ADDIS ABABA UNIVERSITY

COLLEGE OF VETERINARY MEDICINE AND AGRICULTURE

RESPONSE OF BROILER CHICKENS FED PELLETED OR NON-PELLETED DIETS, CONTAINING GRADED LEVELS OF RAW, FULL-FAT SOYBEAN

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RESPONSE OF BROILER CHICKENS FED PELLETED OR NON-PELLETED DIETS, CONTAINING GRADED LEVELS OF RAW, FULL-FAT SOYBEAN

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DEDICATION

This thesis paper is dedicated to my family for their unreserved partnership and love in the success of my life.

STATEMENT OF AUTHOR

First, I declare that this thesis is my original work and that all sources of material used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for MSc degree in Animal Production at Addis Ababa University, College of Veterinary Medicine and Agriculture and is deposited at the University/College library to be made available to borrowers under rules of the Library. I surely declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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BIOGRAPHICAL SKETCH

The author was born in Addis Ababa on October 31, 1993 from her father Ato Kebede Mekonen and her mother W/ro Aberash Bekele. She obtained her elementary education from different schools in Addis Ababa and did her high school education at Dr. Haddis Alemayehu Secondary School. She completed her preparatory education at Bole Senior Secondary School. Then, from November 2012 to June 25, 2015, she joined Mizan-Tepi University and graduated with Bachelor of Science in Animal Science. In November 2015, she joined Mizan Tepi University and served as Graduate Assistant with the rank of Assistant Lecturer. Subsequently, in September 2019 she joined Addis Ababa University, College of Veterinary Medicine and Agriculture, Department of Animal Production for MSc Program in Animal Production.

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LISTS OF ABBREVIATIONS

AA	Amino Acid
ANFs	Anti-nutritional factors
BW	Body weight
BWG	Body weight gain
CF	Crude Fiber
CP	Crude protein
CSA	Central Statistical Authority
DM	Dry matter
DZARC	Debrezeit Agricultural Research Center
EE	Ether extract
EIAR	Ethiopian Institute of Agriculture Research
FAD PReP	Foreign Animal Disease Preparedness and Response Plan
FAO	Food and Agricultural Organization
FCR	Feed conversion ratio
FFSBM	Full-fat soybean meal
FI	Feed intake
GLM	General linear model
LRFSB	Level of Raw Full Fat Soybean
ME	Metabolizeable energy
PLC	Private Limited Company
RFSB	Raw full-fat soybean
SBM	Soybean meal
SPSS	Statistical package for the social sciences
TI	Trypsin inhibitors

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ABSTRACT

A feeding trial was conducted to enhance the utilization of locally produced full-fat soybean by the broiler industry. This study was conducted at Debre-Zeit Agricultural Research Center (DZARC), Ethiopia. The study had three phases, such as starter (1-14d), grower (15–28d) and finisher (29–49d) phases. A completely randomized design (CRD) was used in starter phase, with three treatments (commercial soybean meal (SBM) was replaced by raw full-fat soybean (RFSB) at 0, 10 or 20%) and each was replicated eight times. A total of 408 unsexed one-day-old Cobb-500 broiler chicks were purchased from local commercial hatchery farm and were randomly allocated to replicates. All diets were formulated based on international recommendation. A 2 x 3 factorial arrangement was also used in both second (grower) and third (finisher) phase-trials, which had six experimental diets. These six treatments were formed by dividing the original three diets (containing 0, 10 or 20% of raw full-fat soybean (RFSB) into two and then by pelleting anyone from each respective group and leaving the other as mash. Then, every treatment had four replications and 17 birds in each. Chemical compositions of feed ingredients were analyzed and data of initial body weight of chicks, feed offered, feed leftover, body weight (BW) of chickens and mortality were collected. At the end of the experiment, two birds (one male and one female) per replicate were randomly selected and humanly slaughtered. Weights of dressed, eviscerated, cut parts of carcass and visceral organs were weighed and recorded. The result indicated that Feed intake *(FI),* Body weight gain *(BWG),* Body weight *(BW) and* Feed conversion ratio *(FCR) of broilers were not significantly affected (P>0.05) by supplementation of a leveled raw full-fat soybean (RFSB) on diets at starter, grower and finisher phases. However, the interaction effect between the feed form and levels of raw full-fat soybean (RFSB) influenced (P<0.05) the* Feed intake *(FI),* Body weight *(BW) and* Body weight gain *(BWG), at grower stage. The* Feed conversion ratio *(FCR) value of broilers, at grower phase was significantly (P<0.05) different between birds fed pelleted and non-pelleted ration. The* Feed intake *(FI), at finisher stage was also significantly (P<0.05) influenced by the feed forms. However, weights of dressed, eviscerated, cut parts of the carcass and visceral organs were not significantly (P>0.05) affected by both of raw full-fat soybean (RFSB) supplementation, up to 20% and feed forms. It is concluded that the commercial soybean meal (SBM) can be replaced by locally produced raw full-fat soybean (RFSB) up to 20% without pelleting the diets*

Keywords: Anti-nutritional factors, Broilers, Raw Full-Fat Soybean, Soybean Meal, Visceral Organs.

1. INTRODUCTION

Agriculture, particularly livestock sector, plays an important role in economic growth by enhancing food security and rural development in developing countries (FAO, 2018). Poultry sector is continuously growing in many parts of the world. The increasing human population, greater purchasing power and urbanization have been strong drivers of growth (FAO, 2019). As reported by Central Statistic Authority of Ethiopia (2018), the chicken population is estimated to be 56.06 million, and kept for both egg and meat production purposes (Shapiro *et al.,* 2015; CSA, 2018). The majority of the breeds kept are indigenous ones, which constitute about 88.19 percent (CSA, 2018). Chicken production is an important sector in Ethiopia and are also sources of food, nutrition, incomes (Tadesse, 2015). Local chickens in the country play a vital role in many poor rural households and these birds are generally managed by women and children, which are often essential elements of female-headed households (CSA, 2018).

In Ethiopia, trends of meat production is moderately rising, with some fluctuations (CSA, 2018; FAO, 2018; Birhanu, 2019). According to Ethiopian livestock master plan, chicken meat production is projected to increase from 48,900 tons in the year 2015 to 164,000 tons in the year 2020, which is a 235% increase (Shapiro *et al.,* 2015). However, consumption of poultry meat and egg in the country is very low compared to other countries. On the other hand, the demand for poultry products is generally increasing rapidly (Dana *et al.,* 2006; FAO, 2018). Generally, the demand of animal source foods is not yet met in Ethiopia (FAO, 2018). Currently broiler industry is immensely supplying animal proteins, but it is highly constrained by the availability, quality, and cost of feed ingredients, regardless of the system of production in developing countries (Shapiro *et al.,* 2015; Ugwuowo *et al.,* 2019). Feed is one of the factors which determine the poultry, particularly broiler production and represents the major cost of production, constituting up to 70 percent of the total (Ravindran, 2013; Ugwuowo *et al.,* 2019). Energy and crude protein intakes are generally essential in broiler production (Shapiro *et al.,* 2015; Waldroup and Smith, 2017). Underfeeding and malnutrition limits the ability of an animal to reach its genetic potential (Shapiro *et al.,* 2015). However, some feed ingredients, particularly those sources of the crude protein are very expensive and sometimes inaccessible to the producers.

Soybean (*Glycine max* (L.) is leguminous plants and its meal is the most important protein source that has been used to feed farm animals (Heuzé *et al.,* 2020). Soybeans represent about 55% of the total global production of oilseeds (Cromwell, 2017). It is the by-product of the extraction of soybean oil which represents two-thirds of the total world output of protein feedstuffs (Cromwell, 2012; Oil World, 2015). Globally, soybean meal accounts for nearly 69% of all protein sources used in animal feeds (Cromwell, 2017), and dominates the market for protein supplements for poultry (Cromwell, 2017; Waldroup and Smith, 2017). There are a number of reasons for this, including its consistency in nutrient content, its availability, and its high content of crude protein (Waldroup and Smith, 2017). In addition, it also contains substantially higher metabolizeable energy content than other oilseed meals (Ravindran, 2013). However, in addition to the quality, which is largely dependent on the processing technology and origins (Park *et al.,* 2002; Serrano *et al.,* 2012), commercial soybean meal is very expensive and inaccessible to the small-scale producers.

Full-fat soybean, on the other hand can be obtained either after heat treatment or from the raw full-fat soybean, which is known to be raw full-fat soybean (RFSB) (Erdaw, 2016b). Literatures, are also suggesting the possibility that both the commercial SBM and the dietary oil, in chicken diets could partially be replaced by full-fat SBM (Hamilton and Mcniven, 2000; Mirghelenj *et al.,* 2013; Erdaw *et al.,* 2017b; Rada *et al.,* 2017). Since full-fat soybeans (FFSB) provides an excellent source of energy and protein for animals (Perez-Maldonado *et al.,* 2003), some other countries, for example, South Africa, is also using around 53% of all domestically processed SBM as a full-fat soybean (FFSB) for poultry and pig (NAMC, 2011). However, raw, full-fat soybean (RFSB) contains various anti-nutritional factors (ANFs) for poultry, the most problematic one is protease inhibitor (Perez-Maldonado *et al.,* 2003). Anti-nutritional factors (ANFs) can cause the depression in broiler performance (Perez-Maldonado *et al.,* 2003), which contribute to a reduction in nutrient utilization. ANFs elicit their negative effects via different mechanisms, including binding to digestive enzymes and nutrients or increasing gut viscosity (Ao, 2011).

Although tolerance of ANFs depends on the age of the birds (Perez-Maldonado *et al.,* 2003; ASA, 2004; Erdaw, 2016a) excessive levels of ANFs reduce the nutritional quality of the feeds

(Stein *et al.,* 2008, Erdaw *et al.,* 2017a). Fortunately, some ANFs can be denatured by heat (Perez-Maldonado *et al.,* 2003), but the common problem with the process of heating the soybean is lack of optimum combination of temperature-intensity and time-duration. Either under or overheating the soybean can reduce the quality of the meal. Studies have been showing that RFSB can be added, under limited extent, to diets of chickens (Erdaw *et al.,* 2017c).

In Ethiopia, 26 different soybean varieties are released with variable maturity and adaptability to different agro ecologies (Desissa, 2019). The country produced an estimated volume of 150,000 tons of soybeans in 2014/15 (Sopov and Sertse, 2015). In 2014, 3,324 tons of soybean was exported and earned US$ 1,461 million whereas at the same time 1,057 tons soybeans and its products imported with expense of US$ 1,475 million (Sopov and Sertse, 2015). This data shows that the country is exporting large volumes of low-value soybeans (raw material).on the other hand the country is still facing with shortage of both dietary oil and the byproducts, including soybean meals. This might be happened because of the shortage of oil-extracting factories (Sopov and Sertse, 2015; Desissa, 2019). Consequently, the price of whole soybean grain, in the local market is cheaper by 50% than that of the byproducts, for example the commercial SBM. So far, there is no or limited researches conducted in the country on locally produced raw full-fat soybean grains as a feed ingredient to be used in diets of chickens particularly for broiler chickens. Locally produced RFSB grain was not yet tested, particularly when it is gradably included in diets and then found in its pelleted or non-pelleted forms. Therefore, the general objective of this study was to enhance the utilization of locally produced raw full-fat soybean by the chicken industry through conducting feeding trial.

Specific Objectives

- To assess the effects of replacing commercial soybean meal by a graded levels of raw full-fat soybean, as a feed ingredient, in diets of broiler chickens.
- To evaluate effects of pelleting diets, containing graded levels of raw full-fat soybean on the performance of broilers.

2. LITERATURE REVIEW

2.1. Chicken Production Systems in Ethiopia

The potential contribution of poultry industry, to improving food security, nutrition and meat consumption is huge (Shapiro *et al.,* 2015). Chicken production plays a key role in the livelihoods of the rural residents, particularly to the developing countries that is being an immediate income source and by improving the nutritional status of the rural households (Tadele *et al.,* 2018). In Ethiopia, indigenous chickens are reared for basic social and economic needs in the households (Moges *et al.*, 2010). Indigenous chickens are better adapted to harsh environment, tolerant to diseases and parasite and are good brooders (Alemneh and Getabalew, 2019).

The managerial practices of chicken production can vary by breed types ,input and output levels, mortality rates, types of producer, purpose of production, length of broodiness, growth rate and number of chickens reared (Moges *et al.,* 2010). The poultry sector in Ethiopia can be characterized into three major production systems, namely, large-scale commercial, small-scale commercial and scavenging. This is based on some parameters, such as breed, flock size, housing, feeding, health, technology and biosecurity (Tadesse, 2015). Similarly, Hailemariam *et al.* (2017) reported that chicken production systems in Ethiopia are classified into three such as small, medium and large scale. Moreover as reported by Mengesha (2012) the most common production system in Ethiopia is traditional (extensive) type. However, with an increasing demand for meat, in both national and regional levels, it is not possible to meet the demand with these existing extensive chicken production systems. Thus, commercial production system is expected to meet such demands of poultry products, including the chicken meat.

2.2. Patterns of Broiler Chickens Production and Meat Consumption in Ethiopia

Consumption of poultry products, especially poultry meat, has globally increased over the years, and this trend is expected to continue (Ravindran, 2013). Production of poultry is a highly

growing agribusiness (Teshome *et al.*, 2019). The growth of broiler industry has been phenomenal in many countries (Gietema, 2005). Broiler chickens are meat-type chicken breeds and raised for meat production and supplies the populations with animal proteins (FAD PReP, 2013; Ugwuowo *et al.*, 2019). They are produced from special chicken breeds and nowadays they are usually hybrid birds (Gietema, 2005).Ethiopia had a huge number of livestock population, but meat production is still low and contributes to about 0.2 percent of the world's total meat production (Birhanu, 2019). In Ethiopia, levels of selling and consumption of both chicken meat and egg could varies from year to year, which may contribute for a varied *per-capita* consumption figures of chicken products and the variation is also common on incomes generated from it too (Abadi, 2017). Over the past several decades, the consumption of poultry meat, in Ethiopia was very low, and remains far below African and global averages. The prospects for the future growth of commercial poultry in Ethiopia is high, with an average poultry meat consumption of about 0.66 kg *per capita* compared with about 1.64 kg in East Africa and around 6.73 kg in Africa (FAO, 2019). The trends in consumption and the *per capita* intake of energy and protein derived from poultry meat have not changed much from 2003 to 2013 (FAO, 2019). Forecasts indicate that Ethiopian poultry sector is expected to grow annually by between 6–10 percent until 2025 (FAO, 2019).

According to the report of Teshome *et al.* (2019), broiler production systems can be classified in two different categories, such as commercial broiler production system, which involves an average of 10,000 broilers kept under indoor conditions as one batch with a medium bio- security level, and small scale broiler production system. Their flock sizes usually range from 2000-5000 broiler chicks kept for operating and most of these farms obtain their feeds and day old chickens from the large scale commercial broiler farms and involved in the supply of broiler meat to various supermarkets and hotels through middlemen. However, since the margin of the profit per chicken is usually small, broiler production is often a large-scale enterprise. Thousands of chickens have to be reared by a single producer in order to make a reasonable income (Gietema, 2005).

2.3. Chicken Feed Resources in Ethiopia

Feed is the most important input for poultry production and it is one of the factors, which determine the success of the poultry business (Ravindran, 2013; Rohaeni, 2019). In Ethiopia, the extensive poultry production systems entirely dependent on the scavenging feed resources, within the local environment, such as household wastes and food leftovers, field crops, worms and insects (FAO, 2019). As reported by different authors (Abera and Geta, 2014; Tadesse, 2015; Waktole *et al.*, 2018) scavenging is the main feed resource of rural poultry and with rare supplementary feed to their chickens (Moges *et al.*, 2010). Similarly, the chicken owners commonly supplement feeds for their chickens, such as wheat, barley, maize, sorghum and household wastes (Nigatu and Bezabih, 2014 ; Yadessa *et al.*, 2017; Edmew *et al.*, 2018; Assefa *et al.*, 2019; Tadele *et al.*, 2020). The most common poultry feed ingredients in Ethiopia are cereal grains, milling by products (e.g. wheat shorts and middling) and oil seed cakes (e.g. noug seed cake, cotton seed cake, sunflower seedcake, sesame seedcake, groundnut cake and linseed cake) (FAO, 2019).

In the intensive systems, poultry fed compound rations (FAO, 2019). The diets are formulated from a mixture of ingredients, including cereal grains, cereal by-products, fats, plant protein sources, animal byproducts, vitamin and mineral supplements, amino acids and feed additives (Ravindran, 2013). In Ethiopia, seasonality, shortage and prices of feed ingredients are key challenges for sustainable and affordable delivery of compound feeds (Bediye *et al.*, 2018). Maize and soybean is the major raw materials used in poultry rations. However, there are still substantial gaps in the supply of major raw materials used in poultry feeding, particularly maize and soybean (FAO, 2019). For instance, the price trends of soybean meal taking base year of 2010/11 to 2016 increased up to 60 percent across five years (Bediye *et al.*, 2018). In addition, various inputs including premixes, minerals and vitamins are currently imported from abroad using hard currency and their prices are very high (Bediye *et al.*, 2018). Hence, price and quality of feeds are the most important factors limiting commercial poultry production in the country (FAO, 2019). Research in promoting the commercial feed sector (use of alternative check feeds for compound feeds; innovative approaches in import substitution via local production of feed supplements; and on-farm testing) are also very weak (Bediye *et al.*, 2018). So to overcome

shortage of raw materials for feed ingredients, there are wide opportunities exist to produce maize and soybean for feed production in Ethiopia. Additionally, huge land is available for commercial production of these commodities (Bediye *et al.*, 2018). As the demand for poultry products increasing in developing countries, it has a profound effect on the demand for feed and raw materials (Ravindran, 2013). It was suggested by different scholars (Al-Sardary, 2010; Erdaw *et al*., 2017a, 2017d; Rada *et al*., 2017; Erdaw and Beyene, 2018) broilers diet containing SBM could be partially replaced by raw full fat soybean at optimum level with different feed forms. Conducting on station feeding trial of broilers based on locally available RFSB will help to overcome the problem related with feed cost and quality. Moreover, it enhances the utilization of locally produced raw full-fat soybean by the chicken industry as cheap feed ingredients as compared with soybean meal.

2.4. Nutritional Requirements of Broilers

Through selection and genetic improvement broilers reached to an efficient feed conversion, fastest growth rate and better ability to grow well on cheaper low density feeds. Broiler performance varies from country to country (Vantress, 2013). Among different commercial broilers chicken breeds that are available in the world, Cobb-500 is a flexible broiler breed that can bring good costs from low amino acid density feeds, or will respond with accelerated growth and breast yield using high amino acid levels (Vantress, 2015). Compared with other broiler breed, Cobb-500 stands higher productivity and less growth of fattening period. In 35 days, the average weight is 1.9 kg should be in 42 days - 2.4 kg (Vantress, 2018).

Broiler diets are formulated to provide balanced array of nutrients that are essential for health and efficient production (Vantress, 2018).Nutrients required by birds vary according to species, age and the purpose of production (Ravindran, 2013). Most of feed formulated by poultry nutritionists are designed to attain maximum profitability of live birds or designed to optimize yields of certain carcass components, such as breast muscle (FAD PReP, 2013). The basic nutritional components required by the birds are water, amino acids, energy, vitamins and minerals (Vantress, 2018). To satisfy requirements of broilers, feeds are often supplemented with synthetic amino acids, such as methionine, lysine, and threonine, which are the limiting amino

acids in broiler feed (FAD PReP, 2013). To meet the nutritional requirement of commercial broilers high protein and energy levels are needed. To attain the desired body weight gain of broilers, at starter, grower and finisher phases, feed should contain crude protein (%) of 21-22, 19-20 and 18-19, and Metabolizeable energy (kcal/kg) 3035.37, 3107.07 and 3178.78, respectively (Vantress, 2013).

2.5. Feed Intake and Efficiency

Successful broiler development is dependent on optimal feed intake throughout the growing period (Jafarnejad *et al.,* 2010). Feed intake is the major factor that influences body weight gain and feed efficiency (Ferket and Gernat, 2006). Optimal feed intake and growth are dependent on a number of factors, such as dietary (dietary nutrient composition, feed formulation and feedstuff inclusion levels, and feed pellet quality) and managerial (feed and water availability to the birds, environmental management, stocking density), and disease control) (Ferket and Gernat, 2006; Jafarnejad *et al.,* 2010). Moreover, there are many other factors which affect feed intake and level of nutrient intake of chicken production (Abebe *et al.,* 2015). A deficiency or excess of dietary nutrients will negatively impact feed intake, but for most nutrients, levels within commercially acceptable ranges have a limited effect on feed intake (Classen *et al.,* 2017). Modern commercial broilers will not grow to their full genetic potential unless they consume their full nutritional requirement each and every day (Ferket and Gernat, 2006). So, growth rate and efficiency are linked to the ability to consume, digest, absorb and metabolize dietary nutrients (Scott, 2005; Ferket and Gernat, 2006). When feed intake is increased, a greater proportion of nutrients is used for growth and feed conversion ratio (FCR) is improved (Scott, 2005). The FCR is a measure of how well a flock converts feed intake (feed usage) into live weight and it is the most commonly used parameter to determine broiler nutritional requirement (Rostagno *et al.,* 2007).The Feed efficiency are not only change in efficiency of muscle deposition, but also a reduction in the time taken to reach market weight and decreased maintenance costs (Scott, 2005).

2.6. Soybean for Broiler Diets

Soybean (*Glycine max* (L.) is a leguminous oilseed crop and one of the world's largest and most efficient sources of plant protein (Nahashon and Kilonzo-Nthenge, 2011). It is by far the most important oilseed crop in the world and is grown for a number of industrial and agricultural uses (Dei, 2010; Modika, 2011). Soybean play an important role in the diets of many regions throughout the world and have been referred to as the miracle bean for their high nutritive value where they are compared with other legumes (Messina, 1999). Because it contain highly valuable proteins and oils (on average ranging from 39-41% CP and 18-21% oil) which make them good feed alternatives to animal proteins and oils (Modika, 2011). Content of crude fiber is lower in comparison to another vegetable high protein feeds. It is also characterized the highest digestibility of protein, lysine and methionine (Banaszkiewicz, 2011). Use of soybean products in non-ruminant diets can give reasonable performance only if diets are formulated correctly or their anti-nutritive factors removed (Dei, 2010). Soybean products are the main feed-stuffs in feed formulation (Rocha *et al.,* 2014). However, the supply and quality of SBM fluctuates, and the meal is expensive due to processing and transportation costs. Although there is a growing interest in the use of RFSB for birds, its nutritive value is negatively affected by the presence of ANFs (Erdaw *et al.,* 2016a; Rada *et al.,*2017).

2.6.1. Raw soybean

Raw full fat soybeans are obtained from whole soybean without cooking or removing any of the oil (Van Eys, 2004). Raw soybean contains several ANFs, such as protease inhibitors, lectins (hemagglutinins), and allergens (glycinin and β-conglycinin), which are heat unstable and therefore can be inactivated by heat treatments (Rocha *et al*., 2014; Ravindran, 2013). Raw soybeans are usually processed in order to improve their nutritional value, either by removing ANFs or by making the protein less degradable for ruminants (Heuzé, 2020). An increased use of grain legumes as feed limited by ANFs which decrease nutritive value of grain legumes and, if taken in larger amounts, cause health problems (Mikic *et al*., 2009). The ANFs present in raw full-fat soybeans damage the integrity of the intestinal epithelium and negatively affect both gross and microscopic pancreatic structure (Mikic *et al.*, 2009; Rocha *et al*., 2014). As reported Rada *et al.* (2017) RFSB to the broiler diets up to 80g/kg is possible without having a

significantly negative effect on the growth rate and FCR Commercial SBM could be replaced at up to 25% by RFSB for broilers with supplementation of microbial protease and phytase (Erdaw and Beyene, 2018). Unfortunately; increasing RFSB in diets of poultry increased both trypsin activity and weights of pancreas (Rada *et al.*,2017). Similarly feed intakes and body weight gains were reduced due to increasing levels of RFSB (Erdaw and Beyene, 2018).

2.6.2. Full-fat soybean

Full-fat soybean is whole soybeans in which the oil is not extracted. These products are produced by a variety of processes such as extruding (dry or wet), cooking/ autoclaving, roasting/toasting, micronizing and jet-sploding to inactivate the ANFs (Dei, 2010). All of these processes have different impacts on the nutritive value of the products depending on heat damage or degree of inactivation of ANFs. Full-fat soybeans, either toasted or extruded, are also an excellent protein source for broilers. Because of having high oil (180 to 220 g/kg) and protein contents (370 to 420 g/kg), with an acceptable amino acid profile, full-fat soybean (FFSB) provides excellent sources of energy and protein for both animals and humans (Waldroup, 1982; Vasconcelos *et al*., 2009). FFSB is attractive because its energy content is significantly higher than SBM. FFSB would make a comparable nutritive contribution to a poultry diet, it could replace SBM as well as certain amounts of other feedstuffs supplying protein and energy to the diet (Paulding *et al.*, 1986). According to the report of Ali *et al.* (1993) FFSB up to a level of 25% did not affect the broiler performance as compared to only SBM. Al-Sardary (2010) reported that inclusion of 25% FFSB in the starter and up to 35% in the finisher of broiler diets instead of SBM would improve performance. Leeson and Atteh (1996) evaluated the response of broiler chicks on dietary values of extruded FFSB and they found that lower extrusion temperatures do not reduce trypsin inhibitor activity to a satisfactory level that may not enable to include such extruded soybeans for broilers. Properly heat processed FFSB are capable of improving broiler performances, which sometimes similar to those birds, which fed on SBM based diets (Leeson and Atteh,1996).

2.6.3. Soybean meal

Soybean meal (SBM) is the material remaining after extraction of oil from SB flakes, (Mukherjee *et al*., 2016) and it is the most important protein source in non-ruminant diets.

Soybean meal or soybean cake or soybean chips are the direct product after most of the oil is extracted from whole soybeans by pressure or solvents, and SBM is derived from grinding the soybean cake, chips or flakes (Erdaw *et al.*, 2016a; Heuzé *et al.*, 2020). It has high CP and a balanced amino acid profiles of which tends to be deficient in cereal grains which constitute large portions of diets of monogastric animals (Nahashon and Kilonzo-Nthenge, 2011). The use of soybean meal as a protein source in broiler chicken feed leads to good growth if supported with the addition of synthetic methionine (Rohaeni, 2019). According to their digestibility and amino acid composition, soybean matches or exceeds all other common plant proteins sources (Waldroup and Smith, 2017). The origin of the soybean meal can influences the protein quality and amino acid digestibilities (Park *et al.,* 2002; Serrano *et al.,* 2012).

2.6.4. Chemical composition and nutritive value of soybean

Soybean is one of the most economical and valuable agricultural commodities because of its unique chemical composition and has highest protein content around 40% (Liu, 1997). The high biological value of soybean proteins and due to its favorable attributes, such as relatively high protein content and suitable amino acid profile except methionine, minimal variation in nutrient content and relative free from intractable anti-nutritive factors, increases their universal acceptability in animal feed (Dei, 2011). Genotype, planting area, soil type, agricultural practices, and environmental conditions, during the growing season and storage affect the chemical composition of the soybeans (Grieshop and Fahey, 2001).The chemical composition, protein quality and nutritive value of commercial SBM depend on the country of origin of the beans (García-Rebollar *et al.,* 2016). The nutrient composition for SBM, raw and full-fat soybean are shown in Table 1.

Table 1. Nutritional composition of soybean meal, raw, and full-fat soybean

Soybean products	DM %	CP %	CF %	EE %	Ash %	References
SBM	91.48	42.29	3.79	1.92	-	Erdaw *et al*. (2017a)
	92.10	46.58	4.70	2.25	6.60	Milczarek and Osek (2019)
	90-90.10	45.20-48.34	3.96-7.22	-	-	Park *et al*. (2002)
	89.89	35.4	7.35	6.01	6.85	Egorov *et al*. (2019)
	94.17	40.04	6.14	10.8	5.5	Embaye *et al*. (2018)
	88.9- 89.2	46.4-48.2	3.63-6.08	1.09-2.05	6.26-7.95	Ravindran *et al.* (2014b)
	86.3- 95.9	48.9-58.5	1.6-5.7	0.4-3.8	6.1-9.2	Heuzé *et al*. (2020)
RFSB	89.72	37.50	5.03	18.04	4.77	Van Eys et al.(2004)
	91.60	30.55	22.09	22.09	4.90	Milczarek and Osek (2019)
	92.36	38.24	6.2	14.73	-	Erdaw *et al*. (2017b)
	86.6	38.36	4.8	17.8	-	Sakkas *et al*. (2019)
	90.9- 92.9	39.4- 44.4	-	-	-	Sharma *et al*. (2014)
FFSB	89.44	37.08	5.12	18.38	4.86	Van Eys *et al*. (2004)
	90.08	35.1	7.29	18.04	4.35	Egorov *et al*. (2019)
	87-93.4	35.1-39.9	5.18-8.81	17.7-23.8	4.63-4.94	Ravindran *et al*. (2014a)
	95.06	38.0	5.1	20.9	5.5	Senkoylu *et al*.(2005)
	90	38	5	18	4.6	Johnson and Smith (2018)

DM: Dry matter; CP: Crude protein; CF: Crude fiber; EE: Ether extract

2.6.5. Anti-nutritional factors of soybean

Soybean is a good source of protein and energy, however it contains ANFs that limit inclusion in feeds for non-ruminant animals and also negatively affect the quality of feed (Rocha *et al.,* 2014; Erdaw and Beyene, 2018). ANFs may be defined as those substances generated in natural feed stuffs by the normal metabolism of species and by different mechanisms (e.g., inactivation of some nutrients, diminution of the digestive process or metabolic utilization of feed which exert effects contrary to optimum nutrition) (Kumar, 1992). Being an ANF is not an intrinsic characteristic of a compound but depends upon the digestive process of the ingesting animal, e.g., Trypsin inhibitors (TI) which are ANFs for monogastric animals; do not exert adverse effects in ruminants because they can degrade the TI in the rumen (Patel *et al.,* 2013). Trypsin inhibitors cause pancreatic hypertrophy/hyperplasia with consequent inhibition of growth, soybeans also contain lectin compound that bind with intestinal cells and interfere with nutrient absorption and other compounds such as saponins, lipoxidase, phytoestrogens and goitrogens whose anti-nutritional effects are not known (Nahashon and Kilonzo-Nthenge, 2011). The effects of these factors on monogastric animals may cause unfavorable physiological effects of the digestive absorptive, protective or secretory systems (Buttle *et al.,* 2001). Some ANFs in soybean are shown in Table 2.

Table 2. Some anti-nutritional factors in soybean

Heat labile	Heat stable
Protease inhibitor	Saponins
Lectins	Tannins
Goitrogens	Strogens
Antivitamins	Oligosacharides
	Antigens
	Phytate

Source: Peisker (2001).

2.6.6. Methods of reduction of anti-nutritional factors of soybean

Nowadays, the main challenges in poultry production are how to reduce feeding cost and improve product quality. The uses of unconventional feedstuffs contribute to decrease feeding cost and environmental impacts. The problem of feeding these materials is that they contain different levels of ANFs (Yacout, 2016). Pelleting, milling expanding or extrusion of feed processing techniques depending on facility and purpose of production increase the physical density of the feed and lead to increased feed intake, reduced time spent of feeding, improved growth rate and improved feed to gain ratio. Subsequently, improved feed conversion and better performance can often be observed when feeding processed diets compared to mash (Ahmed and Abbas, 2013; Sibanda and Ruhnke, 2017). The physical form of feed (mash, pellet, and crumble) is a key factor in meat yield of broilers (Ahmed and Abbas, 2013). Feed form (mash, pellet, and crumble) primarily affects feed intake and consequent live weight gains rather than FCR (Lilly *et al.,* 2011).

The elimination of ANFs can be achieved through various processing methods. These methods have different impact on the nutritional quality of the product. Thermal treatment is one of the most common methods of reducing the adverse effects of ANF in feed including enzyme inhibitors, haemaglutinins, plant enzymes, cyanogenic glycosides, goitrogens, phyto-oestrogens, saponins, gossypol, tannins, amino acid analogues, alkaloids, mineral and vitamin binders (Sibanda and Ruhnke, 2017; Lokuruka, 2011; Ljøkjel *et al.,* 2000). Heat processing of raw soybeans improves its nutritional values by destroying the trypsin inhibitors and other ANFs. Other benefits of thermal treatment include the ease of handling the finished product, improved hygienic status of the feed, and reduced ANFs (Sibanda and Ruhnke, 2017). One method of heat processing of raw soybeans is dry roasting through a rotating chamber where they are directly exposed to a flame (MacIsaac *et al.,* 2005). However, Ljøkjel *et al.* (2000) reported that heat treatment of SBM at 130 ^{0}C caused significant reduction of the content of Arg, Lys and Cys by 4.1, 8.2 and 12.5%, respectively. During processing, high temperature is the primary factor responsible for the deactivation of the anti-growth factors present in raw soybeans (Danielson *et al.,* 1988). But both under- and over-processing of soybeans can reduce the nutritive value of the meal (Rocha *et al.,* 2014; Erdaw, 2016b). Over processing of RFSB resulted in a portion of the

lysine being rendered unavailable for poultry because of the Maillard reaction (KarrLilienthal *et al.,* 2004; Lokuruka, 2011). Uses of too high temperature cause decrease of protein and some amino acids availability, especially lysine (Banaszkiewicz, 2011).

Nowadays, various commercial feed mills are producing different forms of broilers feed for different age groups of birds. Pelleting is one of the processing methods that is employed by the feed manufactures to improve the performances of farm animals performance and it is the most prevalent heat treatment in the production of poultry feed (Abdollahi *et al.,* 2013; Chehraghi *et al.,* 2013). Pelleting is a combination of heating, friction, pressure and it reduces particle size, improves average daily feed intake, agglomeration of individual particles into a product of defined shape, size and durability (Abdollahi *et al.,* 2011; Ahmed and Abbas, 2013; Sibanda and Ruhnke, 2017). Feeding high-quality pellets improves animal performance and feed conversion compared with feeding over poorer quality pellets (Dozier *et al.,*2010; Garcia-Maraver, 2015). Reasons for the enhanced performance may be due to decreased feed wastage, reduced selective feeding, decreased ingredient segregation, less time and energy expended for pretension , destruction of pathogenic organisms, thermal modification of starch and protein, improved palatability (Garcia-Maraver, 2015). However, feeding pelleted rations is not enough to ensure enhanced performance of poultry because broiler performance may rely on pellet quality (Lilly *et al.,* 2011). The quality of pellets must also be taken into account during processing (Briggs *et al.,* 1999).

In addition to heating and pelleting, the nutritive value of RFSB can be improved by supplementing with microbial feed enzymes, such as phytase and protease, which have been developed and are used primarily to improve digestibility of nutrients or to reduce the ANF (Bedford, 2000; Erdaw *et al*., 2016a; Erdaw, 2016b). Broiler diets are commonly supplemented with exogenous enzymes in order to increase nutrient digestibility, decrease digesta viscosity, decrease diet cost and decrease nutrient excretion (Bedford, 2000; Erdaw, 2016b). Commercial SBM could be replaced with RFSB up to 25% in broiler diets if the diets are supplemented with appropriate microbial protease and phase (Erdaw *et al.,* 2017b).

3. MATERIALS AND METHODS

3.1. Description of the study area

The study was conducted at Debrezeit Agricultural Research Center (DZARC) which is found in Bishoftu town. Bishoftu is located in Oromia Regional State, East Shewa Zone at a distance of 47 km from Addis Ababa, Ethiopia.

3.2. Study Animals and Husbandry Practices

For this study, a total of 408 one day-old Cobb 500, unsexed broiler chicks, with average initial weight of 46.43±0.58 g, were purchased from commercial hatchery farm, named as ELERA PLC. All birds were raised uniformly in 24 floor-pens with *teff* straw was the bedding material. Infrared bulb with 250 watts was used in each pen to generate electric heat. Brooding guards were also used in every pen. Temperature of these pens was managed by controlling the height of the li`ght bulb. The space within the guards of the pens were 1.25m by 1m sufficient enough that allows the chicks to adjust themselves with that of an intensity of heat, which supposed to be generated by bulb (s). Feed was provided *ad libitum* and the birds were free access to water. HB1 vaccination was given to birds via eye drop as per the recommendation on day 3. Then on days 7 and 14 Gumboro was administered as eye drop. Lassota was also given to them on the 18^{th} days. The drinkers were washed on daily basis with clean water. The leftover feed was removed after being measured and the new diets were also offered to the birds on daily basis. Bio-security measures were applied and not compromised on the health and welfare of animals involved. Birds were handled in accordance with standards Ethical Guidelines for the Use of Animals in Research (NENT, 2018).

3.3. Experimental Design and Broiler Diet

The raw soybean seed was purchased from a local supplier in Addis Ababa. The chemical composition of feed ingredients was analyzed at DZARC and Bless Agri Food Laboratory Services PLC before the execution of the experiment and the composition was illustrated in Table 3. Before mixing in diets, the raw soybean seeds were cleaned and then hammer-milled to

pass through a 2-mm sieve. Diets were formulated for starter, grower and finisher periods, that at least satisfying the birds minimum nutrient (major) requirements and these were 22 % CP vs 3090, ME, kcal/kg, 21% CP vs 3095, ME, kcal/kg and 20% CP vs 3135, ME, kcal/kg, respectively.

Table 3. Chemical composition of feed ingredients

Feed ingredients	DM (%)	CF (%)	CP (%)	Ash (%)	Calcium
Bone and Meat Meal	95.78	3.54	46.87	32.64	7.8
Soybean Meal	91.89	6.45	43.37	6.22	0.201
Raw soybean	92.36	15.73	33.04	5.11	-
Maize	89.7	2.53	8.69	2.72	0.182

This experiment had three phases, which included starter (0-14 d), grower (14-28d) and finisher (28-49) phases. Phase one was conducted, with a completely randomized design, supplementing with graded levels of RFSB (commercial soybean meal (SBM) was replaced by raw full-fat soybean (RFSB) at 0, 10 and 20%) in starter diets for broiler chicks. Each of the three treatment was replicated 8 times using 17 birds per replicate. Chicks were randomly distributed along the replicates and these birds were fed on mash form of the diets. Duration of feeding these starter diets lasted at 14 days. After 14 days, each of these three treatment was then allowed to split into two. Anyone of these split-out, from each of the three treatment was then pelleted and the other one from each was left as mash. Consequently, the next two (grower and finisher) phases of this experiment were found, with a total of six treatments and each of this was also replicated four times, with 17 birds each. A factorial arrangement, with a completely randomized design was used in both of these phases. This feeding trial was involving two forms of broiler diet (pelleted and non-pelleted), with that of supplementing graded levels of RFSB (commercial SBM was replaced by RFSB at 0, 10 and 20%). All diets were formulated based on international recommendation. The diet was pelleted at GUTS Agro Industry PLC. Feed composition of each phase described in Table 5. Every added feed to each pen was individually weighed. All birds were weighed as group from the start to the end of the experiment in regular one-week period.

Table 4.Treatment layout for starter, grower and finisher phases

Levels of RFSB, %	Phases of the experiment		
		After splitting and pelleting one diet	
	Starter phase	Grower phase	Finisher phase
0	T_1 (Control)	Non-pelleted	T_1
		Pelleted	T_2
10	T_2	Non-pelleted	T_3
		Pelleted	T_4
20	T_3	Non-pelleted	T_5
		Pelleted	T_6

Table 5. Ingredient composition of the experimental diets (g/kg) fed to starter (0-14d), grower (14-28d) and finisher (28-49d) phases of broiler

	Starter			Grower			Finisher		
Ingredients	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
Maize grains	580.5	590	582	608.5	614.5	617	629.5	629	631.5
Raw soybean	0	30	60	0	30	60	0	30	60
Food oil (un-saturated)	10	5	2.5	17.5	12.5	7.5	25	21.5	18
Soybean meal	300	270	240	300	270	240	300	270	240
Meat and bone meal	80	79.2	87.7	50	51.5	56	20	25	27.5
Limestone	8	8	8	6	6	6	4	4	4
Salt	3	3	3	3	3	3	3	3	3
DL-Methionine	3	3	3	3	3	3	3	3	3
L-Lysine	6	6	6	6	6	6	6	6	6
Premix	5	5	5	5	5	5	5	5	5
Dicalcium Phosphate	4	4	4	4	4	4	4	4	4
Choline chloride	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

3.4. Data Collection

The following data were collected, such as nutritional composition of feed ingredients, including RFSB, initial body weight of chickens, feed offered; feed leftover, live body weight of chickens. Mortality and reasons of the occurrence was recorded.

3.4.1. Feed intake

The measured amount of feed was offered *ad libitum* base throughout the experimental period. Feed refused from each pen was collected the next morning at 08:00 AM before the next daily offer was given. The feed offered and refused was recorded for each pen. The amount of feed consumed was determined as the difference between the feed offered and refused using the following formula.

$$\text{Feed intake(g/b)} = \frac{\text{Feed offered(g)} - \text{Feed refused(g)}}{\text{Number of birds present}}$$

3.4.2. Body weight gain

Broilers were weekly weighed always in a group during the experimental period. The chicks were weighed per replicate on the first day after being randomly assigned to respective pens by sensitive balance and the weight per chick was calculated as an average weight of chicks in the pen and recorded to form the initial body weight. Body weight gain per chicken for each pen was computed using the following formula

$$\text{Body weight gain(g)} = \frac{\text{Final body weight} - \text{initial body weight}}{\text{Number of birds}}$$

3.4.3. Feed conversion ratio

The feed conversion ratio (FCR) was determined by dividing feed intake with body weight gain.

$$\text{Feed conversion ratio} = \frac{\text{Feed intake(g)}}{\text{Body weight gain(g)}}$$

3.4.4. Carcass, parts yield and visceral organs measurements

At the end of the experiment two birds (one male and one female) per replicate were randomly selected. These birds were humanly slaughtered. After bleeding, birds were placed in a scalding tank. And then, the dressed weight (after legs, head, and feather removed) weighted. Then, the eviscerated weights were weighed after removal of the visceral organs. The carcass parts: breast, drumstick, thighs were cut up and weighed. The visceral organ weights (heart, liver, proventriculus and gizzard, duodenum and pancreas, small and large intestine) were weighed.

Dressed carcass weight: This was measured after the removal of blood, legs, head and feather and the dressing percentage calculated as the proportion of dressed carcass weight to slaughter weight multiplied by 100.

Eviscerated carcass weight: This was determined after removing blood, feather, lower leg, head and visceral organs. The eviscerated carcass percentage was determined as the proportion of the eviscerated weight to slaughter weight multiplied by 100.

3.5. Statistical analysis

All the collected data were arranged on Microsoft Excel 2010 before the actual data analysis was conducted. Descriptive statistics and One-way ANNOVA were used to test the values of parameters, such as FI, BW, BWG, and FCR on starter phase as shown in Model 1. General linear Model (GLM) was used to analyse the main effects of the treatments on BWG, FI, FCR, carcass yield, cut part and visceral organ as shown in Model 2; using SPSS (V. 20 IBM Corp, 2011) software. The significant mean values, at $p < 0.05$, was separated by Duncan's Multiple Range Test (Duncan, 1955).

ANNOVA Model 1: (FI, BW, BWG and FCR)

$$Y_{ij} = \mu + T_i + e_{ij}$$

- where: Y_{ij} = the observed j variable in the i^{th} treatment
- μ = overall mean of the response variable
- Ti = the effect due to the i^{th} RFSB Level (i = 0, 10, 20)
- eij = random residual error

ANNOVA Model 2: (FI, BW, BWG FCR, Carcass yield, cut part and visceral organ)

$Yijk = \mu + R_i + P_j + R_i*P_j + e_{ijk}$,

where: Y_{ijk} = the observed k variable in the i^{th} RFSB level and j^{th} form of diet

- μ = overall mean of the observed variable
- R_i = effect due to i^{th} RFSB level (i = 0, 10 and 20)
- P_j = effect due to j^{th} form of diet (j = Pelleted and Non-Pelleted)
- R_i*P_j = effect due to the interaction between i^{th} RFSB level and j^{th} form of diet
- e_{ijk} = random residual error

4. RESULTS

4.1. Response of Broiler Fed Graded Level of RFSB at Starter Phase

The result of the study on feed intake, body weight gain, feed conversion ratio and body weight of broiler chickens fed on diets, containing graded level of RFSB at starter phase is presented in Table 6. There was no significant difference (P>0.05) in the feed intake (FI) of birds during the starter phase. Similarly, there was no significant difference (P>0.05) in body weight gain (BWG). There was no significant difference (P>0.05) between group of birds in the feed conversion ratio (FCR). However, it was observed that as the level of RFSB increases from 0 to 10 or 20%, the FCR efficiency was increased. This implies reduced feed efficiency.

Table 6. Feed intake (g/b), body weight gain (g/b), feed conversion ratio and body weight (g) of broiler chickens between hatch and 14 days of age

Feed form	RFSB (%)	Feed intake	BWG	FCR	Body weight	
		1-14d	1-14d	1-14d	initial	14d
	0	326.78	214.31	1.53	46.25	260.6
Mash	10	333.99	213.23	1.57	46.25	259.62
	20	330.47	205.30	1.61	46.75	251.93
SEM		2.36	2.46	0.01	0.12	2.48
P-value		0.479	0.279	0.054	0.141	0.306

RFSB (%) =Level of Raw full fat soybean (SBM was replaced by RFSB at 0, 10 and 20%, equivalent to 0, 30 and 60 g/kg of diet, respectively); SEM= pooled standard error of means; BWG= Body weight gain, FCR= Feed conversion ratio.

4.2. Response of Broiler to Feed Form and Graded Levels of RFSB at Grower Phase

The gross response of birds at grower phase fed on pelleted and non-pelleted diets, containing 0, 10 and 20% RFSB supplementations is presented in Table 7. In grower phase, feed form and level of RFSB did not affect (P>0.05) the feed intake of birds. But, the interaction effect on FI of birds between feed form and level of RFSB was significant (P<0.05).

Body weight gain at grower phase was not affected (P>0.05) by level of RFSB. However, there was significant difference observed on BWG between bird fed on non-pelleted and pelleted diets. Significant difference (P<0.05) was observed in the interaction between the feed form and level of RFSB, bird consumed 20% pelleted gain more body weight than the birds consumed 20% non-pelleted. But, the birds that consumed non-pelleted diet with 0% RFSB supplementation gained more weight than the pelleted one.

The FCR of growers was significantly different (P<0.05) between birds fed pelleted and non-pelleted diets. The non-pelleted one was efficient than the pelleted. But, the FCR was not affected (P>0.05) by level of RFSB and the interaction effect.

Body weight of birds at grower phase was not significantly affected (P>0.05) by level of RFSB. But, the interaction effect between feed form and level of RFSB was significant (P<0.05) on the body weight of birds. The birds that consumed non-pelleted had significant difference (P<0.05) of body weight compared with the bird feed the pelleted. Bird consumed 0% pelleted weigh less weight than the birds consumed 0% non-pelleted.

4.3. Response of Broiler to Feed Form and Supplements of RFSB at Finisher Phase

The gross response of finisher birds fed on pelleted and non-pelleted diets, containing 0, 10 and 20% RFSB supplementation are presented in Table 8. In finisher phase, interaction effect between feed form and level of RFSB did not affect (P>0.05) the feed intake of birds. But, the feed intake was significantly (P<0.05) affected by feed form. The pelleted diet was consumed more than the non-pelleted feed.

Body weight gain, FCR and final BW at finisher phase were not significantly affected (P>0.05) by both level of RFSB and feed form (P>0.05). Moreover, BWG, FCR and final BW were not affected (P>0.05) by the interaction effects between the feed form and level of RFSB.

Table 7. Feed intake (g/b), body weight gain (g/b), body weight (g) and feed conversion ratio of broiler chickens between hatch and 28 days of age

Feed form	RFSB (%)	Feed intake	Body weight gain	FCR	Body weights at
		1-28d	1-28d	1-28d	28d
Pelleted	0	1121.34	566.73	2.0	612.88
	10	1207.74	655.98	1.84	702.04
	20	1259.53	712.642	1.77	759.14
Non-pelleted	0	1280.88	758.34	1.76	804.78
	10	1249.95	737.11	1.85	783.82
	20	1184.03	683.44	1.73	730.19
SEM		14. 6	6.47	0.02	6.52
Main effects					
RFSB *(%)*	0	1201.11	662.53	1.88	708.82
	10	1228.84	696.54	1.85	742.93
	20	1221.78	698.04	1.75	744.67
Feed form					
Pelleted		1196.2	645.12^{b}	1.87^{b}	691.35^{b}
Non pelleted		1238.29	726.3^{a}	1.78^{a}	772.93^{a}
Source of variation:		*P*-value			
RFSB (%)		0.727	0.064	0.055	0.064
Feed form		0.167	0.000	0.046	0.000
RFSB X Feed form		0.015	0.000	0.056	0.000

RFSB (%) =Level of Raw full-fat soybean (SBM was replaced by RFSBM at 0, 10 and 20%, equivalent to 0, 30 and 60 g/kg of diet, respectively); SEM= pooled standard error of means; FCR=Feed conversion ratio. ^{ab} *= indicate that column with different superscript are significantly different at p<0.05. Whilst computing the final BW and BWG, 16-17 unsexed birds were considered per replicate.*

Table 8. Feed intake (g/b), body weight gain (g/b), body weight (g) and feed conversion ratio of broiler chickens between hatch and 49 days of age

Feed form	RFSB (%)	Feed intake	Body weight gain	FCR	Body weights at
		1-49d	1-49d	1-49d	49d
Pelleted	0	4745.27	2186.64	2.19	2232.77
	10	4711.75	2402.53	1.96	2448.59
	20	4595.32	2497.89	1.89	2544.39
Non-pelleted	0	4551.85	2376.31	1.89	2422.75
	10	4454.5	2289.37	1.95	2336.1
	20	4515.39	2390.67	1.91	2437.42
SEM		38.25	40.09	0.03	40.09
Main effects					
RFSB *(%)*	0	4648.56	2281.48	2.04	2327.76
	10	4583.13	2345.96	1.95	2392.35
	20	4555.36	2444.28	1.90	2490.90
Feed form					
Pelleted		4684.11[a]	2362.35	2.02	2408.58
Non-pelleted		4507.25[b]	2352.12	1.92	2398.76
Source of variation		*P*-value			
RFSB (%)		0.602	0.274	0.142	0.272
Feed form		0.033	0.900	0.086	0.904
RFSB X Feed form		0.639	0.238	0.066	0.239

RFSB (%) =Level of Raw full-fat soybean (SBM was replaced by RFFSBM at 0, 10 and 20%, equivalent to 0, 30 and 60 g/kg of diet, respectively); SEM= pooled standard error of means; FCR =Feed conversion ratio. [ab] *= indicate that column with different superscript are significantly different at p<0.05. Whilst computing the final BW and BWG, 16-17 unsexed birds were considered per replicate.*

4.4. Effects of Feed Form and Supplement of RFSB on Carcass Characteristics

The carcass characteristics of broilers, fed on pelleted and non-pelleted diets, containing graded levels of RFSB are presented in Table 9. According to the findings of the present study, there was no significant difference (P>0.05) on the slaughter, dressed, eviscerated weights and weights of carcass cuts (drumsticks, thighs and breasts) of birds fed on pelleted and non-pelleted diets, containing 0, 10 and 20% of RFSB.

4.5. Effects of Feed Form and Supplement of RFSB on Visceral Organs Development

Values of internal organ measurements of broiler fed pelleted and non-pelleted ration are presented in Table 10. According to the findings of the present study, there were no significant differences (P>0.05) found on the development of visceral organs, such as heart, liver, small and large intestine, gizzard and proventriculus, pancreases and duodenum of broiler fed on diets, containing graded levels (0, 10 and 20%) of RFSB. These organs were not either affected by pelleted or non-pelleted diets too.

4.6. Mortality and Culling

Only 4 birds were died and the other 10 birds were also purposely culled during entire experimental periods. , which was totally 3.4%. The 10 birds were culled due to severe leg weakness. Apart from the birds culled or found dead, no health problems were observed.

Table 9. Influence of diets, containing graded levels of raw full-fat soybean (RFSB) and feed forms on carcass yield and cut parts (g/bird)

Feed form	RFSB (%)	BW/bird	Dressed %	Eviscerated %	Drumstick	Thigh	Breast
Pelleted	0	2192.50	86	70.25	213.50	238.50	498.00
	10	2214.50	88	73.75	207.50	289.25	490.25
	20	2271.25	88.3	75.25	214.00	271.75	504.00
Non-pelleted	0	2070.25	91.5	74.75	202.25	253.50	473.75
	10	2160.00	87.3	74.25	200.50	254.00	490.50
	20	2038.00	89.3	75.25	204.25	248.00	467.00
SEM		57.6	44.13	42.05	5.78	8.22	11.05
Main effects							
RFSB level (%)	0	2131.38	88.75	72.5	207.88	246.0	485.88
	10	2187.25	87.63	74	204.0	271.63	490.38
	20	2154.63	88.75	75.25	209.13	259.88	485.5
Feed form	Pelleted	2226.08	87.42	73.08	211.67	266.5	497.42
	Non-pelleted	2089.42	89.33	74.75	202.33	251.83	477.08
Source of variation				P-value			
RFSB (%)		0.924	0.971	0.730	0.932	0.460	0.980
Feed form		0.251	0.325	0.384	0.430	0.384	0.370
RFSB X Feed form		0.817	0.669	0.621	0.988	0.442	0.786

RFSB (%) = Level of Raw full-fat soybean (SBM was replaced by RFSB at 0, 10 and 20%, equivalent to 0, 30 and 60 g/kg of diet, respectively); SEM = pooled standard error of means, BW = body weight. Two (one male and one female) per replicate and totally eight birds per a treatment were randomly selected and scarified in testing effects of test-diets on the carcass characteristics.

Table 10. Influence of diets, containing graded levels of raw full-fat soybean and feed-forms on development of internal organs (g/bird)

Feed form	RFSB (%)	Heart	Liver	S+L	G+P	P+D
Pelleted	0	11.50	52.75	66.50	88.25	25.00
	10	10.25	46.75	63.75	85.75	25.00
	20	11.50	52.75	63.25	83.50	24.50
Non-pelleted	0	10.25	47.25	65.50	83.25	27.00
	10	10.50	45.50	62.25	76.25	25.25
	20	10.00	51.25	55.50	80.25	24.50
SEM		0.299	1.494	2.228	2.018	0.650
Main effect						
RFSB level (%)	0	10.88	50.0	66.0	85.75	26.0
	10	10.38	46.13	63.0	81.0	25.13
	20	10.75	52.0	59.38	81.88	24.5
Feed form						
Pelleted		11.08	50.75	64.5	85.83	24.83
Non-pelleted		10.25	48.0	61.08	79.92	25.58
Source of variation				P-value		
RFSB (%)		0.779	0.289	0.492	0.601	0.646
Feed form		0.180	0.370	0.453	0.160	0.571
RFSB X Feed form		0.449	0.811	0.791	0.810	0.794

RFSB (%) = Level of Raw full-fat soybean (SBM was replaced by RFSB at 0, 10 and 20%, equivalent to 0, 30 and 60 g/kg of diet, respectively); SEM= pooled standard error of means. G+P= Gizzard + Proventriculus, P+D= Pancrease + Duodenum, S+L= Small + Large Intestines. Two (one male and one female) per replicate and totally eight birds per a treatment were randomly selected and scarified in testing effects of test-diets on internal organ developments. Digesta content was not emptied from intestines, gizzard or duodenium.

5. DISCUSSIONS

5.1.Gross Response of Broiler Chickens

There was no significant difference in the FI, BWG, BW and FCR of birds fed diets, containing a leveled RFSB supplementation at the starter phase. In agreement with Erdaw *et al*. (2017a) who reported that broilers aged from day 1 to 10 that consumed up to 20% (60g/ kg) showed no significant difference in FI. In contrary to this, the same authors reported that, as level of RFSB increased from 0 to 75 g/kg, the BWG and feed efficiency reduced. In line with the finding of Rada *et al.* (2017) broilers fed raw full-fat soybean up to 4, 8 and 12 % equivalent of 40, 80 and 120g/kg body weight were not significantly influenced up to 10 days of age. Though it was not statistically significant similar trends was observed in this current study, as the level of RFSB increases from 10 to 20% in diets, the feed efficiency was reduced and body weight gain was retarded. This is in agreement with Rada *et al.* (2017) and Erdaw *et al.,* (2017a) who reported that broilers aged from day 0 to 10 consumed increased level of RFSB showed significant reduction in feed efficiency. The depressed performance observed for broiler chicks suggest that younger birds are more susceptible to the effects of trypsin inhibitors (Perez-Maldonado *et al.,* 2003).

In grower phase, FI, BWG, FCR and BW were not affected by an increased level of RFSB in the diets. This is in contrary to Rada *et al*. (2017) who reported that as RFSB increases to 12% the body weight can be reduced. In agreement with Erdaw *et al*. (2017a) increasing the level of RFSB in the current diets did not affect FI, BWG and FCR, during 1 to 28 d of age. Similar findings were also reported by Al-Sardary (2010) and Rada *et al.* (2017). However, the feed form significantly influenced the BWG, BW and FCR of this study that was birds fed on non-pelleted diets were superior than those on pelleted ones. In most cases the birds that fed on pelleted diet gained superior body weight and improved feed efficiency (Dozier *et al.,* 2010). But, the variation in this finding might be happened due to a non-gradual shifting of birds from mash-form of diets to pelleted-ones which might contributed for the reduced FI. In addition, it might be due to the poor quality of the pelleted diets (Dozier *et al.,* 2010; Lilly *et al.,* 2011; Ahmed and Abbas, 2013; Erdaw *et al.,* 2017d) .This is supported by Sibanda and Ruhnke (2017) who

reported that the nutritional quality of pellets can be significantly influenced by the duration and temperature of heat exposure. Abdollahi *et al.* (2013) also reported that due to the heat, moisture and mechanical pressure applied during conditioning and pelleting, some chemical and physical alterations occur that may have beneficial or detrimental effects on feed components, gastrointestinal development and subsequent bird performance. Similarly, under-processing or over-heating had an effect on broiler performances (Perez-Maldonado *et al.*, 2003).

The FI, BWG and BW were influenced, in grower stage by the interaction effects between the feed form and level of RFSB supplementation. But, this is in disagreement with the reports of Erdaw *et al*. (2017d) that there was no interaction effect between RFSB and pelleting methods on the FI, BWG, or FCR of birds to 14 days of age. Birds consumed diets, containing 20% RFSB in the form of the pelleted had higher feed intake and gained more weight than those on non-pelleted diets. Under-processing will be associated with incomplete inactivation of anti-nutritional factors, insufficient starch gelatinisation and inadequate protein denaturation, whilst over-processing can result in the formation of Maillard reaction products, and inactivation of supplemental enzymes and vitamins (Abdollahi *et al.*, 2013).

The FI at finisher stage was influenced by fed form. Birds that fed the pelleted diet consumed more than those on the non-pelleted. This result might be supported by Lilly *et al.* (2011) and Chehraghi *et al*. (2013) who reported that the highest FI was observed in birds fed on pelleted diets and the lowest FI was observed in crumble and mash group. Improved feed efficiency and better performance can often be observed when feeding processed diets compared to the mash form (Sibanda and Ruhnke, 2017). As reported by Abdollahi *et al*. (2013) pelleted diets to enhance the economics of production by increasing the FI, and thus growth performance and feed efficiency. In line with this, Erdaw *et al*. (2017d) reported that birds consumed more amounts of non-steam-pelleted feed and also gained more weight than birds fed on steam-pelleted ones of the same diets**.** However, BWG, FCR and BW at finisher phase were not significantly affected by level of RFSB supplementations and feed form. In agreement with this, scholars (Al-Sardary, 2010; Ahmed and Abbas, 2013; Erdaw *et al.*, 2017a; Erdaw *et al.*, 2017d) similarly reported on effects of feed forms. In agreement with the current finding Rada *et al*. (2017) reported that RFSB up to 8 % (80g/kg) could be used in the broiler diets without having a

significantly negative effect on the growth rate and FCR. Similarly Erdaw *et al.* (2018) suggested that commercial SBM could be replaced by RFSB up to 25 % (75 g/kg) in broiler diets with microbial protease and phytase supplementation. Study showed that growth rate and FCR were negatively influenced when 12 % (120g/kg) of RFSB were included in the diet (Rada *et al*., 2017).

5.2. Carcass Characteristics and Visceral Organs Development

There was no significant difference on the slaughter, dressed, eviscerated weights and weight of carcass cuts, including drumstick, thighs and breasts of birds fed on pelleted and non-pelleted diets, containing 0, 10 and 20% RFSB supplementation. In agreement with Al-Sardary (2010) who reported that broilers fed up to 20 % (200g/kg) RFSB supplementation had no significant difference observed in live body weight, thigh and breasts. Similarly, Erdaw *et al*. (2017a) reported that up to 20% RFSB supplementation had no significant difference on dressed percentage, drumstick, thighs and breasts. Rocha *et al*. (2014) reported also that up to 15% RFFS (equivalent of 150g/kg diet) supplementation did not affect the live weight of birds.

There was no significant difference on the development of visceral organs such as heart, liver, small and large intestine, gizzard and proventriculus, pancreases and duodenum of broilers fed on pelleted or non-pelleted diets, containing graded levels of RFSB supplementation. There were no significant differences on weights of heart, gizzard and liver was observed on broilers fed on pelleted or mash diets (Ahmed and Abbas, 2013). Though not statistically significant, broilers fed on non-pelleted diets with RFSB showed heavier weights of pancreases and duodenum than those on the pelleted ones. In agreement with this finding, Rocha *et al*. (2014) reported also that broilers fed on diets, containing up to 15% (equivalent of 150 g/kg) RFSB had heavier pancreas weight at 21 d of age. Similarly, (Erdaw *et al*. 2017b; Erdaw *et al* 2017d) reported that by increasing the levels of RFSB supplementations, in diets, it increased the weights of the pancreas at d 10, d 24, and d 35. Rada *et al*. (2017) also confirmed that broiler fed 4, 8 and 12% RFSB showed heavier pancreases weight.

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

It could be concluded that broiler chickens fed on diets, containing 0, 10 and 20% RFSB supplementation had no effects on FI, BWG, BW, FCR, during the starter phase. Similarly, in grower phase, level of RFSB supplementation had no effect on FI, BW, BWG and FCR. However, the BWG and FI were affected by the interaction effects of feed form and by a graded level of RFSB supplementations on diets, at grower phase. The birds that consumed diet containing 20% RFSB in the form of the pelleted had higher FI and BWG than the non-pelleted ones. The FCR was also significantly different between birds fed pelleted and non-pelleted ration. The FI, at finisher phase was influenced by fed form. However, BWG, BW, FCR were not significantly affected by level RFSB and feed form. The dressed, eviscerated, carcass-cuts and weights of visceral organ developments were not affected by inclusion of a levelled RFSB as well as the diet forms. In general, it is possible to replace the commercial SBM by locally produced RFSB, up to 20% without need of pelleting the diet.

6.2. Recommendations

- Based on the result of the present study it can be recommended that commercial SBM can be replaced, up to 20% by locally produced RFSB, which is relatively cheaper.
- It is recommended that locally produced RFSB (≤20%) can be used in broiler diets, without pelleting.

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8. APPENDICES

Appendix A. Photos taken during the experimental periods



Figure 1. House preparation and cleaning



Figure 2. At the time of feed preparation



Figure 3. Form of feeds and routine farm activity during experiment



Figure 4. During chick arrival and time of rearing



Figure 5. Cobb 500 broiler Male(left) and Female(right) before slaughter



Figure 6. Dressed and carcass cut parts



Figure 7. Live body weight and carcass measurement