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ADDIS ABABA UNIVERSITY

COLLEGE OF VETERINARY MEDICINE AND AGRICULTURE

DEPARTMENT OF ANIMAL PRODUCTION STUDIES

EVALUATION OF THE FEEDING VALUE OF SORGHUM (*Sorghum bicolor* L.) ON GROWTH PERFORMANCE AND CARCASS CHARACHTERSTICS OF COBB-500 CHICKENS

MSc THESIS

HANA TADESSE KEBEDE

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BISHOFTU, ETHIOPIA

EVALUATION OF THE FEEDING VALUE OF SORGHUM (*Sorghum bicolor* L.) ON GROWTH PERFORMANCE AND CARCASS CHARACHTERSTICS OF COBB-500 CHICKENS

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

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

By
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As MSc research advisors, we hereby certify that we have read and evaluated this Thesis prepared under our guidance by **Hana Tadesse Kebede** title: **Evaluation of the Feeding Value of Sorghum (*Sorghum bicolor* L.) on Growth Performance and Carcass Characteristics of Broiler Chicken**, we recommend that it can be submitted as fulfilling the MSc Thesis requirement.

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As members of the Examining Board of the final MSc open defense, we certify that we have read and evaluated the Thesis prepared by: **Hana Tadesse Kebede** Entitled "**Evaluation of the Feeding Value of Sorghum (*Sorghum bicolor* L.) On Growth Performance and Carcass Characteristics of Cobb-500 Chickens**" and recommend that it can be accepted as fulfilling the Thesis requirement for the degree of Masters of Science in **Animal Production Studies**.

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DEDICATION

This Thesis is dedicated to my beloved families, my husband Mr. Tewodros Fekadu for his love, encouragement and moral support throughout my life, my daughter Hasset Tewodros and my son Nathan Tewodros for their unreserved love.

STATEMENT OF THE AUTHOR

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

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BIOGRAPHICAL SKETCH

The author was born on Feb 29, 1994 G.C in Addis Ababa, Ethiopia. She attended her elementary education in Tesfakokeb elementary School and her secondary and preparatory education in Addis Ketema Secondary and Preparatory School in Addis Ababa. She completed her Bachelor of Science Degree in Animal, Rangeland and Wildlife Sciences from Mekelle University in 2013 G.C.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDICES

LIST OF FIGURES

LIST OF ACRONYMS

ADG	Average Daily Gain
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemist
BW	Body Weight
CF	Crude Fibre
CSA	Central Statistics Agency
DZARC	Debre Zeit Agricultural Research Centre
EE	Ether Extract
FAO	Food and Agricultural Organization
FCR	Feed Conversion Ratio
MARC	Melkassa Agricultural Research Centre
SAS	Statistical Analysis Software
SEM	Standard Error of Mean
SVM	Sorghum Variety Melkam

ABSTRACT

A feeding trial was conducted to evaluate the feeding value of sorghum (Sorghum bicolor L.) on the feed intake, growth performance and carcass characteristics of Cobb-500 chickens at Debre Zeit Agricultural Research Center (DZARC). The experiment was conducted for 56 days. The experimental diets were formulated containing (0, 20, 30, 40 and 50%) sorghum variety Melkam (SVM) for T_1, T_2, T_3, T_4 and T_5, respectively. A total of 210 un-sexed day-old Cobb-500 broiler chicks were randomly allocated to the five dietary treatments. Chemical compositions of feed ingredients were analyzed and body weight (BW), feed intake, carcass characteristics, meat quality parameters and mortality rate were measured and recorded. Feed conversion ratio (FCR) and BW changes were calculated from feed intake and BW. The results indicated that inclusion of SVM in to the broiler diet didn't bring a significant change on the feed intake, BW gain and FCR of chickens in the starter phase (0-21 days of age). However, significant differences ($P<0.05$) were observed among the treatments in FCR, average daily BW gain (ADG) and BW change of broiler chickens in the finisher phase (22-56 days of age). The FCR and BW change–were increased in a diet containing high level (40 and 50%) of SVM. The carcass yield, weight of vital organs and cut up parts of broiler chicken did not differ ($P>0.05$) significantly due to variations of sorghum level in the diet. There was a significant ($P<0.05$) difference among all the treatment groups in economic analysis. There was significant ($P<0.05$) difference in net income (NI) between treatments, and the highest net profit per bird was found on a broiler diet containing 50% SVM. From this study it can be concluded that SVM could be economically and safely included in to the broiler diets up to 50% as alternative energy source to maize.

Keywords: Broiler chicken, Carcass characteristics, Feed intake, Growth performance, Sorghum.

1. INTRODUCTION

Poultry plays a significant role in cultural and social benefits; and family nutrition. It is an important economic activity in Ethiopia which serves as a source of income and creating employment opportunities especially to smallholder farmers (Milkias, 2016; Tolasa, 2021). Cost of feed in poultry production accounts for more than 75% of the total cost of production (Mohamed *et al.,* 2015). The industry has suffered as a result of shortage of feed supply and an ever-increasing price of feed ingredients. The most essential and expensive nutrient in poultry ration is energy feedstuffs and under normal condition birds eat to fulfill their energy needs as a result feed's energy content in the diet is important because it governs the feed intake of birds.

Cereal grains are the major source of energy in poultry diets (Masenya *et al.*, 2021). However, most energy-feed ingredients that improve chickens' performance and health are becoming scarce and expensive for use in chicken production due to strong competition by industries and humans. From cereals, maize is an important source of energy in poultry feeds and accounts for about 50-70% of poultry ration (Prakash, 2013). However, an increasing demand of maize for livestock feeds, human consumption and some industrial uses has pushed its market price to an alarming height (Yami, *et al.,* 2020). Because of its relatively higher moisture requirement for growth the use of maize in drier areas in most part of the country may be limited in the future. The situation, therefore, requires research interest in sourcing alternative and locally available energy feedstuffs in poultry feeds. One of such alternatives is sorghum grain.

Sorghum is an important cereal crop that can play a key role in animal feeds and nutrition (Awika *et al*. 2015). It is drought tolerant and grows effectively on relatively poor soils with lower moisture conditions and can give a sustainable yield in the rain and dry seasons. The adaptive agronomic characteristics of sorghum make it suitable for cultivation in different environmental conditions (Hadebe *et al.,* 2017).

According to Daramola *et al.* (2019) the metabolizeable energy (ME) and crude protein content (CP) of sorghum is 3264 kcal/kg dry matter (DM) and 10.4%, respectively, which are comparable with maize (3319 kcal/kg DM of ME and 10.4% CP). It is also reported that sorghum has 94.3% DM, 13.03% CP, 2.94% Ether Extract (EE), and 3.59% Crude Fiber (CF) (Mohammed *et al.*, 2013). The percent of total ash (1.2) and Crude Fat (7.8) are higher than that of maize (1% ash and 5.5% CF) and cost wise Sorghum is also relatively with comparable price to that of maize compared to other cereals like wheat. Sorghum has better amino acid profile and comparable digestibility to that of maize (Dechassa *et al.*, 2020). All nutritional properties make sorghum grain a spotlight for better production and utilization as an important feed for poultry. Sorghum grain is probably the next alternative to maize in poultry feeding (Masenya *et al.*, 2021). Therefore, the overall objective of this study was to evaluate the feeding value of sorghum variety (Melkam) in broiler diets with the following objectives:

- To evaluate the effect of different levels of Sorghum on growth performance and feed utilization efficiency of Cobb-500 chickens,
- To assess the effect of different levels of Sorghum on the carcass characteristics of Cobb-500 chickens; and,
- To evaluate the economic efficiency of the inclusion of Sorghum in the diet of broiler chickens.

2. LITERATURE REVIEW

2.1. Sorghum Production in Ethiopia

Ethiopia is the third largest sorghum producer in Africa next to Nigeria and Sudan (FAO, 2017). The country is often regarded as the center of domestication for sorghum due to the highest genetic diversity of the country (Fetene, 2014). In the country, sorghum is also the third most important crop in production and area of coverage following *Teff* and Maize. The country 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) only kafir is not grown in Ethiopia (CSA, 2017).

Currently, sorghum production in Ethiopia is estimated to be 4.6 million metric tons from nearly 2 million hectares of land and produced by 5 million farmers. The national average grain yield of sorghum is around 2.3 tons per hectare (CSA, 2021). It accounts around 14.58% area covered by cereals and 16% of the total area allocated to grains (CSA, 2021). It grows in between 400 m and 2500 m altitude, mostly at lower altitudes along the country's Western, South-Western, North Eastern, Northern and Eastern peripheries (EIAR, 2014). The crop is staple food on which the lives of millions of poor Ethiopians depend (Adugna, 2014). Important characteristic reported from the Ethiopian sorghum varieties include drought and cold tolerance, disease, pest and grain mold resistance, good grain quality and also high lysine and protein content (EIAR, 2014).

In global sorghum breeding program, Ethiopia serves as sorghum genetic resource reservoir ranking first among countries that have contributed sorghum collections at the International Crops Research Institute for the Semi-Arid Tropics (ICRISA). Since today, in Ethiopia, considerable sorghum breeding progress has been made in germplasm collection, developing variety, screening germplasm for resistance to disease, insect, drought and striga and identification source of resistant in germplasm. Currently sorghum breeding program in the country focused on local landraces improvement and evaluating high yielder early maturing varieties introduced materials that can escape drought in the dry lowlands. For the last four decades, about 49 improved sorghum varieties with various desirable characteristics were released to the four major agro ecologies of Ethiopia (Chemeda, 2018).

2.2. Nutrient Composition of Sorghum

In reference to the work of Salissou (2014), the crude protein content (% CP) of sorghum (11) is a little higher than maize (8.4) but comparable to wheat (12.1). Sorghum has high tryptophan content but low levels of lysine when it's compared to maize. Sorghum has a comparable amino acid digestibility with maize (Salissou, 2014). Sorghum contains about 2.5% - 3.4% CF, 10.4% CP, and 3264 kcal/kg ME (Daramola *et al.,* 2019). According to Mohammed *et al.* (2013) sorghum has about 94.3% DM, 13.03% CP, 2.94% EE and 3.59% CF. On the other hand, the low tannin sorghum (1.23% tannin) contains 3214 kcal/kg DM ME and the CP contents of sorghum are in the range between 10.83 to 12.79%, 3.52 to 4.23% EE and 2.16 to 3.02% CF as reported by Medugu *et al.* (2014) and Abah *et al*. (2020). The mineral composition of sorghum is similar to millet, lower than wheat and higher than maize and contains also higher amount of phosphorus and potassium (Jocelyne *et al.,* 2020).

Nutritionally, sorghum has high carbohydrate content in the 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 high-fat content than wheat but, it is lower than that of maize (Jimoh and Abdullahi, 2017). Sorghum grain has high level of phytase in addition to minerals. The enzymatic degradation of phytase increases the 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 pollution in the environment (Oatway *et al.,* 2014).

The nutritional properties of sorghum are variety dependent and unique. Some varieties contain tannins as natural antioxidants and polyphenols (Dykes and Rooney, 2016). Sorghum has vital content of dietary fiber, fat-soluble B vitamins, and minerals (Dechassa *et al.,* 2020). The amount of yellow xanthophylls that is needed for skin coloration for broilers found in sorghum is lower than the amount of yellow xanthophylls found in Maize. Areas where a lighter meat product is preferred by the customer sorghum may be used to reduce yellow carcass color for marketing advantage (Salissou, 2014). The chemical composition of sorghum is mainly affected by climate, soil conditions and fertilizers. For example, high nitrogen fertilizer level increases the grains protein content and decreases the amount of starch in the grain (Masenya *et al.,* 2021).

2.3. The Potential Use of Sorghum as Broiler Feed

Broilers chickens play a significant role in the provision of animal protein required by human to meet his daily protein intake (Lakurbe *et al*., 2019). Broilers have high growth rate, high feed conversion ratio and also short generation interval (Kralik *et al.,* 2017) 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 (Kralik *et al*., 2017) Poultry meat is nutritious, tender, juicy, tasty and generally appealing and accepted when processed (Omole *et al.,* 2016).

When we considered any ingredient for use in broiler diets several factors need to be considered to determine the potential of a feed. These include growth performance, feed utilization efficiency and meat quality. In poultry feeding, sorghum grain is the next alternative feed ingredient to maize when considering the nutritional value, cost, and availability (Ravindran, 2014: Hassan *et al.,* 2021). According to Rajasekher *et al.* (2015), without affecting the body performance of bird's, sorghum can replace maize in poultry feed. Kumar *et al.* (2017) reported that feeding red sorghum-based diet to broiler chicken with a tannin content of 16 g/kg did not have any negative influence on the feed utilization, blood biochemistry and gross pathological changes even at 100% replacement of maize. However, when the tannin content is higher than 23 g/kg, it would have a negative effect on the immunity of the chickens. The development of low tannin sorghum could raise its value to comparable levels with maize in the poultry diet.

The primary reason for including sorghum in to broilers diet is its high energy concentration which is mainly derived from its starch component (Truong *et al.*, 2017; Ahiwe, *et al*., 2018). However, the utilization of starch/energy in sorghum by poultry is suboptimal. The digestibility of sorghum starch is inferior to that of maize (Liu *et al*., 2016). The 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.

2.4. Digestibility of Sorghum

The digestibility of cereals greatly depends on genetic background. Because of resistance to digestive enzymes of the hard peripheral endosperm layer, sorghum has the lowest starch digestibility. Variations exist among sorghum cultivars, especially those low in tannin which have the same digestibility with maize. There are also large differences between animal species in their capacity to digest cereal starch (Rowe *et al.,* 2014). Even though, within species, age differences also affect the digestibility of feedstuff. The digestibility of sorghum starch across the whole digestive tract of poultry is 99% (Rowe *et al.*, 2014). The actual dietary energy content of any feedstuff depends on its chemical composition since all organic components have an energy-yielding value.

Sorghum 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 been reported in cooked sorghum flours compared to normal maize flour. Both *in vitro* and *in vivo* studies have wide variability in protein digestibility of sorghum varieties (Rowe *et al.*, 2014). In some sorghum varieties, the presence of condensed tannins in the grains is another factor that affects amino acid availability and protein digestibility. When sorghum is cooked its protein digestibility will be lower because of cooking reduced the solubility and digestibility of prolamin and pepsin, receptively. Germinating/malting/of sorghum improves its protein digestibility and reduced the anti-nutritional factor called phytic acid (Elkhalil *et al.,* 2014).

2.5. Limitations in the Use of Sorghum in Poultry Ration

Sorghum contains anti-nutrient compounds, such as tannins and phytic acid that lowers its palatability, protein utilization, and activity of digestive enzymes by non-ruminants (Medugu *et al.,* 2014; Masenya *et al.,* 2021). There is diversity in chemical composition and anti-nutritional factors mainly tannin in different varieties of sorghum resulting in variability in digestibility (Gadzama *et al.,* 2017). Tannins have different biological effects on animal nutrition because of their ability to chelate metal ions, form complexes with macromolecules, and act as antioxidants. They can 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 insulin responses and increase the fecal fat excretion. Tannins also affect the absorption of trace minerals by forming insoluble complexes in the gastrointestinal tract (Mamiro *et al.*, 2015).

Tannins are well known as anti-nutritive factors that hinder the utilization of feeds by mono-gastric animals especially poultry. Tannin's depressed growth rate reduced palatability and feed utilization by forming complexes with proteins and carbohydrates or inhibition of digestive enzymes. Unlike ruminant animals, poultry does 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. A wider range of factors may be involved in regulating the effect of tannins on poultry (Mabelebele *et al.*, 2015).

Hassan, *et al.* (2017) showed that tannin content of 16 g/kg in red sorghum did not affect 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 contained sorghum varieties had low amino acid digestibility and ME 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 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 (Yasin., 2021).

Digestibility and utilization of absorbed nutrients may be reduced by 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 (Nauman *et al.*, 2017). Phytase is also another anti-nutritive factor in poultry diets and sorghum contains phytase at relative and absolute concentrations that are usually higher than other cereal grains (Rooney *et al.*, 2016). The inclusion of Phytase-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 Phytase. 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 gelatinization temperatures in sorghums with lesser concentrations of kafirin and phenolic compounds (Peter *et al*., 2018).

2.6. Mechanisms to Enhance the Nutritional Value of Sorghum

There are different methods to reduce the anti-nutritional factors in Sorghum grain: mechanical, chemical and breeding are among the major techniques to produce low tannin sorghum grain.

2.6.1. Mechanical methods

Grinding and hydro-thermal processing

Grinding grains before mixing into diets can improve the feed homogeneity, increase surface area for enzymatic degradation, and reduce selective feeding. In the chicken industry, cereal grains are usually ground through a hammer mill equipped with screens having openings of 4 to 5 mm (Behnke, 2015). The temperature at which sorghum starch gelatinizes (68 to 78 ºC) 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 90 ºC) may induce the honeycomb 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.*, 2014). Rogers *et al.*, (2015) reported also the whole sorghum can be added to poultry rations without negatively affecting growth.

Biggs and Parsons (2015) fed rations containing 10 and 20% whole sorghum and the birds at three weeks performed well as compared to 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.*, 2015).

Dehulling

Dehulling is other processing method that reduces the tannin content in non-conventional legumes and cereal grains like sorghum. Dehulling process removes the seed coat, which has high crude fiber and often contains pigments as well as anti-nutritional elements. Dehulling sorghum seeds and soaking treatments are needed to reduce the undesirable properties of the seeds and improve the feed quality of sorghum. Dehulling can be done before or after soaking the seeds in water. Dehulling is essential for increasing the usability of sorghum flour as food. Dehulling is carried out in combination with soaking and particle size fractionation to produce sorghum flour with superior characteristics (Antarlina *et al.*, 2021).

Germination

Germination has been documented to be an effective treatment to remove or reduce anti-nutritional factors in feedstuffs. Torki and Farahmand (2014) reported that germinated Sorghum grain is a better alternative for maize than intact Sorghum grain since the total phenolic compounds in sorghum grain decreased upon germination. Toasting/roasting involves dry heat treatment of sorghum. It has been reported to reduce the anti-nutritional factors which are associated with growth retardation in chickens. Animasha *et al.* (2019) reported that the inclusion of roasted sorghum was increased broiler chicken performance.

2.6.2. Chemical methods

Use of enzyme and wood ash are the most common chemical processing methods in sorghum to reduce the tannin content. Addition of enzyme to the diet of poultry may decrease the impact of anti-nutritional factors and enhances the nutrient digestibility (Choct, 2016). Supplementation of feeds for broiler chickens with phytase has improved growth, phosphorus utilization and decreased mortality (Ravindran *et al.,* 2014; Oyango *et al.,* 2015). Selle *et al.,* (2016) reported also addition of Phytase enzyme preps on sorghum-based diets improved weight gain, amino acid, starch digestibility, and broiler performance. Adding enzymes to the diet of poultry depends on many factors, including the type and amount of cereal in the diet; the level of an anti-nutritive factor in the cereal, concentration of enzymes used; the type of bird and their age (Choct, 2016).

Wood ash is an alkaline substance used to reduce tannins in red sorghum, 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 levels without lowering the nutrient content of the grain (Kyarisiima *et al.,* 2014).

2.6.3. Breeding

The higher concentrations of polyphenols, up to 10% of the grain's mass, have played a key role in Sorghum being stigmatized as having lower nutritional quality when incorporated into monogastric animals feed (Hodges *et al*., 2021). Previous studies on Sorghum have identified a diverse range of phenolics, tannins with high degrees of polymerization (Kang *et al.,* 2016). High-tannin sorghum varieties are not commonly used in mono gastric animal feed as deleterious nutritional effects have been observed in animals fed these particular grains (Nyachoti *et al.,* 2016). These negative effects have encouraged sorghum breeders to preferentially select low-tannin varieties for use in mono gastric animal feed. Sorghum grains low in tannin content, such as most red and white varieties in use today, have also been reported as having higher levels of digestible protein (Hodges *et al*., 2021). Currently, Modern feed quality sorghum grain has been bred to reduce anti-nutrients, most conspicuously condensed tannins.

2.7. Effect of Feeding Sorghum on the Growth Performance and Carcass Characteristics of Broiler Chickens

Several researchers studied the utilization of low-tannin sorghum in broiler diets. Ahmed *et al.* (2019) studied the effect of sorghum on the performance of chickens and observed a significant improvement in BW gain of the chickens fed low tannin sorghum; however, no significant difference was observed in feed conversion ratio (FCR). Similarly, Awika *et al.* (2015) reported that low-tannin sorghum has beneficial effects on poultry health due to its photochemical constituents. However, Makled and Afifi (2015) found that BW gains of chicks fed diets with low tannin sorghum did not differ significantly. In another study by Tamburawa *et al.* (2012) it was reported that high tannins content in sorghum resulted in a significant reduction in feed intake of the birds. However, the same study showed that the low-tannin sorghum had no negative effect on feed intake and it was suggested that low tannin sorghum can be used in broiler diets without any negative effects on FCR. Similarly, Reza and Edriss (2014) reported also the growth performance of the chickens was negatively influenced when fed on high-tannin sorghum.

Torres *et al.* (2013) reported that FCR was not significantly affected when yellow corn was replaced with low-tannin sorghum at a ratio of 50% in broiler diets. It was also reported by Ahmed *et al.* (2019) that replacing yellow corn with low-tannin sorghum had no significant effect on muscle and organ weights except abdominal fat weight which was significantly increased by replacing 50% yellow corn with sorghum. Similarly, Kumar *et al.* (2017) reported that carcass and breast muscle weights were not influenced by different low tannin red sorghum levels in broiler diets. Torres *et al.* (2013) found that feeding sorghum diets did not affect the villus height and crypt depth.

According to Reyes Sanchez *et al.* (2016) slaughter weight and carcass weight were negatively affected by increased tannin concentration in a sorghum-containing diet. However contrary to this finding some other scholars reported that birds fed high tannin had higher slaughter weight and carcass weight than those fed low tannin sorghum varieties. This contradiction could be attributed to the inconsistencies seen in the performance parameters. Muchenje *et al*. (2021) reported that replacing maize grain with sorghum did not affect the meat quality parameters, except for breast meat, which was highest in the whole sorghum group and lowest in the crushed millet group. Similar results were reported by Mancini *et al.* (2015) replacing maize grain with sorghum grain promoted similar meat lightness values. Lightness is a good indicator of the freshness of meat and has a direct influence on the final purchase decision of consumers.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The present experiment was conducted at Debre Zeit Agricultural Research Center (DZARC), poultry research farm, which is located at about 47 km east of Addis Ababa, Ethiopia. It is found at an altitude of 1920 m.a.s.l and latitude of 8°44’ N and longitude of 38°38’E. The area has a mean annual rainfall of 892 mm and mean temperature of 25°C. The relative humidity ranges from 48% to 68% (DZARC, 2013).

3.2. Experimental Ration and Treatments

Table 1: Chemical composition of the feed ingredients used in the present experiment

	Parameters							
Ingredients (%)	**DM**	**CP**	**EE**	**CF**	**ASH**	**Ca**	**P**	**ME (Kcal/kg)**
Maize	89.70	9.00	4.07	3.54	1.51	0.182	0.3	3325
Nougseed cake	85.76	32.00	8.03	22.26	5.49	0.26	0.65	2650
SVM	90.21	12.80	3.64	3.36	1.42	0.04	0.32	3793
Wheat middling	90.20	15.60	0.32	9.20	4.5	0.11	1.15	2515
Soybean Meal	91.48	42.29	1.92	3.79	4.42	6.22	0.7	2461
Maize middling	90.09	9.62	13.50	6.13		0.05	0.04	3777
MBM	95.78	43.00	15.6	3.54	32.64	7.8	64.2	2750

CP: crude protein, DM: dry matter, EE: ether extract, CF: crude fiber, MBM: meat and bone meal, ME: Metabolizeable energy in kcal per kg of DM, SVM: Sorghum variety melkam

Chemical composition of the major feed ingredients (Table 1) was determined from representative samples of maize, wheat middling, soybean meal (SBM), Sorghum variety Melkam (SVM), Nougseed cake, maize middling and meat and bone meal. Based on the chemical analysis result, five treatment rations containing SVM at levels of 0 (T_1), 20 (T_2), 30 (T_3), 40 (T_4) and 50% (T_5) inclusion in the total ration were formulated. The rations were formulated to be nearly iso-caloric and iso-nitrogenous (Table 2) with metabolizeable energy (ME) content of 3000 kcal/kg, DM and crude protein (CP) content of 22% during the starter phase of 1 to 21 days of age and ME content of 3200 kcal/kg DM and CP content of 20% for finisher phase of 22 to 56 days of age (Leeson and Summers, 2005).

The feed ingredients used in the formulation of the different experimental rations were maize, wheat middling, SBM, SVM, Nougseed cake, maize middling, meat and bone meal, vitamin-mineral premix, salt, limestone, lysine and methionine. All the feed ingredients except SVM were purchased from the nearby market and SVM was purchased from the niche area Fedis.

The proportion of ingredients used in formulating broiler starter and finisher rations are presented in Table 2.

Table 2: **Proportion of ingredients used in formulating broiler starter and finisher rations**

Ingredients (%)	**Starter Diets**					**Finisher Diets**				
	T_1	**T_2**	**T_3**	**T_4**	**T_5**	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**
Maize	41.00	20.00	10.00	8.00	3.00	42.80	34.50	25.00	15.00	3.00
Nougseed Cake	8.00	5.20	5.00	6.00	6.00	2.00	1.65	2.00	2.00	6.00
SVM	0.00	20.00	30.00	40.00	50.00	0.00	20.00	30.00	40.00	50.00
Wheat Middling	8.40	8.00	9.00	5.90	6.00	5.00	1.85	3.00	2.00	6.00
Soybean Meal	21.20	22.00	21.50	22.00	18.00	20.00	18.65	16.50	17.52	18.00
Maize middling	14.00	17.00	16.50	11.00	9.00	22.50	15.00	14.50	15.00	9.00
MBM	5.40	6.00	6.00	5.00	6.10	5.75	6.45	7.00	6.00	6.10
Limestone	0.65	0.55	0.65	0.70	0.50	0.75	0.60	0.60	0.68	0.50
Salt	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
DL-Methionine	0.15	0.10	0.15	0.20	0.20	0.10	0.15	0.15	0.15	0.20
DL-Lysine	0.30	0.25	0.30	0.30	0.30	0.20	0.25	0.35	0.25	0.30
Premix*	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
CP (%)	20.88	21.19	21.30	21.31	21.63	18.86	18.83	18.72	18.86	18.72
ME (kcal/kg)	2856	2883	2867	2863	2891	3002	3014	3011	3012	3011

CP: crude protein; MBM: meat and bone meal; ME: Metabolizeable energy; SVM: Sorghum variety melkam; T1-T5: diets containing 0, 20, 30, 40, 50% SVM respectively; Vitamin-Mineral Premix*= 50 kg contains, Vit A 1000000 IU, Vit D3 200000 IU, Vit E 10000 mg, Vit K3 225 mg, Vit B1 125 mg, Vit B2 500 mg, Vit B3 1375 mg, Vit B6 125 mg, Vit B12 1 mg, Vit pp (Niacin) 4000000 mg, Folic acid, 100 mg, Choline chloride 37500 mg, Anti-oxidant (BTHT) 0.05%, Manganese 0.60%, Zinc 0.70%, Iron 0.45%, Copper 0.05%, Sodium 0.01%, Selenium, 0.004%, Calcium 2.7%.

3.3. Management of Experimental Chicks

Before the commencement of the actual experiment, experimental pens, watering and feeding troughs were thoroughly cleaned, disinfected and sprayed against external parasites. A total of 210, unsexed day-old Cobb-500 broiler chicks with initial body weight (BW) of 39.48±1.47 g (mean±SD) were randomly divided into five dietary treatments and three replications per treatment in a completely randomized design experiment, thus having 14 chicks per replicate or pen. The birds were vaccinated against Newcastle (HB1 at day 14 and Lasota a booster dose at day 24) and Marek’s disease at first day of age, all given through an eye drop. Other health precautions and sanitary measures were also taken throughout the study period.

The chicks were brooded using 250-Watt infrared electric bulbs with gradual height adjustment as sources of heat and florescent lump for lighting in a deep litter house covered with *Teff* straw at a depth of 7-10 cm. Feed and clean tap water was offered *ad libitum* throughout the experimental period irrespective of the treatments with a round feeder and drinker in each pen. The chicks were initially weighed and allowed to continue with the assigned experimental diets for 56 days feeding period. Chicks were vaccinated against Marek’s on the 1st day and birds were administered with anti-stress vitamins and antibiotics in a solution form after each vaccination period. Brooding temperature was kept at 32°c at the beginning of the first week and decreased gradually in subsequent weeks until it was adjusted to ambient temperature at around 21°C. The feeders and water troughs were cleaned daily.

3.4. Data Collection

3.4.1. Feed intake and growth performance

The experiment was conducted for eight weeks (from day 1 to day 56 of age) of Cobb-500 chicks during which amount of feed offered and refused per bird was recorded daily. Amount of feed consumed was calculated from the difference between the feed offered and refused. Chicks were weighed at the start to take initial BW and then every week to take weekly BW. The BW change was calculated as the difference between the final and initial BWs and average daily BW gain (ADG) was also calculated by considering the BW and the number of experimental days. Feed conversion ratio was also calculated by dividing the total feed consumption to the BW change during the whole experimental period.

FCR = Feed intake/body weight gain

3.4.2. Carcass characteristics

On the 56th days of the feeding trial, two birds (one male and one female) from each replicate were randomly selected, starved for 12 hours, weighed and slaughtered for carcass evaluation. The birds were de-feathered by inserting in boiled water. Carcass parts (thigh and drumstick, breast, wings, back), giblets (heart, liver, and gizzard) and gastrointestinal tracts with and without contents were measured. Dressed and carcass cuts, edible and non-edible offal were weighed and recorded following the procedure described (Kubena *et al.*, 1974; Kekeocha, 1985). Dressed carcass weight was determined after removing blood and feather. The dressing percentages were determined as the proportion of dressed weight and slaughter weight multiplied by 100. Drumstick, thigh and breast, wings, and back meat were separated and weighed. Fat deposition around the proventriculus, gizzard, abdominal wall and cloacae were collected and weighed. The edible offal (giblets) which includes the heart, gizzard, and liver were separately weighed. The weight of crop, proventriculus, liver, small intestinal (duodenum, jejunum and ileum), caeca, and large intestine were weighed with and without their contents.

3.4.3. Organoleptic assessment

Meat samples from breast and thigh-drumstick were evaluated for color, taste, flavor, juiciness, tenderness and overall acceptability by sixteen panelists from DZARC staff members by the procedure mentioned by Peryam and Girardot (1952). The samples were cut into pieces and wrapped individually in aluminum foil and roasted in an oven at 180°C for 15 minutes. Pieces from each sample were provided to panelists randomly in such a way that everyone got the sample from breast and thigh-drumstick. All panelists that participated in sensory evaluation had training on how to assess sensory evaluation. The trainings were done through instruction and understanding of the descriptors being used during these meat samples evaluations. Each panelist was provided with water to serve as neutralizers between the products. The samples were assessed on the 5-point hedonic scale (Excellent=5, Very good=4, Good=3, Fair=2 and Poor=1).

3.4.4. Partial economic analysis

To estimate the cost-benefit of feeding different levels of SVM, partial budget analysis was done by considering the difference between the feed consumption costs incurred to rear the chicks among the treatment diets during the experimental period and the sale of broiler meat in kg at the end of the experimental period, considering the other costs are fixed (similar) among the treatments. Net income was assumed to be the difference between the total cost of feeds incurred during the period and the total return from the sale of kg meat.

Total feed consumed per bird = total feed intake during the experimental period * cost of feed.

The marginal rate of return (MRR) which measures the increase in net income (NI) from diets with the test feed minus NI from control diet is associated with each additional unit of expenditure on feed. It is the change in total cost (ΔTC) from diets with the test feed minus TC from control diet.

$$MRR = \Delta NI/\Delta TC$$ (Miles and Jacob, 2000).

3.5. Laboratory Analysis

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

3.6. Statistical Analysis

Data were statistically analyzed using General Linear Models Procedure of the Statistical Analysis System (SAS, 2009 version 9.1.3 computer software program subjected to the analysis of variance (ANOVA). Differences between treatment means were separated using Duncan multiple range test.

The model for the data analysis was:

$$Yij = \mu + Ti + \varepsilon ij$$

Were,

Yij = individual observation,

μ = the overall mean,

Ti = Effect of i^{th} treatment,

εij = error component.

4. RESULTS

In this study, different parameters, such as feed intake, body weight gain, feed conversion ratio, average daily weight gain, carcass characteristics, sensory evaluation and partial budget analysis in broiler chickens were evaluated.

4.1. Chemical Composition of Experimental Feeds

The laboratory chemical analysis of the major feed ingredients used in this experiment is presented in Table 3.

Table 3 : **Chemical composition of major feed ingredients**

	Parameters						
Ingredients (%)	**DM**	**CP**	**EE**	**CF**	**Ca**	**P**	**ME (Kcal/kg)**
Maize	89.70	9.00	4.07	3.54	0.182	0.3	3325
Nougseed cake	85.76	32.00	8.03	22.26	0.26	0.65	2650
SVM	90.21	12.80	3.64	3.36	0.04	0.32	3793
Wheat middling	90.20	15.60	0.32	9.20	0.11	1.15	2515
Soybean Meal	91.48	42.29	1.92	3.79	6.22	0.7	2461

DM: dry matter; ME: Metabolizeable energy; CP= crude protein; CF=crude fiber; EE= ether extract; Ca= calcium; P= phosphorus; SVM: sorghum variety Melkam.

According to the proximate analysis of the current study, the ME and CP contents of SVM is 3793 kcal/kg of DM and 12.8%, respectively which is slightly higher than maize (3319 kcal/kg and 9%, respectively), which indicates that SVM to be as a good feed ingredient in replacing maize in the poultry diets formation. The energy value of SVM was higher than all major feed ingredients used in this study. The %CF of SVM for the present study was 3.36% which is a lower value than Nougseed cake (22.26%) of the same study.

Based on the result of the current study, sorghum has a good potential to be used as an alternative energy source feed in poultry diets to bridge the gap of feed shortage and also minimizing the feed cost and computation with humans.

4.2. Feed Consumption and Growth Performance

The results on the average feed intake, feed conversion ratio, body weight gain and the final body weight of the experimental chickens at the end of starter and finisher phases are presented in Table 4.

Based on the statistical analysis of the data there was no significant difference ($P>0.05$) between all the treatment groups in average daily feed intake and total feed consumption of the birds in both starter and finisher phases of the feeding trial. There were no significant ($P>0.05$) differences in FCR values between all the treatment groups during the first three weeks of the experimental period. However, during the finisher phase the FCR of the birds was significantly ($P<0.05$) influenced by inclusion of SVM in the diet. As shown in Table 4, significantly higher FCR was recorded for the groups fed on a diet with 50% SVM but, statistically similar with those groups fed a diet containing 40% of SVM during the finisher phase. The improvement in feed consumption of the groups placed on the treatment containing 40 and 50% SVM during the finishing phase might be due to adaptation to the SVM gradually with time.

The body weight of the chickens at the end of the starter phase (3 wks) and the average daily gain of the chickens were not influenced ($P>0.05$) by the inclusion of different levels of SVM in the diet. However, during the finisher phase, inclusion of varied levels of SVM on the chicken’s diet showed a significant ($P<0.05$) effect on the final BW at 56 days of age and BW gain of the chickens.

Birds which were fed on a diet containing 50% SVM were found to be heavier in live BW (2.07 kg) and higher in average daily BW gain (42.48 g) as compared to the control group and those groups fed on a diet with 20 and 30% SVM, however, statistically comparable with those groups fed on diets containing 40% of SVM. It was found that higher levels of SVM had a positive effect on the BW of the chickens in the finisher phase.

Table 4: Average feed intake (g), body weight gain (g) and feed conversion ratio of the experimental birds

Treatments	Starter (1-21 days)							Finisher (22-56 days)					
	TFI	ADFI	IBW	FBW	BWG	ADG	FCR	TFI	ADFI	FBW	BWG	ADG	FCR
T1	790	37.80	37.99	386.68	348.70	16.60	2.28	3600	103.12	1880^{b}	1490^{b}	42.58^{b}	2.81^{ab}
T2	780	37.45	37.99	376.92	328.74	15.78	2.27	3570	102.42	1840^{b}	1480^{b}	42.28^{b}	2.80^{ab}
T3	800	36.72	38.64	377.38	338.74	16.13	2.28	3570	100.27	1870^{b}	1490^{b}	42.82^{b}	2.75^{ab}
T4	840	38.55	37.95	392.38	354.43	16.88	2.29	3610	103.46	2010^{a}	1610^{a}	46.40^{a}	2.56^{bc}
T5	790	38.81	39.30	380.03	340.73	16.23	2.45	3600	102.96	2070^{a}	1690^{a}	48.48^{a}	2.12^{c}
SEM	10.14	0.93	1.30	5.56	5.51	1.25	0.02	22.9	8.80	4.52	3.93	3.21	0.03
P-Value	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	*	*	*

a-b, Means in a column having no common superscripts differ significantly ($P<0.05$); SEM: pooled standard error of mean, SVM: Sorghum variety Melkam; TFI: Total feed intake, ADFI: Average daily feed intake, ADG: Average daily gain, BWG: body weight gain, IBW: initial body weight: FBW: final body weight; FCR: Feed conversion ratio, T1-T5: diets containing 0, 20, 30, 40, 50% SVM, respectively.

4.3. Carcass Characteristics

The results on the carcass characteristics of the experimental chickens fed different levels of SVM on 56th days of the feeding trial are presented in Table 5.

Table 5: Carcass characteristics of the experimental chickens (weight in g)

Treatments	Parameters								
	Slaughter wt	Dressed wt	Dressing %	Thigh wt	Breast wt	Drumstick wt	Wing wt	Heart wt	Liver wt
T1	1940	1430	73.7	114	590	103	42	11	37
T2	2030	1570	75.3	123	650	109	43	11	41
T3	2060	1510	73.3	129	630	100	40	12	38
T4	2040	1470	72.0	130	636	102	39	9.7	45
T5	2050	1530	74.3	131	688	103	43	9.8	36
SEM	5.39	4.43	12.9	3.51	5.40	10.6	3.64	5.76	3.04
P-value	NS	NS	NS	NS	NS	NS	NS	NS	NS

SEM: pooled standard error of mean, SVM: Sorghum variety Melkam; wt: weight; T1-T5: diets containing 0, 20, 30, 40, 50% SVM respectively.

The results showed that there was no significant ($P>0.05$) difference between all the treatment groups in carcass yield and weights of different internal organs and cutup parts. This indicated that inclusion of SVM into broilers diet didn’t have an impact on the anatomical and physiological makeup of the experimental birds. Thigh and breast weight recorded from the groups fed on the treatment containing 50% SVM was numerically higher than the other groups. The results on the weights of the gastro intestinal parts of the experimental chickens are presented in Table 6.

Table 6: The weight (g) of the gastro intestinal parts of the experimental birds

Treatments	Abdominal fat (%)	Gizzard with	Gizzard without	SI with	SI with out	LI with	LI with out	Caeca	Spleen
T1	2.36^{b}	50.00	35.10	61.33	53.33	3.73	3.03	11.72	1.55
T2	2.40^{ab}	50.10	36.67	58.33	47.33	3.85	2.93	13.00	1.93
T3	2.52^{ab}	49.17	33.83	55.00	41.22	5.55	4.15	12.47	1.85
T4	2.93^{a}	47.16	33.33	52.30	43.83	4.83	3.40	11.28	2.03
T5	2.89^{a}	53.33	40.00	61.00	48.50	4.58	3.25	11.60	1.52
SEM	0.90	8.90	3.90	5.00	8.20	1.13	0.55	2.40	0.53
P-value	*	NS	NS	NS	NS	NS	NS	NS	NS

a,b, Means in a column having no common superscripts differ significantly ($P<0.05$); whereas, within the same column, values with no or same superscripts differ not significantly ($P>0.05$), SEM: pooled standard error of mean, SVM: Sorghum variety Melkam, SI: Small intestine, LI: Large intestine. T1-T5: diets containing 0, 20, 30, 40, 50% SVM, respectively.

As shown in Table 6, inclusion of SVM into broilers diet didn’t have a significant ($P>0.05$) effect on the weight of gastrointestinal parts of the chickens. However, there was a significant ($P<0.05$) difference between the treatment groups and the control group in the percentage of abdominal fat. Those groups fed a diet with no SVM had lower abdominal fat as compared to the other groups.

4.4. Sensory Evaluation

The results of the sensory test, on the roasted breast, thigh and drumstick meat are presented in Table 7 and 8, respectively.

Table 7: Sensory evaluation of the breast meat

	Parameters					
Treatments	**Colour**	**Taste**	**Flavour**	**Juiciness**	**Tenderness**	**Overall acceptability**
T1	4.25	4.25	4.38	4.25	4.25	4.62
T2	4.00	4.00	3.88	3.75	3.73	4.13
T3	3.75	3.88	3.63	3.63	3.68	3.88
T4	3.88	4.00	4.13	4.00	3.88	4.00
T5	3.50	4.00	4.13	4.25	4.37	3.88
SEM	1.11	0.79	0.90	0.81	0.72	1.21
P-value	NS	NS	NS	NS	NS	NS

SEM: pooled standard error of mean, SVM: Sorghum variety Melkam; T1-T5: diets containing 0, 20, 30, 40 and 50% SVM, respectively.

Table 8: Sensory evaluation of thigh and drumstick meat

	Parameters					
Treatments	**Colour**	**Taste**	**Flavour**	**Juiciness**	**Tenderness**	**Overall acceptability**
T1	4.25	4.38	4.25	4.25	4.25	3.75
T2	4.75	4.00	4.00	3.88	4.13	3.88
T3	4.00	4.00	3.75	4.25	4.03	3.13
T4	4.63	4.13	4.38	4.38	4.40	4.38
T5	4.25	4.38	3.88	4.25	4.10	3.63
SEM	0.56	0.59	0.38	0.61	0.20	1.79
P-value	NS	NS	NS	NS	NS	NS

SEM: pooled standard error of mean, SVM: Sorghum variety Melkam; T1-T5: diets containing 0, 20, 30, 40, 50% SVM, respectively.

The result indicated that inclusion of SVM into broiler diets at all levels in the present study didn’t have a significant (P>0.05) effect on the color, taste, flavor, juiciness, tenderness and overall acceptability of roasted breast, thigh and drumstick meat. All the treatment groups recorded grade point of >3 on the hedonic scale. The sensory test results suggest that inclusion of SVM in to broiler diets had no negative implication on consumer’s preference.

The analysis of data on mortality revealed that there was no significant (P>0.05) difference between all the treatment groups in percentage of mortality during the entire experimental period. This result indicated that the inclusion of sorghum up to 50% in to broiler diet didn’t have a negative impact on the health status and survival rate of the broiler chickens.

4.5. Partial Budget Analysis

The results of the partial budget analysis of broiler diets with varied levels of SVM based on 8 weeks of the experimental period are presented in Table 9.

Table 9: Economic analysis of including sorghum variety Melkam in to Broiler diets

	Experimental diets					
Items	T1	T2	T3	T4	T5	P-value
Feed cost (Birr/kg)	28.57	31.85	33.27	35.40	36.59	*
Feed consumed (kg)	4.40	4.35	4.37	4.44	4.39	NS
Total feed cost (Birr/bird)	125.80	138.38	145.23	157.16	160.61	*
LW at 8 wks (kg)	1.88	1.84	1.87	2.01	2.07	*
Sale of birds (Birr/kg LW)	250.00	250.00	250.00	250.00	250.00	
Total income (Birr/bird)	470.00	460.00	467.50	502.50	517.50	*
Net income (Birr/bird)	344.20	321.62	322.27	345.34	356.89	*
∆ Feed cost (Birr/bird)	-	12.58	19.43	31.36	34.81	*
∆ Total income (Birr/bird)	-	-10.00	-2.50	32.50	47.50	*
∆ Net income (Birr/bird)	-	-22.58	-21.93	1.14	12.75	*
MRR (∆NI/∆FC)	-	-1.80	-1.13	0.036	0.37	*

SVM: Sorghum variety Melkam; T1-T5: diets containing 0, 20, 30, 40, 50% SVM, respectively, LW: Live weight, MRR: Marginal rate of return, FC: Feed cost.

During the analysis, it was assumed that the cost of feed and the sale of live birds at the end of the feeding trial were the only source of costs and profits, respectively. The other costs such as purchasing of chicks, labor and transportation costs were considered as similar among all treatments. Generally, the highest feed cost per bird (160.10 Birr) was recorded on a diet containing 50% SVM and the lowest feed cost (125.80 Birr) was on the control group. There was difference in net income (NI) between treatments, and the highest net profit per bird was found on a broiler diet containing 50% SVM due to higher body weight gains.

5. DISCUSSION

5.1. Chemical Composition of Experimental Feeds

Chemical compositions of the major feed ingredients used in the present study are shown in Table 3. According to the proximate analysis of the current study, the ME and %CP contents of SVM is 3793 kcal/kg of DM and 12.8%, respectively and it was comparable with the previous findings by Medegu *et al*., 2016 (3800 kcal/kg of DM in ME and 11.6% CP) and Mohammed *et al.,* 2013 (3750 kcal/kg of DM in ME and 13.03% CP). However, the values obtained in the present study was higher than the reports of Nyamambi *et al.,* 2014 (3270 kcal/kg of DM in ME and 9.5% CP) and Daramola *et al.* (2019) (10.4% CP).

In the present study, both the energy and protein content of SVM (3793 kcal/kg of DM and 12.8%, respectively) were slightly higher than maize (3319 kcal/kg and 10.1%, respectively), which indicates that SVM to be as a good feed ingredient in replacing maize in the poultry diets formation. The energy value of SVM was higher than all major feed ingredients used in this study.

The %CF proximate chemical composition content of SVM for the present study was 3.36% which was a lower value than Nougseed cake (22.26%) of the same study but comparable with maize (3.54%) and soybean meal (3.79%). According to Sharif *et al*. (2014) SVM compositions is largely dependent on the type of sorghum and efficiency of the milling system and contain 7–11% fiber, the value of which is lower than the CF content reported from the current study. The CP content of SVM recorded from the current study was lower than that reported for the conventional Sorghum (13%) by NRC (1994). The variation in the nutritional composition of SVM in different studies may be due to variation in variety of the sorghum grain and the nature of the milling process.

Based on the result of the current study, sorghum has a good potential to be used as an alternative energy source feed in poultry diets to bridge the gap of feed shortage and also minimizing the feed cost and computation with humans. Sorghum seems to be capable of replacing larger proportion of maize energy in poultry ration. This in turn will lead to significant savings from the quantity of maize fed to poultry since maize is widely used as staple human food in Ethiopia.

5.2. Feed Consumption and Growth Performance

In this study it was observed that including sorghum at different levels to broiler diet didn't have a significant (P>0.05) effect on the feed intake of the chickens during the starter and finisher phases of the feeding trial. This suggests that the astringent effects of tannins could not impede upon the high appetite levels of broiler chickens. The preset result is in agreement with the previous findings (Mohamed *et al.*, 2015; Ukoha *et al.*, 2019; Farahat *et al.*, 2020) who observed no significant differences in feed intake of the chickens consumed varied levels of sorghum in the diet, indicating that maize can be replaced by sorghum grain without significantly affecting the chickens performance. Contrary to the present finding different researchers (Silviera *et al.*, 2017; Saleh *et al.*, 2019) reported that including sorghum grain in the diets of broiler chickens had an effect on the feed intake of chickens. The current study disagreed also with the findings of Maidala *et al.* (2016) and Masenya *et al.* (2021) who replace maize grain with whole sorghum grain that resulted in a poor overall feed intake and growth performance from weeks 3 to5 of age.

In the present study, there was no significant difference on the FCR values between all the treatment groups during the starter phase of the feeding trial, which is consistent with the previous studies by Farahat *et al.* (2020) who reported on inclusion of sorghum to broilers diet had no significant effect on the FCR of the chickens during the starter period. The present finding is also in line with the works of Torres *et al.* (2013); Mohamed *et al.* (2015) and Saleh *et al.* (2019) who reported that replacing yellow corn with low-tannin sorghum in broilers diet didn't affect the FCR of the chickens in the starter phase. However, the current findings are in disagreement with the finding of other scholars (Yunusa *et al.*, 2015; Maidala *et al.*, 2016) who reported that inclusion of sorghum in the broilers diet had a significant effect (P<0.05) on the FCR of chickens during the first three weeks.

The observed better FCR by the chickens during the finisher phase that fed SVM at inclusion levels of 40% and 50% was in agreement with reports of Shelton, (2014) and Abubakar *et al.* (2020) who observed differences in chickens that were fed a diet containing sorghum during the finishing period. The finding of the current study is contrary to the previous findings Mohamed *et al.* (2015) and Truong *et al.* (2017)) who found non-significant (P>0.05) difference among the treatments in feed conversion ratio of the chickens during the finisher phase of the experimental period.

The results obtained in the present study indicated that the BW of chickens at the end of the starter phase and the average daily gain of the chickens were not influenced by the inclusion of different levels of SVM in the diet. The absence of influence on the BW and average daily gain of chickens during the starter phase due to inclusion of different levels of SVM in the diets was in agreement with the findings of Mohamed *et al.*, (2015) who reported no significance difference in daily as well as final body weight gain of the chickens in the starter phase. Contrary to these findings Yanusa *et al.* (2015) reported that daily weight gain was significantly influenced by the dietary treatments contained different levels of sorghum in the starter phase. Medugu *et al.* (2014) replaced sorghum with maize in broiler diet and observed a significant difference in the average daily gain between dietary treatments that disagree with the present study.

However, in the present study, inclusion of varied levels of SVM on the broiler diet during the finisher phase showed an effect on the final BW of the chickens at 56 days of age and BW gain of the chickens. It was found that higher levels of SVM had a positive effect on the BW of the chickens. Birds fed on a diet containing 50% SVM in their diets had achieved the highest BW as compared to those fed a diet with lower level of SVM. This present study results were consistent with the findings of; Saleh *et al.* (2019) and Abubakar *et al.* (2020) who reported BWG and final BW of chickens was significantly improved by feeding low tannin sorghum. However, contrary to this finding other scholars (Mohamed *et al.*, 2015) investigated and reported that including sorghum to broilers diet didn’t influence the overall BW gain and final live weight of chickens in the finisher phase.

5.3. Carcass Characteristics

In carcass traits, weight of vital organs and cut up parts such as the breast, thigh and drumstick of broiler chicken did not bring a difference due to variations of sorghum levels in the diet. This indicated that inclusion of SVM into broilers diet didn’t have an impact on the anatomical and physiological makeup of the birds. The results pertaining to carcass characteristics is consistent with the previous works of Silviera *et al.* (2017) and Gheorghe *et* *al.* (2018) who reported that feeding broiler chickens with sorghum grain had no effect on the weight of organs and different carcass cut up parts of broiler chickens.

The present result is also consistent with Saleh *et al.* (2019) who reported that replacing yellow corn with low-tannin sorghum in broilers diet didn't show a significant effect on the muscle and organs weight. In a similar way of the present findings, Kumar *et al.* (2017) reported that inclusion of different levels of low tannin red sorghum in broilers diet didn't influence the carcass and breast weights of the chickens indicating that the tannin present in the diet did not exert any effect on the availability of methionine and cyteine as the breast weight is influenced by the methionine and cyteine levels in diet. However, contrary to the present finding (Gebeyew, 2015; Rachman, 2018; Masenya *et al*, 2021) reported that feeding sorghum to broiler chickens show a significant effects on the carcass characteristics and different internal organs.

In the present study, it observed that there were no change on the weight of gastrointestinal tracts (GIT) that agreed with the findings of the study conducted by Liu *et al.* (2016); Usman and Garba (2016) who reported when Cobb-500 chickens fed with sorghum based diet showed no differences in the GIT.

The average weight of gizzard did not differ among the treatment groups that fed different levels of SVM. This was in agreement with the findings of Issa *et al.* (2014) and Kumar *et al.* (2017) who observed no significant difference in liver and gizzard weights of broiler chickens when maize grain was substituted with sorghum grains. The results of current study regarding the weights of GIT was also aligned with the finding of Gebeyew (2015) who reported that the weight of the gizzard that feed sorghum showed no difference among the treatments. In contrary, Sannamani (2014) reported significantly higher weight of gizzard in broilers fed red sorghum-based diet which was attributed to lower dietary energy level on inclusion of sorghum in diet. These result also contradicts with Masenya, *et al*. (2021) who reported feeding whole sorghum grain to broilers reduced the gizzard and liver weights.

In the present study, there was differences among the dietary treatments in the percentage of abdominal fat, which is consistent with the findings of Ahmed *et al.* (2019) and Saleh *et al.* (2019) who stated that replacing yellow corn with low-tannin sorghum had significant effect on the abdominal fat, which was significantly increased in diets with 40% sorghum. The finding of the current study contradicts with the reports of Gebeyew (2015) and Al-Mashhadani *et al.* (2021) who observed no significant difference in the percentage of abdominal fat between treatments. The higher abdominal fat content of broilers fed sorghum diet as compared to the control group in the current study may be attributed by the higher energy and crude protein content of the Sorghum variety Melkam (3793 kcal/kg and 12.8%), respectively.

5.4. Sensory Evaluation

In the present study no difference was observed among all the treatment groups in color, taste, flavor, tenderness and juiciness of the roasted breast, thigh and drumstick meat. The result indicated that inclusion of SVM into broilers diet didn’t have an effect on the overall acceptability of roasted breast, thigh and drumstick meat. All the treatment groups recorded grade point of >3 on the hedonic scale. The sensory test results suggest that inclusion of SVM in to broiler diets had no negative implication on consumer’s preference.

5.5. Partial Economic Analysis

The results obtained on the partial economic analysis indicated that there was a significant difference in net income (NI) between treatments, and the highest net profit per bird was found on a broiler diet containing 50% SVM. The price of broiler diets (birr/Kg) showed proportional increment with replacement of maize with SVM in the diet of the experimental chickens but when we compare the net income from the control group, treatment that contain SVM 50 % have higher net return. The present study reveals that the inclusion of sorghum at 50% in to broilers diet is potentially more profitable than the rest of the treatments. The result of the current study is in agreement with the previous findings of Gebeyehu *et al.* (2015) reported that broiler chick fed on ration containing 45% Sorghum returned a higher profit than those groups fed on ration containing 0, 15 and 30% Sorghum. The present finding is contrary to Lakurbe *et al.*, (2018) who reported that feeding chickens a diet with sorghum decrease the cost of experimental ration.

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

The current results revealed that inclusion of sorghum in to broiler diet did not have an effect on the feed consumption, efficiency and body weight gain of chickens in the starter phase. However, significant differences were observed among treatments in feed conversion efficiency and body weight gain of broiler chickens in the finisher phase of the feeding trial.

The carcass yield, weight of vital organs and cut up parts of carcass of Cobb-500 chickens did not differ significantly due to variations in the sorghum levels in the diet. This indicated that inclusion of SVM into broilers diet didn't have an impact on the anatomical and physiological makeup of the birds. But there was a significant difference among the treatment groups in the percentage of abdominal fat. Those groups fed a diet with no SVM had lower abdominal fat as compared to the other groups. There was no significant difference observed among all the treatment groups in color, taste, flavor, tenderness and juiciness of the roasted breast, thigh and drumstick meat.

The energy value of SVM was higher than all major feed ingredients used in this study, indicating that SVM has a good potential to be used as an alternative energy source feed in poultry diets to bridge the gap of feed shortage and also minimizing the feed cost and competition with humans.

6.2. Recommendation

Based on the results of the current study Sorghum variety Melkam could be economically and safely included in to broilers diet up to 50% as energy source to reduce the cost and competition of maize between human being and chickens.

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7. APPENDIXS

Appendix Table 1. **Experimental layout**

Treatments		**Levels**	**No. of chicks per replicate**			**Total number of chicks**
			R_1	R_2	R_3	
Control	T1	0%	14	14	14	42
	T2	20%	14	14	14	42
	T3	30%	14	14	14	42
SVM	T4	40%	14	14	14	42
	T5	50%	14	14	14	42
Overall			70	70	70	210

SVM: sorghum variety Melkam; R: replication 1, 2 and 3; T: treatment 1,2,3,4,5; 0%, 20, 30%, 40% and 50% are levels of SVM inclusion in the total rations, respectively for the treatments.

Appendix Table 2: Analysis of variance of feed intake (g) per bird in the starter phase

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	4	16.57830	4.144576	2.34	0.12
Error	10	17.68366	1.768366		
Corrected total	14	34.26197			

CV = 3.49

Appendix 3: Analysis of variance of body weight gain (g) per bird in the starter phase

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	4	2212.3619	553.0904	1.0	0.45
Error	10	5516.8734	551.6873		
Corrected total	14	7729.2353			

CV = 6.90

Appendix 4: Analysis of variance of feed conversion ratio per bird in the starter phase

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	4	0.115173	0.02879	2.03	0.17
Error	10	12.45453	1.24545		
Corrected total	14	17.47604			

CV = 5.05

Appendix 5: Analysis of variance of average feed intake (g) per bird in the finisher phase

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	4	19.44646	4.8616	0.55	0.70
Error	10	88.05446	8.8054		
Corrected total	14	107.50093			

CV = 2.89

Appendix 6: Analysis of variance of body weight gain (g) per bird in the finisher phase

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	4	165151.70	41287	10.50	0.0013
Error	10	39338.47	39338		
Corrected total	14	204490.17			

CV = 4.70

Appendix 7: Analysis of variance of FCR per bird in the finisher phase

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	4	0.53726	330.13431	5.24	0.015
Error	10	0.25646	0.025646		
Corrected total	14	0.79373			

CV = 5.91

Appendix 8: Analysis of variance of slaughtering weight (g)

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	4	103680	25920.00	0.48	0.75
Error	25	1349200	53968.00		
Corrected total	29	1452880			

CV = 11.21

Appendix 9: Analysis of variance of Dressed weight (g)

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	4	89929.86	22482.46	0.51	0.73
Error	25	1108113	44324.53		
Corrected total	29	1198043			

CV = 11.22

Appendix 10: Analysis of variance of Eviscerated weight (g)

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	4	60153.33	15038.33	0.63	0.65

Error	25	598033.33	23921.33		
Corrected total	29	658186.66			

CV = 10.44

Appendix 11: Analysis of variance of Thigh weight (g)

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	4	1021.20	255.300	0.73	0.58
Error	25	8790.66	351.626		
Corrected total	29	9811.86			

CV = 15.11

Appendix 12: Analysis of variance of Breast weight (g)

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	4	19015.86	4753.96	0.88	0.49
Error	25	135232.8	5409.31		
Corrected total	29	154248.7			

CV = 11.87

Appendix 13: Analysis of variance of Drumstick weight (g)

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	4	364.4666	91.1166	0.86	0.50
Error	25	2656.500	106.260		
Corrected total	29	3020.966			

CV = 10.06

Appendix 14: Analysis of variance of Gizzard weight with content (g)

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	4	261.66667	65.41667	0.74	0.58
Error	25	2225	89.0000		
Corrected total	29	2486.6667			

CV = 9.12

Appendix 15: Analysis of variance of Gizzard weight without content (g)

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	4	173.86667	43.4667	1.10	0.38
Error	25	987.5000	39.5000		
Corrected total	29	1161.3667			

CV = 17.12

Appendix 16: Analysis of variance of Small intestine weight with content (g)

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	4	1013.3333	253.3333	1.68	0.18
Error	25	3770.8333	150.8333		
Corrected total	29	4784.1667			

CV = 19.12

Appendix 17: Analysis of variance of Small intestine weight without content (g)

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	4	832.2000	208.0500	1.14	0.36
Error	25	4572.500	182.9000		
Corrected total	29	5404.400			

CV = 19.33

Appendix 18: Analysis of variance of Large intestine weight with content (g)

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	4	13.3820	3.34550	2.95	0.039
Error	25	28.3450	1.13380		
Corrected total	29	41.7270			

CV = 23.60

Appendix 19: Analysis of variance of Large intestine weight without content (g)

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	4	5.558000	1.38950	2.50	0.068
Error	25	13.91667	0.55666		
Corrected total	29	19.47466			

CV = 22.25

Appendix 20: Analysis of variance of Cloaca weight with content (g)

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	4	11.82466	2.95616	0.35	0.84
Error	25	210.0500	8.40200		
Corrected total	29	221.8746			

CV = 24.12

Appendix 21: Analysis of variance of Cloaca weight without content (g)

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	4	24.92533	6.23133	1.03	0.41

Error	25	150.9816	6.03926		
Corrected total	29	175.9070			

CV = 21.06

Appendix 22: Analysis of variance of Spleen weight (g)

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	4	21.2886	0.32216	0.61	0.66
Error	25	13.2850	0.53140		
Corrected total	29	14.5736			

CV = 11.03

Appendix 23: Analysis of variance of Net income (birr)

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	4	2895.506	723.876	15.96	0.002
Error	10	453.6424	45.3642		
Corrected total	14	3349.149			

CV = 1.99

8. LIST OF PICTURES

Figure 1: Experimental Pen and Chickens

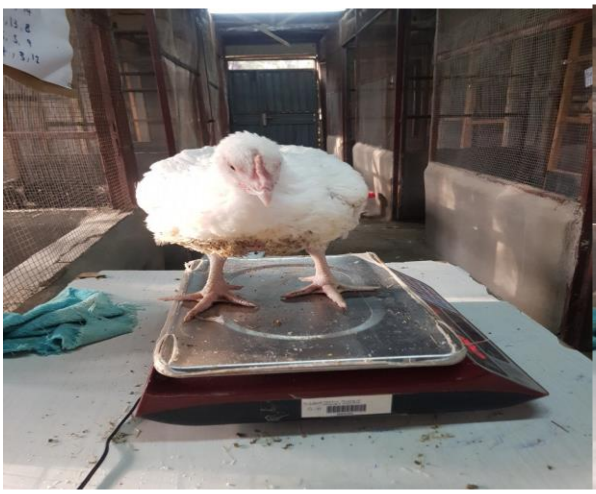

Figure 2: Body weight measurement of female chicken

Figure 3. Body weight of male chicken

Figure 4: De-feathering of slaughtered chickens

Figure 5: Data collection on Carcass traits and Offal’s

Figure 6: Samples of thigh, drumstick and breast meat

Figure 7: Training for panelists on sensory evaluation at DZARC nutrition laboratory

Figure 8: Sensory Evaluation of roasted breast, thigh and drumstick meat