to maximize nutrient utilization and growth performance in poultry (Ezeogou *et al*., 2008).

Whole sorghum added to pelleted rations for broilers as Rogers *et al.*(2009)found that when compared to pellets made with ground sorghum, the birds fed pelleted rations with whole sorghum particles performed equally well. Another group has also presented work that indicates the whole sorghum can be added to poultry rations without negatively affecting growth. Biggs and Parsons (2009) fed rations with 10 and 20% whole sorghum and the birds at three weeks performed as well as those fed ground sorghum. The research work generally indicated that feeding whole grain as a portion of the diet would increase ME and amino acid availability. However, the birds did tend to select the whole particles that could affect growth rate (Rodgers *et al*., 2009).

2.6.2. Methods of detoxifying tannins

In order to inactivate or reduce anti-nutrients in non-conventional feeds, have some simple processing methods (Babour *et al*., 2001; Farran *et al*., 2001). These strategies are broadly classified as physical and chemical methods.

2.6.2.1. Physical methods

Cooking*:* effectiveness of cooking inactivates the activities of tannins. Cooking and soaking methods have used and the stability of anti-nutritional factors could be reduced by up to 15% when cooked for 45 min (Bressani, 2002). Cooking is to reduce the anti-nutritional factors and thereby enhance the nutritional value of root and tuber crops (Agwunobi *et al*., 2002; Akpan and Umoh, 2004). Tannin content 71.91% is destroyed after 30 minutes of cooking. In addition, most of the anti-nutritional factors in legume seeds destroyed after cooking the seeds for a minimum of 30 min (Balogun *et al*., 2001). The anti-nutritional properties in sickle pod (*Cassia tora*) seed were reduced and safe for inclusion in livestock rations for optimum growth and development when the seeds cooked for 45 minutes (Buba *et al*., 2010). No adverse effect in terms of performance of broiler chickens fed cooked diet. However, cooking in water for 60 min at 100°C may denature protein making it unavailable and may induce loss of vitamins and minerals in legumes (Uchegbu *et al*., 2008).

Soaking*:* Soaking as processing method to reduce tannin in non-conventional legume and cereal grains; 24hrs soaking duration produced better results and would be preferred for tannin and cyanide in feed ingredients. However, some metabolic reactions take place during soaking which will affect some of the constituents' compounds (Ahamefule and Odemelam 2008).

Germination (Sprouting*):* Germination has been documented to be an effective treatment to remove or reduce anti-nutritional factors in feedstuffs. Sprouting initiates three main types of chemical changes in the seed as follows; I) the breakdown of certain materials, ii) transport of minerals from one part of the seed to another, especially from the endosperm to the embryo or from the cotyledons to the growing parts; and, iii) the synthesis of new materials from the breakdown product. Depending on variety, total phenolic compounds in sorghum grain decreased upon germination. Condensed tannin located in the pericarp and testa, after germination (Torki and Farahmand-Pour, 2007) concluded that germinated sorghum grain could be better alternative for maize than intact sorghum grain.

Dehulling: It has also shown that the effect of tannins can eliminated or neutralized by dehulling. It improved protein quality of *Phaseolus vulgaris* and suggested that this could be due to the removal of the seed coat tannin which may have caused decrease in protein digestibility (Bressani, 2002).

Autoclaving*:* Autoclaving is a more sophisticated, but effective method of processing seeds for eliminating anti-nutrient (Abeke and Otu, 2008). However, autoclaving is expensive because it requires adequate supply of electricity and technical knowledge. Autoclaving of jack bean was satisfactory technique for ensuring survival of birds. They however, stated that there was little nutritional advantage in autoclaving of this product for more than half an hour (Kessler *et al.*, 1990).

Toasting/roasting*:* Toasting involves dry heat treatment of legume bean seeds and other seeds for incorporation in poultry diets. Sometimes, some quantity of water is sprayed on the seed before they are toasted. Toasting has reported to be effectively reducing the anti-nutritional factors of raw soybean, which are associated with growth retardation in chickens (Akpodiete *et al*., 2001). Omoikhoje *et al.* (2009) reported that inclusion of roasted fluted pumpkin pod and husk waste was increased broiler chicken performance and did not affect palatability of the diets (El-Boushy and Vandal Poel, 2001). A major problem of toasting may be that of charring of the seed if not property stirred (Abeke and Out, 2008).

2.6.2.2. Chemical methods

Use of wood ash*:* Wood ash, an alkaline substance used by local people of southwestern Uganda to reduce tannins in red, bird resistant sorghum that is cultivated in that region. The effectiveness of the alkali treatment depends on the types and concentration of the alkali and the prevailing conditions. Soaking of high-tannin sorghum in wood ash extract was effective in reducing tannin level without lowering the nutrient content of the grain (Kyarisiima *et al*., 2004).

Addition of tallow (fat): The mean Apparent Metabolizable Energy (AME) values of low-and high-tannin sorghums were 13.4 and 11.9 mg/kg, respectively and observed that the nutritional value of high-tannin sorghums improved if its AME value increased by the addition of animal fat.

Use of enzymes*:* There is a report on the effectiveness of enzymes to enhance nutrient digestibility (Choct, 2006) when sorghum added in the poultry ration. Phytase improves phosphorus utilization in poultry (Oyango *et al*., 2005; Ravindran *et al*., 2006). Supplementation of feeds for broiler chickens with phytase has improved growth and bone mineralization and decrease mortality. However, Torki and Farahmand-Pour (2007) observed no significant effect of enzyme supplementation on performance of broiler chickens fed sorghum based diets.

Urea treatment*:* Feeding with jack bean meal containing tannins treated with urea solution involving young broiler chicks demonstrated that jack beans so processed could be tolerated by broiler chicks up to 25% inclusion level in the diet without adverse effects on performance (Akinmutimi *et al*., 2000).

2.6.2.3. Enzymes for sorghum based diets

Most cereal grains and poultry benefit to some extent by the addition of enzymes that either increase nutrient availability or decrease the impact of anti-nutritional factors. The use of glucanase enzymes is to mitigate the negative effect of viscosity in wheat and barley. Sorghum, with possible anti nutritional factors and difficult to digest protein layers would seem a good candidate for enzymes to improve feeding values. Adding enzymes to the diet of poultry depends on many factors, including the type and amount of cereal in the diet; the level of anti-nutritive factor in the cereal, which can vary within a given cereal; the spectrum and concentration of enzymes used; the type of bird and their age (young bird tend to respond better to enzymes than older birds) (Lobo, 2000).

2.7. Sorghum Production and Productivity in Ethiopia

The presence of wild and cultivated sorghums in Ethiopia reveals that Ethiopia is the primary center of origin and center of diversity (Mekibeb, 2009). The diversity of sorghum, studying genetic diversity and biochemical composition of sorghum germplasm from Ethiopia is very important for several reasons (Ayana, 2001). The low productivity of sorghum in the developing countries can be attributed to biophysical, socio-economic and policy related factors affecting directly and indirectly sorghum production.

In sub-Saharan Africa, agricultural production is dominated by cereal-based systems. Ethiopia is the third largest sorghum producer in Africa after Nigeria and Sudan (FAO, 2017). In Ethiopia, sorghum is the third most important crop in area of production after tef and maize, and third in volume of production following maize and *teff* (CSA 2017). It is the third most important cereal crop after maize and rice in sub-Saharan Africa (Girma *et al*, 2018).

The growth and yield of sorghum, one of the major crops in these dry land regions of Africa, is often limited by drought. In the dry land environments, drought is not only the result of limited annual rainfall, but is also due to the rainfall characteristics, mainly the delay in the onset and early cessation of the main rainfall. The authors (Girma *et al.*, 2018) reported that the potential of sorghum production affected by abiotic and biotic factors and socio-economic constraints. Diseases, insect pests and weeds are key biotic impediments to yield and quality losses in sorghum production.

In Ethiopia, the sorghum varieties that have officially promoted and sourced from other countries, or locally bred using externally sourced genetic resources and landraces (Girma *et al.*, 2018). Ethiopia has a diverse wealth of sorghum germplasm adapted to a range of altitudes and rainfall conditions. From the five morphological races of sorghum (bicolor, guinea, caudatum, durra and kafir), all, except kafir, are all grown in Ethiopia. Important traits reported from the Ethiopian sorghum include cold tolerance, drought resistance, resistance to sorghum shoot fly, disease and pest resistance, grain quality and resistance to grain mould, high sugar content in the stalks, and high lysine and protein content. Ethiopian often regarded as the centre of domestication of sorghum because of the greatest genetic diversity in the country for both cultivated and wild forms (Fetene, 2011).

3. MATERIALS AND METHODS

3.1. Study Area

The experiment was conducted at Debre Zeit Agricultural Research Center (DZARC), located 47 km South East of Addis Ababa at an altitude of 1900 meters above sea level and at $8^{o}44'$ N latitude and 38^{o}, 38'E longitude. The average annual rainfall and average minimum and maximum temperatures for the area are 1100 mm, and $8.9^{o}C$ and $28.3^{o}C$, respectively (DZARC, 2003).

3.2. Experimental Rations and Treatments

Feed ingredients used in the formulation of the experimental rations for the study were white maize, wheat middling, nougseedcake, soybean meal (SBM), the two sorghum varieties*melekam* (SVM) and*degalit* yellow (SVD), meat and bone meal, vitamin mineral premix, salt, limestone, lysine and methionine. Representative samples of feed ingredients used for the experimental ration were taken and analyzed for proximate compositions (Table 1). The two sorghum varieties*melkam* and *degalit* yellowweresourced from Melkassa Agricultural Research Center (MARC). White maize, nougseed cake and soybean meal (SBM) were milled in sieve size of 5 mm and stored until required for the formulation of experimental rations.

Based on the chemical analysis result, 7 treatment rations (i.e., T_1= diet formulated without sorghum; T_2=diet containing 20%SVM; T_3=diet containing 30%SVM; and T_4=diet containing 40%SVM, and T_5=diet containing 20%SVD; T_6=diet containing 30%SVD; and T_7=diet containing 40%SVD) were formulated to achieve the nutrient requirements of layer chicken. Treatment rations were formulated to be nearly isocaloric and isonitrogenous (Table 1), to meet the minimum ME of 2,750 kcal/kg DM and 16% of CP requirement of laying hens (NRC, 1994).

Table 1: Proportion (%) of ingredients used for formulating layer experimental diets

Ingredients (%)	**Treatments**						
	T_1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	**T_7**
White Maize	59.65	45.00	34.11	28.00	45.00	36.00	28.00
Wheat Middling	9.00	4.00	7.00	2.40	4.00	4.00	3.00
Soybean Meal	18.00	17.00	15.00	15.50	16.00	15.00	13.40
Nougseed Cake	3.00	3.00	3.00	3.00	4.00	4.00	5.00
Meat and Bone Meal	0.50	1.00	1.00	1.00	1.00	1.00	0.60
SVM	0.00	20.00	30.00	40.00	0.00	0.00	0.00
SVD	0.00	0.00	0.00	0.00	20.00	30.00	40.00
Salt	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Limestone	8.50	8.65	8.50	8.70	8.60	8.60	8.60
Vitamin-mineral premix	0.50	0.50	0.50	0.50	0.50	0.50	0.50
DL-Lysine	0.30	0.31	0.35	0.35	0.35	0.36	0.35
DL-Methionine	0.15	0.14	0.14	0.15	0.15	0.15	0.15
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

SVD= sorghum variety degalit yellow; SVM= sorghum variety melkam; T_1=diet formulated without sorghum (control diet); T_2= diet formulated with 20% SVM; T_3= diet formulated with 30% SVM; T_4= diet formulated with 40% SVM and T_5= diet formulated with 20% SVD; T_6= diet formulated with 30% SVD; T_7= diet formulated with 40% SVD.

3.3. Management of Experimental Birds

A total of 210 twenty two weeks old Bovan's Brown layer hens with initial BW (mean±SD) of 1.59±0.04 kg were equally divided into the seven dietary treatments with three replications each with 10 hens. A complete randomized designs (CRD) used in a 2*3+1 factorial arrangement (two sorghum varieties (SVM, SVD), their three levels each and the control diet) as described below (Table 2). A wire-mesh-partitioned deep litter floor house covered with disinfected *teff* straw litter material used. Before the beginning of the actual experiment, the experimental pens, watering and feeding troughs, and laying nests carefully cleaned, disinfected, and sprayed against external parasites. The birds sourced from Alema Koudjis P.L.C., thirty hens used in each dietary treatment that were further divide into 3 groups of 10 hens. Ten (10) birds randomly assigned to one of the 21 pens and vaccinated against Newcastle diseases the other vaccine were vaccinated before 22 weeks. Other health precautions and sanitary measures were also taking throughout the study period. The bird offered the experimental ration at 125gper day throughout the experimental periods.Therecommended layersoffering range was 120 – 150g (Olomu, 1995).Clean water was available at all the times. Diet offered in a round feeder and water in a plastic fountain. Fluorescent lamps placed for the lighting system and birds were adapted to respective treatment diets for a week before the commencement of the actual data collection.

Table 2 : Layout of the experimental design

Treatments		**Level of sorghum Varieties**	**No. of hens/ Replication**			**Total number of hens in each treatment**
			R1	R2	R3	
Control group	T 1	0%	10	10	10	30
	T 2	20%	10	10	10	30
SVM	T 3	30%	10	10	10	30
	T 4	40%	10	10	10	30
	T 5	20%	10	10	10	30
SVD	T 6	30%	10	10	10	30
	T 7	40%	10	10	10	30
Total			70	70	70	**210**

SVD: sorghum variety degalit yellow; SVM: sorghum variety melkam; T_1: control diet formulated without sorghum varieties, T_2: diet formulated with 20% SVM inclusion, T_3: diet formulated with 30% SVM inclusion, T_4: diet formulated with 40% SVM inclusion, T_5: diet formulated with 20% SVD inclusion, T_6: diet formulated with 30% SVD inclusion, T_7: diet formulated with 40% SVD inclusion; Rep.: replication; R_1, R_2 and R_3: replication 1,2 and 3.

3.4. Measurements

The experimental period was conducted after one week adaptation period from 22 to 32 weeks of age of the Bovan's Brown hens. The amount of feed offered and refused per pen was recorded daily.

3.4.1. Bodyweight

Hens were weighed at the start and end of the experiment andBW change was calculated as the difference between the final and initial BW.BWC = Final live weight (kg) -Initial live weight (kg).

3.4.2. Feed intake

The amount of feed consumed was determined as the difference between the feed offered and refused. Feed offered and refused were sampled daily per pen and combined per treatment for the entire experimental period for chemical analysis.

3.4.3. Egg production,egg mass and egg weight

Eggs were collected three times a day from each pen at local time 2:00 AM, 7:00AM and 11:00 AM. The sum of the 3 collections along with the number of birds alive on each day were recorded and summarized at the end of the period. Eggs collected daily were weighed immediately after collection for each pen and average egg weight was computed by dividing the total egg weight to the number of eggs. Egg mass per hen was calculated as total egg mass divided by number of hens. Hen-day egg production (HDEP) and hen-housed egg production (HHEP) as a percentage were determined following the formula given below (Hunton, 1995).

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

$$\%\text{ HHEP (Hen-housed egg production)} = \frac{\text{Sum of daily egg counts}}{\text{Number of hens originally housed}} \times 100$$

3.4.4. Feed conversion ratio

Feed conversion ratio to estimate the efficiency of birds that fed the treatment diet and the control calculated as:

$$\text{FCR} = \frac{\text{Kg of feed consumed}}{\text{Total egg production}}$$

3.4.5. Egg quality

For the measurement of egg quality, six eggs per replicate randomly taken at the middle and end of the experimental period from the freshly laid eggs. The external egg quality parameters were assessed in terms of egg weight and egg shape index. Internal egg quality also assessed after breaking and separating each of the components in terms of shell weight, shell thickness, yolk weight and color, albumen weight and heights and Haugh Unit. Eggs were broken, near to the sharpen end, carefully drop the contents to avoid mixing of yolk and albumen, on a flat glass and measured the parameters. The shell, albumen, and yolk were carefully separated and were weighed individually using a sensitive balance of 0.01 g of precision. Shell thickness, taken by removing the internal membrane and the thickness, measured by taking the average of the blunt, middle, and sharp points of the egg using a digital caliper (Aberra, 2010). Height of the thick albumen of each egg measured with the micrometer andthe Haugh Unit calculated using the formula (Haugh, 1937):

$100 \log_{10} (h + 7.57 - 1.7W^{0.37})$,

Where, h = observed albumen height (mm) and W = weight of egg (g).

The Haugh unit is mainly influenced by the albumen height and egg weight (Aberra, 2019).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 also computed using the following formula used to determine egg shape index:

$$\text{Egg shape index} = \frac{\text{Width of egg}}{\text{Length of egg}} \times 100$$

The length and width of the egg measured by using digital caliper and the egg shape index computed (Panda, 1996).

3.5. Laboratory Analysis

Representative samples of feed ingredients and treatment diets were analyzed for DM, CF, total ash, EE and Kjeldahl nitrogen (N) and the CP content was determined as N x 6.25 (AOAC, 1990).

The chemical analysis was conducted at DZARC animal nutrition laboratory. Metabolize Energy (ME) of the experimental diets was estimated as follows: ME (Kcal/kg DM) = 3951+ 54.4 (EE) 88.7 (CF) - 40.8 (Ash)(Wiseman, 1987)

3.6. Partial Budget Analysis

To estimate the profitability of feeding different levels and varieties of sorghum, the partial budget was calculated as the difference between the feed costs incurred during the experimental period per bird for the eggs and birds sales following the procedures of Miles and Jacob (2000). The net income (NI) was calculated by subtracting total cost (TC) from the total return (TR).NI = TR−TC

TC=FC/bird = (TFI X cost/100Kg)/100, Where, TFI= Total feed intake and FC = feed cost

The marginal rate of return (MRR) which measures the increase in net income (ΔNI (NI from diets with the test feed (different levels and varieties of sorghum) minus NI from control diets)) associated with each additional unitof expenditure (ΔTC (TC from diets with the test feed minus TC from control diets)) was computed as:

MRR = ΔNI/ΔTC (Miles and Jacob, 2000).

3.7. Statistical Analysis

Data were analyzed by employing GLM ANOVA procedure using Statistical Analysis System (SAS, 2008) version 9.1.3 computer software program Subjected to analyze by one and two - way ANOVA so as to explain main effect and interaction term. Individual treatments were separated by Tukey's l.s.d.

The model for the data analysis was: $Y_i = \mu + T_i + +E_{ij}$.

Where: Y_i is the response variable,

μ is the overall mean,

T_i is the treatment effect

E_{ij} is error associated with the experiment

4. RESULTS

4.1. Chemical Composition of Experimental Feed ingredients

The chemical compositions of the two sorghum varieties are presented below in table 3. Most of the nutrient values of the two sorghum varieties are comparable with each other. However, slightly the CP for SVD (13.4%) is higher than SVM (12.8%). The metabolisable energy of the two sorghum varieties showed that, they were also comparable with the metabolisable energy of maize.

Table 3: Proximate analysis of the samples feed ingredients

Ingredients	Nutrients (%)							
	DM (%)	(%)CP	(%)CF	(%)EE	(%)Ash	(%)Ca.	(%)P	ME (kcal/kg DM)
White maize	89.3	8.4	2.3	4.4	2.6	0.04	0.3	3258
SVM	90.21	12.8	3.36	3.64	1.42	0.04	0.32	3793
SVD	90.78	13.4	3.92	3.52	1.44	0.04	0.32	3736
Nougseed cake	87.6	34.6	17.2	7.1	6.3	0.26	0.65	2400
SBM	88.4	43.5	6.1	0.36	3.7	0.3	0.65	2180
Wheat middling	90.2	15.6	9.2	0.32	4.5	0.11	1.15	1980

DM: dry matter; ME: Metabolizable energy; CP= crude protein; CF=crude fiber; EE= ether extract; Ca= calcium; P= phosphorus; SBM: soybean meal; SVD: sorghum variety degalit yellow; SVM: sorghum variety melkam. ME (kcal/kg DM)= 3951+54.4EE-88.7CF-40.8Ash; NFE= 100-(Moisture + CP + EE + CF + Ash)

The %CP and ME (Kcal/kg DM) content of the experimental diets were slightly closer to the recommended range. The recommended range of %CP and ME is 16-17% and 2800 – 2900 Kcal/kg DM, respectively for layers (NRC, 1994).

Table 4 The proximate analysis of the treatment diets

Treatments	Nutrients								
	DM (%)	CP %	CF %	EE %	Ash %	NFE	Ca (%)	P (%)	ME (Kcal/kg DM)
T1	92.03	15.62	10.3	3.59	11.55	50.97	3.43	0.47	2761.45
T2	92.91	15.978	9.2	3.337	13	51.395	3.5312	0.452	2786.09
T3	92.02	15.941	9.233	3.186	11.93	51.73	3.471	0.47	2818.61
T4	93.1	16.2139	8.6	3.021	13.05	52.215	3.545	0.4369	2820.08
T5	93.14	16.015	8.63	3.388	13.5	51.607	3.5118	0.452	2819.03
T6	96.36	16.164	9.54	3.232	10.32	57.104	3.5092	0.4505	2859.57
T7	96.38	16.126	7.65	3.087	14.1	55.417	3.4647	0.422	2865.1

T_1=diet formulated without sorghum (control diet); T_2= diet formulated with 20% SVM; T_3= diet formulated with 30% SVM; T_4= diet formulated with 40% SVM and T_5= diet formulated with 20% SVD; T_6= diet formulated with 30% SVD; T_7= diet formulated with 40% SVD. DM: dry matter; NFE = nitrogen free extract; ME: Metabolizable energy; CP= crude protein; CF=crude fiber; EE= ether extract; Ca= calcium; P= phosphorus; SBM: soybean meal; SVD: sorghum variety degalit yellow; SVM: sorghum variety melkam. ME (kcal/kg DM) = 3951+54.4EE-88.7CF-40.8Ash; NFE= 100-(Moisture + CP + EE + CF + Ash)

4.2. Feed Intake, Body Weight Changes and Feed Conversion Ratio

The study on nutritional evaluation of the two sorghum varieties (SVD and SVM) on the performances of Bovan's Brown hens at different levels were tested on their feed intake, BWchange and feed conversion ratiois presented in table 5. The total as well asaverage feed intakes did not show a difference (P>0.05)among the treatments. There was highly significant different(P<0.05) in final BW of hens which fed on treatment diets. Hens fed on T_2, T3 and T4 were higher than T1 in final BW but not significant difference each other. Final BW was higher in hens fed on T5, T6 and T7 than T1, T2, T3 and T4. In general hens fed on T6 were shown highest FBW than the rest of the treatments. Body weight change was highly significant different (P<0.05) across the treatments. The highest and the lowest BW change were recorded on T6 and T2 respectively. Final body weight decreased when for T_5, T_7, T4, T3, T2 and T_1. The feed conversion ratio wasnot shown a difference (P>0.05) across all the treatments.

Table5: Feed intake, body weight and feed conversion ratio of Bovans Brown hens fed different levels of sorghum varieties.

Parameters	Treatments								
	T1	T2	T3	T4	T5	T6	T7	P-value	Sig
Total feed intake (kg/hen)	9.00	8.73	8.56	8.61	8.87	8.48	9.13	0.6161	NS
Average feed intake (g/hen/day)	116.95	113.39	111.16	111.77	115	110.15	118.57	0.6161	NS
Initial BW (kg/hen)	1.54	1.59	1.61	1.61	1.63	1.59	1.56	0.3596	NS
Final BW(kg/hen)	1.65^{c}	1.67^{bc}	1.70^{bc}	1.70^{bc}	1.74^{ab}	1.80^{a}	1.72^{abc}	0.0197	**
BW change (g/hen)	107.89^{cd}	76.33^{e}	89.83^{de}	92.67^{cde}	110.33^{c}	209.83^{a}	161.39^{b}	0.0001	**
Feed Conversion Ratio	1.81	1.88	1.98	1.57	1.80	1.73	1.56	0.2692	NS

*$^{a-e}$Means within a row with different superscripts differ significantly (P<0.05); BW: body weight; **= highly significant, NS: Non-significant; Sig.: significant level; SVD: sorghum variety degalit yellow; SVM: sorghum variety melkam; T_1: diet formulated without sorghum (control diet); T_2: diet formulated with 20% SVM; T_3: diet formulated with 30% SVM; T_4: diet formulated with 40% SVM and T_5: diet formulated with 20% SVD; T_6: diet formulated with 30% SVD; T_7: diet formulated with 40% SVD.*

There were no significant differences (P>0.05) in birds performance among the treatments in total as well as average feed intakes due to variety differences of sorghum that the birds fed in this study. Final BW was higher (P<0.05) for hens that fedon *degalit* yellow sorghum variety than birds fed on sorghum variety *melkam*. Hens fed on the control dietand sorghum variety *melkam*had no significance differences (P>0.05) in final BW. Hens fed on control diet, sorghum varieties *melkam* and *degalit* yellow had a significant differences (P<0.05)in BW change and birds that fed sorghum variety *degalit* yellowshowed significantly (P<0.05)higher BW change than birds that fed sorghum variety *melkam*. Hens fed on control diet and both sorghum varietieswere not shown significant difference (P>0.05) in feed conversion ratio between each other as shown in (Table 6).

Table6: Feed intake and body weight performances of Bovans Brown hens fed on different sorghum varieties.

Parameters	Sorghum Varieties				
	Control	**Melkam**	**Degallit yellow**	**P-value**	**Sig.**
Total feed intake (kg/hen)	9.00	8.63	8.82	0.4518	NS
Average feed intake (g/hen)	116.95	112.11	114.58	0.4518	NS
Initial BW(kg/hen)	1.54	1.60	1.59	0.1891	NS
Final BW(kg/hen)	1.65^{b}	1.69^{b}	1.75^{a}	0.0049	**
BW change (g/hen)	107.89^{b}	86.28^{b}	160.52^{a}	0.0002	**
Feed Conversion Ratio	1.81	1.81	1.69	0.5873	NS

$^{a\text{-}b}$*Means within a row with different superscripts differ significantly at (P<0.05); BW: body weight; NS: Non-significant; Sig.: significant level; **: highly significant*

Results on feed intake, BW changes and feed conversion ratio of Bovans Brown hens fed different levels of sorghum varieties are presented in table 7. Hens fed on 40% *degalit* yellow (SVD 40%) resulted higher in total as well as average feed intakes than other levels of sorghum varieties. But, statically there were no significance differences (P>0.05) observed between the levels.

There was significant different between all levels of sorghum varieties in final BW of hens. Highest final BW was recorded in hens fed on 30% of *degalit*yellow than other levels of the sorghum levels and the lowest finalBW was resulted in birds that fed oncontrol diet. There were no significant difference (P>0.05) within the levels of sorghum variety *melkam*.Body weight changes were higher

(P<0.05) in 30% *degallit* yellow than other levels. There were a higher significant differences (P<0.05) in terms of BW change at all levels of sorghum varieties. Significantly (P<0.05), finalBW and BW changeswere highest for hens fed on 30% *degalit yellow* than the rest of other levels. Lower BW change was recorded in birds that fed on level of 20% *melkam* treatment diets. The highest and lowest feed conversion ratio (FCR) was recorded in 40%SVD and 30%SVM respectively, than other levels. However, the feed conversion ratio was not shown a difference (P<0.05) across all levels of sorghum varieties.

Table7: Feed intake, body weight and feed conversion ratio of Bovans Brown hens fed different levels of sorghum varieties.

Parameters	**Levels of sorghum varities**								
	Control	**20% SVM**	**30% SVM**	**40% SVM**	**20% SVD**	**30% SVD**	**40% SVD**	**P-value**	**Sig**
Total feed intake (kg/hen)	9.00	8.73	8.56	8.61	8.87	8.48	9.13	0.6161	NS
Average feed intake (g/hen/day)	116.95	113.39	111.16	111.77	115	110.15	118.57	0.6161	NS
Initial BW (kg/hen)	1.54	1.59	1.61	1.61	1.63	1.59	1.56	0.3596	NS
Final BW(kg/hen)	1.65^{c}	1.67^{bc}	1.70^{bc}	1.70^{bc}	1.74^{ab}	1.80^{a}	1.72^{abc}	0.0197	**
BW change (g/hen)	107.89^{cd}	76.33^{e}	89.83^{de}	92.67^{cde}	110.33^{c}	209.83^{a}	161.39^{b}	0.0001	**
Feed Conversion Ratio	1.81	1.88	1.98	1.57	1.80	1.73	1.56	0.2692	NS

*$^{a-e}$Means within a row with different superscripts differ significantly (P<0.05); BW: body weight; NS: Non-significant; Sig.: significant level; SVD: sorghum variety degalit yellow; SVM: sorghum variety melkam. **: highly significant*

4.3. Egg Production

The current study on different sorghum varieties and levels fed to Bovan's Brown hens to test their egg production performances is presented in table 8. The study showed that highest egg production per henwas recorded on T7 and the lowest was resulted in T3. But it was no significantly different in T1, T2, T4, T5 and T6.The lowest egg mass observed in hens that fed on treatment diets of T_3 and the highest egg mass observed in hens that fed on treatment diets of T7butthere wasno significant difference (P>0.05) in egg mass (kg) of hens fed on $T_{1,}$ $T_{2,}$ $T_{4,}$ T_5 and T_6. The lowest average egg weight was produced in hens fed on T6 and highest was recorded on T2. As the study showed that, HDEP% and HHEP% were highest in T7 than other treatments.

Table 8: Egg production performance of Bovans Brown hens (22-33weeks age) fed on the test diets.

Parameters	Treatments								
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	P-value	Sig.
Egg production per hen (No.)	58^{ab}	56^{ab}	52^{b}	58^{ab}	59^{ab}	59^{ab}	66^{a}	0.0257	*
Egg mass (kg)	3.39^{ab}	3.32^{ab}	2.99^{b}	3.38^{ab}	3.42^{ab}	3.36^{ab}	3.78^{a}	0.0269	*
Average Egg weight (g)	58.42^{ab}	59.36^{a}	57.39^{ab}	57.97^{ab}	58.06^{ab}	57.07^{b}	57.42^{ab}	0.0405	*
HDEP (%)	75.36^{a}	72.68^{a}	67.71^{b}	75.72^{a}	76.49^{a}	76.45^{a}	85.43^{a}	0.0457	*
HHEP (%)	75.36^{ab}	72.68^{abc}	67.71^{bc}	64.24^{c}	76.49^{ab}	76.45^{ab}	79.18^{a}	0.0383	*

$^{a-c}$Means within a row with different superscripts differ significantly (P<0.05); Sig.: significant level; SVD=sorghum variety degalit yellow; SVM=sorghum variety melkam; T_1: diet formulated without sorghum (control diet); T_2: diet formulated with 20% SVM; T_3: diet formulated with 30% SVM; T_4: diet formulated with 40% SVM and T_5: diet formulated with 20% SVD; T_6: diet formulated with 30% SVD; T_7: diet formulated with 40% SVD; HDEP: Hen-day egg production; HHEP: Hen-housed egg production*; *significant;*

Considering effects due to sorghum varieties egg production of hens is presented in (table 9). The study showed that there was no difference in hens fed on control diet, sorghum variety *melkam* and sorghum variety *degalit* in egg production per hen. Even though there was significant difference between varieties in egg production, the hens fed on diets based on *degalit* yellow sorghum variety were produced higher number of eggs per hen than hens fed on *melkam* sorghum variety and control diet. Egg mass (kg/hen), Average egg weight (g) and HDEP (%) were not statically different between the two sorghum varieties and control diet. But hens fed on sorghum Variety *degalit* had performed higher HHEP % than sorghum Variety*melkam* and control diet.

Table 9: Egg production performance of Bovan's brown hens fed on sorghum varieties.

Parameters	**Sorghum Varieties**				
	Control	***Melkam***	***Degalit* yellow**	**P-value**	**Sig.**
Egg production per hen(No.)	58	55	61	0.1750	NS
Egg mass (kg)	3.3893	3.2303	3.5175	0.2585	NS
Average egg weight (g)	58.4118	58.2407	57.5193	0.3503	NS
HDEP (%)	75.358	72.035	79.459	0.1750	NS
HHEP (%)	75.358^{ab}	68.211^{b}	77.374^{a}	0.0101	*

$^{a-b}$*Means within a row with different superscripts differ significantly (P<0.05); *P<0.05; NS: Non-significant; Sig.: significant level; HDEP: Hen-day egg production; HHEP: Hen-housed egg production. *; significant;*

There was significant different (P<0.05) on egg production per hen in between the treatment diets that included different levels of sorghum varieties as shown on (table 10). Based on this, the highest and the lowest egg production per hen was recorded on hens fed on 40% level of *degalit* yellow and hens fed on SVM 30%, respectively. But there was no significant difference (P>0.05) in egg production per hen between hens fed on control diet, 20%SVM, 40%SVM, 20% SVD and 30% SVD. The same trend observed on bird's performances of the egg mass. The highestand the lowest egg weight were observed in hens fed on 20%SVDand30%SVD. But, statistically not different observed between hens fed on sorghum varieties levels at control, 30%SVM, 40%SVM, 20%SVD and 40% SVD. A lower HDEP % performance of birds was observed in hens fed on SVM 30%. But insignificant difference observed in hens fed on other levels of treatment diets except hens fed on 30%SVM. Numerically highest %HDEPwas observed on 40%SVD than other levels. There was significant difference observed between treatment diets included different levels of sorghum varieties in HHEP%. The highest and the lowest %HHEP was observed in hens fed on 40%SVD and 40%SVM, respectively. But there was no significant difference in %HHEP observed in hens fed on control diets, 20%SVM, 20%SVD and30%SVD.

Table10: Egg production performance of Bovans Brown hens fed on different levels of sorghum varieties.

Parameters	Treatments								
	Control	**20% SVM**	**30% SVM**	**40% SVM**	**20% SVD**	**30% SVD**	**40% SVD**	**P-value**	**Sig.**
Egg production per hen (No.)	58^{ab}	56^{ab}	52^{b}	58^{ab}	59^{ab}	59^{ab}	66^{a}	0.0257	*
Egg mass (kg)	3.39^{ab}	3.32^{ab}	2.99^{b}	3.38^{ab}	3.42^{ab}	3.36^{ab}	3.78^{a}	0.0269	*
Average Egg weight (g)	58.42^{ab}	59.36^{a}	57.39^{ab}	57.97^{ab}	58.06^{ab}	57.07^{b}	57.42^{ab}	0.0405	*
HDEP (%)	75.36^{a}	72.68^{a}	67.71^{b}	75.72^{a}	76.49^{a}	76.45^{a}	85.43^{a}	0.0457	*
HHEP (%)	75.36^{ab}	72.68^{ab}	67.71^{bc}	64.24^{c}	76.49^{ab}	76.45^{ab}	79.18^{a}	0.0383	*

*$^{a-c}$ Means within a row with different superscripts differ significantly (P<0.05); Sig.: significant level; SVD=sorghum variety degalit yellow; SVM=sorghum variety melkam; HDEP: Hen-day egg production; HHEP: Hen-housed egg production. *; significant; **: highly significant*

4.4. Egg Quality Parameters

Egg quality parameters produced from Bovan's Brown hens fed on different treatments is presented in Table 11. There was significant difference observed between treatment diets. The smallest weight of sampled egg was recordedin T6 than other treatments. But there was no significant difference between all treatments except T6. There wereno significant differences (P>0.05)observed among alltreatments in egg shape index, shell thickness, yolk weight and yolk color. There was significant difference between treatments diets in albumin height, albumin weight and HU. The higher albumin height was observed on control diet (T1), T2, T3, T4 and T5. But there was no significant difference between each other. The same trend was recorded in HU as albumin height. The highest and the lowest albumin weight were observed on T4 and T6 respectivelyand statisticalynot significant difference with birds fed on T_2, $T_{3,}$ T5 and T_7.

Table11: Effect of treatments on egg quality parameters

Parameters	**Treatments**								
	T_1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	**T_7**	**P-value**	**Sig**
Sample egg weight (g)	60.29^a	60.72^a	59.72^a	61.17^a	60.28^a	55.88^b	60.98^a	0.0506	*
Egg shape index	77.72	79.43	77.95	79.04	79.23	79.19	77.75	0.2292	NS
Shell thickness (mm)	0.40	0.40	0.40	0.41	0.41	0.41	0.39	0.7249	NS
Albumin height(mm)	11.06^a	10.67^a	10.67^a	10.78^a	10.72^a	9.17^b	8.89^b	0.0048	**
Albumin weight(gm)	34.91^{bc}	36.41^{ab}	35.49^{ab}	37.28^a	35.64^{ab}	33.10^c	36.77^{ab}	0.0065	**
Haugh Unit	89.63^a	87.21^a	87.59^a	87.77^a	87.58^a	79.04^b	75.26^b	0.0035	**
Yolk weight(gm)	14.64	14.06	14.75	14.52	14.52	14.53	14.65	0.5475	NS
Yolk color (Roche fan)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	NS

[a-c]Means within a row with different superscripts differ significantly ($P<0.05$); NS: Non-significant; Sig.: significant level; SVD=sorghum variety *degalit* yellow; SVM=sorghum variety *melkam*; T_1: diet formulated without sorghum (control diet); T_2: diet formulated with 20% SVM; T_3: diet formulated with 30% SVM; T_4: diet formulated with 40% SVM and T_5: diet formulated with 20% SVD; T_6: diet formulated with 30% SVD; T_7:diet formulated with 40% SVD. ***: highly significant*

Egg quality parameters produced from Bovan's Brown hens fed on different sorghum varieties is presented in Table 12. There was no significant difference ($P>0.05$) in weight of sampled egg, egg shape index, egg shell thickness, albumin weight, yolk weight and yolk colorfor both sorghum varieties and the control experimental diets. Albumin height was higher ($P<0.05$) in hens fed on the control diet andfed on sorghum variety *melkam*and significantly ($P<0.05$) low in birds that fed on sorghum variety *degalit*yellow. The same was observed on albumin weight also and it was higher from birds that fed sorghum variety *melkam* than the control diet and non-significantly differ from birds that fed sorghum variety *degalit* yellow. The HU value was higher ($P<0.05$) in birds that fed the control diet and sorghum variety *melkam*and lower for birds that fed onsorghum variety *degalit* yellow.

Table12: Effect of sorghum varieties on egg quality parameters

Parameters	Sorghum Varieties				
	Control	***Melkam***	***Degalit* yellow**	**P-value**	**Sig.**
Sample egg weight (g)	60.29	60.53	59.05	0.3971	NS
Egg shape index	77.72	78.81	78.72	0.3623	NS
Shell thickness (mm)	0.41	0.40	0.40	0.9465	NS
Albumen height (mm)	11.06^{a}	10.70^{a}	9.59^{b}	0.0112	*
Albumen weight(g)	34.91	36.40	35.17	0.1847	NS
Haugh Unit	89.63^{a}	87.52^{a}	80.62^{b}	0.0116	*
Yolk weight(g)	14.64	14.44	14.56	0.7202	NS
Yolk color (Roche fan)	1.00	1.00	1.00	-	NS

$^{a-b}$Means within a row with different superscripts differ significantly (P<0.05); *: P<0.05; NS: Non-significant; Sig.: significant level *; significant;*

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Egg quality parameters produced from Bovan's Brown hens fed on different levels of sorghum is presented in Table 13. In weight of sampled egg there was no significant different (p>0.05) in most of the levels except 30% of *degalit*yellow, which showed (55.88 g) the lowest weight than other treatments. There was no significant difference (P>0.05) in all levels of sorghum varieties and control diet in egg shape index and egg shell thickness. Both albumin height and HU were showedno significant difference (P>0.05) in control, 20% SVM, 30%SVM, 40%SVM and 20%SVD. In the same manner,albumin height and HU were shown no difference in between 30% SVD and 40%.SVD.Highest and lowest albumin weight wasrecorded in 40% of sorghum variety *melkam* and 30% sorghum variety*degalit* respectively than other levels sorghum varieties. But there was no significant difference in albumin weight between

20% SVM,30% SVM,20% SVD and40% SVD. Yolk weight and yolk color were no difference (P>0.05) across all levels of both sorghum varieties and in control diet.

Table13:Egg quality characteristics produced from Bovan Brown hens fed on sorghum varieties levels

Parameters	Treatments								
	Control	20% SVM	30% SVM	40% SVM	20% SVD	30% SVD	40% SVD	P-value	Sig.
Sample egg weight (g)	60.29^{a}	60.72^{a}	59.72^{a}	61.17^{a}	60.28^{a}	55.88^{b}	60.98^{a}	0.0506	*
Egg shape index	77.72	79.43	77.95	79.04	79.23	79.19	77.75	0.2292	NS
Shell thickness (mm)	0.40	0.40	0.40	0.41	0.41	0.41	0.39	0.7249	NS
Albumin height(mm)	11.06^{a}	10.67^{a}	10.67^{a}	10.78^{a}	10.72^{a}	9.17^{b}	8.89^{b}	0.0048	**
Albumin weight(gm)	34.91^{bc}	36.41^{ab}	35.49^{ab}	37.28^{a}	35.64^{ab}	33.10^{c}	36.77^{ab}	0.0065	**
Haugh Unit	89.63^{a}	87.21^{a}	87.59^{a}	87.77^{a}	87.58^{a}	79.04^{b}	75.26^{b}	0.0035	**
Yolk weight(gm)	14.64	14.06	14.75	14.52	14.52	14.53	14.65	0.5475	NS
Yolk color (Roche fan)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	NS

$^{a-b}$Means within a row with different superscripts differ significantly (P<0.05); NS: Non-significant; Sig.: significant level; SVD: sorghum variety degalit yellow; SVM: sorghum variety melkam.; significant; **: highly significant*

4.5. Partial Budget Analysis

The partial budget analysis is presented in Table 14, 15 and 16 as effects of treatment, levels and varieties of experimental diet on experimental hens.

The partial budget analyses of Bovan's Brown hens fed on treatment diets are presented in Table 14. It indicated that the highest feed cost per hen was recorded on T4 (158 birr) as compared to the other treatments. The highest total income (376.02birr/treatment) was obtained from hens fed on T7 higher as compared to other treatments. However there was no significant different (P>0.05) in net income (NI) per hens between treatments. The highest and lowest feed cost per each production of egg was recorded on T3(2.9 birr) and T1 (2.2 birr), respectively.

Table 14: The Partial budget analysis for Bovan's brown layer hens fed on treatment diets.

Parameters	Treatments							
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**Sig. level**
Feed cost (birr/hen)	127^{f}	142^{e}	150^{c}	158^{a}	143^{d}	150^{c}	157^{b}	**
Hen sale (birr/kg)	80	80	80	80	80	80	80	NS
Egg produced (No./hen)	58^{ab}	56^{ab}	52^{b}	58^{ab}	59^{ab}	59^{ab}	66^{a}	*
Egg price (birr/Pc)	4.5	4.5	4.5	4.5	4.5	4.5	4.5	NS
Total Income (TI) (birr/bird)	341.12^{ab}	331.85^{ab}	314.60^{b}	342.35^{ab}	345.05^{ab}	345.00^{ab}	376.02^{a}	*
Net Income (NI) (birr/bird)	214.12	189.85	164.60	184.35	202.05	194.9	219.02	NS
Δ Feed Cost (ΔFC) (birr/bird)	-	15	23	31	16	23	30	*
Δ Total Income (ΔTI) (birr/bird)	-	-9.27	-26.52	1.23	3.93	3.88	34.9	*
Δ Net Income (ΔNI) (birr/bird)	-	-24.27	-49.52	-29.77	-12.07	-19.22	4.88	*
MRR (Δ NI/ ΔFC)	-	-1.62	-2.15	-0.96	-0.75	-0.84	0.16	*
Feed cost per Egg production(birr/egg)	2.2^{b}	2.6^{ab}	2.9^{a}	2.8^{a}	2.43^{ab}	2.6^{ab}	2.4^{ab}	*

**; significant; **: highly significant; MRR: marginal rate of return; SVD=sorghum variety degalit yellow; SVM=sorghum variety melkam; T_1: diet formulated without sorghum (control diet); T_2: diet formulated with 20% SVM; T_3: diet formulated with 30% SVM; T_4: diet formulated with 40% SVM and T_5: diet formulated with 20% SVD; T_6: diet formulated with 30% SVD; T_7: diet formulated with 40% SVD*

The partial budget analyses of Bovan's Brown hens fed on sorghum varieties are presented in table 15. The study showed that, there was significant difference (P<0.05) in feed cost (birr/hen) in between control diet and sorghum varieties. However, feed cost (birr/hen) was not significantly different (P>0.05) within both sorghum varieties. The study showed that, both total income(TI) and net income (NI) were not significantly different (P>0.05) between control diet and both sorghum varieties (SVM and SVD). However, the highest feed cost per each production of egg (birr/egg) was recorded on sorghum Variety *melkam*(2.75) as compared to sorghum Variety *Degalit* (2.46 birr) and control diet(2.2). Even though the study showed no significant difference (P>0.05) in total income (TI) and net income(NI) between varieties, hen fed on sorghum Variety *Degalit*had shown better total income(TI) and net income (NI) (355.33 birr and 205.33 birr) than sorghum Variety *melkam* (329.60 birr and 179.60 birr) and on control diet (341.12 birr and 214.12 birr) respectively.

Table15: The Partial budget analysis for Bovans' brown layer hens fed on sorghum varieties (SVM and SVD).

Parameters	Varieties of Sorghum			
	Control	***Melkam***	***Degalit* yellow**	**Sig. level**
Feed cost (birr/hen/)	127^{b}	150^{a}	150^{a}	*
Hen sale (birr/kg)	80	80	80	NS
Egg produced (No./hen)	58	55	61	NS
Egg price (birr/Pc)	4.5	4.5	4.5	NS
Total Income (TI) (birr/bird)	341.12	329.60	355.33	NS
Net Income (NI) (birr/bird)	214.12	179.60	205.33	NS
Δ Feed Cost (ΔFC) (birr/bird)	-	23	23	NS
Δ Total Income (ΔTI) (birr/bird)	-	-11.52	14.21	*
Δ Net Income (ΔNI) (birr/bird)	-	-34.52	-8.79	*
MRR (Δ NI/ ΔFC)	-	-1.5	-0.38	NS
Feed cost per Egg production(birr/egg)	2.2^{b}	2.75^{a}	2.46^{ab}	*

**: P<0.05; $^{a-c}$ Means within a row with different superscripts differ significantly (P<0.05); NS: Non-significant; Sig.: significant level; Av. FBW: average final body weight; MRR: marginal rate of return;SVM: sorghum Varity melkam; SVD: sorghum Varity Degality.*

The partial budget analyses of Bovan's Brown hens fed on different levels sorghum varieties is presented in Table 16. It indicated that the highest feed cost per hen was recorded on 40%SVM (158 birr) as compared to the other levels. There was significant difference (P< 0.05) in between treatments and the highest total income (376.02 birr/treatment) was obtained from hen fed on 40%SVD as compared to other levels of sorghum varieties. However there was no significant different (P>0.05) in net income (NI) per hens between different levels of sorghum varieties. The highest and lowest feed cost per each production of egg was recorded on 30%SVM (2.9 birr) and control diet (2.2 birr), respectively.

Table16: The Partial budget analysis for Bovans' brown layer hens fed on different levels of sorghum varities.

Parameters	**Levels of Sorghum Varieties**							
	Control	**20% SVM**	**30% SVM**	**40% SVM**	**20% SVD**	**30% SVD**	**40% SVD**	**Sig. level**
Feed cost (birr/hen)	127^{f}	142^{e}	150^{c}	158^{a}	143^{d}	150^{c}	157^{b}	**
Hen sale (birr/kg)	80	80	80	80	80	80	80	NS
Egg produced (No./hen)	58^{ab}	56^{ab}	52^{b}	58^{ab}	59^{ab}	59^{ab}	66^{a}	*
Egg price (birr/Pc)	4.5	4.5	4.5	4.5	4.5	4.5	4.5	NS
Total Income (TI) (birr/bird)	341.12^{ab}	331.85^{ab}	314.60^{b}	342.35^{ab}	345.05^{ab}	345.00^{ab}	376.02^{a}	*
Net Income (NI) (birr/bird)	214.12	189.85	164.60	184.35	202.05	194.9	219.02	NS
Δ Feed Cost (ΔFC) (birr/bird)	-	15	23	31	16	23	30	*
Δ Total Income (ΔTI) (birr/bird)	-	-9.27	-26.52	1.23	3.93	3.88	34.9	*
Δ Net Income (ΔNI) (birr/bird)	-	-24.27	-49.52	-29.77	-12.07	-19.22	4.88	*
MRR (Δ NI/ ΔFC)	-	-1.62	-2.15	-0.96	-0.75	-0.84	0.16	*
Feed cost per Egg production(birr/egg)	2.2^{b}	2.6^{ab}	2.9^{a}	2.8^{a}	2.43^{ab}	2.6^{ab}	2.4^{ab}	*

MRR: marginal rate of return; SVD=sorghum variety degalit yellow; SVM=sorghum variety melkam.

5. DISCUSSION

5.1. *Chemical Composition of Experimental Feed ingredients*

According to the current result of the proximate analysis, the two sorghum varieties also (SVD; CP=13.4, CF=3.92, ash=1.44; and SVM; CP=12.8, CF= 3.36, ash= 1.42) had higher values than the finding of Tamburawa *et al.* (2012) in CP (10.4%) and EE (3.4%) but lower in ash (3.8%) value. However, the tested sorghum varieties (SVD and SVM) were comparable with the finding of Mohammed *et al* (2013) who reported %CP=. 13.03, % CF = 3.59, ash =1.52. According to the result SVM (3793 $Kcal^{-1}$ kg and 12.8 %CP) and SVD (3736 $Kcal^{-1}$ kg and 13.4 %CP) were in line with Nyamambi *et al.* (2007) who reported that the metabolisable energy and percentage crude protein content of sorghum are 3270 kcal /kg and 9.5%, respectively.

The energy and protein content of SVM and SVD used in the present study is 3793 $Kcal^{-1}$ kg DM , 12.8 %CP and 3736 $Kcal^{-1}$ kg DM , 13.4 %CP Kcal/kg DM, respectively which is comparable with 3800.1 Kcal/kg DM ME and 11.6% CP that reported by Medegu *et al*.(2010). Douglas *et al.*(1990) reported ME of 3838 and 3200 kcal/kg for low and high-tannin sorghum, respectively. Both energy and protein content of the two sorghum varietieswere slightly higher than maize (3319 kcal/kg metabolisable energy and 10.1% crude protein content of maize), which indicate that the two sorghum varieties to be good feed ingredient to replace maize in poultry ration. The CF of the two sorghum varieties used in the present study was 3.36 and 3.92 which was consistence with Eekeren *et al.*(2006) and Zena (2011), respectively. Jacob *et al*. (1996) also reported crude fiber contents of serana sorghum (2.7%) and white sorghum (3.4).

5.2. Feed Intake, Body Weight Changes and Feed Conversion Ratio

Feeding value of both sorghum varieties (SVM and SVD) in Bovan Brown layer chickens at different levels each (20%, 30% and 40%) not showed a significant effect on their total as well as average daily feed intake across treatment diets, level of sorghum varieties and type of sorghum varieties. This was similar with the finding of Adamu *et a*l. (2017) who noted that replacement of 0%, 25%, 50%, 75% and 100% red sorghum varietyto the Isa Brown layers diet not showed a significant difference these parameters. This also agree with the finding of Freitas *et al.* (2014) who reported that replacement of corn with sorghum in the diets of Japanese quails showed no significant effect on feed intake. However, the average daily feed intake of hens varied from 110.15 to 118.57g in treatment diets and level of sorghum varieties. It also varied from 112.11g – 114.58g in terms of sorghum varieties. The daily feed intake of hens in this study was not agreed with the finding of Adamu *et a*l. (2017) and lower than the range of 120 – 150g recommended for layers (Olomu, 1995). Final BW and BW change in the current study showed significance effect on hens fed on treatment diets and different level of sorghum varieties. Regarding varieties, Final BW and BW change was shown significant effect on hens. The study showed that, highest final BW (1.8kg) and BW change (209.83g.) recorded in hens fed on T_6(30% of SVD). This showed that, highest BW change (209.83g) obtained than from the report of (140.43 g) by Edache *et al.* (2005). The results on FCR in the present study was agreed with the findings of Freitas *et al.* (2014) who reported non-significant differences in feed intake, egg production, FCR on Japanese quails in an experiment to replaced corn with sorghum.

5.3. Egg Production

Egg production parameters (egg production per hen, egg mass, HDEP and HHEP) were significantly different for hens fed in all treatment diets and in between different levels of both sorghum whereas egg production per hen, egg mass and the percentage (HDEP) did not significantly different across both varieties of sorghum. Those egg production per hen in number (55 and 61), egg mass (3.2303 kg-3.5175 kg) and HDEP% (72.035 and 79.459) for SVM and SVD, respectively and did not significantly different in both varieties. The result on HDEP% in the present study was higher than from the finding of Adamu *et a*l. (2017) that showed the values varied from 59.80 - 70.25%. From the present study, HDEP% (72.035% and 79.459%) was also higher compared to the finding of Issa *et al*. (2007) reported a 57% egg production for layers fed sorghum and 47% for birds fed a corn-based diet. The study also showed higher value of HDEP (72.035 and 79.459) than the study reported by Isika *et al*. (2006) for the layers fed on palm oil and animal fats. The HDEP% not affected by the dietary levels of sorghum varieties.

Egg production and feed intake tended to be greater in layers fed sorghum-based diets even though no differences in average egg weight and was agreed with the findings of Isa (2009) who reported a non-significant difference among the birds that fed corn and the sorghums. The present results on egg production parameters (HHEP and HDEP percentages) were in agreement with the findings of Gowda *et al*. (1984) and Ambula *et al.* (2003) that egg production did not decrease when layers fed diets with sorghum at 32 to 50% of their diets or when sorghum was the sole cereal in their diet. Feed conversion ratio was not significantly different among all treatments and different levels of sorghum varieties. It also true for both sorghum varieties. The current study was agreed with the findings of Salissou (2009) who reported no significant differences in average egg weight and FCR among birds that fed corn and sorghum based diets. Similarly, FCR due to type of variety was reported to be unaffected by inclusion of sorghum in the diets of layers (Thakur *et al*., 1985; Rama Rao *et al*., 1995) which was agreed with the present result.

5.4. Egg Quality Parameters

The study conducted by Usman and Garba (2012) reported that when Isa brown chicken were fed with a maize and sorghum based diet formulation, there was no significant differences in the egg weight, yolk weight, albumen weight, Haugh unit and shell thickness. Both internal and external egg quality in the present study affected positively by feeding evaluation of both sorghum varieties (SVM and SVD) at different levels in Bovan Brown hens. Most egg quality parameters, both the external as well the internals, were not significantly changed due to the different treatment diets comprising the levels and type of sorghum varieties. However, the higher the value of the HU showed in the present study revealed the better the quality of eggs obtained due to the treatments and type of variety of sorghum which are classified according to the United States Department of Agriculture (USDA) as AA (72 to100), A (60 to71), B (30 to 59) and C (< 29) (Oluyemi and Robert, 2000; USDA, 2000). In this regards, the eggs obtained from the control group, all treatment diets which include different levels of sorghum varieties and from SVM and SVD can be classify as AA, best quality. Similar to the present study, Oluyemi and Robert (2000) also reported that unit score of 72 and above been graded as the best quality. This showed that, the quality of the eggs, regarding the HU, in the current study were under AA grade in diets, which contain 20%, 30% and 40% of both sorghum varieties (SVM and SVD). Improvement of albumen height in the present study also agreed with the findings observed by Price (2000) and Kaijage *et al*. (2004). The higher the HU, the more desirable is the egg quality (Fayeye *et al.*, 2005).

ISA (2009) reported that the minimum shell thickness of 0.35 and shape index of 74 is indicators of quality egg. In the present study, shell thickness (mm) was in the range (39-41) in treatments diets and levels of sorghum; and from 40-41 in sorghum varieties (SVD and SVM) while shape index was ranged from 77.72 - 79.43.The lowest shell thickness was from the T7 (40%SVD) while the highest one was from birds fed T4 (40% SVM), T5 (20%SVD) and T6 (30%SVD). In addition, the lowest shape index was observed on control diet (T1) while the highest shape index was from T2 (20%SVM). This implies that, substitution of inclusion of SVM at 20% inclusion level results in better egg quality in terms of shell thickness and shape index.Good shell thickness is an important bio economic trait in commercial egg production as it may help to reduce the percentage of cracked eggs and decrease the rate of loose for producers.

5.5. Partial Budget Analysis

In the current study, feed cost increases from T_1 to T_7, as increases as the level of both sorghum varieties in the diet containing 20%, 30% and 40% and in both sorghum varieties than control group that due to the high price of sorghum varieties purchased from central market not niche area (local area where sorghums are potentially produced in low land area). The prices of other ingredients and sorghum varieties considered in the present study were the central market not the niche area. In this study, highest net return was recorded from hens fed on T_7 (40%SVD) than other treatments, levels of sorghum varieties. From the two sorghum varieties, the highest net return recorded from hens fed on SVD than SVM and control diet. The present study was inconsistent with the findings of Reddy *et al*. (2005) that feed cost per production of an egg was low in sorghum diets compared to maize control diet. This might be happened due to the difference in egg production (no.) per hen and was different among the treatments and levels of sorghum varieties (which ranges from 52 to 66) and in between sorghum varieties 58 (control), 55(SVM) and 62 (SVD).

6. CONCLUSION AND RECOMMENDATIONS

6.1.Conclusion

From the two sorghum varieties (SVM and SVD), SVDmainly at T_7 (40%) level of experimental diet, improved in average daily feed intake, feed conversion ratio, average egg production, HDEP (%) , HHEP (%) and egg mass in Bovan Brown layer chickens. On the other hand, SVD at (T_6 or SVD at 30% level inclusion in test diets) showed higher final BW and BWC on hens. However, it was less in Albumin height and HU than SVM as well as control diet. Generally, SVD (T_7 or SVD at 40% level of inclusion in the layers diet) had shown improvement in feed intake, FCR and egg production and numerically it contributed to better net income than SVM in Bovan Brown layer chickens. The present study showed that maize can be replaced by sorghum varieties (SVD and SVM) without affecting BW, FCR, feed intake, net income and egg production performance of layer chickens.

6.2. Recommendations

Based on the above conclusion, the following recommendations were forwarded. The use of sorghum for human consumption is relatively low as compared to maize. Because of multiple use of maize and its relatively higher moisture requirement for growth, use of maize in drier areas, most part of the country may be limited in the future. In comparison to maize, sorghum can be grown successfully on relatively poor soils and with lower moisture condition. So that;

- Sorghum varieties, SVD up to 40% in layer diets can be included to reduce the competition of maize between human being and layer diets as energy source.
- Regarding feasibility still there is a huge room to be least cost in the ration formulation if the sorghum pricing is at the gate price or at the niche market.
- In our country there are limited finding in the area of feeding of sorghum for poultry mainly for layers. So, for the future researcher should do further investigation and give suggestion about the feeding value of sorghum varieties in layers and broilers diets to use in diets for feed processers and poultry producers.

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8. APPENDICES

8.1. Appendix table on treatment Analysis

Appendix table 1Analysis of Variance of Total Feed Intake per hen

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	6	1044196.478	174032.746	0.75	0.6166
Error	14	3229881.664	230705.833		
Corrected Total	20	4274078.142			

CV= 5.48

Appendix table2: Analysis of Variance of Body Weight Change

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	6	40731.95767	6788.65961	69.19	<.0001
Error	14	1373.59259	98.11376		
Corrected Total	20	42105.55026			

CV= 8.17

8.2. Appendix table on level of Sorghum varieties Analysis

Appendix table 3Analysis of Variance of Total Feed Intake

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr> F**
Model	6	1044196.478	174032.746	0.75	0.6166
Error	14	3229881.664	230705.833		
Corrected Total	20	4274078.142			

CV= 5.48

Appendix table 4: Analysis of Variance of Average Egg Weight

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr> F**
Model	6	10.74919661	1.79153277	1.46	0.0405
Error	14	17.15019492	1.22501392		
Corrected Total	20	27.89939153			

CV= 1.91

Appendix 5**:** Analysis of Variance of Egg mass(kg)

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr> F**
Model	6	0.93247996	0.15541333	1.26	0.0257
Error	14	1.73055638	0.12361117		
Corrected Total	20	2.66303634			

CV= 10.41

Appendix table 6: **Analysis of Variance of Yolk Weight**

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr> F**
Model	6	0.88753968	0.14792328	0.86	0.5475
Error	14	2.41166667	0.17226190		
Corrected Total	20	3.29920635			

CV= 2.86

8.3. Appendex table on Sorghum varities Analysis

Appendix table 7: **Analysis of Variance of Average Egg Weight**

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr> F**
Model	2	3.06915802	1.53457901	1.11	0.3503
Error	18	24.83023351	1.37945742		
Corrected Total	20	27.89939153			

CV= 2.026

Appendix table 8: **Analysis of Variance of Yolk Weight**

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr> F**
Model	2	0.11815697	0.05907848	0.33	0.7202
Error	18	3.18104938	0.17672497		
Corrected Total	20	3.29920635			

CV= 2.894466

Appendix table9: **Analysis of Variance of Egg Mass in kg**

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	2	0.37163296	0.18581648	1.46	0.2585
Error	18	2.29140338	0.12730019		
Corrected Total	20	2.66303634			

CV= 10.56819

Appendix table 10: **Analysis of Variance of Feed Intake per Bird**

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	2	0.88482525	0.44241262	1.30	0.2961
Error	18	6.11095233	0.33949735		
Corrected Total	20	6.99577758			

CV= 6.892865

Appendix table 11: **Analysis of Variance of Feed Price in birr/kg**

Source	DF	Sum of Squa	Mean Square	F Value	Pr> F
Model	2	14.62691429	7.31345714	17.97	<.0001
Error	18	7.32640000	0.40702222		
Corrected Total	20	21.95331429			

CV=4.187810

Appendix table 12: **Analysis of Variance of total feed cost**

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	2	830.843183	415.421591	8.18	0.0030
Error	18	914.153741	50.786319		
Corrected Total	20	1744.996924			

CV= 5.546354

8.4. List of Figures

Figure 1 Figure 1

2. Measuring of feed ingredients **2.** feeding of experimental feed for hens

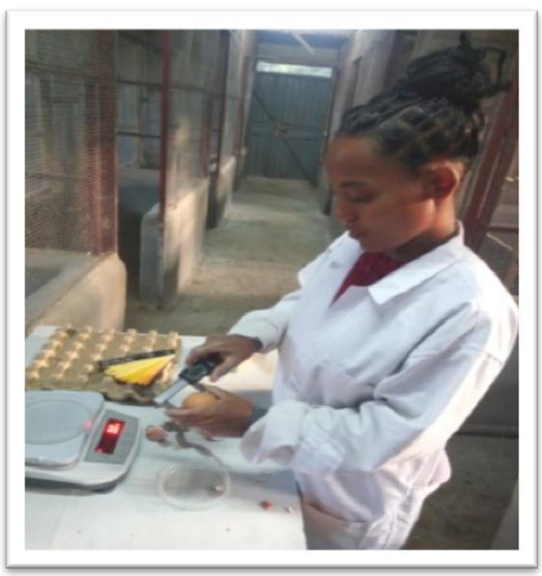
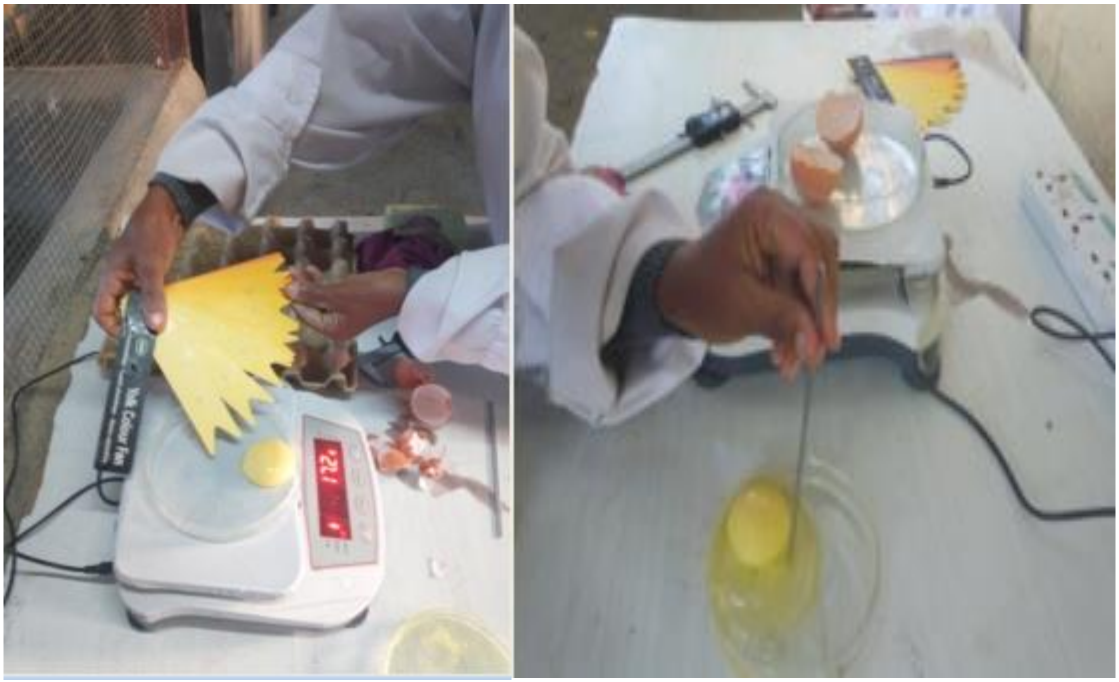


Figure 3: Egg width (left) and length (right) measurement using digital caliper



A, b.

Figure 4: Yolk color determination by using Roche color fan (A) and Albumin height measuring by using micrometer (b)

a b

Figure 5 Data recording (a) and egg weight measuring by using sensitive balance (b)