EFFECT OF DIFFERENT GARLIC (*Allium sativum l.*) EXTRACT LEVELS INCLUSION ON GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF COMMERCIAL BROILER

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BY

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SEPTEMBER, 2022

WOLKITE, ETHIOPIA

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EXAMINERS' APPROVAL SHEET

We, the undersigned, members of the Board of Examiners of the final open defense by Ayelu Dagnachew have read and evaluated here thesis entitled "**Effect of Different Garlic *(Allium sativum l.)* Extract Levels Inclusion on Growth Performance and Carcass Characteristics of Commercial Broiler**'' and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master of Science in Animal Production.

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DEDICATION

This thesis paper is dedicated to my mother W/ro Zenebech Shenkute , my Father Dagnachew Azerefegn, my brothers Abreham Dagnachew, Ayenachew Dagnachew, W/ Aregay Dagnachew, Kifle Dagnachew and my sister Mulu Dagnachew for their unreserved partnership in the success of my life.

STATEMENT OF THE AUTHOR

First, I declare that this thesis is my *bonafide* work and that all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillments of the requirement for MSc degree at Wolkite University and is deposited at the University Library to be made available to readers under rules of the Library. I solemnly 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 Ayelu Dagnachew Azerefegn was born on May 1995 in Menz Keya Gebreal Woreda, North Shewa Zone of Amhara Regional State, Ethiopia from her father Dagnachew Azerefegn and her mother Zenebech Shenkute. She attended her junior and elementry education in Kimir dingay elementary school from 2004 to 2011, then after she attended her Senior Secondary and preparatory education at Zemero Preparatory and Senior Secondary School from 2012 to 2015.

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LIST OF ABBREVATIONS AND ACRONYMS

ADG	Average Daily Gain
AGP	Antibiotic Growth Promoter
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemist
BWG	Body Weight Gain
Ca	Calcium
CACC	Central Agricultural Census Commission
CF	Crude Fiber
CP	Crude Protein
CRD	Completely Randomized Design
CSA	Central Statistical Agency
DFI	Daily feed intake
DM	Dry Matter
DoFED	Department of Finance and Economic Development of Gurage Zone
ECE	Economic Efficiency
EE	Ether Extract
FAO	Food and Agricultural Organization
FBW	Final body weight
FCR	Feed Conversion Ratio
FI	Feed Intake
GEX	Garlic Extract
GIT	Gastro Intestinal Tract
GLM	General Linear Model
IBW	Initial Body Weight
Kcal	Kilo Calarie
Kg	Kilogram
m a s l	Meter above sea level
ME	Metabolizable Energy
MG	Maize Grain

NABC	Netherlands Africa Business Council
NC	Negative control
NR	Net return
NSC	Noug Seed Cake
PC	Positive Control
REE	Relative Economic Efficiency
SAS	Statistical Analysis System
SBM	Soybean Meal
SNNP	Southern Nation Nationality and People
TI	Total Income
WB	Wheat Bran

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EFFECT OF DIFFERENT GARLIC (*Allium sativum l.*) EXTRACT LEVELS INCLUSION ON GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF COMMERCIAL BROILER

ABSTRACTS

Commercialization of chicken farming and improvement of production efficiency has led to be the adoption of a range of additives as growth promoter. Antibiotic-based growth promoter have long been utilizing as animal feed additives. Wide spread usage of these substances has resulted in an escalation of antibiotic resistance and the accumulation of antibiotic residues in animal product. Because of these weaknesses there is rising interest in employing natural growth promoters. Therefore, this study has conducted on the effects of different garlic extract levels inclusion on the growth performance and carcass characteristic of broiler. The experiment was arranged in a completely randomized design (CRD) with four treatments, each replicated three times with 15 birds each. 180 chicks with similar body weight were used for this trial and were randomly distributed to the four treatments. They were T1 (NC, basal diet and drinking water), T2 (PC, basal diet + drinking water with oxtetracycline (0.2 g/ 10 litter), T3 (basal diet + drinking water (1.5% GEX)) and T4 (basal diet + drinking water (3% GEX). During the trial periods daily feed intake and weekly body weight were recorded and carcass evaluation was made. The result obtained that, the body weight gain and feed conversion ratio of birds were significantly (P<0.05) improved by 1.5 and 3% GEX inclusion levels. Most of carcass trait such that slaughter, dressing, breast, liver and GIT weight were highly (P< 0.05) affected by 1.5 and 3% GEX inclusion levels. Reduced abdominal fat weight and percentage (P< 0.05) was recorded in GEX inclusion levels. Generally, based on the results of the current study garlic extract at 1.5 and 3% inclusion levels in drinking water should be considered as potential growth promoters that may replace the antibiotic in broiler farm.

Keywords: Additives; Garlic extract; Growth Performance; Carcass Characteristics; Broiler

1. INTRODUCTION

Food security and poverty reduction are important policy concerns in the Ethiopian government's development agenda, owing to the fact that approximately 23% of the population lives below the poverty line (WFP, 2014). Poor human nutrition has persisted due to a lack of appropriate calories and protein in diet or a lack of food availability (Abedullah *et al*., 2007). If food self-sufficiency and malnutrition are to be achieved in developing nations particularly Ethiopia, due to this attention must be paid to chicken production (Melkamu, 2013). Chicken plays an important role in alleviating protein deficit by producing eggs and meat, all of which are important sources of edible animal protein (FAO, 2010a). Chicken production has the opportunity to reduce poverty through income generation and household food security (Abubakar *et al.*, 2007). It also has immense potential to promote rapid economic growth and benefiting the most vulnerable members of society in particular. Furthermore, it requires little financial investment and provides quick profits (Rajendran and Samarendu, 2003).

Commercialization of chicken farming and improvement of feed nutritional efficiency has led to be the adoption of a range of feed additives (Ohimain *et al*., 2012). Feed additives used in chicken farms including organic and inorganic substances are those mix with feed and drinking water of chickens (Bali *et al*., 2011; Abouelfetouh *et al*., 2012). Based on the results of Pirgozliev *et al*. (2019) for many years feed additives has been utilizing to increase animal performance and it is employed in the broiler business to improve immunological response, feed efficiency and growth performance. Feed additives provide an economic benefit by lowering production costs as a result of raise production efficiency (Al-Massad *et al*., 2018). Any effort to minimize feed costs may result in a substantial reduction in overall production costs in chicken farm (Thirumalaisamy *et al*., 2016).

Antibiotic based growth promoters has long been utilizing as animal feed additives, since they are well known for supporting growing animals in digesting their diet more effectively and developing strong and healthy individuals (Sojoudi *et al*., 2012). An antibiotic have an effect on chicken gut micro biota and has been widely utilizing to prevent poultry diseases in order to enhance egg and meat production. Antibiotics commonly used in animal farms include *oxytetracycline, virginiamycin, salinomycin, neomysin, doxycycline* and *avilamycine* (Kumar *et* *al*., 2011). However, scientific investigations (Carvalho and Santos, 2016) confirm wide spread usage of these substances has resulted in an escalation of antibiotic resistance and the accumulation of antibiotic residues in feed and the environment. This ultimately endangers both human and animal health (Diarra *et al*., 2010). Because of these weaknesses, the search for alternative compounds that eliminate these dangers is necessary (Manesh, 2012). There is rising interest in employing natural growth promoters such as probiotics, prebiotics or their combination and Phytogenic components as an additive in chicken diets and drinking water (Khan *et al*., 2010).

Phytogenic components are plant-derived natural bioactive substances that can stimulate appetite, assist endogenous secretions such as enzymes and have antibacterial activities by their improving livestock performance and health (Wati *et al.,* 2015; Jarriyawattanachaikul *et al.,* 2016). Phytogenic components are extremely beneficial because they improve digestive and immunological functions (Murugesan *et al.,* 2015). Li *et al. (*2015) reports that Phytogenic compounds can substitute antibiotics as a growth promoter in broiler chickens. This is due to the large number of active ingredients found in phytogenic products, such as *antioxidants* and *antimicrobials* to facilitate the health status and performance improvements of broilers (Wati *et al.,* 2015; Jarriyawattanachaikul *et al*., 2016).

Garlic (*Allium sativum l.*) is a well-known medicinal plant species that is employ in organic chicken production (Puvaca *et al*., 2014). It is used as natural feed supplement, increased broiler growth and feed conversion ratio while decreasing mortality (Stanaćev *et al.,* 2010). Garlic supplementation in broiler has been known for its potent immune-stimulating effects as well as its favorable benefits on bird digestion due to its high aromatic essential content (Al-Massad *et al*., 2018). It contains several active ingredients, the most important of which is *allicin* (Rahmatnejad and Roshanfekr, 2009). *Allicin* has been shown to lower low density lipoprotein, triglyceride and cholesterol levels in broiler serum and tissues (Vidica *et al*., 2012). Garlic powder supplementation at 3% level in broiler finisher diets improves feed conversion ratio and it attains the best growth performance (Onu, 2010). Garlic has significant effect as growth promoter on the improvement of the performance of broiler chicken and reducing the costs of production (Massad *et al*., 2018).

Inclusion of garlic (*Allium sativum l.*) as feed additive in the broiler diet can improve growth performance and carcass characteristics of broiler chickens separately and mixing with other herbal medicinal plant (Jamal and Omar, 2011; PUVACAL *et al*., 2015; Raeesi *et al*., 2010). All performance attributes show curvilinear tendencies in relation to the amount of garlic powder added to the diet with the level 3% providing is the best results (Melaku *et al*., 2019). However, that inclusion of garlic in to the diet of broilers in the form of powder Zena *et al*. (2017) studies showed does not bring about a significant effect on feed intake, body weight gain and feed conversion ratio. Inclusion of garlic in the form of powder is costly and this results in the needs to search for other preparation as well as administration methods. Garlics in the form of aqueous extract added in to drinking water and diet of broiler chicken can improve growth performances and carcass characteristics (Nohman *et al*., 2015; Khan *et al.*, 2017 and Islam *et al*., 2017).

Garlic extract enhances the production potential, economic returns and protects the birds from different diseases (Noman *et al*., 2015). So, it can be effectively used to replace the antibiotic growth promoter in the chicken industry. These can be very good reasons to propose that, the utilization of Garlic (*Allium sativum l.)* in the form of aqueous extract should be also particular benefit and be useful as a substitute for antibiotics. However, there are no reported studies about the effect of different inclusion levels of garlic extract on the performance of broiler chickens in Ethiopia. Therefore, this study has conducted on the effects of different garlic extract levels inclusion on the growth performance, the carcass characteristics and economic efficiency of broiler chicken.

1.1. Objectives

`1.1.1. General Objective

- ❖ Evaluating the effect of different garlic extract levels inclusion on the growth performance, the carcass characteristics and economic efficiency of broiler chicken.

1.1.2. Specific Objectives

- ➢ To evaluate the effects of inclusion of different levels of garlic extract in drinking water of broiler chicken on their growth performance.

- To evaluate the effects of inclusion of different levels of garlic extract in drinking water of broiler chicken on their carcass characteristics.
- To evaluate the economic efficiency of inclusion of different garlic extract levels in broilers drinking water.

1.2. Research Questions

1. What is the effect of different garlic extract levels inclusion on the growth performance of broiler chicken?
2. What is the effect of different garlic extract levels inclusion on carcass characteristics of broiler chickens?
3. What is the effect of administering different garlic extract levels through drinking water on economic efficiency of broiler production?

2. LITRATURE REVIEW

2.1. Broiler Production

Broiler chickens has been submitting to an intensive genetic selection that has been increasing the growing rate and made them the fastest growing farmed species (Meluzzi and Sirri, 2009). Broiler chickens are especially bred for rapid growth and are slaughtered when they reach around 1.8 to 2.2 kilogram body weight, which happens between the ages of 6 and 8 weeks. Other researchers also reported that the broilers live weight is 2.5kg at fattening period of around 56 days (Teshome *et al*., 2019). Due to their high growth rate and great feed conversion ratio, broiler production is one of the most cost-effective and simple ways of bridging supply-demand gap for animal protein (Rynsburger, 2009).

The production is obtained mostly in intensive systems by using uniform and standardized tools and techniques as for genotype, feeding, housing and management (Meluzzi and Sirri, 2009). Whereas, compared to other livestock species, broilers have a relative advantage in terms of easy management, quick returns on capital inputs and widespread acceptance of their meat for human consumption (Rynsburger, 2009)). The global consumption, production and trade of poultry meat have grown faster than any other farm animal meat (Chang, 2007). This sector of agriculture is expected to continue to grow because poultry meat is more versatile, cheaper and potentially provides more health benefits than do other meats (Cochran, 2011). A broiler has emerged as the fastest growing segment for poultry industry with the increased acceptance of chicken meat in city, town and villages (Musa *et al*., 2006).

The United States is the world's biggest producer of poultry meat followed by Brazil and China. Because feed costs make up about 70% of the total cost of poultry production systems, countries that have access to cheap feeds have the advantage. This is how the United States and Brazil are the world's two largest and most efficient broiler producers because they are major grain producers (Cochran, 2011).

2.2. Broiler Production in Ethiopia

In Ethiopia commercial broiler poultry is classified into three types based on production scale comprising of; small-scale (50 to 1000 birds), medium-scale (1000 to 10,000 birds) and large-scale (over 10,000 birds) (Vernooij *et al*., 2012). Large scale intensive poultry production is practiced in Ethiopia at government poultry multiplication and distribution centers located in various regions (Wondimneh *et al.,* 2019). Small scale intensive system with small number of exotic chickens (50-1,000) is also operational in urban and peri-urban areas using relatively modern management system. According to FAO (2008), the sources of breeding stock and commercial feed to the private small scale poultry production sector are the large scale private commercial poultry farms and government owned breeding and multiplication centers. The total number of annual broiler chicken production from commercial broiler farms is 1, 939,000. Among the broiler chickens used in the system of production the Cobb 500 and Ross 308 are the most common broiler strains (Teshome *et al*., 2019). Ethiopia's estimated annual poultry meat production efficiency is 61,840 tons accounting for 1.3% of African production and 11.7 % of East African production (FAOSTAT, 2016).

In Ethiopia commercial chicken production is run as a large business and is highly dependent on the market for inputs (FAO, 2008). There is formal marketing operation in the urban and peri urban areas where large scale commercial chicken production takes place. The large commercial chicken units have sales agreement with their clients (large hotels) to supply eggs and chicken meat to the residence and hotels. Dressed chicken carcass and table eggs are sold either in supermarkets or small shops (FAOSTAT, 2016).

2.3. Broiler Feed

Successful broiler production is based on providing the birds with feed of the greatest possible quality in terms of components used, processing methods used and the form in which the diet is supplied to broilers. The science of nutrition involves providing a balance of nutrients that best meets the need of broilers optimum growth, maintenance, finishing, work, reproduction and production (Arbor, 2009). The broiler diets are composed primarily of a mixture of several feedstuffs such as cereal grains, soybean meal, animal by-product meals, fats, vitamin and mineral premixes. These feedstuffs together with water provide nutrients that are essential for birds as well as the nutrient content of feeds also should be designed to provide the proper balance of energy, protein, minerals, vitamins and vital fatty acids for optimal growth and performance (NRC, 1994).When formulating broiler diets the main emphasis is placed on the crude protein (CP) because protein is the critical constituent of broiler diets and together with the other main nutrients such as carbohydrates, fat, water, vitamins and minerals are essential for life (Cheeke, 2005).

According to Chinrasri (2004), defined nutrient requirement as the amount of nutrients needed by broilers to maintain their activities, maximize growth, feed utilization efficiency and optimize fat accumulation. Broiler chickens have high protein requirements to meet the demands of rapid growth, carcass composition and overall product cost (Sklan and Noy, 2003). NRC (1994) recommended that 23%, 20% and 18 % dietary protein levels for the broiler chickens during the starter (0-3weeks), grower (3-5weeks) and finisher phases (6-8weeks) respectively for optimal growth and maximum productivity as well as it should be getting also 3200 kcalME/kg DM from 0-8 weeks of age. Horton *et al.* (2002) reported that, protein deficiency in a feed reduced growth in broiler chickens as a consequence of depressed appetite and thus intake of nutrients. Birds usually consume just enough feed to meet their energy requirements (Nahashon *et al*., 2006).

The primary goal of livestock production is to get high yields at a reasonable cost. Animal care, nutrition, genetic enhancement, the use of medicines and similar technologies to promote growth are all essential ways for achieving these objectives (Armut and Filazi, 2012). In particular the use of yield-increasing materials in broiler production results in an increase in the yield over a short time period accompanied by lower feed consumption. From which mechanisms feed additives are used in broiler to prevent the growth of pathogenic microorganisms that may cause digestive system diseases and to allow the birds to benefit from the higher levels of nutrients present by altering the micro flora of their digestive systems in favor of beneficial bacteria (Huyghebaert *et al*., 2011).

2.4. The Use of Antibiotic Growth Promoter in Chicken Production

The term "antibiotic growth promoter" refers to any drug that eliminates or inhibits bacteria and used as Feed additives in farm animals (Hughes and Heritage, 2004). Feed additives are products used in animal nutrition for purposes of improving the quality and digestibility of feed and the quality of food from animal origin or to improve the animal's performance and health (Mantovani *et al*., 2006). According to Yadav *et al*. (2016), antibiotics have subsequently become a crucial aspect of controlling animal health in agriculture and they are also provided to food animals together with chickens by a variety of ways including injections, orally in feed and water and subcutaneously.

The growth promoter effect of antibiotics was discovered in the 1940s, when it was observed that animals feed dried mycelia of Streptomyces. In 1951, the Food and Drug Administration of the United States permitted the use of antibiotics as animal supplements without a veterinarian prescription (Jones and Ricke, 2003). Also in the 1950s and 1960s, each European state approved its own national regulations about the use of antibiotic in animal feeds. In the next 50 years the use of antibiotics as feed additives in pig and poultry production became virtually universal (Hashemi and Davoodi, 2010). Because of their ease of use and low cost antibiotics have been widely used in chicken production around the world (Yadav *et al*., 2016).

According to Hassan *et al*. (2013), the antibiotics as growth promoter are effective in farm animal due to produce one or more of the following mechanisms: its enhanced the growth of nutrients-synthesizing microbes because of reduced that of nutrient destroying microorganism and inhibit the growth of organisms that produced excessive amount of ammonia and other toxic nitrogenous waste products in the intestine, its improved availability or absorption of certain nutrient because they may improve feed or water consumption, antibiotics may instances prevent or cure actual pathological disease which occur either in the intestinal tract or systemically and it's also minimize the maintenance expenses linked to intestinal epithelium turnover. The enormous benefits received from the use of antibiotic feed additives in food producing animals are sometimes disregarded topics in the debate over the hazards connected with their usage.

The scientifically proven advantages of utilizing low levels of antibiotics in animal diets are listed below (Cervantes, 2012). The use of antibiotics as a feed additive assists in the prevention of subclinical infections in poultry, such as necrotic enteritis. This is the primary reason antibiotic feed additives are utilized at sub therapeutic doses in animal feeds; they are used to avoid subclinical disease. Subclinical necrotic enteritis in chicken has been demonstrated to have a considerable negative influence on flock performance and processing plant condemnations

(Khaldhusdal, 2001). The capacity of an antibiotic feed additive to manage Clostridium perfringens, the cause of clinical and sub-clinical necrotic enteritis in chickens is closely connected with its ability to enhance performance parameters including growth rate and feed conversion ratio. Al-Massad *et al*. (2018) also reported that, the chicken industry uses antibiotics to increase meat production through improve feed conversion ratio, growth rate promotion and disease prevention. This is primarily the suppression of gastrointestinal infections and the manipulation of micro biota due to antibiotic substance used in the broiler (Singh *et al*., 2013; Torok *et al*., 2011).

The other importance of antibiotic growth promoters is reduction of human pathogens by improving flock uniformity, enhancing intestinal strength, minimizing gastrointestinal ruptures during evisceration and processing as well as by reducing shedding of human pathogens such as Salmonella and Campylobacter species of bacteria, finally the use of antibiotic feed additives in animal feeds ultimately improves the safety of the end output for cunsumers (Hurd, 2005). Campylobacter spp. prevalence has been found to be about three times higher in organically raised chickens than in conventionally grown chickens (Huda *et al*., 2008). In intensive broiler farming often employed antibiotics are *tetracycline, bacitracin, tylosin, salinomycin, virginiamycin and bambermyci* (Diarra and Malouin, 2014).

2.5. Limitation of Antibiotic Growth Promoter

Despite its numerous advantages, the use of antibiotics in chicken is being questioned due to rising antibiotic resistance (Mehdi *et al*., 2018). The ability of germs to reproduce in the presence of an antibiotic that inhibits or kills microorganisms of the same species is referred to as antibiotic resistance (Nibir, 2019). Antibiotic abuse and the resulting selection pressure have reduced therapeutic effectiveness and established populations of antibiotic-resistant bacteria (Al-Massad *et al*., 2018). Resistance is conferred through gene mutation or acquisition by mobile genetic elements such as transposons, integrons, plasmids or phages (Kempf and Zeitouni, 2012). Chicken has a high frequency of Enterobacteriaceae resistant to amino sides and tetracycline in its digestive system and within meat (Yulistiani *et al*., 2017). Once acquired antibiotic-resistant bacteria can colonize the human intestine and the genes coding for antibiotic resistance in these bacteria can be transmitted to other bacteria in the human endogenous micro flora (Stanton, 2013).

Antibiotics abuse has led to medication residues in animal products in addition to the development of bio-resistance (Ronquillo and Hernandez, 2017). Antibiotic abuse and the resulting selection pressure have reduced therapeutic effectiveness and established populations of antibiotic-resistant bacteria (Al-Massad *et al*., 2018). Antibiotic residues in chicken products can really be harmful to human health (Kummerer, 2009). It is also in large concentrations are emitted into the environment via urine and animal faces. The release of considerable quantities of antibiotics into the environment entertains the cycle of antibiotic biotransformation and bioaccumulation in the environment (Carvalho and Santos, 2016). According to Mehdi *et al*. (2018), restricted aquatic environments such as ponds and lakes as well as soils near to urban areas are the most vulnerable to antibiotic contamination.

2.6. Plant Extracts (Phytogenic) as Alternative to Antibiotic Growth Promoter

Many countries have recently reduced or prohibited the use of antibiotic feed additives due to their negative effects on both animals and humans (Oleforuh-Okoleh *et al*., 2014). Consumer pressure and worries about the adverse implications of antibiotic usage as well as the restriction on antibiotics have motivated researchers to consider alternatives to antibiotics (Diarra and Malouin, 2014). Other researcher also indicated that, to preserve gut health and performance by reducing infections and improving nutrient digestion and absorption antibiotic alternatives are necessary (Dhama *et al*., 2014). The aim of these alternatives is to maintain a low mortality rate, a good level of chicken performance, preserving environment and consumer health (Al-Massad *et al*., 2018). There are a number of non-therapeutic alternatives that can substitute antibiotics use. Among those the most popular for chicken productions are organic acids, probiotics, phytogenic, symbiotic, herbal drugs, vitamins, minerals and plant extracts (Upadhayay and Vishwa, 2014).

Those antibiotic alternatives should have the following characteristics: they should improve performance effectively, they should have little therapeutic use in human or veterinary medicine, they should not cause deleterious disturbances of the normal gut flora, they should not be involved with transferable drug resistance, they should not be absorbed from the gut into edible tissue and they should not cause cross-resistance to other antibiotics at actual use level, It should not promote Salmonella shedding, should not be mutagenic or carcinogenic, should not cause environmental pollution, should be readily biodegradable and should be non-toxic to birds and human handlers (Yadav *et al*., 2016).

Phytogenic feed additives derived from plants, herbs and spices are used as a form of powder and extraction to improve animal performance incorporated within feed and drinking water. They have been also very successful because of their positive effects on growth, improved immune system and reduced stress response (Al-Massad *et al*., 2018). Recent results showed that Phytogenic feed additives are good alternatives to antibiotics (Frankic *et al*., 2009; Toghyani *et al*., 2011; Ghasemi *et al*., 2014) and promoted growth performance of broiler chicken (Toghyani *et al*., 2011; Ghasemi *et al*., 2014; Li *et al*., 2015).

Plant extracts from aromatic spices (cinnamon, clove, etc.), pungent spices (pepper, garlic, and ginger) and herbs spices (rosemary, thyme, mint, etc.) are utilized in African countries (Elagib *et al*., 2013; Gopi *et al*., 2014; Heinzl and Borchardt, 2015). Rahimi *et al*. (2011) also said that supplementing broiler diets with those plant extracts increased FI, FCR, BWG and improved endogenous digestive enzyme secretion. Furthermore Molla *et al*. (2012) and Saminathan *et al*. (2013) reported that herbs such as black pepper can be used as alternative growth promoters without negatively impacting broiler performance. Other researchers have reported that garlic extracts can prevent infectious disease and relax chicken air sacs by providing proper air circulation as well as improve broiler growth and carcass parameters (Dhama *et al*., 2014a; Dhama *et al*., 2015 and Nakielski, 2015).

Plant extracts commonly referred to as photobiotic, they have been utilizing effectively in the production of chicken and also have been demonstrating to be a viable alternative to antibiotics because of its *antibacterial, anti-inflammatory, antioxidant* and *antiparastic* effects or properties (Cao *et al*., 2013). Other researchers also said that, those properties they possess are also a major reason for their successful use in chicken farm (Akyildiz *et al*., 2016; Karangiya *et al*., 2016). *Terpenoids, phenolics, glycosides and alkaloids* are also minor metabolites found in plant extracts (Cao *et al*., 2013). These metabolites are important mechanisms that result in improved broiler growth performance and health status (Akyildiz and Denli, 2016).

2.7. Garlic (*Allium sativum l.*)

2.7.1. Garlic Production in Ethiopia

Garlic also known as *Allium sativum l.* is a member of the *Amaryllidiaceae* family, which also includes onions, shallots and leeks. It is one of the most significant crops grown all over the world including Ethiopia (Mohammed *et al*., 2017). The native land of garlic is Middle Asia (Jančić, 2004)**.** Ethiopia has various agro-ecologies which are suitable for the production of vegetables including garlic. In Ethiopia, garlic is a fundamental flavoring component of many dishes. Furthermore, it is an important cash crop for smallholder farmers in Ethiopia (Emana *et al*., 2015). According to Abrha and Gebremedhin (2015), the highland parts of southern Tigray are suitable places for garlic growth many farmers in this zone substantially plant this crop which is adopted as a primary source of income. In Ethiopia a total of 15,381.01 ha of land was under garlic production during the 2015/16 main cropping season, taking up about 6.71% of land area covered by all root crops at country level and yielding about 138664.30 tons of those cultivated by small scale farmers sharing about 2.99% to the total country level root crop production (CSA, 2016).

2.7.2. Medicinal Values of Garlic

Garlic (*Allium sativum l.*) is a common herbal plant used as a spice and remedy. It has been used throughout history for culinary and medicinal purposes (Pandey, 2012). Garlic is a vital component of the medicinal system, because it has a broad antibiotic spectrum that acts against both Gram positive and Gram negative bacteria, it is also used to treat bacterial infections all over the world (Khusro *et al*., 2014). The principal bioactive constituents of garlic include *allicin, ajoene* and *flavonoid* molecules making it an excellent source of antioxidants (Kim *et al*., 2007).). Garlic extracts have gained popularity as feed additives due to its extensive ranges of medical characteristics including *antibacterial*, *antiviral, antifungal, antiprotozoal, hepatoprotective* and other activities that have not been found to have any harmful consequences (Rehman and Munir, 2015). Farmers in Ethiopia were attempting to treat their birds in a traditional manner. About 48.5% of respondents were feeding garlic-onion and alcohol with softened “Injera” to sick birds in a survey on the use of garlic as a traditional treatment for birds (Mengesha *et al*., 2011).

2.8. Use of Garlic as Chicken feed additive

2.8.1. Effects on Growth Performance of Broiler

Garlic as a natural growth promoter can be potential alternative for common artificial growth promoters like antibiotics and in this respect it can improve growth rate and feed conversion ratio (Demir *et al*., 2003; Lewis *et al*., 2003; Makwana *et al*., 2015). Broilers' feed supplemented with garlic is found to enhance growth performance and improvement of digestive system there by optimizing the nutritional absorption from feed (Taufic and Maruddine, 2019). According to Rahimi *et al*. (2011) garlic supplementation in the diet can increase broiler growth performance. Garlic extract given continuously in commercial feed as a feed additive resulted in a significant improvement in broiler body weight and reducing bird mortality during the broiler rearing period (Brzóska *et al*., 2015). It has improved production potential of broiler while also boosting the consumer's immune system (Khan *et al*., 2017).

The addition of commercial garlic powder in the amount of 2% in broiler chicken diet had a significant effect on the production performance before higher final body weight (Zekic *et al*., 2014). The incorporation of garlic at 3% in feed significantly increased growth and other performance parameter of broiler chicks without any negative effects as confirmed by blood profiling (Elagib *et al*., 2013). Among garlic extracts administrated in drinking water of broiler, 1% garlic extract showed better growth performance than 2% garlic extract (Noman *et al*., 2015). Frankic *et al*. (2009) and Jo *et al*. (2009) reported that the effect of onion and garlic extract had a positive implication on BWG and feed conversion efficiency of broiler chickens.

Herbal products have been used as growth promoters because the ingredients found in herbs are used as digestion stimulants and to aid in the growth of broiler chickens (Frankic *et al*., 2009). Garlic contains an active ingredient called *alliin,* which, when garlic is crushed in aerobic conditions, is converted by the enzyme *allinase* into *allicin* (Lanzotti, 2006). The intermediate compound is alkyl sulphonic acid, which has the capacity to acidify the digesta of animals and the sulphides released from *allicin* exert strong antibacterial and antioxidant activity as well to promote the health of farm animals (Bozin *et al*., 2008).

2.8.2. Effects on Carcass Characteristics of Broiler

Garlic *(Allium sativum l.)* is one of such potential alternative feed additive which has recently been reported as having a wide range of beneficial effects on the production performance in poultry farm (Alloui *et al*., 2014). Garlic extracts as additives improved broiler performance, carcass parameters and may decrease both abdominal fat and serum cholesterol (wibabaw *et al*., 2016; Khan *et al.*, 2017). Raeesi *et al.* (2010) also reported that, the significant higher carcass and breast yield, lower abdominal fat, decreased heart, pancreas, gizzard, bursa and spleen weight in 0.5, 1 and 3% garlic supplemented birds. The chicken fed a diet containing 3% garlic powder had the highest hot weight, dressed weight, breast weight, fleshed breast weight and fleshed breast percentage (Eligab, 2013).

Other researcher's contradict those ideas; garlic supplementation had no significant effects on major carcass components or organ characteristics (Javandel *et al*., 2008) and Gbenga *et al*., 2009). The addition of 1% and 3% garlic to the broiler diet had no effect on the relative weights of the carcass, fat pad and digestive organs (Raeesi *et al*., 2010). Singh *et al*. (2015), also observed that no effect of whole bulb garlic powder supplementation at 1.0, 1.5 and 2.0% level on the carcass characteristic except the heart weight which was highest in 1% GP inclusion group. Issa and Omar (2012) conducted a study to investigate effects of garlic powder at 0.2 and 0.4% in feed and reported that no significant effect on carcass cuts or visceral organs. Based on the results of Zena *et al*. (2017), the inclusion of garlic powder on the diet of broiler at the levels of 1 and 2 % do not affect carcass yields of broiler.

Table 1. Summary of response of broilers to dietary inclusion of different levels of garlic as phytogenic.

Dietary dose of garlic	Treatment effects	References
	Improved carcass weight	
1% and 2% garlic extract	Improved BWG	Noman *et al*. (2015)
100 mg/kg garlic Essential	Improved BWG and FCR	Ameera *et al.* (2013)

oil	Improved carcass parameters	
2.5 – 5% garlic extract	Improved BWG and FCR Improved abdominal fat	Wibabaw *et al*. (2016)
1, 1.5 and 2.25% garlic extract	Improved BWG and FCR Improve carcass weight Reduced abdominal fat content Reduced mortality rate	Broszisk *et al*.(2015)
9% garlic solution	Improved FI and final body weight Improved growth performance	Fadlalla *et al*. (2010)
1% and 2% garlic extract	Improved carcass quality	Islam *et al.* (2017)
50ml garlic extract /liter of drinking water	Improved hematological and serum cholesterol parameters	Oleforuh-Okoleh *et al.* (2015)

2.9. Implication of Natural Feed Additives on Economics of Broiler Production

Highest revenue and net return was obtained from birds fed on natural feed additive supplemented diet (Oleforuh-Okoleh *et al*., 2014). According to Puvaca *et al*. (2016), lowest feed cost for per kg body weight gain at herbal supplementation in the diet of broiler chickens. They also reported that supplementation of herbal powder in diet leads to higher economic efficiency index as well lower cost in broiler production. The use of garlic powder as a feed supplement in broiler diets considerably improved the growth, economic and productive efficiency of broiler chicks (Al-Massad *et al*., 2018). Hossain *et al*. (2014) reported that significantly higher profitability per broiler and benefit cost ratio in 1% garlic and 1 % cinnamon supplemented groups as compare to control group. EL-Faham *et al*. (2014) also found better economical and relative efficiency values in chicks fed diet contained herbal substance as compared with control group. Findings of Moustafa (2006), Issa and Omar (2012) also indicted that, improved the economic efficiency of broilers on supplementation of herbal extracts. Other researchers also reported that, phytogenic substance as feed additives have showed better economic efficiency on broiler farms (Abd El- Latif, *et al*., 2002; Abaza *et al*., 2008; Omar *et al*., 2016; shinde *et al*., 2017).

3. MATERIAL AND METHODS

3.1. Experimental Site

The experiment was conducted at Wolkite University poultry farm located in Gurage Zone, Southern Ethiopia. The experimental site is located 176 Km away from Addis Ababa to south west direction. It has geographically located at about 7^0 8'- 8^0 5' N and 37^0 5'-38^0 7' E with an elevation of 1800 m.a.s.l. The mean annual temperature ranges from 14 to 24^0C with an average of 20.5^0C and relative humidity of 47% (DoFED, 2015).

3.2. Experimental Feed Ingredients

The basal diet used for the experiment was formulated using major feed ingredients available in the study area which includes; Maize grain (MG), Nug seed cake (NSD), Soybean meal (SBM), Wheat bran (WB), Limestone, DL,Methionine, L,Lysine, Broiler premix and Salt (Zena *et al*., 2017). Maize grain (MG) and salt were obtained from local market in Wolkite town. Nug seed cake (NSD) was purchased from Admas union oil extraction plant located in Wolkite town,. Soybean meal (SBM) was sourced from an oil extraction plant located in Bishoftu town.Wheat bran (WB) was purchased from Woliso wheat flour factory. DL, Methionine L, Lysine, Broiler premix and limestone were purchased from GASCO Trading PLC, Addis Ababa.

3.3. Laboratory Analysis of Feed Samples and Experimental Ration

Proximate analyses of major feed ingredients were done at Wolkite University food engineering laboratory. Chemical composition of the major feed ingredients and the composite starter and finisher feeds were determined from representative samples taken from each ingredient. The samples of each ingredient were analyzed for dry matter (DM), crude fiber (CF), total ash (TA), ether extract (EE) and Kjeldahl nitrogen (N) using a method of the Association of Official Analytical Chemists (AOAC, 1998). The crude protein (CP) content of each of the ingredients was determined as N x 6.25. Calcium and total phosphorus contents were determined at Debre Zeit National Veterinary Institute in the nutrition and biochemistry laboratory by atomic absorption and vanado-molybdate method, respectively (AOAC, 1998). The metabolizable energy values (ME) was calculated indirectly from the EE, CF and ash adopting the equation proposed by Wiseman (2013), as:-

ME (Kcal/kg DM) = 3951 + 54.4 EE - 88.7 CF - 40.80 Ash.

Table 2. Chemical composition of major feed ingredients in DM basis.

Chemical composition	Chemical composition of feed ingredients in %			
	MG	SBM	NSC	WB
DM	90.73	96.93	94.16	90.46
Ash	1.08	6.23	6.96	2.15
CF	1.76	3.51	20.89	9.06
CP	8.20	43.06	34.00	16.4
EE	3.4	9.54	10.5	4.41
Ca	0.05	2.83	2.75	1.10
P	0.32	0.62	0.60	1.06
ME(Kcal/kg DM)	3597	3876.7	2344.2	3191

DM = Dry Matter; CF = Crude Fiber; CP = Crude Protein; EE = Ether Extract; ME = Metabolizable Energy; MG = Maize Grain; SBM = Soybean Meal; NSC = Noug Seed Cake; WB = Wheat Bran

The large size ingredients were grind (milled) with appropriate sieve size of 3 mm by feed grinder machine at woliso town commercial feed producer factory. Broiler starters' (1 to 28 days of age) and finishers (29 to 56 days of age) diets were formulated on the basis of the results of the laboratory analysis of the individual ingredients using a least cost feed formulation software (feed win). The feed ingredients were mixed together by feed mixer machine at woliso town commercial feed producing factory to form balanced experimental ration. Starter and finisher diets were formulated to meet nutrient requirements according to the NRC (1994) for broiler chickens. The ingredients and calculated nutrient composition of the basal diet are presented in the Table 3 below.

Table 3. Ingredients and nutrient composition of basal diets (%).

Ingredients	Starter diet (0-28 days)	Finisher diet (29-56 days)
Maize grain	40.9	47.9
Noug seed cake	30	23
Soybean meal	15	15
Wheat bran	12	12
Broiler premix*	1	1
Limestone	0.5	0.5
Salt	0.3	0.3
Methionine	0.2	0.2
Lysine	0.1	0.1
Total	100	100
Calculated nutrients content in %		
DM	91.83	91.59
Ash	8.5	6.2
CF	8.60	7.26
CP	22.19	20.39
EE	6.50	7.60
Ca	1.60	1.41
P	0.53	0.51
ME(Kcal/kg DM)	3151.31	3239.00

**Broiler premix 1% per kg contains: Vitamins: Vitamin A, 250 000 IU; Vitamin D3, 1 000 mg; Vitamin E, 215 mg; Vitamin K3, 115 mg; vitamin B1, 700 mg; vitamin B2, 1275 mg; vitamin B3, 1250mg; vitamin B6, 3 mg; vitamin B12, 5000 mg; Vitamin PP (niacin), 105 mg; folic acid, 37500 mg;. Trace elements: Iron, 0.5%; Copper,0.07%; Manganese, 0.5%; Zinc,0.7%; Selenium, 0.003 %; Minerals: Calcium, 30.7%. Other Additives: Anti-oxidant (BHT, Ethoxyquin, propyl Gallate) 0.03%.*

3.4. Preparation of Experimental Treatments

The experimental treatment was garlic extract as additives. Fresh garlic cloves (*Allium sativum l.*) used for the study were purchased from vegetable market in Wolkite town. The Superficial bulk of garlic was removed manually and then washed with clean tap water properly. Garlic extract were prepared by crushing peeled garlic cloves and blending with clean tap water (1:1, w/w) by blender machine (wibabaw *et al*., 2015) and kept overnight (Obochi *et al*., 2009). Then after Garlic extract was filtered using a cheese cloth. Finally, it was stored at 4°C in a refrigerator to maintain the active ingredients. During the whole process of the experimental period, the filtered extract were further mixed into the drinking water at a dosage of 1.5 cc/100 cc drinking water (Treatment 3); 3 cc/100 cc drinking water (Treatment 4); while the control groups (Treatment 1) "negative control groups (NC)" were given drinking water only and those chicks grouped under Treatment 2 were allowed to drinking water containing antibiotics "positive control groups (PC)''.

3.5. Experimental Design and Treatment

The Experiment was conducted in two phases which lasts for a period of 56 days, starter period (1 to 28 days of age) and finisher period (29 to 56 days of age). Unsexed commercial hybrid day old broiler chicks of ROSS 308 strain which were received from ELEFORA Agro-Industries PLC farm were used for the experiment. Chicks with extreme high and low weights were discarded and arrived to experimental site. A total of 180 chicks were randomly divided in to four treatment groups and three replications per treatment in a CRD with 15 chicks with uniform average group weight per replicate or pen. Floor system housing, each with dimension of 1 * 1.5 m was prepared. The chicks were penned at a stocking density of 10 chicks per m^2. The floor of house or pen was covered with teff straw.

These basal diets (either starter or finisher) were given for every group. The antibiotics and the garlic extracts were administered orally to the chicks of the three dietary groups via drinking water at the following concentrations.

T1: basal diet and drinking water with no additive (NC)

T2: basal diet and drinking water containing 0.2g/10L oxytetracycline (PC)

T3: basal diet and drinking water containing 1.5% Garlic extract

T4: basal diet and drinking water containing 3% Garlic extract

3.6. Management of Experimental Bird and Preparation of Poultry Equipment

Before the commencement of the actual work, the experimental house was prepared and divided into twelve separate pens using wood board and wire meshes with the appropriate door for each pen. Before placing the experimental birds into the pens; heating unit (electric system) were checked for normal functioning whole unit of house (pens) was cleaned and disinfected with formalin two weeks before the chicks are introduced. The pens were littered with fresh, properly dried and disinfected teff straw at a depth of about 10 cm.

After the arrival of the chicks, they were assigned (placed) into each pen with basal diet and cleaned drinking water along with appropriate treatment. In the first week of feeding trial the feed was given to the chicks flat surfaced feeders. Thoroughly cleaned and disinfected plastic drinkers were also placed in each experimental pen. After the first week of experimental period, the flat surfaced feeders were replaced by hanging type plastic feeding troughs. The chicks were vaccinated twice at the age of day 1^{st} and 7^{th} against Infectious Bursal Disease (IBD) through ocular routes and two times against New Castle Disease (NCD) at the age of 14^{th} and 28^{th} day with drinking water. Throughout the trial additional health precautions and sanitary procedures were implemented.

The house was electrically heated using 200 watt bulbs per pen as source of heat and light with gradual height adjustment and in the absence of electric light charcoal was used as source of heat for brooding and solar battery as source of light. The brooder temperature was maintained at about 35-32°C for the first 7 days of age. After 7 days the temperatures was gradually reduced by 2 °C every week up to the end of the experiment.

Ventilating by removing the outer covering of the house during high temperature and the reverse during decreased temperature, addition of fresh litter material and others were followed. Feed and clean tap water with the respective treatments was offered *ad libitum* throughout the experimental period. They were fed twice a day at 8:00am and 1:00pm hours throughout the experimental period.

3.7. Measurements

3.7.1. Performance evaluation

The experiment lasts for 8 weeks, during which the daily feed intake and weekly body weight (BW) measurements were considered. The growth performance data were collected considering, Daily Feed Intake (DFI), weekly body weight, Body Weight Gain (BWG) and Feed Conversion Ratio (FCR). Feed was weighed every morning using a sensitive balance with 0.01 sensitivity and offered to the respective group. Feed refusals were collected every other morning, weighed after removal of the external contaminants and FI was calculated as the difference between feed offered and feed refused for each replication. The chicks were weighted at the beginning of the experiment as initial body weight and then weekly in a pen group using sensitive balance and the pen average BWG was computed as the difference between the end and beginning body weights.

Average daily gain (ADG) was calculated as the ratio of BWG to the number of experimental days.

$$\text{ADG} = \frac{\text{Total body weight gain}}{\text{Number of experimental days}}$$

Feed Conversion Ratio (FCR) is computed as the ratio of feed consumption to BWG.

$$\text{FCR} = \frac{\text{Feed consumed}}{\text{Body weight gain}}$$

The water consumption of birds were also measured throughout the experimental period to measure the amount of test ingredients used (garlic and oxytetracycline) for evaluation of production economics of broiler based on the methods applied in the current study. The total amount of water consumed was measured every time while water is administered to each pen. The amount of antibiotics and garlic (oxytetracycline) taken by the birds was also measured.

3.7.2. Carcass evaluation

At the end of the experiment, two birds were purposely selected from each replicate based on average group weight for carcass evaluation. The birds were starved for overnight (except for water) and leg-banded for identification immediately before slaughtering. After taking the slaughtered weight measurement data, each bird was killed and bled hanged from a bleeding cone for about three minutes. Following bleeding, the birds were de-feathered manually after scalding in hot water for approximately two minutes.

Dressed and eviscerated weights were calculated following the method of FAO (2001). Dressing carcass weight was measured after removal of blood and feather. Dressing percentage was also calculated as the proportion of dressing carcass weight to slaughter weight multiplying by one hundred. Eviscerated carcass weight were determined after removing blood, feather, kidney, lungs, pancreas, crop, proventriculus, small intestine, large intestine, caeca, leg, head and urogenital tracts from dressing carcass. Eviscerated percentage was determined as the proportion of the eviscerated weight to slaughter weight multiplied by one hundred.

From eviscerated carcass drumsticks with thighs, breast meat, wings, neck and back were separated and weighed separately and their individual weight was divided by slaughter weight and multiplied by one hundred to determine percentage weight of each component. The commercial carcass yield was calculated by including drumsticks with thighs, wings, breast, back and neck. The edible carcass yield was calculated by including the edible offal to the commercial carcass parts considering the common practices in Ethiopia. The different values for the measurements of interest were computed employing the following formula (FAO, 2001):

Dressing weight = Drumsticks with thighs + Wings + Breast + Back + Neck + Heart + Liver + Gizzard + Feet + Head + Viscera (inedible offal)

Eviscerating weight = Dressing weight - Viscera (inedible offal)

Commercial carcass weight (Ready-to-cook) = Drumsticks with thighs + Wings + Breast + Back + Neck

Edible carcass yield = Commercial carcass weight + Edible offal (Heart, Liver and Gizzard)

Fat around the proventriculus and gizzard and against the abdominal wall and the cloacae were collected and weighed using sensitive balance. Fat percentage was calculated as the proportion of fat weight to slaughter weight and multiplied by one hundred. The edible offal (giblets) which includes the heart, gizzard and liver as well as the inedible offal (feet, head, fat and GIT) were weighed and expressed in relation to the slaughter weight.

3.7.3. Economic appraisal

The following parameters were evaluated to estimate the economics of production: The costs (cost/kg) for the starter, finisher and entire period of feeding were considered by incorporating the cost of supplementation of antibiotics as well as different levels of garlic extract. The cost per kg weight gain was calculated according to the procedures of Ukachukwu and Anugwa (1995), which involves taking the product of cost per kg of feed and feed-to-gain ratio of birds.

The average selling prices of broilers was obtained by using the average carcass weight of birds multiplied by the price of broiler carcass in the supermarkets on selling time. Total income (TI) generated/bird, net returns (NR)/bird, economic efficiency (ECE) {(NR/total cost of production)*100} were computed. Relative economic efficiency (%) (REE) was also calculated based on the formula{(ECE of treatment/ECE of control)*100}. The economic analysis was done assuming that purchasing price of birds, labor and other expenses remain at Birr 40 birr/bird, whereas the income analysis was done based on Birr 170/kg of carcass in supermarket.

3.8. Statistical data Analysis

All collected data during the experimental period were subjected to analysis of variance (ANOVA) using the general linear model (GLM) procedure by Statistical Analysis Systems software (SAS). Duncan's multiple range tests was used to detect differences among the treatment means. Differences among the treatment means and significance was considered at ($P < 0.05$).

The following model was used for the purpose of analysis:

$$Y_{ij} = \mu + \alpha_i + \varepsilon_{ij}$$

Where: Y_{ij} = the jth observation with treatment i

μ = overall mean

α_i = the ith treatment effect

ε_{ij} = the random error term normally and independently distributed ($0, \delta^2$)

4. RESULTS

4.1. Growth Performance

The effects of feeding different levels of garlic extract on FI, FBW, BWG and FCR of broiler chickens are presented in Table 4. Compared to the control groups inclusion of different levels of garlic extract in broiler drinking water did not have any significant effect on Total Feed Intake (TFI) *(P>0.05)* and Daily Feed Intake (DFI) *(P>0.05)* during the starter phase. During the finisher period, birds kept on T3 and T4 had significantly lower TFI *(P<0.05)* and DFI *(P<0.05)* as compared to those kept on the antibiotic group (T2). Correspondingly, birds kept on T3 also had significantly lower TFI *(P<0.05)* and DFI *(P<0.05)* as compared to negative control. Total Feed intake (TFI) and daily feed intake (DFI) for the entire experiment was significantly lower for T3 *(P<0.05) than T1 and T2,* as well as T4 *(P<0.05)* as compared to T2 *(P<0.05)*.

Final body weight (FBW) of birds during starter and finisher phase were highly affected by the inclusion of garlic extract. At the end of the starter period birds kept on T4 achieved a significantly higher FBW *(P<0.05)* compared to the negative control and the antibiotic treatment. Similarly birds kept on T3 had significantly higher FBW *(P<0.05)* as compare to T1. At eight weeks of age the result showed that FBW was significantly higher for T4 *(P<0.05)* as compared to T1 and T2 while T3 did not bring about any significantly effect on the finisher FBW *(P>0.05)* of broiler chicken. Birds kept on T1 had significantly lower BWG *(P<0.05)* during the starter phase of experimental period as compare to other treatment except the groups treated with antibiotics (T2). On the other hand, birds kept on T4 were superior interms of BWG *(P<0.05)* as compared to T1 and T2. According to the results obtained in the current study, the BWGs during the finisher phase were not significantly *(P>0.05)* affected by the additives. However, birds kept on T4 had significantly higher BWG *(P<0.05)* and ADG *(P<0.05)* during the entire experimental period as compared to the other treatments except T3.

Birds kept on T4 and T1 had significantly higher FCR *(P<0.05)* as compared to T2 during the starter period of the trial whereas during the finisher phase no significant difference was observed between groups in terms of FCR *(P>0.05)*. But, during the overall experimental period T3 and T4 had significantly lower FCR *(P<0.05)* than the control groups.

Table 4. The effects of different garlic extract levels inclusion in drinking water on growth performance of broilers during the starter and finisher phase and the entire experiment.

Variables	Stage (Days)	Treatment					P Value
		T1	T2	T3	T4	SEM	
	0-28	1486.4	1492.9	1498.6	1494.0	2.068	0.295
TFI	29-56	3223.7^{a-b}	3262.9^{a}	3067.6^{c}	3109.9^{b-c}	17.714	0.014
(gm/bird)	0-56	4710.1^{a-b}	4755.9^{a}	4566.1^{c}	4603.8^{b-c}	17.461	0.016
	0-28	53.09	53.32	53.52	53.36	0.074	0.295
DFI	29-56	115.1^{a-b}	116.5^{a}	109.6^{c}	111.1^{b-c}	0.633	0.014
(gm/bird)	0-56	84.11^{a-b}	84.93^{a}	81.54^{c}	82.21^{b-c}	0.312	0.016
IBW (gm/bird)	Day 1	35.11	35.10	35.23	35.19	0.031	0.419
FBW	28th	716.2^{c}	730.4^{b-c}	764.4^{a-b}	772.4^{a}	5.247	0.015
(gm/bird)	56th	1824.9^{b}	1829.4^{b}	1837.0^{a-b}	1845.8^{a}	2.030	0.029
	0-28	681.1^{c}	695.3^{b-c}	729.2^{a-b}	734.4^{a}	5.354	0.020
BWG	29-56	1108.7	1089.0	1072.6	1073.4	5.707	0.127
(gm/bird)	0-56	1789.8^{b}	1794.3^{b}	1801.8^{a-b}	1810.6^{a}	2.022	0.029
ADG (gm/bird)	0-56	31.16^{b}	32.04^{b}	32.17^{a-b}	32.33^{a}	0.036	0.029
	0-28	2.18^{a}	2.15^{b-c}	2.06^{a-b}	2.00^{c}	0.016	0.034
FCR (FI	29-56	2.91	2.97	2.86	2.90	0.014	0.123
gm/BWG)	0-56	2.63^{a}	2.65^{a}	2.53^{b}	2.54^{b}	0.009	0.004

a-c Means with different superscripts within the same row are significantly different (P<0.05); SEM: Standard error of mean; FI: Feed intake; DFI: Daily feed intake; IBW: Initial Body Weight; FBW: Final Body Weight; BWG: Body Weight Gain; ADG: Average daily gain; FCR: Feed conversion Ratio; T1 = basal diet and drinking water with no additive. T2 = basal diet and drinking water with Oxytetracycline (PCON). T3 = basal diet and drinking water with 1.5% GEX. T4 = basal diet and drinking water with 3% GEX. P= Probability.

Mortality rate for birds kept in the different groups during the experimental periods is shown in Figure 1. Mortality rates assessed during the time of this experiment were relatively higher for T1 (4.4%) happened when at 1st and 3rd weeks as well as T2 (2.2%) when at 2nd week, whereas hundred percent livability was observed for birds kept on T3 (1.5% garlic extract in drinking water) and T4 (3% garlic extract in drinking water).

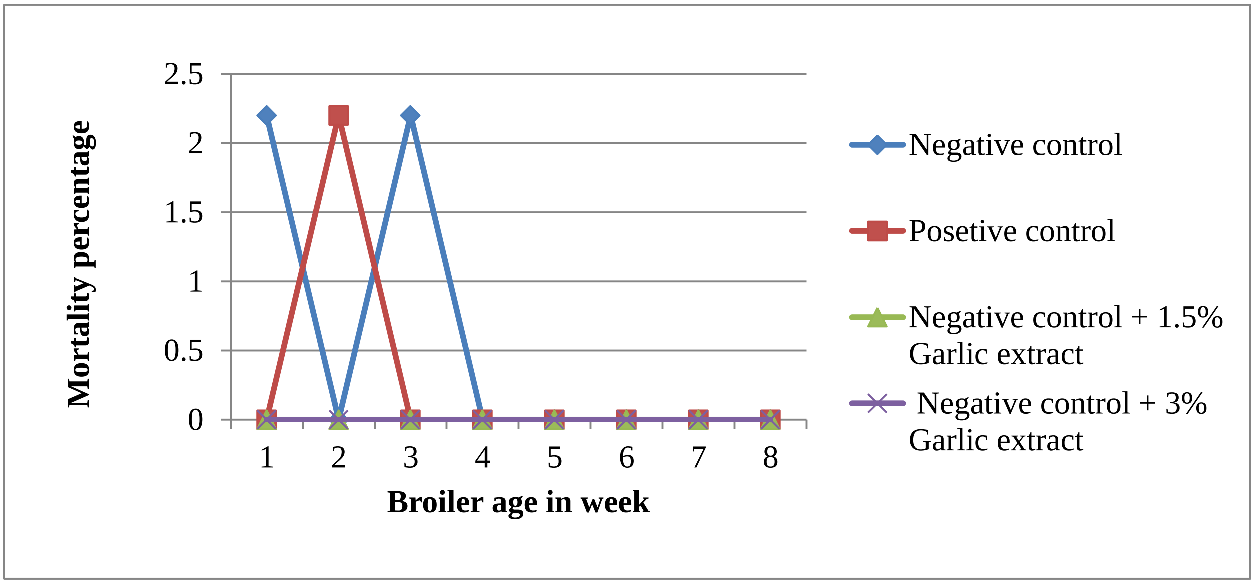

Figure 1. Mortality of birds under the different groups during the different phases of the experiment.

4.2.Caracas yield

The effects of the inclusion of different levels of garlic extract on the slaughter weight, dressed weight and eviscerated weight of broilers is shown in Tables 5. The slaughter weight was significantly higher for T4 *(P<0.05)* followed by T3, T2, T1 respectively. The dressed weight and dressing percentage was also significantly lower for T1 *(P<0.05)* as compared to T4 and T3 but not significantly different from T2 *(P>0.05).* Similarly, dressed weight and dressing percentage was also significantly higher for T4 (*P<0.05)* as compared to T1 and T2. The eviscerated weight was also significantly higher for T3 and T4 *(P<0.05)* as compared to T1. Correspondingly eviscerated percentage value of T3 was higher significant than T1 *(P<0.05).*

Table 5. The effects of different garlic extract levels inclusion in drinking water on slaughter weight, dressed weight and eviscerated weight of broilers during the entire experiment.

Variables	Treatments				SEM	P-value
	T1	T2	T3	T4		
Slaughter weight (gm)	1823^{b}	1828^{b}	$1836^{a\text{-}b}$	1841^{a}	1.846	0.035
Dressed weight (gm)	1615^{c}	$1629^{b\text{-}c}$	$1648^{a\text{-}b}$	1661^{a}	4.140	0.019
Dressing (%)	88.6^{c}	$89.1^{b\text{-}c}$	$89.8^{a\text{-}b}$	90.2^{a}	0.159	0.028
Eviscerated weight (gm)	1273^{b}	$1283^{a\text{-}b}$	1297^{a}	1296^{a}	2.343	0.018
Eviscerated (%)	69.8^{b}	$70.2^{a\text{-}b}$	70.7^{a}	$70.4^{a\text{-}b}$	0.087	0.046

a-c Means with different superscripts within the same row are significantly different (P<0.05) T1 = basal diet and drinking water with no additive. T2 = basal diet and drinking water with Oxytetracycline (PCON). T3 = basal diet and drinking water with 1.5% GEX. T4 = basal diet and drinking water with 3% GEX. SEM = Standard error of the mean, P = probability.

As shown in Table 6, no significant difference *(P>0.05)* was observed in the weight and percentage of commercial cuts among all the treatments except for breast weight. Among groups T2, T3 and T4 showed significantly higher breast weight as compared to T1 *(P<0.05)*. Weight of commercial and edible carcass were significantly higher for T4 *(P<0.05)* as compared to T1 and T2, whereas no significant difference were observed between T3 *(P>0.05)* and T4 *(P>0.05)* on commercial and edible carcass weight. The results also revealed that T3 *(P<0.05)* had highly significant effect on commercial and edible carcass weight as compared to T1, whereas there was no significant difference *(P>0.05)* observed on the commercial carcass percentage and edible carcass percentage among all the treatments.

Table 6. The effects of different garlic extract levels inclusion in drinking water on the commercial cuts of broilers.

Variables	Treatments				SEM	P- value
	T1	T2	T3	T4		
Breast weight (gm)	492[b]	498[a-b]	501[a]	506[a]	1.253	0.031
Breast (%)	27.0	27.2	27.3	28.0	0.062	0.154
Drumsticks with thighs(gm)	372	368	372	376	0.924	0.235
Drumsticks with thighs (%)	20.4	20.1	20.3	21.8	0.046	0.205
Back weight (gm)	155	157	156	160	0.579	0.594
Back (%)	8.52	8.56	8.52	8.67	0.037	0.940
Wing weight (gm)	64.2	65.3	64.6	65.4	0.155	0.091
Wing (%)	3.52	3.57	3.52	3.55	0.006	0.061
Neck weight (gm)	48.3	49	48.6	48.7	0.126	0.428
Neck (%)	2.65	2.68	2.65	2.64	0.005	0.162
Commercial carcass weight (gm)	1133[c]	1136[b-c]	1143[a-b]	1150[a]	1.236	0.005
Commercial carcass (%)	62.2	62.2	62.3	62.5	0.056	0.204
Edible carcass weight (gm)	1207[c]	1211[b-c]	1218[a-b]	1225[a]	1.285	0.005
Edible carcass (%)	66.2	66.3	66.4	66.5	0.059	0.265

a-c Means with different superscripts within the same row are significantly different (P<0.05); T1 = basal diet and drinking water with no additive. T2 = basal diet and drinking water with Oxytetracycline (PCON). T3 = basal diet and drinking water with 1.5% GEX. T4 = basal diet and drinking water with 3% GEX. SEM = Standard error of the mean, P = probability

The data on the weight and percentage of the edible offal (giblet) are indicated in Table 7. The findings on the weight and percentage of the edible offal (giblet) showed the absence of significant difference *(P>0.05)* among treatment groups, except for the weight of the livers which was significantly lower for T1 *(P<0.05)* compared to all other groups.

Table 7. The effects of different garlic extract levels inclusion on weight of giblets.

Variables	Treatments				SEM	P- value
	T1	T2	T3	T4		
Liver weight (gm)	33.6^{b}	34.3^{a}	35.4^{a}	34.0^{a}	0.047	0.033
Liver (%)	1.84	1.86	1.96	1.84	0.002	0.131
Gizzard weight (gm)	31.7	31.9	31.8	31.9	0.063	0.558
Gizzard (%)	1.74	1.75	1.74	1.73	0.004	0.577
Heart weight (gm)	8.39	8.98	8.71	8.62	0.069	0.085
Heart (%)	0.46	0.49	0.47	0.47	0.004	0.088

a-c Means with different superscripts within the same row are significantly different (P<0.05); T1 = basal diet and drinking water with no additive. T2 = basal diet and drinking water with Oxytetrcycline (PCON). T3 = basal diet and drinking water with 1.5% GEX. T4 = basal diet and drinking water with 3% GEX. SEM = Standard error of the mean, P = probability.

The effects of various levels of garlic extract on non-edible parts including the weights of feet, head, fat contents and GIT are presented in Table 8. The average value of weight and percentage of abdominal fat were significantly lower *(P<0.05)* for T2, T3 and T4 as compared to T1. At the same time, the reported results on GIT weight for T2, T3 and T4 showed the existence of highly significant difference *(P<0.05)* as compared to T1, however, the GIT percentage among treatments was not significantly *(P>0.05)* affected.

Table 8. The effects of different garlic extract levels inclusion on non-edible parts.

Variables	Treatments				SEM	P-value
	T1	T2	T3	T4		
Feet weight (gm)	67.6	68.3	68.1	67.9	0.125	0.121
Feet (%)	3.70	3.74	3.71	3.69	0.006	0.121
Head weight (gm)	39.4	40.5	40.2	41.3	0.262	0.177
Head (%)	2.16	2.22	2.19	2.24	0.016	0.384
Fat weight (gm)	15.1^{a}	13.3^{b}	13.5^{b}	13.6^{b}	0.082	0.002
Fat (%)	0.83^{a}	0.73^{b}	0.73^{b}	0.74^{b}	0.005	0.002
Weight of GIT (gm)	74.9^{b}	75.9^{a}	75.5^{a}	76.2^{a}	0.113	0.024
GIT (%)	4.11	4.15	4.12	4.14	0.010	0.418

a-c Means with different superscripts within the same row are significantly different (P<0.05); T1 = basal diet and drinking water with no additive. T2 = basal diet and drinking water with Oxytetracycline (PCON). T3 = basal diet and drinking water with 1.5% GEX. T4 = basal diet and drinking water with 3% GEX. SEM = Standard error of the mean, P = probability.

4.3. Economic appraisal

Economic evaluation data were summarized in Table 9. The price figures are based on the market prices for feed ingredients, additives and broiler carcass during the time of the experiment. The amount of money (Birr) spent for the purchase of feed required to bring about 1kg live weight gain for the overall period were higher for T2 and T1 respectively as compared from T3 and T4. The total cost of feed per kg of carcass per bird was also higher for T2 and T1 respectively as compared to T3 and T4. On the other hand, the total cost of production for T4, T3 and T2 respectively were higher and the lowest total cost of production was reported in the case of negative control group (T1). The highest total income (TI) was observed in T4 followed by birds kept on T3, T2 and T1 respectively. The lowest Net return (NR), Economic efficiency (ECE) and Relative economic efficiency (REE), on the other hand was observed in treatment group containing 3% GEX (T4).

Table 9. The effects of different garlic extract levels inclusion in drinking water on selected economic parameters.

Variables	Treatments			
	T1	T2	T3	T4
Cost per kg of starter diet (Birr)	21.4	21.4	21.4	21.4
Cost per kg of finisher diet (Birr)	19.4	19.4	19.4	19.4
Total cost of feed/bird (Birr)	94.5	95.4	91.7	92.4
Total cost of antibiotic/ bird (Birr)	-	0.2	-	-
Total cost of garlic/bird (birr)	-	-	5.5	10.5
Feed cost/kg of gain (0-28th day)	46.8	46	44	43.6
Feed cost/kg of gain (29-56th day)	56.5	58.2	55.6	56.3
Feed cost/kg of gain (1-56th day)	52.8	53.2	50.9	51.1
Total cost of production /bird (Birr)	134.5	135.6	137.2	142.9
Feed cost/kg carcass/bird (Birr)	83.4	84	80.2	80.4
Total income/bird (Birr)	192.6	193.1	194.3	195.5
Net return/bird (Birr)	58.1	57.5	57.1	52.6
Economic efficiency (ECE)	43.2	42.4	41.6	36.8
Relative economic efficiency (REE)%	100.0	98.1	96.3	85.2

T1 = basal diet and drinking water with no additive. T2 = basal diet and drinking water with Oxytetracycline. T3 = basal diet and drinking water with 1.5% GEX. T4 = basal diet and drinking water with 3% GEX.

5. DISSCUSIONS

5.1. Growth Performances

5.1.1. Feed consumption

In the curent study, the effects of oral administration of garlic extract on the performance and carcass characteristics of broiler were investigated. In this regard, the overall results of feed intake by garlic extract (GEX) treatment groups are negatively influenced as compared to control and antibiotics. The finding of current study also has similarity with the results of (Tucker, 2002; Thakar *et al*., 2004; Sarica *et al*., 2005) who reported that, lower significant effect of GEX on the feed consumption of broiler chickens. The finding is in good agreement with the report of Borek (2010) where the presence of garlic solution at a concentration of 0.25% has no positive influnce on feed intake of broiler chiken. The current results are also supported by Bowker and Zhuang (2013) who report that, the addition of garlic solutions 1 up to 5% does not have a significan effect on feed intake of broiler. The results of the current study also in line with (hossia, 2020) who indicate that, broilers kept under with 1 clove of garlic per 2 litter of drinking water show no improvement interms of feed consumption as compared to birds confined under control group. However, the observed indicated that, no significant difference among both levels of GEX treatment group's interms of feed intake value. This finding is supported by Wibabaw *et al*., (2015) who indicate that, no significant different of feed intake value performed between additions of various levels of 2.5 and 5% Garlic extract in drinking water of broiler chicken.

Lower feed intake observed on birds' exposed to the GEX containing groups in the current study might be related with the consumption of a reduced amount of water that should be associated with the pungent smell of garlic. According to Hossia (2020), changes in palatability namely odor and taste of water caused by garlic has lower significant effect on broiler chicken feed consumption. This result is supported by Kellerup *et al*. (2012) who report that, decrease in water consumption associated with a reduction in broiler feed intake in broiler farm. The results of low feed intake observed in the current study on birds' assigned to the GEX containing treatments is also supported by Zena *et al.* (2017) who suggest that, the absence of substantial benefits of Garlic powder on fed intake (FI) of broilers may be due to the strong odor of the garlic.

Similarly, Wibabaw *et al*. (2015) also report that, the lack of improved performance in GEX on broiler feed intake is most likely due to the pungent garlic odor.

The current study finding is in contrast with the report of Javandel *et al*. (2008) who found that feed consumption are considerably greater in birds fed with garlic concentrations at levels of 0.125 and 0.25%. The result of current study is not in agreement with the finding of (Elagib, 2013) who indicates that, birds exposed to diets containing 3% garlic showed significantly higher feed consumption value. Similarly, Wibabaw *et al*. (2015) also conclude that, administration of Garlic extract in drinking water results in a significant increase in feed efficiency compared to control groups.

5.1.2. Body weight gain

According to the result of the current study, during the starter period FBW and BWG improvement of the birds kept on treatment containing 1.5% GEX is comparable with the birds kept on the antibiotic containing group. The result of current finding is in line with the report made by Islam *et al*. (2017) who indicate that, up to four weeks of the broiler age there is no observed significance influence of at 1% GEX containing treatment groups when it compared from the antibiotic groups. In this regard, adaptation to garlic treatment it may be one factor. Wibabaw et al. (2015) and Zena *et al.* (2017) also suggested that, it should be needed chickens to adapt this kind of additive. Supplementing proper amount of active ingredient (allicin) also another factor, because this is an important for body weight improvement of birds. (Sasi *et al*., 2021) suggested that, allicin supplementation enhances pancreatic enzyme activity and generates a favorable environment for food digestion.

The results of the present study showed that during the starter period garlic extract at 1.5% is highly affected FBW and BWG as compared to negative control group. This finding is similarity with the result of Brzóska *et al.* (2015) who reported that, the dietary supplementation of liquid garlic at the levels of 1.50 and 2.25 ml kg–1 significantly increased body weight of birds than the negative control group. However, the findings of current study treatment groups obtained 3% GEX showed the significantly higher FBW and BWG as compared to both negative control and antibiotics groups. The observed FBW and BWG increases with increasing level of inclusion of GEX at the starter period. Odunowo and Olumide (2019) suggested that, could majorly be attributed to benefits of the amount of phytogenic compound in the garlic which helps to increase growth performance of experimental birds.

The observed in the overall of the trial period birds allocated with GEX treatment groups has better performance of FBW, BWG and ADG. The result of the current study are also supported by the reports of Islam *et al*. (2017) who indicate that, garlic extract (GEX) supplementation in broiler drinking water has a substantial impact on body weight gain from 7 to 35 days of age when compared from control groups. Similarly, the findings made by Alçiçek *et al*. (2003) also indicate that using essential herb oils enhanced broiler chicken body weight at the end of 42 days. This finding is agreement with the result of Noman *et al*. (2015) who report that, a treatment level of 1% and 2% garlic extract groups show better final body weight performance as compared to positive and negative control groups. Correspondingly, the results of the current study is supporte by the finding of Brosna *et al*. (2015) and Brzóska *et al*. (2015) who indicate that, during the overall study times the dietary supplementation of garlic extract at the levels of 1.5 and 2.25 ml kg^{-1} significantly enhanced FBW and BWG as compared to the treatments of negative control group. The result of the current study also has similarity with the finding of Wibabaw *et al*. (2015), who revealed that, 2.5 and 5.0% garlic extract added to drinking water improved FBW and BWG of broiler. However, the current finding indicated that, no significant difference between both levels of GEX treatment group's interms of FBW and BWG performance. The finding of current study has similarity with the results of Dieumou *et al*. (2011) who indicate that, there is no significant difference between the weight gains of birds supplemented with garlic extract at 40 and 60 ppm/kg, but these values is significantly higher than the value recorded in birds on the negative controls.

A number of researchers have suggested and reported the beneficial effect of garlic extracts on growth promoting in broilers (Javed *et al*., 2009; Mahmood *et al*., 2009; Elagib *et al*., 2013), it brings about significant effect on body weight gain by increasing the numbers of villus and goblet cells in the duodenum. As a result of these intestinal morphological changes, the overall feed absorptive process in the birds is better activated (Adibmoradi *et al*., 2006). *Allicin* a potent plant chemical is primary active component of garlic. It breaks down quickly into a number of organosulfur compounds containing bioactive properties (Chang and Cheong, 2008). *Allinase* and its principal substrates *alliin, allicin* and *allyl sulphides* are present in the aqueous extract of crushed garlic bulbs (Staba *et al*., 2001). Other researcher also suggested that the antibacterial compound dialkyl polysulphide present in garlic extract is playing a pivotal role in increasing BWG of broilers (Ross *et al*., 2001). It possesses antibacterial, antiviral, antiparasitic, antifungal, anticholesteremic, antioxidant, anticancer and vasodilator properties (Hanieh *et al*., 2010).

The result of current study are not in agreement with the reports of Kari *et al*. (2017) who revealed that garlic has no influence on broiler BWG and growth performance. Similarly, Karangiya *et al*. (2016) also reporte that, 1% garlic has no significant effects on FBW and BWG of broilers as compared to control groups. Sarica *et al*. (2005) on the other hand report that, chickens fed on diets containing 0.3% and 0.6% garlic extract has the same weight gain with control groups which all are not in agreement with the result of the current study.

5.1.3. Feed conversion ratio

In the overall, the current trial indicated the presence of significant improvement interms of FCR following the uses of 1.5 and 3% GEX which is in agreement with Melaku *et al*. (2019) who indicate that, broiler feed containing garlic powder at level of 3% show better FCR than the control groups. The results of the current study is also in agreement with the finding of Islam *et al*. (2015) who report that, poor FCR is observed in negative control groups and better FCR was performed in 1 and 2% garlic extract supplemented groups. According to Javed *et al*. (2009) better FCR and weight gain has happened due to the positive effect of garlic aqueous extract given to the birds. The current result is also in similarity with some other studies Rehman *et al*. (2012) and Senthikumar *et al*. (2015) who conclude that, mean FCR values are significantly influenced by water based infusion of garlic. Similarly, Onyimonyi *et al*. (2012) and Akoy (2015) also report that, the provision of garlic extracts to the broiler chicken has a positive effect on FCR of broiler. They also report that, the use of herbal extracts specially garlic improved FCR as compared to the antibiotic virginiamycin in broilers.

Karim *et al*. (2017) suggested that, the improvement in FCR upon the supplementation of garlic extracts has probably due to the increasing activity of sulfur compounds mainly *alliin, allicin, ajoene* of garlic, which brings about better feed conversion value indicating high feed efficiency. The improvement attained on the FCR and digestibility could be attributed to the improvement of digestive enzymes secretion (Rahimi *et al*., 2011). Similarly, Incharoen *et al*. (2010)

demonstrated that garlic supplementation in broiler can increase the intestinal villus height, villus area, cell area and intestinal cell mitosis which results in better feed conversion efficiency. Zena *et al*. (2017) also suggested that, higher or lower FI and BWG do not actually indicate the good or bad performance of birds rather FCR show the actual performance. Lower FCR indicates improved performance due to lower FI and greater BWG.

The results of the current finding is contradicted with the reports of Taufik and Maruddine (2018) who revealed that, supplementation of GEX with 3, 6 and 9% levels had no effect on FCR of broiler. Similarly, Raeesi *et al*. (2010) also conclude that, addition of garlic powder at dose of 0.5, 1 and 3% in broiler's diet from day old to finisher did not affect FCR. , those all are disagree with the result of the current finding. But, the suggestion of Sapsuha (2006), feed conversion efficiency is influenced by several factors, i.e. feed quality, chicken's strain and treatments administration methods. Similarly, Amrullah (2003) also reporte that, besides feed quality and feeding method can noticeably affected FCR of broiler.

5.1 4. Mortality

An important observation from current study, the garlic extract inclusion levels are reduced bird mortality on the overall rearing periods. The current finding result is supported by Brzóska *et al. (*2015) indicate that, garlic extract inclusion levels at 1.5 and 2.25 ml kg^{-1} reduced mortality rate of broiler as compared to control groups. Garlic's antibacterial action on harmful bacteria in the gastrointestinal tract and immune system activation reduce chicken mortality rates. Other researchers also suggest that, garlic and garlic products have shown a broad antibiotic spectrum against both gram-positive and gram-negative bacteria (Harris *et al*., 2001) and have been effective against many common pathogenic, the intestinal bacteria that cause diarrhea in humans and animals (Tatara *et al*., 2008). Garlic has been extensively researched for its medicinal benefits and has been shown to have immune modulatory characteristics through activating the immune system (Kyo *et al*., 2001). In the current study observed that mortality happened during the starter period of rearing birds kept under control groups. The results similarity with Brzóska *et al. (*2015) who reported that, chicken mortality is highest during the first period of rearing (0–28 days) when the immune system is not fully functional and chickens are exposed to pathogenic bacteria in feed and faces at a time when the digestive system and the gastrointestinal tract are not fully developed.

5.2. Carcass yield

5.2.1. Slaughter weight

In the current study, the addition of garlic extract (GEX) at higher level in broiler drinking water has brought about a higher improvement effect on slaughter weight of birds as compared to controls. Which are consistent with final body weight recorded at the end of the experiment. This indicates that the addition of level of GEX in drinking water simultaneously also improves the slaughter weight of the broilers. The result of current study is in agreement with Brzóska *et al*. (2015) who report that, chicks which are reared with liquid garlic extract at inclusion level of 1, 1.5, and 2.25 ml kg-1 showed higher slaughter weights. The result of current study also has similarity with the results of Nikola *et al*. (2016) who indicate that, broilers assigned to the treatments containing a garlic powder of 0.5 and 1% level showed significant increases in the slaughter weight of broiler. Correspondingly, the results obtained in the current study is in agreement with the reports of Odunowo and Olumide (2019) which indicate that, Garlic powder supplementation at levels of 0.2, 0.4 and 0.8% are accompanied with significantly higher slaughter weight when comparing them with birds of control groups.

On the other hand, the observed in current study is not in agreement with the findings of zena *et al.* (2017) who report that, the inclusion of garlic powder at 2% levels did not significantly affect slaughter weight of birds when compared them with the control diet, his also suggest that it might be associated with variations in garlic preparation and its administration methods could also be the factors for either negative or positive feedback for slaughter weight of broiler.

5.2.2. Dressed weight and its percentage

As far as the dressing weight and dressing percentage of broiler chickens are concerned, there is a significant effect among treatment groups administered with garlic extracts having a level of 1.5% as compared to negative control group. On the other hand treatment groups containing GEX at the level of 3% showed highly significant values of dressing weight and dressing percentage than both positive and negative control groups. The results of current study on the dressing weight and dressing percentage of broilers is in agreement with the report of Noman *et al*. (2015) and Islam *et al*. (2017) indicate that among the treatments 1% GEX containing groups has highest dressing weight and dressing percentage followed by Positive control and the lowest values are for the Negative control group. The result of the current study are also supported by the findings of Makwana *et al*. (2018) who report that, significantly higher values of average dressing weight and percentages in the treatment groups containing garlic powder at levels of 0.1, 0.5 and 1% than control groups. Ashayerizadeh *et al*. (2009) also report, significant increase in dressing percentage on garlic supplementation groups. Dressing weight and its percentage is significantly higher in chickens from the 2.25 ml kg^{-1} liquid garlic extract containing group as compared to chickens from the control group (Brzóska *et al*., 2015). According to Odunowo and Olumide (2019), Garlic powder supplementation at levels of 0.2, 0.4, and 0.8% has similar effect on dressing weight and dressing percentage of broiler like that of the current study. Similarly, the reports of Feyad *et al*. (2019) indicate that, an increase in dressing weight and its percentage of birds are associated with feeding of birds on garlic extracts at level of 500 mg/kg diet as compared to control groups which all are in agreement with the results of current study.

On the other hand, the results of the current study contradicted with the reports made by Yadav *et al*. (2016), the absence of any significant effect on dressing weight and the dressing percentage of broilers supplemented with garlic extracts. The results of the current study also are not in agreement with the findings of Ahmed (2005) and Adibmoradi *et al*. (2006) who report that, the inclusion of garlic extract in broilers diet has not any significant effect on dressing percentage values. Similarly, Bamgbose *et al*. (2007) also revealed that, the existence of non-significant differences in the dressing percentages of the experimental birds fed on garlic supplemented diet disagreed with the current findings. Karangiya *et al*. (2016) and Nikola *et al*. (2016) on the other hand reporte that, the inconsistent outcomes which contradicted with the findings of current study indicating the existence of significant reduction in dressing weight and dressing percentage of broilers through the inclusion of Garlic powder at rate of 1% inclusion.

5.2.3. Eviscerated weight and its percentage

The current finding indicated the positive effects on eviscerated weight of birds associated with inclusion of garlic extract as compared to negative control groups. In terms of eviscerated percentage, treatment containing 1.5% GEX resulted in better effect than other groups, however significant differences are not observed among other treatment groups for this variable. The results of current finding are in line with the results of Brzóska *et al*. (2015) which indicate that, the supplementation of birds with liquid garlic extract at a level of 2.25 ml kg-1 significantly increased the eviscerated weight and eviscerated percentage of chickens as compared to those of the control treatment group. The result obtained in the current work is also in line with the findings of Dieumou *et al*. (2011) who indicate that, the birds supplemented with garlic oil at levels of 60 ppm and 40 ppm showed significantly higher values of eviscerated weight and percentage as compared to those of control groups. At the same way, Garlic powder supplementation at levels of 0.2, 0.4 and 0.8%, also showed the existence of highly significant differences in the eviscerated weight and eviscerated percentage as compared to control group (Odunowo and Olumide, 2019), which is in line with the results reporte in the current work.

The results of the current study is not in agreement with the findings of Mandel *et al.* (2009) which disclose that, essential oils has no significant effect on measurements of eviscerate weight of broiler chickens. The result of the current finding also contradicted with the reports of Amouzmehr *et al*. (2012) who indicate that, application of garlic extracts at levels of 0.3% and 0.6%, has no significant effect on eviscerate weight and its percentage.

5.2.4. Commercial cuts

Treatment effects described in this study did not significantly affect commercial carcass cuts and their percentage except for the breast weight where significantly higher yield were recorded for 1.5 and 3% inclusion levels of GEX when compared to that of negative control groups. This result is it might be comparable with the slaughter weight. The current finding result is supported by Brzóska *et al*. (2015) who report that, the higher slaughter weight of chickens fed with liquid garlic at levels of 1, 1.5 and 2.25ml kg^{-1} resulted in higher hot carcass weight, cold carcass weight and weight of breast muscles. The results of the current study are in line with the findings reporte by Kamel (2001) who revealed that, broiler chickens fed with herb extract has higher breast weight as compared to control group. The results of current study conversely are not in agreement with the results of Saad (2015), which confirmed the absence of significant treatment effects in relative weight of breast while using garlic powder at levels of 1, 2 and 3%.

The reported results of the current study also indicated that there is no significant different between treatment groups on the remaining commercial carcass cut up, which are drumstick with thigh, back, nake and wing. The results of the current finding also agree with that of Amouzmehr *et al*. (2012) who indicate that, treatments containing GEX of 0.3% and 0.6% did not induce any significant effect on the commercial carcass composition variables including breast, thigh weight and their percentage. The current study is in line with the finding of Hernandez *et al*. (2004) who report that, the use of herb extracts for broiler has no significant effect on carcass cut up characteristics. Similarly, research works reported by Gbenga *et al*. (2009) indicate that, carcass cut up and organ characteristics of broilers fed diets containing garlic are not affected by experimental treatments and Brzóska *et al*. (2015) also disclose that expression of the weight of various commercial carcass parts as a percentage showed no significant differences between the groups of liquid garlic extract at inclusion levels of 1 ml, 1.5 ml and 2.25 ml kg^{-1} as compared to those of control groups.

Correspondingly, the research works on the use of different levels of garlic powder disclosed the absence of significant differences in all carcass characteristics of birds fed on diets containing 0.125, 0.25, 0.5, 1 and 2% garlic powder and control diet (Javandel *et al.*,2008 and Onu 2010). Nikola *et al*. (2016) on the other hand report that, the use of 0.5 % and 1% garlic powder did not show the presence of significant difference in the percentage of breast, drumstick with thigh and back while. The current findings result contradicted with the report of Raeesi *et al.* (2010) who indicate that, supplementation of 1% garlic powder caused higher Drumstick with thigh yield and its percentage.

5.2.5. Weight of giblets

Based on the results of current work, there is no significant difference in giblet weight as well as their percentages birds kept on different treatments except from liver weight where significantly higher yield are recorded for both GEX inclusion levels when compared to that of negative control groups. The current study result is similarity with Brzóska *et al*. (2015) who report that Chickens receiving 1.50 ml liquid garlic per kg-1 broiler diet has significantly higher liver weights compared to the other groups of broilers. The current study result is supported by Tchakounte *et al.* (2006) who indicate that, liver of birds on garlic supplemented diets are more developed thus indicating an intense activity of this organ by natural growth promoter. According to Singh *et al*. (2015) Plants and plant derived products being natural, non-toxic and residue free. Similarly suggest that, improvements in the weight of the internal organs like liver arise because of increased metabolic rate of the organs in attempt to reduce the toxic elements or anti-nutritional factors to non-toxic metabolites.

The findings of the current work on other organ excluded liver is supported by the results of Makwana *et al*. (2018) who report that, gizzard remained comparable (P>0.05) among different dietary treatment groups. Similarly, the results are in agreement with the results obtained by Sarica *et al*. (2005) which indicate, the use of two herbs (extracts of thyme and garlic) has no significant effect on different components of carcass as well as heart weight, gizzard weight and their percentages of broiler chickens. Feyad *et al*. (2011) also conclude that, the difference is not significant for giblet weight (heart, gizzard, spleen and pancreas) of the broilers fed rations with or without supplementation of garlic. Similar figures are also report by Odunowo and Olumide (2019) where the heart and gizzard also do not exhibit any significant variations among the garlic dietary treatments as compared to control groups.

On the contrary, 0.5% garlic supplemented group has the greatest relative heart weight compared to non-supplemented groups whereas relative gizzard weight is also higher at levels of 0.5, 1 and 3% compared to control group (Raeesi *et al*., 2010). The current study is in disagreement with that of Dieumou *et al*. (2009) who reported that, garlic dosage effects showed that a decrease in relative weight of gizzard as compared to the control.

5.2.6. Non edible parts

Fat deposition in the abdominal area of broilers is considered as waste in the poultry industry; since it represents a loss in the market and consumer acceptability and enhances expense during the treatment of effluent produced when processing broilers. The results of current study indicate that the inclusion of different levels of GEX and antibiotics incorporated in broiler drinking water reduced the weight and percentage of abdominal fat as compared to negative control which is in agreement with the findings of Wibabaw *et al*.(2015) where the Garlic extract at levels 2.5% and 5.0% in drinking water resulted in a significant reduction levels of cholesterol in both breast meat and abdominal fat of birds and increase percentages of those carcass quality traits.

The results of current study is agreement with karim *et al*. (2017) who indicate that, the garlic group at levels of 0.25, 0.5 and 0.75% showed significantly low abdominal fat weight as compared to the control and antibiotic group. Similar findings are also reported by Sarica *et al.* (2005) and Raeesi *et al*. (2010) indicate that, broilers fed on Garlic groups accumulate low amount of abdominal fat than the control groups. Similarly, Huda *et al*. (2015) report that, garlic powder at 1, 2 and 3% inclusion levels in the diets of broilers apparently reduced abdominal fat percentage in a significant manner as spices and herb extracts have lipotropic effects.

Reduction of abdominal fat upon the supplementation of garlic is probably due to the presence of sulfur compounds (Oleforuh-Okoleh *et al*., 2014). Some of the active components in the herb extract affect lipid metabolism through fatty acid transportation (Cross *et al*, 2007). Amagase *et al*. (2001) suggest that, the bioactive components of garlic which include sulpture containing compound such as *alliin, diallylsulphides* and *allicin*. When a clove of garlic crushed, *alliin* which is the cyclo-oxygenase and lipoxygenase group of enzymes is converted to its anti-microbial active form of *allicin* (Metwally, 2009).This can enhance the lipid utilization and reduce abdominal fat (Cross *et al*, 2007). The organosulfure content of garlic is primarily that of *alliin* derivatives which are reported to be the cause of its low effect on lipids (reza, 2013). Similarly, Ademola *et al*. (2009) also report that, garlic in a diet decreased production of abdominal fat pads, serum cholesterol and triacylglycerol of broiler chickens.

Unlike the current findings, so many contradicting results have been report by different authors. Garlic solution supplementation at 0, 0.2, 0.4, 0.6, 0.8 and 1% did not produce significant difference on carcass quality primarily on abdominal fat (Taufic and Mruddin, 2018). The current findings are also disagreement with the findings of Pourali *et al*. (2010) indicate that, the supplementation of garlic has effect on the increment of the fat content of broiler chicken there by affecting the carcass quality of broilers. The same author indicate that, the carcass quality of chickens fed with diet containing 2% of garlic is not different with that of the control group. The results of current study is no in line with the finding of Alçiçek *et al*. (2003) who reporte that, use of herb extract resulted had no significant effect on abdominal fat percentage. Similar opposing research finding is conducted by Raeesi *et al*. (2010) indicate that, relative weight of abdominal fat is higher in 3% garlic supplemented groups than control groups. Amouzmehr *et al*. (2012), on the other hand reported that, application of two herb extracts garlic and thyme at levels of 0.3% and 0.6% have no significant effect on performance and percentage of abdominal fat.

The results of the current study showed that inclusion of different levels of GEX and antibiotics resulted in significantly higher effect on the GIT weight as compared to negative control groups. The observed results of current study finding similarity with Adibmoradi *et al.* (2006) studied on the effect of dietary garlic meal at 0.125, 0.25, 0.5, 1.0 and 2.0% levels on histological structure of small intestine in broiler chickens. Results revealed that, villus height increases linearly in duodenum, jejunum and ileum as the incorporation level of garlic increases from 0.125 to 2.0%. Similarly, Oladele *et al*. (2012) studied the effect of garlic meal at 0.125, 0.25 and 0.5% level on the absorptive surface of the small intestine of broiler and report the highest villus length, width and cryptal depth in 0.125% garlic meal supplemented group, resulting in increased absorptive area of the intestine and ultimately higher body weight gain and lower FCR. The current finding result is agreement with Saeid *et al.* (2013) reported that, the improved intestinal morphological characteristics like villi length and small crypts in birds receiving 0.5% garlic powder containing diet as compare to control. Singh *et al*. (2015) suggest that, increased villus height/crypt depth ratio can also indicate absence of toxin, improved absorption of nutrients, decreased secretion in gastrointestinal tract, diarrhea, increases disease resistance and higher overall performance.

The current finding result is not in agreement with Hernandez *et al*. (2004) who revealed that no significant differences are observed between herb extract and control groups for large or small intestine weight of broiler. The Current study result also contradict with the finding of Javandel *et al*. (2008) who report that, there is no significant effect on intestine percentage of broilers fed with the diet containing garlic powder at level up to 2%. Similarly, Raeesi *et al*. (2010) report that, garlic powder addition at different levels in the broiler diet has no significant effects on relative weights of digestive organs.

The current finding result also showed that, birds kept on different levels of GEX supplementation showed no significant effect on head, feet weight and its percentage as compared to negative control groups. The result of current study was also in agreement with Karim *et al*. (2017) who report that, garlic powder at levels of 0.25, 0.5 and 0.75 were had no significant effect on head and feet weight as compared to control groups. The higher body weight and lower offal weight indicates the best performance of broiler (Plumber and Kiepper, 2011).

5.3. Economic appraisal

The results of the current findings indicated that birds kept on T4 gave the highest total income (TI) followed by birds kept on T3, T2 and T1. Based on the findings of Gerard *et al*. (2011) the antimicrobial growth promoters have made a significant contribution to intensive husbandry profitability as a result of its effect on the improvement of the production performance of the chicken. However, birds kept on T1 gave the highest net revenue (NR) and economic efficiency (ECE) whereas, the lowest NR and ECE is obtained from birds kept on T4. The inclusion of GEX at both levels in the current study have shown a lower value of ECE when compared them to the negative and positive controls; implying that the treatments are costly from the economic point of view. This is directly related to the actual market price of test ingredients in the area. The results of current study in relation to ECE is in line with the report made by Zena *et al*. (2017), which concluded that from an economic point of view, the inclusion of herbal additive increased the cost of production which also significantly affected the relative economic efficiency (REE). However, the findings of the current study is not in agreement with the reports of Khan *et al.* (2017) indicate that garlic extract administration in drinking water of broiler has reducing effect on the cost of production and improved the economic return.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

Antibiotic growth promoters have made a tremendous contribution to the profitability of the broiler chicken industry. However, as a consequence of the increasing concern about the potential public health problems because of antibiotic resistant strains of bacteria, the scientists are being challenged to develop an alternative for AGP. If natural herbs as alternative to AGP can be found, the scientists could use as incorporated in the diet and drinking water that would meet the needs of the commercial broiler industry without using AGP. From this study it can be concluded that incorporation of different levels of GEX in drinking water of broiler chicken do not adversely affect FI of broiler. The study showed that garlic extract brings about significant effect on FBW and BWG at inclusion levels. The significant weight gain improvement in birds kept on higher inclusion levels (3%) of garlic extract. Incorporation of garlic extract at both inclusion levels also has a positive effect on FCR.

This study demonstrated that carcass characteristics of broiler chicken expressed interms of slaughter, dressing, dressing percentage and eviscerated weight are significantly improved through the use of garlic extract as additive incorporated in drinking water. In addition to the above, inclusion of GEX brings about a significant improvement in breast meat weight which as the best part of chicken meat because of its low fat content. Incorporation of GEX with drinking water have a significant effect in reducing abdominal fat contents of broiler carcass, abdominal fat in broiler carcass is considered as a waste and its existence reduces the carcass quality. From an economic point of view, the inclusion of garlic extract (GEX) in drinking water especially at 3% inclusion levels increased the cost of production which slightly affected the REE.

Due to the increasing pressure to eliminate antibiotic growth promoters in animal feed garlic extract are alternatives to improve poultry production without relying on antibiotics. Besides its positive effect as health promoter as reported in different studies, garlic extract at 1.5 and 3% inclusion levels can be effectively and safely used to replace the antibiotic growth promoter in the broiler chicken industry.

6.2. Recommendations

Based on the findings of this study, the following recommendations are forwarded.

- Garlic extract especially at 3% inclusion levels in drinking water of broiler chicken should be considered as potential growth promoters that replace the antibiotic growth promoter in broiler production.
- Further research is needed to provide concrete information on the effect of garlic extract as health promoter in broiler production.

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8. APPENDICES

8.1. Supplementary Tables

Appendix Table 1. Cost of feed ingredient and additives

Feed ingredients	Price/Kg (Birr)
Maize	20
Soybean meal	21
Nuog seed cake	20
Wheat bran	20
Limestone	5
Salt	14
Broiler premix	95
Methionine	260
Lysine	165
Garlic	50
Antibiotics (oxytetracycline)	130birr/100g

Appendix Table 2. Consumption of total amount of water and treatments by broiler chicken during the entire experimental period.

Parameters	Treatments			
	T1	T2	T3	T4
Total water intake/bird (L)	8.85	8.74	7.38	6.95
Total antibiotic intake/ bird at 0.2g/10ml drinking water(g)	-	0.17	-	-
Total garlic intake at 1.5% GEX added in drinking water (kg)	-	-	0.11	-
Total garlic intake at 3% GEX added in drinking water (kg)	-	-	-	0.21

Appendix Table 3. Analysis of the effect of feeding different garlic extract levels inclusion in drinking water on performance of broilers

Parameters	Source of variation	Sum of squares	Df	Mean square	F value	P value
FI (0-28 Days)	Treatment	225.1	3	75.1	1.47	0.295
	Error	409.7	8	51.2		
	Total	634.9	11			
FI (29-56 Days)	Treatment	76685.4	3	25561.8	6.80	0.014
	Error	30053.3	8	3756.7		

	Total	106738.7	11			
FI (0-56 Days)	Treatment	70999.7	3	23666.6	6.48	0.016
	Error	29199.8	8	3650.0		
	Total	100199.4	11			
DFI(0-28 Days)	Treatment	0.3	3	0.1	1.47	0.295
	Error	0.5	8	0.1		
	Total	0.8	11			
DFI(29-56 Days)	Treatment	97.8	3	32.6	6.80	0.014
	Error	38.3	8	4.8		
	Total	136.1	11			
DFI(0-56 Days)	Treatment	22.6	8	7.5	6.48	0.016
	Error	9.3	3	1.2		
	Total	32.0	11			
IBW	Treatment	0.04	3	0.01	1.06	0.419
	Error	0.09	8	0.01		
	Total	0.13	11			
FBW(28th Day)	Treatment	6501.4	3	2167.1	6.58	0.015
	Error	2636.5	8	329.6		
	Total	9137.9	11			
FBW(56th Day)	Treatment	754.5	3	251.5	5.10	0.029
	Error	394.7	8	49.3		
	Total	1149.2	11			
BWG(0-28 Days)	Treatment	6040.1	3	2013.4	5.87	0.020
	Error	2745.0	8	343.1		
	Total	8785.1	11			
BWG(29-56 Days)	Treatment	3002.5	3	1000.8	2.57	0.127
	Error	3119.7	8	390.0		
	Total	6122.2	11			
BWG(0-56 Days)	Treatment	746.8	3	248.9	5.09	0.029
	Error	391.6	8	48.9		
	Total	1138.3	11			
ADG(0-56 Days)	Treatment	0.24	3	0.079	5.09	0.029
	Error	0.12	8	0.016		
	Total	0.36	11			
FCR(0-28 Days)	Treatment	0.04	3	0.015	4.78	0.034
	Error	0.02	8	0.003		
	Total	0.07	11			
FCR(29-56 Days)	Treatment	0.02	3	0.006	2.62	0.123
	Error	0.02	8	0.002		
	Total	0.04	11			
FCR(0-56 Days)	Treatment	0.03	3	0.011	10.13	0.004
	Error	0.01	8	0.001		
	Total	0.04	11			

Appendix Table 4. Analysis of the effect of garlic extract levels inclusion in drinking water on slaughter weight, dressed weight and eviscerated weight of broilers

Parameters	Source of variation	Sum of Squares	Df	Mean Square	F value	P value
Slaughter weight	Treatment	577.0	3	192.3	4.72	0.035
	Error	326.3	8	40.8		
	Total	903.3	11			
Dressed weight	Treatment	3741.3	3	1247.1	6.08	0.019
	Error	1641.9	8	205.2		
	Total	5383.2	11			
Dressing (%)	Treatment	4.7	3	1.6	5.19	0.028
	Error	2.4	8	0.3		
	Total	7.1	11			
Eviscerated weight (g)	Treatment	1206.4	3	402.1	6.12	0.018
	Error	525.7	8	65.7		
	Total	1732.0	11			
Eviscerated (%)	Treatment	1.1	3	0.4	4.20	0.046
	Error	0.7	8	0.1		
	Total	1.9	11			

Appendix Table 5. Analysis of the effect of different garlic extract levels inclusion in drinking water on the commercial cuts of broilers

Parameters	Source of variation	Sum of Squares	Df	Mean Square	F value	P value
Breast weight	Treatment	280.7	3	93.56	4.98	0.031
	Error	150.3	8	18.79		
	Total	150.3	11			
Breast (%)	Treatment	0.3	3	0.11	2.30	0.154
	Error	0.4	8	0.05		
	Total	0.7	11			
Drumsticks with thighs(g)	Treatment	53.5	3	17.84	1.74	0.235
	Error	81.8	8	10.22		
	Total	135.3	11			
Drumsticks with thighs (%)	Treatment	0.1	3	0.05	1.92	0.205
	Error	0.2	8	0.03		
	Total	0.3	11			
Back weigh	Treatment	8.1	3	2.69	0.67	0.594
	Error	32.1	8	4.02		
	Total	40.2	11			
Back (%)	Treatment	0.006	3	0.002	0.13	0.940
	Error	0.1	8	0.016		

	Total	0.1	11			
Wing weight	Treatment	2.6	3	0.88	3.07	0.091
	Error	2.3	8	0.29		
	Total	4.9	11			
Wing (%)	Treatment	0.005	3	0.002	3.73	0.061
	Error	0.004	88	0.000		
	Total	0.009	11			
Neck weight	Treatment	0.6	3	0.20	1.03	0.428
	Error	1.5	8	0.19		
	Total	2.1	11			
Neck (%)	Treatment	0.0	3	0.001	2.23	0.162
	Error	0.0	8	0.000		
	Total	0.0	11			

Appendix Table 6. Analysis of different garlic extract levels inclusion in drinking water on commercial and edible carcass weight of broilers

Parameters	Source of variation	Sum of Squares	Df	Mean Square	F value	P value
Commercial carcass weight	Treatment	539.65	3	179.88	9.83	0.005
	Error	146.37	8	18.30		
	Total	686.01	11			
Commercial carcass (%)	Treatment	0.22	3	0.07	1.92	0.204
	Error	0.30	8	0.04		
	Total	0.52	11			
Edible carcass weight	Treatment	572.93	3	190.98	9.66	0.005
	Error	158.12	8	19.77		
	Total	731.06	11			
Edible carcass (%)	Treatment	0.20	3	0.07	1.60	0.265
	Error	0.34	8	0.04		
	Total	0.54	11			

Appendix Table 7. Analysis of the effect of different garlic extract levels inclusion in drinking water on the giblets weight of broilers

Parameters	Source of variation	Sum of Squares	Df	Mean Square	F value	P value
Liver weight	Treatment	0.3894	3	0.1298	4.86	0.033
	Error	0.2138	8	0.0267		
	Total	0.6032	11			
Liver %	Treatment	0.0005	3	0.0002	2.52	0.131
	Error	0.0005	8	0.0001		

	Total	0.0001	11			
Gizzard weight(g)	Treatment	0.1039	3	0.0346	0.74	0.558
	Error	0.3753	8	0.0469		
	Total	0.4792	11			
Gizzard %	Treatment	0.0004	3	0.0001	0.70	0.577
	Error	0.0014	8	0.0002		
	Total	0.0017	11			
Heart weigh	Treatment	0.5348	3	0.1783	3.17	0.085
	Error	0.4505	8	0.0563		
	Total	0.9853	11			
Heart %	Treatment	0.0016	3	0.0005	3.12	0.088
	Error	0.0013	8	0.0002		
	Total	0.0029	11			

Appendix Table 8. Analysis of the effect of feeding different garlic extract levels inclusion in drinking water on weight of non-edible parts of broilers

Parameters	Source of variation	Sum of Squares	Df	Mean Square	F value	P value
Feet weigh	Treatment	1.021	3	0.340	1.81	0.223
	Error	1.503	8	0.188		
	Total	2.524	11			
Feet (%)	Treatment	0.004	3	0.001	2.64	0.121
	Error	0.004	8	0.000		
	Total	0.007	11			
Head weight	Treatment	5.196	3	1.732	2.11	0.177
	Error	6.561	8	0.820		
	Total	11.756	11			
Head %	Treatment	0.010	3	0.003	1.16	0.384
	Error	0.024	8	0.003		
	Total	0.010	11			
Abdominal fat wt	Treatment	6.440	3	2.147	26.36	0.002
	Error	0.651	8	0.081		
	Total	7.092	11			
Abdominal fat %	Treatment	0.021	3	0.007	25.28	0.002
	Error	0.002	8	0.000		
	Total	0.023	11			
Weight of GIT	Treatment	2.539	3	0.846	5.49	0.024
	Error	1.234	8	0.154		
	Total	3.773	11			
GIT %	Treatment	0.004	3	0.001	1.06	0.418
	Error	0.009	8	0.001		
	Total	0.012	11			

8.2. Appendix Figures

Appendix figure 1. Pen preparation at as starting time

Appendix figure 2. experimental pen befor the arrival of day old chicke

Appendix figure 3. Experimental feed

Appendix figure 4. Management of experimental birds

Appendix figure 5. Peeling of garlic

Appendix figure 6. Blending of garlic

Appendix figure 7. Garlic extract after filtering

Appendix figure 8. Measuring feed using digital weighing scale