USE OF PHYTOADDITIVES IN BROILER DIET WITH LOWER NUTRIENT DENSITY

THESIS

BY

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CERTIFICATE-I

This is to certify that the thesis entitled **"Use of phytoadditives in broiler diet with lower nutrient density"** submitted in partial fulfillment of the requirements for the award of degree of **Master of Veterinary Science** in the discipline of **Animal nutrition** of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur is a bonafide research work carried out by **Sahil Sharma, V-2019-30-003** son of Sh. Sat Pal Sharma under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

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This is to certify that the thesis entitled, **"Use of phytoadditives in broiler diet with lower nutrient density"** submitted by **Sahil Sharma, V-2019-30-003** son of Sh. Sat Pal Sharma to the CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur in partial fulfillment of the requirements for the degree of **Master of Veterinary Science** in the discipline of **Animal Nutrition** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

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ABBREVIATIONS

Abbreviations	Meaning
%	Per cent
°C	Degree Celsius
µL	Micro liter
AAS	Atomic Absorption Spectrometer
AGP	Antibiotic growth promoter
AIA	Acid insoluble ash
ALT	Alanine transaminase
ANOVA	Analysis of variance
AOAC	Association of official analytical chemists
AST	Aspartate aminotransferase
BW	Body weight
Ca	Calcium
CBC	Complete blood count
CF	Crude fiber
CFU	Colony forming units
CP	Crude protein
CRBD	Complete randomized block design
d.m.b.	Dry matter basis
DCP	Di- calcium phosphate
DM	Dry matter
EDTA	Ethylene diamine tetra acetic acid
EE	Ether extract
EEF	European economic factor
et. al.	Et alia (and others)
EU	European union
FCR	Feed conversion ratio
FI	Feed Intake
FI/DAY	Feed intake per day
Fig.	Figure
Fl	Femtoliter

Hb	Hemoglobin
HDL	High density lipoprotein
i.e.	Id est (that is)
I.U.	International units
ICAR	Indian council of agricultural research
Kg	Kilo gram
L	Liter
LDL	Low density lipoprotein
LSP	Limestone powder
MCH	Mean corpuscular hemoglobin
MCHC	Mean corpuscular hemoglobin concentration
MCV	Mean corpuscular volume
ME	Metabolizable Energy
mg	Milligram
mg/dl	Milligram per deciliter
Min	Minute
mL	Milliliter
mm	Millimeter
NFE	Nitrogen free extract
nm	nanometer
OD	Optical density
P	Phosphorus
P<0.05	Significant at per cent level
PCV	Packed cell Volume
Pg	Pico gram
pH	Negative log of $[H^+]$ ions
Ppm	Parts per million
RBC	Red blood cell
rpm	Rounds per minute
SD	Standard deviation
SGOT	Serum glutamic oxaloacetic transaminase
SGPT	Serum glutamic pyruvic transaminase
Spp.	Species

TA	Total Ash
TEC	Total erythrocyte count
TLC	Total leukocyte count
Viz.	Namely
WBCs	White blood cells

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ABSTRACT

A study was conducted to evaluate phyto-additive viz. garlic powder (0.5%), cinnamon extract (0.1%) and a combination of garlic powder and cinnamon extract as an additive in poultry broiler diet with lower energy density under complete randomized design. For this purpose, vencobb-400 strain day old broiler chicks (n=195) were divided into 5 main treatment groups viz. T_0, T_1, T_2, T_3 and T_4. Each treatment group was further divided into 3 replicates with 13 chicks in each. T_0 served as positive control offered standard diet offered corn- soy flake-based ration (starter 21.95% CP and 2875 Kcal/kg ME; Finisher 19.82% CP and 2914 Kcal/kg ME), T_1 served as negative control offered corn-soy based feed with low energy density (starter 21.95% CP and 2593 Kcal/kg ME; Finisher 19.82% CP and 2631 Kcal/kg ME), Treatment T_2 was given standard corn- soy flake-based ration supplemented with 0.5% Garlic Powder (GP) but with low energy density (starter 21.95% CP and 2593 Kcal/kg ME; Finisher 19.82% CP and 2631 Kcal/kg ME), Treatment T_3 was given standard corn- soy flake-based ration supplemented with 0.1% Cinnamon Extract (CE) but with low energy density (starter 21.95% CP and 2593 Kcal/kg ME; Finisher 19.82% CP and 2631 Kcal/kg ME) and Treatment T_4 was given standard corn- soy flake based supplemented with combination of 0.5% GP and 0.1 CE but with low energy density (starter 21.95% CP and 2593 Kcal/kg ME; Finisher 19.82% CP and 2631 Kcal/kg ME). Perusal of results revealed that phyto-additive supplementation namely 0.5 % GP, 0.1% CE and combination of 0.5 % GP + 0.1% CE in low energy density feed positively influenced the growth, nutrient utilization with better feed to gain ratio, both during starter and finisher phase. Overall cinnamon extract supplementation at 0.1 per cent in low energy feed exhibited higher nitrogen retention exhibiting higher live weight gain and feed to gain ratio compared to combination of 0.5 % GP + 0.1% CE. Highest dressing percentage, thigh yield and low abdominal fat with leaner meat was recorded by CE (0.1%) addition and GP (0.5%) + CE (0.1%) combination supplemented to low energy density feed. The organoleptic factors viz. flavor and overall acceptability of the meat was significantly ($P<0.05$) influenced by addition of cinnamon (0.1%) and combination of GP (0.5%) + CE (0.1%) supplementation. Economics of broiler production revealed lowest cost of producing 1 Kg meat by CE (0.1%) supplementation whereas it was highest in GP (0.5%) + CE (0.1%) supplementation. Therefore, it is concluded that compared to garlic powder (0.5%) and combination of garlic powder (0.5%) +cinnamon extract (0.1%), cinnamon extract (0.1%) supplementation alone in low energy density feed offered to broiler birds positively compensate the low energy by influencing the GIT (gastrointestinal tract) environment, lowering bacterial count, leading to better nitrogen retention and growth. Cinnamon extract supplementation at 0.1 per cent increases broiler dressing percentage, positively influences organoleptic values of the meat and reduce the cost of broiler meat production by 5.46% leading to good economic return to the farmers.

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CHAPTER 1

INTRODUCTION

Man can survive without luxuries but cannot survive without food. Livestock products are considered to be the most nutritious, but higher price limits its consumption. Especially in the under developed countries competitive price offered by poultry, which is the cheapest source of good quality protein, Indian agriculture has witnessed poultry sector growing at the fastest rate. Every year, around 50 billion chickens are farmed for meat and eggs. Chicken meat accounts for 20% of total meat production worldwide (second most consumed meat). India is becoming one among the world's leading producers of eggs and broiler meat. While agricultural crop output has been increasing at a pace of 1.5 to 2% per year, egg and broiler production has been increasing at a rate of 8 to 10% per year. India is the world's third largest producer of eggs and fifth largest producer of broilers. In 2018, the Indian poultry market (broiler and eggs) was valued INR 1,750 billion. The market is expected to reach INR 4,340 billion by 2024, expanding at a CAGR of 16.2 percent between 2019 and 2024. (Indian poultry market report 2019: share, size, growth, opportunity and forecast 2011-2018 and 2019-2024- Research and market May 16, 2019).

Poultry production dominates the livestock industry in India. In India, the poultry business has transitioned from a backyard pastime to a significant commercial agri-based enterprise with an annual broiler production of 8-10 percent. There are high producing broiler breeds available with 2.4 to 2.6 kg body weight at 6 weeks of age. Chicken meat is in high demand, and producers are looking for innovative ways to enhance output (Chatterjee and Rajkumar 2015).

Antibiotics and chemotherapeutics in preventive dosages have been utilized in chicken diets for several decades to enhance animal welfare and provide economic benefits in the form of increased animal performance and lower treatment expenses. Antibiotic-induced drug resistance has grabbed the curiosity of scientists and researchers, and as a result, alternatives to antibiotics have stirred the interest of scientists.

To increase productivity and minimise bacterial contamination, a myriad of potentially beneficial substances may be added to a chicken flock's feed or drinking water,

but with consumers increasing concern about purchasing antibiotic-free commodities, phyto additives are being utilised.

Antibiotic Growth Promoters (AGP) are drugs that are used to boost weight gain and feed conversion. However, because AGP has a lingering effect and contributes to antibiotic resistance, there is a push to reduce the use of antibiotics in order to avoid severe consequences for human health. The majority of these AGP have been prohibited by the WHO and the European Union. The tendency now is to use natural alternatives to AGP (Dibner and Richards 2005).

Researchers are seeking for feasible alternatives to minimise or replace the use of antibiotics in chicken production due to the unfavourable effects of antibiotics as growth enhancers. Natural sources of herbs or medicinal plants are one type of comparable alternative. Over the last decade, such alternatives have become more common in layer and broiler diets. According to several accounts, using the complete plant, its blooms, or its leaves will improve poultry performance.

Phytobiotics, often known as phyto additives, are being investigated as an alternative to AGP. Phytobiotics are plant-derived natural bioactive substances that may be introduced into the diet to improve animal performance and well-being. Turmeric, oregano, rosemary, garlic, ginger, green tea, black cumin, coriander, and cinnamon are just a few of the herbs and spices that have been tested in chicken for their prospective use as AGP replacements (Gadde et al. 2017).

Garlic is a member of the Allium genus and is linked to onions. Humans have been using it for thousands of years, and it was utilised in Ancient Egypt for both culinary purposes as well as medicinal and therapeutic advantages. Garlic's use stretched from Ancient Egypt to contemporary cultures such as the Indus Valley civilisation. According to records, Hippocrates, known as the "Father of Western Medicine," recommended garlic for a variety of ailments and illnesses. Garlic has long been utilised as a flavouring agent in food and in traditional medicine. The bulb of garlic is the most often utilised component, and it can be used fresh, as dried powder, or as an oil extract. Allicin, a sulphur-containing molecule, is the main active principle linked with garlic. The majority of the advantages associated with garlic may be ascribed to thiosulfinates, with allicin accounting for almost

70% of total sulfinates. Garlic has antibacterial, anticancer, antioxidant, hepatoprotective, and immunomodulatory effects, among other things. Garlic use in feed formulations has had positive results in terms of weight gain, feed efficiency, and reduced mortality in chicken.

One of the oldest medicinal plants is cinnamon (*Cinnamomum verum* / *Cinnamomum zeylanicum*), often known as dalchini. *Cinnamomum verum*, sometimes known as "genuine cinnamon," is indigenous to India, Sri Lanka, Bangladesh, and Myanmar. Cinnamon is a spice derived from the inner bark of Cinnamomum tree species. Cinnamon is primarily utilised in a range of dishes as an aromatic condiment and flavouring ingredient. Cinnamon has a long history of usage as a digestive aid in traditional medicine. Cinnamon bark may be processed and utilised in a variety of ways, including sticks, chips, powder, and essential oil. Cinnamaldehyde is the primary active principle in cinnamon. Cinnamon's therapeutic qualities include antibacterial, antioxidant, hypocholesterolemic, and blood purifier characteristics. Cinnamon's antimicrobial effects are mostly related to its cinnamaldehyde content, which is followed by eugenol and carvacrol content.

The present study thus will be undertaken with the following objective -

OBJECTIVES:-

1. Evaluate the biological growth performance and economic of broiler birds offered low nutrient density supplemented with phyto additives viz. garlic and cinnamon.
2. Estimating the digestibility of nutrients, gut health and economics of broiler production.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Antibiotic Growth Promoters (AGP)

Antibiotic growth promoters are antibiotics added to the feed of food animals to enhance their growth rate and production performance. AGPs reduce normal intestinal flora (which compete with the host for nutrients) and harmful gut bacteria (which may reduce performance by causing subclinical disease). The effect on growth may be due to a combination of both fewer normal intestinal flora and fewer harmful bacteria, Jensen (1998).

Antibiotic growth promotion in agricultural animal production has been practiced for about 50 years in many countries. Early indications of the beneficial effect on production efficiency in poultry and swine were reported by Moore et al. (1946) and Jukes et al. (1950). Such drugs are used at low doses in feeds and are considered to improve the quality of the product, with a low percentage of fat and high protein content in the meat. They also help to control zoonotic pathogens such as *Salmonella, Campylobacter, Escherichia coli and enterococci*. However, the use of antibiotics, particularly at low doses, is associated with selection for resistance in pathogenic bacteria; it has been argued that the use of such antibiotics may result in bacteria resistant to antibiotics used in clinical or veterinary practice, thus compromising the continued use of antimicrobial chemotherapy, Hughes and Heritage (2004).

The use of antibiotics as growth promoters is rising at an alarming rate especially in poultry production to achieve high efficiency in terms of economy. Antibiotics improve the efficiency of animal growth via their inhibition of the normal microbiota, leading to increased nutrient utilization and a reduction in the maintenance costs of the Gastrointestinal system, Gaskins et al. (2002).

Feed additives, such as AGP, interact with the intestine. In the intestine, feed components, microbiota, and the mucosa interact in an overly complex and dynamic way. Various mechanisms for AGP have been proposed, invariably based on the direct antibiotic influence on the microbial composition of the intestines. In the literature on antibiotics, however, the direct effects of antibiotics on host cells, in particular inflammatory cells, have been described. AGP work as growth permitters by inhibiting the production and excretion of catabolic mediators by intestinal inflammatory cells. Concomitant or subsequent changes in microflora are the consequence of an altered condition of the

intestinal wall. This common, basic mechanism potentially offers an excellent explanation for the highly reproducible effects of AGP, as opposed to those obtained by alternatives aimed at microflora management. Therefore, the search for alternatives could be aimed at non-antibiotic compounds with an effect on the inflammatory system like that of AGP, Niewold (2007).

Miles et al. (2006) studied the effects of addition of bacitracin methylene Di salicylate (BMD) or virginiamycin (VM) to a corn-soybean meal diet on broiler performance and gastrointestinal tract (GIT) growth parameters and morphology at various ages during growth and finishing. Feeding either antibiotic increased BW and decreased intestinal length and weight at all times compared with control birds. The only change found in the duodenum resulting from dietary treatment was an increase in the number of villi per unit length in birds given VM but not BMD or control. In the ileum, the muscularis mucosa was thinner in birds given VM than in those fed the control diet. Chicks supplemented with VM had a smaller total villus area and shorter villus height and crypt depth in the ileum than birds fed the control diet or BMD. Physical changes in the intestine of birds given either antibiotic growth promoter, although not the same, resulted in improved performance.

Engberg et al. (2000) studied the effect of zinc bacitracin and salinomycin on intestinal microflora and performance of broilers. A significant growth-promoting effect was observed in the group receiving zinc bacitracin in combination with salinomycin. Zinc bacitracin significantly reduced the number of coliform bacteria in the ileum and increased the activities of amylase and lipase in pancreas homogenates. Supplementation with salinomycin and zinc bacitracin, alone or in combination, resulted in significantly lower counts of *C. perfringens* as well as *Lactobacillus salivarius*, which was a dominant lactic acid bacterium found in broiler intestinal contents. High numbers of these lactobacilli may play a role in broiler growth depression related to competition in nutrient uptake or impaired fat absorption due to bile acid deconjugation.

Elwinger et al. (1998) studied the effects of the growth promoters avoparcin and avilamycin and the ionophore anticoccidials maduramicin, narasin and monensin on the growth of *Clostridium perfringens* (Cp) in the caeca and on performance of broiler chickens. The supplements were fed as single feed additives or in some combinations. All supplements had an antibacterial effect on Cp and improved growth rate significantly. Carcass yield of birds fed growth promoters avilamycin or avoparcin was significantly higher compared with birds fed anticoccidials.

Izat et al. (1990) studied the effects of Different Antibiotics on Performance, Processing Characteristics, and Parts Yield of Broiler Chickens. Broilers were grown on diets supplemented with bambermycins (BAM, 2.2 ppm), bacitracin methylene disalicylate (BMD, 27.5 ppm), virginiamycin (VM, 11 ppm). The results of the study indicate that antibiotics may influence dressing percentage and parts yield in the absence of improvements in body weight gain or feed utilization.

Gunal et al. (2006) studied the effects of AGP (flavomycin), Probiotic or Organic Acid supplementation on performance, intestinal microflora and tissue of broilers basal diet. Intestinal microbial flora and tissue were determined at 21 and 42 days. Antibiotic or the organic acids mixture treatments significantly decreased total bacteria counts. In addition to that all treatments significantly decreased gram-negative bacteria counts compared to the basal diet. Probiotic treatment significantly increased ileum and jejunum villus height, whereas antibiotic treatment significantly decreased muscularis thickness compared to the basal diet.

Ahmadi (2011) investigated the effect of different level of virginiamycin (VIR) on Growth performance, biochemistry, and hematology blood parameters of broiler chickens. Addition of virginiamycin in diet improved performance traits and important blood parameters, and the best level of VIR to applied nutrition was 20 ppm kg-1 diets.

2.2 Phytobiotics-Alternative to AGP

The animal feed industry worldwide has been using antibiotics for over 50 years. To date antibiotics are used in farm animals at therapeutical levels to control actual disease and at sub-therapeutical levels to promote growth and feed efficiency. The main concern is the emergence of the so-call resistant human pathogens, after the prolonged use of antibiotics in animal feed, Philips (1999).

Antimicrobial compounds are commonly included in poultry diets for promotion of growth and control of diseases. The European Union has banned feed grade antibiotic growth promoters, because of the risk of drug resistance in human pathogenic bacteria, and only two antimicrobial growth promoters are planned to remain in use, Shane (2001). Feeds containing no chemical additives are increasingly used in poultry nutrition. In many countries, efforts are being made to ban all types of antibiotic growth promoters. For this reason, herbs and natural feed additives are being investigated as natural source biologically important substances. Gou et al. (2000) have demonstrated that herbs and herbal products have a positive effect on broiler growth performance.

Resistance to antibiotics is escalating and threatening humans and animals worldwide. Different countries have legislated or promoted the ban of antibiotics as growth promoters in livestock and aquaculture to reduce this phenomenon. Therefore, to improve animal growth and reproduction performance and to control multiple bacterial infections, there is a potential to use probiotics as non-antibiotic growth promoters. Lactic acid bacteria (LAB) offer various advantages as potential probiotics and can be considered as alternatives to antibiotics during food-animal production. LAB are safe microorganisms with abilities to produce different inhibitory compounds such as bacteriocins, organic acids as lactic acid, hydrogen peroxide, diacetyl, and carbon dioxide. LAB can inhibit harmful microorganisms with their arsenal, or through competitive exclusion mechanism based on competition for binding sites and nutrients. LAB endowed with specific enzymatic functions (amylase, protease) can improve nutrients acquisition as well as animal immune system stimulation, Vieco saiz et al. (2019).

Phyto biotics represent a wide range of bioactive compounds that can be extracted from various plant sources, Vidanarachchi et al. (2005). However, mixed results have been seen in terms of animal development and performance. Dietary supplementation with some of the plant–derivatives prevented colonization of the gut by pathogenic bacteria. There is no doubt that several phytobiotics can modify the gut microflora, which, in turn, can bring about a cascade of changes in the animal's responses to nutrients, disease challenge and the environment.

Various plant extracts, essential oils, herbs, and spices are rich in phytochemicals that can be used to stimulate health and growth of animals. Studies have shown that spices and herbs have various beneficial effects such as antimicrobial, antifungal, anticoccidial and anthelminthic effects Araujo and Leon (2001), Tzakou et al. (2001), Fernandes et al. 2005 and Mekala et al. (2006). Animal studies showed that these compounds stimulated growth, increased immunity and livability, improved feed efficiency and nutrient digestibility, reduced blood cholesterol levels, lowered mortality, increased carcass yield and improved meat quality (Tabak et al. 1999, Lewis et al. 2004, Rizzo et al. 2008, Rahmatnejad et al. 2009 and Abou-Elkhair et al. 2014), And biological compounds present in garlic and cinnamon reduced cholesterol levels in the blood and improve meat quality (Kim et al. 2005 and Lijuan at al. 2007).

2.3 Garlic (*Allium sativum*)

Since ancient times, garlic (*Allium sativum)* has attracted people's curiosity as a medication and therapeutic agent. It is widely used as a spice and herbal medicine for the prevention and treatment of a wide range of ailments, from infections to heart disease, Javandel (2008). Garlic's main pharmacological effects are related to organosulphur compounds, Tapiero et al. (2004). Increased benefits associated with garlic consumption can be attributed to the thiosulfinates, the single most abundant class of organosulphur compounds, Lawson and Wang (2001). Allicin accounts for about 70 percent of the total thiosulfinates and is the main bioactive component of garlic, Amagase et al. (2001). Other components of garlic include sulphur compounds (such as alliin, ajoene, and diallyl), minerals (such as copper, calcium, iron, selenium, and zinc), and enzymes (like alliinase, peroxidase, etc.)

2.3.1 Properties of garlic

- Evidences suggest that the active compound of garlic has some beneficial effects for livestock, having hypo cholesterolaemic effects & growth promoting & antioxidant activities (Kim et al. 1997; Konjufca et al. 1997 and Lewis et al. 2003)
- Garlic is considered as plant with antibiotic, anticancer, antioxidant, immunomodulatory, anti-inflammatory & cardio vascular protecting effects (Reuter et al. 1996)
- Garlic also possesses antimicrobial activity (Adibmoradi et al. 2006)

2.3.2 Effect of garlic supplementation in broiler

2.3.2.1 Growth performance

2.3.2.1.1 Body Weight

Issa and Omar (2012) conducted an experiment to investigate the effect of feeding garlic powder (at the rate of 0.2% and 0.4%) on the performance of broilers. No significant effect of supplementation was found on the weight gain of broilers as compared to the control group.

Milosevic et al. (2013) supplemented the diet of broiler chicks with 1.5% and 3% garlic powder and found that there was no significant difference in body weight of supplemented groups when compared to control group.

Kharde and Soujanya (2014) conducted an experiment to study the effect of supplementation of garlic (0.5 and 1 g/kg feed), neem leaf powder (1 and 2 g/kg feed) and

their combination (1g garlic and 2g neem powder/kg feed) on growth performance in broilers. It was found that the supplementation of garlic and neem leaf powder alone or in combination significantly ($p<0.05$) improved the body weight gain in broiler.

Zekic et al. (2014) conducted a study to examine the effect of 2% of garlic powder addition in the broiler chicken diet on broilers chicken production. It was found that the chicken with addition of garlic had recorded significant higher ($p<0.05$) body weight as compared to chicken in control treatment.

Eid and Iraqi (2014) conducted a study to investigate the effect of garlic powder on performance of broilers. Their results showed that the diets containing garlic powder had a highly significant effect on broilers' performance ($P<0.0001$). It improved live body weight (LBW) and decreased mortality rate (MR).

Kumar et al. (2016) conducted an experiment to evaluate the effect of supplementing diverse levels of garlic powder (0.5% and 1%), Tulsi (Ocimum sanctum) leaf powder (0.5% and 1%) and their combination (0.5% and 1%) in diet on growth performance in broiler chicken. The body weight gain was higher ($P<0.05$) in supplemented groups then the control group. The highest ($P<0.05$) weight gain was observed in broilers which were supplemented with combination of garlic powder and Tulsi leaf powder at 0.5% each as compared to other supplemental groups and control group.

Kansal et al. (2017) conducted an experiment to investigate the effect of dietary supplementation of garlic (0.25%, 0.50% and 0.75%) on the performance of broiler chicken. It was observed that birds obtained higher weight gain in 0.50% and 0.75% supplementation groups as compared to control. The best results were obtained at higher levels of inclusion i.e., 0.75%.

Karim et al. (2017) conducted a study to evaluate the effect of garlic as an alternative feed additive in broiler diet. Garlic powder was supplemented at the rate of 0.25%, 0.50% and 0.75% in the diet. Results showed that the body weight and body weight gain did not differ significantly ($P>0.05$) among the treatment groups.

Al-Massad et al. (2018) conducted a study to evaluate the beneficial effects of garlic powder (2.5 Kg/ton, 5 Kg/ton and 7.5 Kg/ton) as a phytogenic supplement on broilers chickens' performance. Results showed that garlic powder improved bird’s body weight. The body weight increased significantly every week with higher rates when garlic powder was supplemented at 5 kg /ton level.

Odunowo and Olumide (2019) supplemented garlic powder (0.2%, 0.4% and 0.8%) in the broiler diet and found that average body weight increased with increasing level of inclusion of garlic in the diet.

Ismail et al. (2021) studied the effect of supplementation of garlic powder (0.25, 0.50 and 0.75 g/kg diet) and phenyl acetic acid (0.25, 0.50 and 0.75 g/kg diet) in broiler chickens. It was found out that body weight at 21 and 42 days of age and body weight gain during 1 to 21, 21 to 42, and 1 to 42 days of age were significantly ($p<0.05$) improved in groups fed diet supplemented with garlic powder and phenyl acetic acid.

2.3.2.1.2 FCR

Issa and Omar (2012) conducted an experiment to investigate the effect of feeding garlic powder (at the rate of 0.2% and 0.4%) on the performance of broilers. It was found that there was no significant effect of garlic powder supplementation on the feed conversion rate as compared to the control group.

Milosevic et al. (2013) supplemented the diet of broiler chicks with 1.5% and 3% garlic powder and found no significant difference in feed conversion ratio between garlic supplemented groups and the control group.

Eid and Iraqi (2014) conducted a study to investigate the effect of garlic powder on performance of broilers. It was observed that garlic supplementation increased feed conversation rate (FCR).

Zekic et al. (2014) conducted a study to examine the effect of 2% of garlic powder addition in the broiler chicken diet on broilers chicken production. Better feed conversion ratio was observed in garlic supplemented group as compared to control group.

Kharde and Soujanya (2014) conducted an experiment to study the effect of supplementation of garlic (0.5 and 1 g/kg feed), neem leaf powder (1 and 2 g/kg feed) and their combination (1g garlic and 2g neem powder/kg feed) on growth performance in broilers. It was found that the supplementation of garlic powder and neem leaf powder alone and in combination significantly ($p<0.05$) improved the FCR.

Varmaghany et al. (2015) studied the effect of garlic bulb supplementation (5g/kg, 10g/kg, and 15g/kg) on growth performance of broiler. The results illustrated that feed conversion ratio was similar among groups at the end of the experiment.

Kansal et al. (2017) conducted an experiment to investigate the effect of dietary supplementation of garlic (0.25%, 0.50% and 0.75%) on the performance of broiler chicken. Improved FCR was observed with garlic supplementation.

Karim et al. (2017) conducted a study to evaluate the effect of garlic as an alternative feed additive in broiler diet. Garlic powder was supplemented at the rate of 0.25%, 0.50% and 0.75% in the diet. Results obtained showed that the total FCR did not differ significantly ($P>0.05$) among different treatment groups.

Al-Massad et al. (2018) conducted a study to evaluate the beneficial effects of garlic powder (2.5 Kg/ton, 5 Kg/ton and 7.5 Kg/ton) as a phytogenic supplement on broilers chicken performance. It was found that the garlic powder supplementation improved feed conversion ratio compared with control group birds.

Odunowo and Olumide (2019) supplemented garlic powder (0.2%, 0.4% and 0.8%) in the broiler diet and found no significant difference in feed conversion ratio among different treatments.

2.3.2.1.3 Feed consumption

Issa and Omar (2012) conducted an experiment to investigate the effect of feeding garlic powder (at the rate of 0.2% and 0.4%) on the performance of broilers. No significant effect of supplementation was found on the feed intake of broilers as compared to the control group.

Eid and Iraqi (2014) conducted a study to investigate the effect of garlic powder on performance of broilers. It was observed that garlic supplementation decreased cumulative feed intake (CFI).

Kumar et al. (2016) conducted an experiment to evaluate the effect of supplementing diverse levels of garlic powder (0.5% and 1%), Tulsi (Ocimum sanctum) leaf powder (0.5% and 1%) and their combination (0.5% and 1%) in diet in broiler chicken. It was observed that feed intake was not affected significantly among different treatments.

Karim et al. (2017) conducted a study to evaluate the effect of garlic as an alternative feed additive in broiler diet. Garlic powder was supplemented at the rate of 0.25%, 0.50% and 0.75% in the diet. It was found that the control group showed significantly ($P<0.05$) higher feed intake than the garlic supplemented groups.

Al-Massad et al. (2018) conducted a study to evaluate the beneficial effects of garlic powder (2.5 kg/ton, 5 kg/ton and 7.5 kg/ton) as a phytogenic supplement on broilers chicken performance. Feed intake was significantly ($P < 0.05$) higher in the birds that were fed on garlic powder supplemented diets compared to the control group under same rearing conditions.

2.3.2.2 Hematological and blood biochemical parameters

2.3.2.2.1 Hematology

Eid and Iraqi (2014) conducted a study to investigate the effect of garlic powder on performance of broilers. Birds fed on diet supplemented with garlic showed a positive significant effect ($P<0.05$) on blood hematology (increased red blood cell, white blood cell and hemoglobin).

Kansal et al. (2017) conducted an experiment to investigate the effect of dietary supplementation of garlic (0.25%, 0.50% and 0.75%) on the performance of broiler chicken. Significant ($p<0.05$) improvement was observed in the total leukocyte count, erythrocytic count, hemoglobin concentration, packed cell volume and differential leukocyte counts of the garlic treated birds.

Onunkwo et al. (2019) carried out a study to evaluate the effect of garlic rhizome powder (0.5%, 1% and 1.5%) on blood profile of broiler at different growth phases. Total leukocyte count, erythrocytic count, hemoglobin concentration and packed cell volume were found to be increased in garlic powder supplemented group as compared to control group.

Ismail et al. (2021) studied the effect of supplementation of garlic powder (0.25, 0.50 and 0.75 g/kg diet) and phenyl acetic acid (0.25, 0.50 and 0.75 g/kg diet) in broiler chickens. It was found that the RBC and Hb were significantly ($p<0.01$) increased in chicks fed garlic powder, when compared to those fed with 0.50 and 0.75 g/kg of phenyl acetic acid and control-diet. Further, chicks fed diet containing 0.75 g garlic powder/kg diet had the highest value of Hb (13.46 g/dL) compared with the other groups. While there was no significant alteration found in PCV and WBC among groups.

2.3.2.2.2 Blood biochemicals

Issa and Omar (2012) conducted an experiment to investigate the effect of feeding garlic powder (at the rate of 0.2% and 0.4%) on the performance of broilers. At the end of the experiment, it was found out that there was significant decrease in cholesterol, triglyceride, and LDL values while there was significant increase in HDL value in garlic supplemented group as compared to control group.

Kansal et al. (2017) conducted an experiment to investigate the effect of dietary supplementation of garlic (0.25%, 0.50% and 0.75%) on the performance of broiler chicken. Cholesterol decreased significantly ($p<0.05$) while there was significant ($p<0.05$) increase in the total protein, albumin, and globulin concentration of the garlic treated birds.

Karim et al. (2017) conducted a study to evaluate the effect of garlic as an alternative feed additive in broiler diet. Garlic powder was supplemented at the rate of 0.25%, 0.50% and 0.75% in the diet. It was observed that the total cholesterol was significantly ($P<0.05$) lower in the garlic supplemented group when compared to the control and antibiotic groups. Garlic group with 0.75% supplementation showed the lowest while control group showed the highest total cholesterol value.

Al-Massad et al., (2018) conducted a study to evaluate the beneficial effects of garlic powder (2.5 Kg/ton, 5 Kg/ton and 7.5 Kg/ton) as a phytogenic supplement on broilers chicken performance. It was found that using garlic in broiler diet reduced the blood cholesterol, Albumin, Triglyceride, and HDL levels as compared to the standard levels.

Onunkwo et al. (2019) carried out a study to evaluate the effect of garlic rhizome powder (0.5%, 1% and 1.5%) on blood profile of broiler at different growth phases. It was found that the cholesterol levels of experimental birds dropped significantly with increasing levels of garlic in the diets. Inclusion of garlic powder on broiler feed had no significant difference ($P>0.05$) on the creatinine level.

Ismail et al. (2021) studied the effect of supplementation of garlic powder (0.25, 0.50 and 0.75 g/kg diet) and phenyl acetic acid (0.25, 0.50 and 0.75 g/kg diet) in broiler chickens. It was observed that there was significant increase in total protein, globulin, and HDL values while there was significant decrease in LDL, total cholesterol, and AST values in the supplemented groups than in the control group. No significant difference was observed in albumin, triglyceride, and ALT values among separate groups.

2.3.2.3 Nutrient utilization

Issa and Omar (2012) conducted an experiment to investigate the effect of feeding garlic powder (at the rate of 0.2% and 0.4%) on the performance of broilers. It was found that the apparent digestibility of total tract dry matter, crude protein and ether extract was improved ($P < 0.05$) by the addition of the garlic powder compared to that in the control diet.

Peinado et al. (2013) investigated the effect of garlic derivative PTS-O (propyl propane thiosulfonate) supplementation in broiler chicks. They found out that nitrogen, energy, and fat digestibility were greater in supplemented group than the control group. Lower number of E. coli and bacteroides were determined in the cecal contents of the birds supplemented with garlic derivative PTS-O. It was concluded that garlic derivative PTS-O modulated intestinal microbiota composition and improved nutrient digestibility.

2.3.2.4 Quality attributes of carcass and meat

2.3.2.4.1 Carcass characteristics

Choi et al. (2010) studied the effect of dietary supplementing garlic powder (0%, 1%, 3% and 5%) and alpha-tocopherol (200 IU in combination with 3% garlic powder) on meat quality of chickens. They found out that the meat pH and TBA reactive substances values were reduced when garlic powder and tocopherol was supplemented in the diet.

Issa and Omar (2012) conducted an experiment to investigate the effect of feeding garlic powder (at the rate of 0.2% and 0.4%) on the performance of broilers. They observed no effect of garlic powder supplementation on dressing percent of broiler as compared to control. There was also no effect on the weight of organs (like heart, liver, and gizzard) and carcass cuts (like thigh, breast, neck and back).

Milosevic et al. (2013) supplemented the diet of broiler chicks with 1.5% and 3% garlic powder. Analysis of the impact of garlic on carcass parts – drumstick, thigh, and breast muscle, showed no significant differences between the groups. But weight of liver and heart was increased and the weight of abdominal fat was decreased in both the supplemented groups.

Dzinic et al. (2013) supplemented the diet of broiler chicks with 2% garlic powder and found out that there was increase in breast yield. The breast muscle contained higher protein levels but lower cholesterol levels as compared to control group.

Kharde and Soujanya (2014) conducted an experiment to study the effect of supplementation of garlic (0.5 and 1 g/kg feed), neem leaf powder (1 and 2 g/kg feed) and their combination (1g garlic and 2g neem powder/kg feed) on carcass yield in broilers. It was found that dietary supplementation of garlic powder and neem leave powder alone and their combination did not significantly ($p>0.05$) influence the dressing yield and giblet yield (liver, heart, and gizzard) in broilers.

Zekic et al. (2014) conducted a study to examine the effect of 2% of garlic powder addition in the broiler chicken diet. It was noticed that addition of garlic in amount of 2% led to statistically significant ($p<0.05$) higher content of protein and lower content of fat in the breast muscle, while moister content and total ash content recorded no statistically significant differences ($p>0.05$). It was also found that that the addition of garlic significantly ($p<0.05$) lowers the level of cholesterol in tissues of chickens.

Kumar et al. (2016) conducted an experiment to evaluate the effect of supplementing diverse levels of garlic powder (0.5% and 1%), Tulsi (Ocimum sanctum) leaf powder (0.5% and 1%) and their combination (0.5% and 1%) in diet in broiler chicken. A significant increase in average dressing percentage was observed with garlic plus Tulsi powder supplementation in broilers. But the per cent weight of liver, heart and gizzard was similar in all the treatments. Abdominal fat was lower in 1% garlic powder and 1% Tulsi powder supplemented group.

Karim et al. (2017) conducted a study to evaluate the effect of garlic as an alternative feed additive in broiler diet. Garlic powder was supplemented at the rate of 0.25%, 0.50% and 0.75% in the diet. It was observed that there were no significant ($P>0.05$) differences in meat yield (breast meat, thigh meat and wing weight) and bone development (thigh bone, drumstick bone, thigh length, drumstick length) among different treatment groups. Garlic group showed significantly ($P<0.05$) low abdominal fat weight compared to the control and antibiotic group. However, the treatments had no significant effect ($P>0.05$) on skin, head, shank, liver, spleen, kidney, heart, gizzard weight in relation to body weight.

Borgohain et al. 2019 conducted a study on 144-day old broiler chicks (Cobb-400 Y) which were randomly distributed into four groups. T_0 contained no garlic powder supplementation while diet T_1, T_2 and T_3 contained 0.5, 1.0 and 1.5% of garlic powder, respectively along with probiotic powder named probios. It was found out that the carcass quality traits like live weight, dressed weight, dressing percentage and giblet weight did not differ significantly ($P<0.05$) among different treatment groups. The per cent yield of cut-up parts like neck, wing, back, breast, thigh and drumstick also did not differ significantly ($P>0.05$) among different treatment groups.

Odunowo and Olumide (2019) studied the effect of supplementation of garlic powder (0.2%, 0.4% and 0.8%) in the broiler diet. They found non-significant difference in the dressing percent and the weight of primal cuts (breast, thigh, drumstick, and wings). Weight of liver, heart and gizzard also did not exhibit any significant variations among the dietary treatments.

Ismail et al. (2021) studied the effect of supplementation of garlic powder (0.25, 0.50 and 0.75 g/kg diet) and phenyl acetic acid (0.25, 0.50 and 0.75 g/kg diet) in broiler chicken. They found that supplementation with garlic and phenyl acetic acid increased the relative weight of immune organs like thymus, bursa of fabricius and spleen.

2.3.2.4.2 Sensory quality attributes

Fadlalla et al. (2010) investigated the effect of adding graded levels (0, 0.15, 0.3, 0.45 and 0.6%) of garlic to the basal experimental diet of the broiler chicks on sensory characteristics of broiler meat and found out that color, flavor, tenderness, and juiciness of samples were not statistically different.

Toghyani et al. (2011) conducted study to investigate the effect of dietary supplementation of cinnamon powder (2 and 4 g/kg) and garlic powder (2 and 4 g/kg) in broilers. Sensory evaluation of thigh meat displayed no difference in taste and flavor attributes.

2.3.2.4 Economics

Zekic et al. (2014) conducted a study to examine the effect of 2% of garlic powder addition in the broiler chicken diet. Results of the economic efficiency analyses found that the cost of broiler chickens per group is growing, in the control group price was 2.02 $/kg, while in the experimental group price was 2.12 $/kg, respectively. This increase in the price of chicken meat is negligible compared to the much better and healthier product that comes at the end which is intended for human consumption.

Karim et al. (2017) conducted a study to evaluate the effect of garlic as an alternative feed additive in broiler diet. Garlic powder was supplemented at the rate of 0.25%, 0.50% and 0.75% in the diet. It was found that Cost of producing per kg live bird was numerically lower in antibiotic and control group compared to the garlic groups. Moreover, when live broiler was sold per kg at equal market price antibiotic and control group showed higher profitability compared to the garlic group.

Al-Massad et al. (2018) conducted a study to evaluate the beneficial effects of garlic powder (2.5 Kg/ton, 5 Kg/ton and 7.5 Kg/ton) as a phytogenic supplement on broilers chicken performance. They concluded that the addition of garlic as growth promoter reduces the costs of production through improve feed conversion ratio, weight gain and feeding efficiency of treated groups compared with untreated groups. The economical evaluation of the experimental diets indicated that, the diet with garlic powder showed higher profitability as compared to the control group.

2.4 Cinnamon (*Cinnamomum zeylanicum*)

Cinnamon *(Cinnamomum zeylanicum)* commonly known as dalchini is one of the oldest medicinal plants. Cinnamon has a long history of use in traditional medicine as a digestive system aid. It is also used as an aromatic condiment and flavouring additive in a wide variety of foods. The essential oil of cinnamon bark is rich in trans-cinnamaldehyde,

and other biologically active substances such as cinnamyl acetate, cinnamyl alcohol, eugenol and carvacrol (Qin et al.,2003). The major active principle in cinnamon is the cinnamaldehyde. Antimicrobial properties of cinnamon are related to its Cinnamaldehyde content followed by eugenol & carvacrol content (Tabak et al., 1999).

2.4.1 Properties of cinnamon

- Antimicrobial properties of cinnamon are related to its Cinnamaldehyde content followed by eugenol & carvacrol content (Tabak et al. 1999)
- Cinnamon oil & its constituents have antibacterial activity against *E. coli, Staphylococcus aureus, Salmonella spp.* Etc. (Chang et al. 2001)
- Cinnamon has strong antibacterial, antiulcer, analgesic, antioxidant & hypocholesterolaemic activities (Lin et al. 2003)

2.4.2 Effect of cinnamon supplementation in broilers

2.4.2.1 Growth performance

2.4.2.1.1 Body weight

Barreto et al. (2008) conducted experiments to assess the efficacy of plant extracts as alternative for antimicrobial growth promoters in broiler diets. They found out that there was no effect on live weight of broiler chicks between 1-21 days and 1-42 days when the diet was supplemented with 1000 ppm cinnamon extract.

Toghyani et al. (2011) conducted study to investigate the effect of dietary supplementation of cinnamon powder (2 and 4 g/kg) and garlic powder (2 and 4 g/kg) in broilers. It was observed that supplementing 2 g/kg of cinnamon markedly enhanced body weight at 28 and 42 days of age ($P<0.05$). Whereas other treatments had a marginally higher body weight in comparison with the control group.

Molla et al. (2012) conducted an experiment on 20 number of day-old broiler chicks in which they were divided into two groups i.e., group A and group B. Group A served as control while group B was supplemented with polyherbal extract (extract of nishyinda (Vitex negundo) leaves, black pepper (Piper nigrum) and cinnamon (Cinnamomum verum)) @ 1 mL/liter in drinking water. It was observed that supplementation of polyherbal extract resulted in significant increase ($P<0.05$) in mean live weight. The birds supplemented with polyherbal (group B) gained higher live weight than the control group.

Sampath and Atapattu (2013) conducted a study to determine the effects of dietary cinnamon bark powder (0%, 0.1%, 0.2%, 0.3%, 0.4% and 0.5%) on growth performance of broiler chicken. Cinnamon powder was supplemented from day 23 to day 43. They concluded that cinnamon powder supplementation had no effects on final live weight and weight gain in broiler chicks.

Sang-Oh et al. (2013) investigated the feeding effect of diets containing 3, 5 and 7 percent of cinnamon powder in broiler chickens. It was concluded that growth performance in broiler chickens fed diets containing cinnamon powder increased significantly ($P < 0.05$) when compared to the control group.

Shirzadegan (2014) studied the responses of modern broiler chicks to the administration of cinnamon powder (0.25%, 0.50%, 0.75% and 1.0%) in the diet. In conclusion the study showed that supplementing different concentrations of cinnamon powder in the diet (especially at a level of 0.50%) increase the final body weight of broiler chickens.

Singh et al. (2014) conducted a study to evaluate cinnamon powder as a phytobiotic alternative to antibiotic growth promoters in broilers. They used cinnamon powder at low (0.5%), medium (1%) and high (1.5%) levels. It was observed that supplementation of cinnamon at all the three levels improved ($P<0.005$) the body weight gain in the broilers during starter and overall period, which was statistically comparable to control and antibiotic groups.

Qotbi (2016) conducted an experiment to evaluate the effects of various levels of cinnamon powder (1.5% and 3%) and cinnamon extract (200ppm and 300ppm) on the performance of broilers. He observed significant difference ($P<0.05$) in average daily gain in broilers supplemented with various levels of cinnamon oil and cinnamon extract. In 1-21 days, the highest average daily gain was related to 200 ppm Cinnamon extract treatment and the lowest average daily gain was related to 300 ppm Cinnamon extract treatment. In 22-42 days, the highest average daily gain was related to 3.0% Cinnamon powder treatment and the lowest average daily gain was related to control treatment. In 1-42 days, the highest average daily gain was related to 300 ppm Cinnamon extract treatment and the lowest average daily gain was related to control treatment.

Chowdhury et al. (2018) conducted a study to evaluate the effect of three diverse types of essential oils (EOs), i.e., cinnamon oil (CNO), clove oil (CLO) and ajwain oil (AJO) as an alternative to antibiotic growth promoter (AGP) in broiler chickens. It was observed that supplementation of either antibiotic growth promoters or cinnamon oil to the basal diet

increased (P = 0.002) the average daily gain (ADG) compared with the control, clove oil and ajwain oil groups.

Khafaji (2018) conducted a study to evaluate the effect of dietary supplementation of cinnamon powder (500 and 1000 mg/kg) on broiler chicks. He found out that there was a significant increase (P<0.05) in the body weight in two treated groups when compared with the control group at the end of experiment.

Gaikwad et al. (2019) conducted an experiment to find the effect of dietary supplement of cinnamon powder (1%, 2% and 3%) and ginger powder (1%, 2% and 3%) on performance of broiler chicks. They found out that the body weight of the 2.0% cinnamon group and 1% ginger group was significantly (P≤0.05) higher than the other groups. They also concluded that dietary inclusion of 2.0 % cinnamon powder and 1.0 % ginger powder can be used as growth promoters in broiler birds.

Behera et al. (2020) conducted a study that involved feeding of ration including cinnamon to varying degrees (0.5%, 1% and 2%) to broiler birds and observing their growth performance. These birds were kept for 35 days under study. It was found that birds supplemented with 0.5% and 1% cinnamon level significantly enhanced the body weight as compared to control group.

2.4.2.1.2 FCR

Barreto et al. (2008) conducted an experiment to assess the efficacy of plant extracts as alternative for antimicrobial growth promoters in broiler diets. They found out that there was no effect on FCR of broiler chicks between 1-21 days and 1-42 days when the diet was supplemented with 1000 ppm cinnamon extract.

Toghyani et al. (2011) conducted study to investigate the effect of dietary supplementation of cinnamon powder (2 and 4 g/kg) and garlic powder (2 and 4 g/kg) in broilers. It was found out that birds receiving supplemented diets at 28-day period had a significantly lower feed conversion ratio compared to the control group (P<0.05). But as broilers aged treatments did not induce any significant impact on feed conversion ratio in the whole period (1–42 days) although it was calculated to be higher in the control and 4 g/kg garlic groups.

Molla et al. (2012) conducted an experiment on 20 number of day-old broiler chicks in which they were divided into two groups i.e., group A and group B. Group A served as control while group B was supplemented with polyherbal extract (extract of nishyinda (Vitex negundo) leaves, black pepper (Piper nigrum) and cinnamon

(Cinnamomum verum)) @ 1 mL/liter in drinking water. They concluded that supplementation with polyherbal extract improved the feed efficiency compared to control but the difference was not significant (P>0.05).

Sampath and Atapattu (2013) conducted a study to determine the effects of dietary cinnamon bark powder (0%, 0.1%, 0.2%, 0.3%, 0.4% and 0.5%) on growth performance of broiler chicken. Cinnamon powder was supplemented from day 23 to day 43. It was found out that dietary cinnamon bark powder tends (p=0.09) to increase the feed conversion ratio (FCR). FCRs of the broilers fed cinnamon powder were higher than the control group.

Shirzadegan (2014) studied the responses of modern broiler chicks to the administration of cinnamon powder (0.25%, 0.50%, 0.75% and 1.0%) in the diet. He concluded that lowest FCR was found in 0.50% cinnamon powder supplemented group.

Qotbi (2016) observed significant difference (P<0.05) in feed conversion ratio in broilers supplemented with various levels of cinnamon oil and cinnamon extract. In 1-21 days, the highest feed conversion ratio was related to 300 ppm Cinnamon extract treatment and the lowest feed conversion ratio was related to 1.5% Cinnamon powder treatment. In 22-42 days, the highest feed conversion ratio was related to control treatment and the lowest feed conversion ratio was related to 1.5% Cinnamon powder treatment. In 1-42 days, the highest feed conversion ratio was related to control treatment and the lowest feed conversion ratio were related to 1.5% Cinnamon powder and 300 ppm Cinnamon extract treatments.

Chowdhury et al. (2018) conducted a study to evaluate the effect of three diverse types of essential oils (EOs), i.e., cinnamon oil (CNO), clove oil (CLO) and ajwain oil (AJO) as an alternative to antibiotic growth promoter (AGP) in broiler chickens. The FCR in the entire period (1 to 39 d) was found to be significantly lower (P < 0.001) in AGP and CNO groups than in the control group.

Gaikwad et al. (2019) conducted an experiment to find the effect of dietary supplement of cinnamon powder (1%, 2% and 3%) and ginger powder (1%, 2% and 3%) on performance of broiler chicks. They concluded that 2.00 percent of cinnamon powder or 1.00 percent of ginger powder had significantly better feed conversion.

Behera et al. (2020) conducted a study that involved feeding of ration including cinnamon to varying degrees (0.5%, 1% and 2%) to broiler birds and observing their growth performance. These birds were kept for 35 days under study. It was concluded that Birds

with 1% supplementation of cinnamon powder had the best FCR as compared to one with 0.5% supplementation and the control group.

2.4.2.1.3 Feed intake

Barreto et al. (2008) conducted experiments to assess the efficacy of plant extracts as alternative for antimicrobial growth promoters in broiler diets. They found out that there was no effect on feed intake of broiler chicks between 1-21 days and 1-42 days when the diet was supplemented with 1000 ppm cinnamon extract.

Toghyani et al. (2011) conducted study to investigate the effect of dietary supplementation of cinnamon powder (2 and 4 g/kg) and garlic powder (2 and 4 g/kg) in broilers. They observed that food consumption was not significantly influenced by the dietary treatments.

Sampath and Atapattu (2013) conducted a study to determine the effects of dietary cinnamon bark powder (0%, 0.1%, 0.2%, 0.3%, 0.4% and 0.5%) on growth performance of broiler chicken. Cinnamon powder was supplemented from day 23 to day 43. It was found out that feed intakes of the broilers fed cinnamon powder were tend to be (p=.0.09) higher than that of control group.

Qotbi (2016) observed significant difference ($P<0.05$) in feed intake in broilers supplemented with various levels of cinnamon oil and cinnamon extract. In 1-21 days (about 3 weeks), the highest feed intake days was related to 200 ppm Cinnamon extract treatment and the lowest feed intake was related to 1.5% Cinnamon powder treatment. In 22-42 days, the highest feed intake days was related to control treatment and the lowest feed intake was related to 1.5% Cinnamon powder treatment. In 1-42 days, the highest feed intake was related to control treatment and the lowest feed intake was related to 1.5% Cinnamon powder treatment.

Chowdhury et al. (2018) conducted a study to evaluate the effect of three diverse types of essential oils (EOs), i.e., cinnamon oil (CNO), clove oil (CLO) and ajwain oil (AJO) as an alternative to antibiotic growth promoter (AGP) in broiler chickens. It was observed that there was no difference in feed intake during entire experiment period (1 to 39 d) among the treatments ($P > 0.05$).

Gaikwad et al. (2019) conducted an experiment to find the effect of dietary supplement of cinnamon powder (1%, 2% and 3%) and ginger powder (1%, 2% and 3%) on performance of broiler chicks. It was observed that the average feed consumption was significantly highest (3966.85 g/b) in control group and lowest (3793.30 ± 05.94 g/b) in 2.0% cinnamon (T2) supplemented group.

2.4.2.2 Hematology and blood biochemical parameters

2.4.2.2.1 Hematology

Toghyani et al. (2011) conducted study to investigate the effect of dietary supplementation of cinnamon powder (2 and 4 g/kg) and garlic powder (2 and 4 g/kg) in broilers. It was observed that white blood cell (WBC), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) were not significantly influenced by experimental diets.

Khafaji (2018) conducted study on 150 one-day-old mixed-sex broiler chicks to find out the effect of cinnamon powder supplementation (500 mg/kg and 1000 mg/kg) in the diet. It was observed that there was a significant increase ($P<0.05$) in the RBC, WBC, PVC and Hb levels in the cinnamon supplemented groups when compared with the control group.

2.4.2.2.2 Blood biochemicals

Byung-Sung (2008) conducted a 35-day trial to determine the influence of dietary cinnamon powder (2%, 3%, 4% and 5%) on broiler chickens. The concentration of triglyceride and HDL-cholesterol were found to be higher in the plasma from broiler chickens fed diets with cinnamon powder ($P<0.05$) but the concentrations of total cholesterol and LDL-cholesterol were significantly lower ($P<0.05$) when compared to the control group.

Toghyani et al. (2011) conducted study to investigate the effect of dietary supplementation of cinnamon powder (2 and 4 g/kg) and garlic powder (2 and 4 g/kg) in broilers. It was observed that feeding 4 g/kg cinnamon resulted in a marked reduction in the concentration of the hepatic enzyme SGPT ($P<0.05$). Treatments did not induce any significant effect on the serum concentration of protein, albumin, total cholesterol, triglyceride and SGOT enzyme.

Koochaksaraie et al. (2011) conducted study to find effect of cinnamon powder (CNP) feeding on some blood metabolites in broiler chicks. Cinnamon powder was supplemented at levels of 250 mg/kg, 500 mg/kg, 1000 mg/kg, and 2000 mg/kg. It was found out that cinnamon powder supplementation had no significant effect on blood cholesterol, ALT and AST levels.

Sampath and Atapattu (2013) conducted a study to determine the effects of dietary cinnamon bark powder (0%, 0.1%, 0.2%, 0.3%, 0.4% and 0.5%) on performance of broiler

chicken. Cinnamon powder was supplemented from day 23 to day 43. In this study no effect of cinnamon supplementation was observed on serum cholesterol levels.

Shirzadegan (2014) studied the responses of modern broiler chicks to the administration of cinnamon powder (0.25%, 0.50%, 0.75% and 1.0%) in the diet. It was observed that the addiction of cinnamon powder to the diets of broiler chicks had no significant effects ($P>0.05$) on cholesterol, triglyceride, and low-density lipoproteins (LDL) levels.

Khafaji (2018) conducted study on 150 one-day-old mixed-sex broiler chicks to find out the effect of cinnamon powder supplementation (500 mg/kg and 1000 mg/kg) in the diet. A significant increase ($P<0.05$) in the total protein and globulin concentration, while non-significant ($P>0.05$) differences in albumin concentration was observed in the supplemented groups in comparison to control group.

2.4.2.3 Nutrient utilization

Sampath and Atapattu (2013) conducted a study to determine the effects of dietary cinnamon bark powder (0%, 0.1%, 0.2%, 0.3%, 0.4% and 0.5%) on growth performance of broiler chicken. Their Study suggested that dietary cinnamon powder had no positive effects on digestion and absorption process and/or nutrient utilization efficiency.

Chowdhury et al. (2018) conducted a study to evaluate the effect of three diverse types of essential oils (EOs), i.e., cinnamon oil (CNO), clove oil (CLO) and ajwain oil (AJO) as an alternative to antibiotic growth promoter (AGP) in broiler chickens. They found that total nitrogen excretion as well as nitrogen excretion per kilogram of body weight or meat, reduced ($P < 0.001$) in antibiotic and cinnamon oil supplemented groups when compared with the control, clove oil and ajwain oil supplemented groups. Likewise, total nitrogen retention or nitrogen retention per kilogram of body weight increased in antibiotic supplemented group compared with the control, clove oil and ajwain oil groups and total nitrogen retention was greater for cinnamon oil group than control, clove oil and ajwain oil groups.

Rashid et al. (2020) in their study concluded that dietary cinnamon promoted the growth of beneficial bacteria *(Lactobacillus* spp.*)* and reduced the pathogenic bacteria *(Campylobacter* and *E. coli)* load as compared to control group in the ileum and cecum of poultry. It helped to modulate gut microbiota and helped in nutrient digestion.

2.4.2.4 Quality attributes of carcass and meat

2.4.2.4.1 Carcass characteristics

Byung-Sung (2008) conducted a 35-day trial to determine the influence of dietary cinnamon powder (2%, 3%, 4% and 5%) on broiler chickens. It was found that there was no difference in the carcass percentage, chicken breast weight and thigh weight between the supplemented group and control groups.

Toghyani et al. (2011) conducted study to investigate the effect of dietary supplementation of cinnamon powder (2 and 4 g/kg) and garlic powder (2 and 4 g/kg) in broilers. In the study it was found out that carcass percentage and abdominal fat pad were not statistically influenced by the dietary treatments. Internal organ weights and carcass characteristics were not significantly influenced by the dietary treatments at 42 days.

Molla et al. (2012) conducted an experiment on 20-day old broiler chicks in which they were divided into two groups i.e., group A and group B. Group A served as control while group B was supplemented with polyherbal extract (extract of nishyinda (Vitex negundo) leaves, black pepper (Piper nigrum) and cinnamon (Cinnamomum verum)) @ 1 mL/liter in drinking water. They found out no difference ($P>0.05$) in dressing percentage or relative gizzard and spleen weights between groups.

Sampath and Atapattu (2013) conducted a study to determine the effects of dietary cinnamon bark powder (0%, 0.1%, 0.2%, 0.3%, 0.4% and 0.5%) on growth performance of broiler chicken. Cinnamon powder was supplemented from day 23 to day 43. They concluded that there was no effect of cinnamon powder supplementation on visceral organ weight, and gizzard, cloacal and total fat contents. Dietary cinnamon bark powder at 0.1 and 0.4% supplementation increased the abdominal fat content compared to control.

Sang-Oh et al. (2013) investigated the feeding effect of diets containing 3, 5 and 7 percent of cinnamon powder in broiler chickens. The dressing percentage and the weight of thigh meat with skin and breast muscle were significantly higher in the cinnamon powder supplemented groups than the control group. The highest levels were observed in the 5.0% cinnamon powder treatment groups, while no significant difference was observed between 3.0% and 7.0% CNP groups. The weight of the gizzard, liver and abdominal fat did not differ significantly among groups.

Shirzadegan (2014) studied the responses of modern broiler chicks to the administration of cinnamon powder (0.25%, 0.50%, 0.75% and 1.0%) in the diet. It was found that the addiction of cinnamon powder to the diets of broiler chicks had no significant effects ($P>0.05$) on abdominal fat, gizzard, and heart weights and on breast protein percentage.

Singh et al. (2014) conducted a study to evaluate cinnamon powder as a phytobiotic alternative to antibiotic growth promoters in broilers. They used cinnamon powder at low (0.5%), medium (1%) and high (1.5%) levels. It was found out that the different dietary treatments did not influence the carcass characteristics significantly.

Chowdhury et al. (2018) conducted a study to evaluate the effect of three diverse types of essential oils (EOs), i.e., cinnamon oil (CNO), clove oil (CLO) and ajwain oil (AJO) as an alternative to antibiotic growth promoter (AGP) in broiler chickens. No significant differences ($P > 0.05$) were observed in dressing percentage and weight of breast, thigh, neck, gizzard, giblets, heart, and abdominal fat among the dietary treatments. Cinnamon oil significantly ($P = 0.019$) increased the weight of wing compared with the control group.

Gaikwad et al. (2019) conducted an experiment to find the effect of dietary supplement of cinnamon powder (1%, 2% and 3%) and ginger powder (1%, 2% and 3%) on broiler chicks. They found out highest dressing percentage in 1 percent garlic powder and 2 percent cinnamon powder group as compare to other treatment groups.

2.4.2.4.2 Sensory quality attributes

Byung-Sung (2008) conducted a 35-day trial to determine the influence of dietary cinnamon powder (2%, 3%, 4% and 5%) on broiler chickens. He concluded that the sensory evaluation of the taste and savor related to cinnamon in fried or boiled chicken meat were significantly better from the broiler chicken fed diets containing cinnamon powder than the control group ($p<0.05$).

Toghyani et al. (2011) conducted study to investigate the effect of dietary supplementation of cinnamon powder (2 and 4 g/kg) and garlic powder (2 and 4 g/kg) in broilers. Sensory evaluation of thigh meat displayed no difference in taste and flavor attributes.

Singh et al. (2014) conducted a study to evaluate cinnamon powder as a phytobiotic alternative to antibiotic growth promoters in broilers. They used cinnamon powder at low (0.5%), medium (1%) and high (1.5%) levels. It was observed that the supplementation of cinnamon powder at all the levels studied improved ($P<0.5$) the sensory attributes (appearance, color, flavor, juiciness, and overall acceptability) of the meat as compared to control group meat.

2.4.2.5 Economics

Molla et al. (2012) conducted an experiment on 20-day old broiler chicks in which they were divided into two groups i.e., group A and group B. Group A served as control while

group B was supplemented with polyherbal extract (extract of nishyinda (Vitex negundo) leaves, black pepper (Piper nigrum) and cinnamon (Cinnamomum verum)) @ 1 mL/liter in drinking water. It was found out that supplementation with polyherbal extract containing cinnamon was more profitable than control group but difference was not significant ($P>0.05$).

Singh et al. (2014) conducted a study to evaluate cinnamon powder as a phytobiotic alternative to antibiotic growth promoters in broilers. They used cinnamon powder at low (0.5%), medium (1%) and high (1.5%) levels. Highest ($P<0.05$) benefit: cost ratio was found in antibiotic supplemented and 0.5% cinnamon supplemented groups, and it was lowest in 1% and 1.5% cinnamon supplemented groups

Gaikwad et al. (2019) conducted an experiment to find the effect of dietary supplement of cinnamon powder (1%, 2% and 3%) and ginger powder (1%, 2% and 3%) on performance of broiler chicks. The highest cost benefit ratio was found in treatment supplemented with 1% ginger powder followed by 2% cinnamon and 1% cinnamon powder supplementation. Supplementation with 2 percent and 1 percent cinnamon powder provided better economic returns as compared to control.

CHAPTER 3

MATERIALS AND METHODS

The following headings outline the methods and materials used in the research work:

3.1 Garlic powder and cinnamon extract

3.1.1 Garlic powder

3.1.2 Cinnamon extract

3.2 Feeding component collection and chemical analysis

3.2.1 Proximate composition

3.2.2 Nitrogen free extract (NFE)

3.2.3 Metabolizable energy (ME)

3.2.4 Estimation of mineral content in feed and faeces

3.3 Experimental plan

3.3.1 Experimental plan

3.4 Feed formulation

3.5 Broiler chicks' management

3.6 Observations recorded

3.6.1 Body weight gain

3.6.2 Feed consumption by each treatment

3.6.3 Feed conversion ratio

3.6.4 Nutrient Digestibility

3.6.5 Thickness of the gizzard

3.7 Physicochemical analysis of meat

3.7.1 Carcass characteristics and weight of liver, heart, gizzard, spleen, bursa, Abdominal fat, skin, head, feet, feathers, wings

3.7.2 Breast muscle yield

3.7.3 Leg muscle yield

3.7.4 Estimation of pH

3.7.5 Proximate composition of meat

3.7.6 Sensory evaluation

3.7.7 Meat cholesterol

3.8 Collection and analysis of blood samples

3.8.1 Collection of blood

3.8.2 Preparation of plasma and serum

3.8.3 Hematological parameters
3.8.4 Biochemical analysis
3.9 Collection and analysis of cecal contents
3.10 Analysis of tibial bone
3.11 Cost benefit ratio
3.12 Statistical analysis

An experiment was conducted on broiler chicken to determine the effect of incorporating garlic (*Allium sativum*) powder and cinnamon (*Cinnamomum zeylanicum*) extract in an energy deficient diet on broiler chicken production performance, immune response, nutrient utilization, and haemato-biochemical parameters. The study was carried out in Metabolic stall, Department of Animal Nutrition, DGCN COVAS, CSKHPKV, Palampur, Himachal Pradesh, India. The experiment was carried out on broiler chickens from day old to 42 days of age.

This chapter provides a brief summary of the experimental design, experimental bird management, and analytical procedures used during the experiment.

3.1 Garlic powder and cinnamon extract

Garlic bulb and cinnamon bark were purchased locally in Palampur, Himachal Pradesh, India.

3.1.1 Garlic powder

Garlic cloves were removed from fresh garlic and laid on a metal plate before being dried in a vacuum oven at 55ºC for around 2 hours. The dish was then taken from the oven, and the garlic bulbs were crushed before being dried in a vacuum oven at 55ºC for another 2 hours. This technique was continued until the garlic bulbs had dried fully. The dried garlic bulbs were then crushed to a fine powder and kept at 4ºC until use.

3.1.2 Cinnamon extract

Cinnamon bark was finely ground into a powder. 50 g of this powder was thoroughly mixed with 400 mL of ethanol and water (50:50) and allowed to stand for 24 hours with periodic mixing. After 24 hours, the filtrate was filtered using No. 1 Whatman filter paper. The filtrate was then dried on a hot plate at a temperature not higher than 45ºC

until a thick syrupy material remained. This material was then transferred to a lyophilization container and frozen at -18ºC in a deep freezer overnight. It was then lyophilized for 48-72 hours to produce a dark chocolate brown powder. This powder was collected and stored at 4ºC until it was utilized.

3.2 Feeding component collection and chemical analysis

The feed ingredients were obtained from the Department of Animal Nutrition's feed store, and the feed was made at the metabolic stall.

For the examination of feed components, proximate technique of analysis was applied. Dry matter (DM), ether extract (EE), crude protein (CP), crude fiber (CF), total ash (TA), acid insoluble ash (AIA), calcium (Ca), and phosphorus (P) were all estimated in samples of feed ingredients.

The sample's metabolizable energy content of feed samples was calculated using the equation provided by Lodhi et al. (1976).

Table 3.1 Chemical composition of feed ingredients on dry matter basis

	CP	EE	CF	NFE	TA	Ca	P	ME
Ingredients	%	%	%	%	%	%	%	Kcal/Kg
Yellow maize	10	3.2	0.55	84.92	1.33	0.09	0.26	3300
Soya flakes	42.5	0.6	10	39.3	7.6	0.41	0.51	2663
DCP	0	0	0	0	100	26	18	0
LSP	0	0	0	0	100	40	0	0

CP: Crude Protein; EE: Ether Extract; CF: Crude Fiber; NFE: Nitrogen Free Extract; Ca: Calcium; P: Phosphorus; ME: Metabolizable Energy

3.2.1 Feed and Feed ingredient analysis

Standard AOAC (2005) procedures were employed to determine the proximate principles of feed components used in the formulation of experimental broiler starter and finisher diets. The feed samples were analyzed for proximate principles. The proximate analysis of the samples was done in the laboratory of the Department of Animal Nutrition. The dry matter was determined by oven drying, total ash by muffle burning, fat by Soxhlet extraction with petroleum ether (by use of Pelican Socs Plus 08AS DLS instrument), protein by Kjeldahl nitrogen

estimation (with the help of instruments: Pelican Kelplus KES 12L R digestion assembly, Pelican p Kelplus Ultimate duo Dist-TS E distillation assembly, SI Analytics Titro Line 7000 titrator), crude fibre by use of Pelican FIBRA Plus FES4 instrument following the procedure as recommended in (AOAC,2005). The calcium in feed samples were analysed in Atomic Absorption Spectrometer (AAS) (LABINDIA AA8000 Atomic Absorption Spectrophotometer) while phosphorus content was estimated spectrophotometrically (Spectronic 200 spectrophotometer) using the method proposed by Parks & Dunn (1963). The metabolizable energy (ME) was calculated using the equation as proposed by Lodhi et al. (1976).

The AOAC procedures were also used for the proximate analysis of fresh meat (2005).

3.2.2 Nitrogen free extract (NFE)

Nitrogen free extract (on dry matter basis) was calculated using the difference method.

$$NFE\ (\%) = 100 - (\%CP + \%CF + \%EE + \%TA)$$

3.2.3 Metabolizable energy (ME)

Equation proposed by Lodhi et al. (1976) was used for estimating ME

$$ME\ (Kcal/Kg) = 32.9(\%CP + \%EE \times 2.25 + \%NFE) - 29.20$$

3.2.4 Mineral estimation in feed and faeces

Digestion of samples was done by wet digestion method in which organic substances are oxidized by using strong acids and oxidizing agents or their combination, and minerals are solubilized without volatilization.

200 mg of respective sample was taken in a quartz crucible and moistened with 2 ml water. 5 ml Aqua regia (Nitric acid: Hydrochloric acid - 1: 3) and few glass beads were added. The mixture was then gently heated on hot plate. Initially it was heated at a temperature of 80°C which was gradually increased to 100°C. Thereafter, 5 ml more Aqua regia and 0.5 ml Perchloric acid was added. Heating was restored at 100°C. When the solution begun to become clear, 2 ml hydrogen peroxide was added. Temperature was increased to 115°C, to ensure the removal of the last traces of organic matter. This complete process took about 4 hours to complete. When solution became clear, it was cooled and final volume (after sample was filtered) was made in volumetric flask.

The atomic absorption spectrophotometer (AAS) technique (LABINDIA AA8000 AAS) was used to estimate the mineral calcium (Ca) content in feed and feed ingredients. The concentration of phosphorus (P) was measured spectrophotometrically (Spectronic 200 spectrophotometer) using the Parks and Dunn technique (1963).

3.3 Experimental plan

A total of 195-day old broiler chicks (Ven cobb) were procured. Individually chicks were weighed at the start of the experiment, then marked and randomly allocated into five feeding groups, T_0, T_1, T_2, T_3, and T_4, according to the experimental plan in the electric battery brooder. Each group comprised of three replicates, 13 chicks in each replicate. Thus, each treatment included 39 birds. On the seventh day of the experiment, the birds were moved from the electric battery brooder to the deep litter system.

The feeding trial comprised of five experimental diets i.e., T_0, T_1, T_2, T_3 and T_4 as per the experimental plan (Table 3.2)

Table 3.2 Experimental plan

Group	Replicates	Feed	Addition
T_0	3	Standard feed formulated	----------
T_1	3	Standard feed formulated but containing 10 percent less ME	----------
T_2	3	Standard feed formulated but containing 10 per cent less ME	+ 0.5% garlic powder from 1-28 days
T_3	3	Standard feed formulated but containing 10 per cent less ME	+ 0.1% cinnamon extract from1-28 days
T_4	3	Standard feed formulated but containing 10 per cent less ME	+ combination of 0.5% garlic powder & 0.1% cinnamon extract from 1-28 days

ME = Metabolizable energy

1. Total number of broilers in experiment - 195
2. Experimental design – Completely randomized block design (CRBD)
3. Total number of treatments – 5 (including control)

4. Total number of replicates per treatment – 3
5. Total number of broilers per treatment – 39
6. Total number of broilers per replicate – 13

3.4 Formulation of feed

Five broiler experimental diets for the two phases (starter and finisher) were formulated based on a lab examination of the chemical composition of feed materials.

Table 3.3 Physical composition of experimental feed during starter phase

Treatment	**T_0**	**T_1**	**T_2**	**T_3**	**T_4**
Ingredients	%	%	%	%	%
Maize	49.5	49.5	49.5	49.5	49.5
Soya flakes	44	44	44	44	44
Palm oil	3	-	-	-	-
Dicalcium phosphate	3	3	3	3	3
Filler (Sodium Bentonite)	-	3	3	3	3
Methionine	0.270	0.270	0.270	0.270	0.270
Salt	0.230	0.230	0.230	0.230	0.230
Premix	+	+	+	+	+
Garlic powder	-	-	++	-	++
Cinnamon extract	-	-	-	+++	+++

(+ = 0.35% or 350 gm in 100 kg, ++ = 0.5% or 500 gm in 100 kg, +++ = 0.1% or 100 gm in 100 kg)
Premix was prepared by mixing the following in 500 gm of maize flour.
VETRIMIX 10g (vitamin A – 82,500 IU, B2 – 50 mg, D3 – 12,000 IU, K – 10 mg /g). VENTRIBEEPLUS 20g (vitamin B1 – 25 mg, B6 – 35 mg, B12 – 250 µg, E – 225 mg, Pantothenate – 225 mg, Niacinamide – 300 mg, Folic acid – 20 mg / 5 g). E-care Se fort 10 gm (Vitamin E – 0.20g, Se – 0.04 mg / g). Super DOT – 50 gm (Dinitro -o- TOULAMIDE – 250 mg, Ethopabate – 16 mg / g). Toxin binder – 50 gm. Trace minerals - 100 gm (Ferrous sulphate – 12 gm, Copper sulphate – 2 gm, Manganese sulphate – 5 gm, Magnesium sulphate – 20 gm, Zinc sulphate – 2 gm, Zinc oxide – 1 gm, Potassium iodide – 2.5 gm, Dicalcium phosphate – 55.5 gm). Carbohydrase – 50 gm. Phytase – 0.6 gm. Choline chloride – 62.5 gm.

Table 3.4 Physical composition of experimental feed during finisher phase

Treatment	T_0	T_1	T_2	T_3	T_4
Ingredients	%	%	%	%	%
Maize	56.5	56.5	56.5	56.5	56.5
Soya fakes	37	37	37	37	37
Palm oil	3	-	-	-	-
Dicalcium phosphate	1.5	1.5	1.5	1.5	1.5
Limestone powder	1.4	1.4	1.4	1.4	1.4
Filler (Sodium Bentonite)	-	3	3	3	3
Lysine	0.200	0.200	0.200	0.200	0.200
Methionine	0.170	0.170	0.170	0.170	0.170
Salt	0.230	0.230	0.230	0.230	0.230
Premix	+	+	+	+	+
Garlic powder (up to 28 days)	-	-	++	-	++
Cinnamon extract (up to 28 days)	-	-	-	+++	+++

(+ = 0.35% or 350 gm in 100 kg, ++ = 0.5% or 500 gm in 100 kg, +++ = 0.1% or 100 gm in 100 kg)
Premix was prepared by mixing the following in 500 gm of maize flour.
VETRIMIX 10g (vitamin A – 82,500 IU, B2 – 50 mg, D3 – 12,000 IU, K – 10 mg /g). VENTRIBEEPLUS 20g (vitamin B1 – 25 mg, B6 – 35 mg, B12 – 250 µg, E – 225 mg, Pantothenate – 225 mg, Niacinamide – 300 mg, Folic acid – 20 mg / 5 g). E-care Se fort 10 gm (Vitamin E – 0.20g, Se – 0.04 mg / g). Super DOT – 50 gm (Dinitro -o- TOULAMIDE – 250 mg, Ethopabate – 16 mg / g). Toxin binder – 50 gm. Trace minerals - 100 gm (Ferrous sulphate – 12 gm, Copper sulphate – 2 gm, Manganese sulphate – 5 gm, Magnesium sulphate – 20 gm, Zinc sulphate – 2 gm, Zinc oxide – 1 gm, Potassium iodide – 2.5 gm, Dicalcium phosphate – 55.5 gm). Carbohydrase – 50 gm. Phytase – 0.6 gm. Choline chloride – 62.5 gm.

These experimental diets were well-balanced in terms of calories, protein, minerals, and vitamins. Each diet was provided to a triplicate batch of chicks, each with 13 birds. The starter diet was offered from day 0 to 21st day, while the finisher diet was offered from the 22nd to 42nd day. Tables 3.3 and 3.4 show the physical makeup of the diets utilized during the starter (1st to 21st day) and finisher (22nd to 42nd day) phases.

3.5 Management of broiler chicks

The broiler chicks were reared in climate-controlled poultry house. The broiler chicks were offered ad libitum feed and lukewarm water upon arrival.

The chicks were weighed and divided into five groups at random in battery brooders according to the experimental protocol. According to the experimental plan, ad libitum experimental diet was offered to the birds and had access to clean drinking water. The chicks were reared in electric battery brooders for the first seven days before being moved to a deep litter system. From 0 to 42 days of age, the broiler chickens were offered pre-weighed formulated feed, twice daily, according to the experimental protocol. Temperature of the room was maintained at 17.4 to 25ºC while relative humidity was maintained at 40 to 60 percent, respectively. Throughout the study, the birds were provided with good ventilation and 24-hour lighting.

3.6 Observations recorded

The following parameters were studied to determine the effect of incorporating garlic powder and cinnamon extract in experimental broiler bird diet.

3.6.1 Body weight gain

From 0 to 42 days of age, the chicks in each experimental group were weighed individually at weekly intervals. The average body weight and weight gain at weekly intervals, as well as for the entire trial period, was then computed.

3.6.2 Feed consumption

The birds in each replicate were given a measured amount of experimental feed twice a day. Feed residue was weighed at weekly intervals, and the average weekly feed intake per bird of each group was computed by subtracting the residue from the total feed supplied and then dividing the total feed intake in that week by the number of birds, taking mortality into account if any.

3.6.3 Feed conversion ratio (FCR)

The ratio of feed ingested to body weight gain is known as the feed conversion ratio. FCR was determined at weekly intervals, phase by phase, and over the entire period.

FCR = Feed intake (gm)/Body weight gain (gm)

3.6.4 Digestibility of nutrients

On 35th day of the experiment, a metabolic trial was carried out to calculate the digestibility of nutrients offered using total fecal collection method. Prior to the start of metabolic trial, all the feeders, waterers, and faeces collecting trays were thoroughly cleaned and dried. Two birds of equivalent body weight were chosen from each replicate and placed in battery brooders. The birds were given a three-day adaption period, during which they were offered the identical treatment feed as in the growth studies.

Following a three-day adaption period, the measured amount of feed was administered for the next five days, both during morning and evening. The leftover feed residue was weighed on a regular basis to record the actual feed consumption for each replicate. The total faeces collection technique was used to calculate the nutritional balance. The faeces voided by each replicate were collected daily in the morning and verified for the presence of any feather or feed particles, which were subsequently manually removed at the time of collection, and the total weight of faeces voided was recorded using analytical balance (Kern PFB 120-3 Kern & Sohn GmbH, Germany).

The faeces were appropriately mixed and separated into two portions. One for estimating nitrogen and the other for estimating dry matter. To eliminate nitrogen loss, 20 mL of 5per cent sulphuric acid was added into the faeces collected for nitrogen estimate, and the faeces collected for dry matter measurement were dried separately at 105 ° c in a hot air oven until the constant weight was attained. The pooled samples were then ground and analyzed in the Department of Animal Nutrition's laboratory for various proximate parameters using AOAC (2005) standard techniques.

3.6.5 Gizzard thickness

At the end of the trial on day 42, three birds were chosen at random from each replicate of the experimental groups that were near to the average weight of the flock and slaughtered. These birds' gizzards were taken and cleaned. The internal kaolin membrane was removed, and the maximum thickness of the gizzard wall was measured with a digital vernier caliper (Aero space 0-150mm).

3.7 Physico chemical analysis of meat

3.7.1 Carcass characteristics and weight of liver, heart, gizzard, spleen, bursa, abdominal fat, skin, head, feet, feathers, and wings

At the end of the feeding trial, three birds of equal body weight from each replicate were slaughtered using the Jhatka method to record carcass weight, dressed weight, dressing %, abdominal fat, and weight of heart, liver, and gizzard. The birds were fasted overnight to empty the intestinal contents before being slaughtered to determine the effect of various nutritional regimens on carcass weight, dressing percentage, muscle yield, and heart, liver, and gizzard weight. Weights were also taken of the head, feet, skin, spleen, bursa, feathers, and wings.

3.7.2 Breast muscle yield

The weight of the boned breast muscle was recorded and expressed as a percentage of the dressed weight. The weight of the breast major and breast minor was also recorded and expressed as a percentage of the dressed weight.

3.7.3 Leg muscle yield

The weight of the thigh and drumstick was measured and expressed as a percentage of the dressed weight.

3.7.4 Estimation of Ph

The pH of fresh minced chicken was measured using a digital pH meter according to the technique described by Trout et al. (1992). 10 g of material was homogenized in 50 ml of distilled water for around 2-3 minutes using a tissue homogenizer. The pH was measured by directly immersing the electrode in the meat homogenate.

3.7.5 Proximate analysis of broiler meat

Proximate analysis of the meat, including dry matter, crude protein, ether extract, total ash, and acid insoluble ash, was done in accordance with AOAC guidelines (2005).

3.7.6 Sensory evaluation

The cooked chicken pieces were assessed using the usual sensory assessment method (Keeton 1983) using 8 point descriptive scale with modifications. One point equaled severely poor, whereas eight points equaled excellent. The raw chicken was sliced into tiny bits around 1 cm in size and seasoned with 1% salt before being pressure cooked to an internal temperature of 80ºC±2ºC in a pressure cooker. The time-temperature was recorded prior to the start of the trials. A panel of 12 scientists and postgraduate students

from DGCN COVAS, CSKHPKV, Palampur (Himachal Pradesh, India) assessed the sensory attributes of chicken (appearance, flavor, juiciness, tenderness, and overall acceptability). The panelists were briefed on the nature of the experiment without exposing the identities of the samples/treatments.

3.7.7 Meat cholesterol

Total cholesterol in meat was measured according to Zaltkis et al. (1953), with minor modifications as reported by Rajkumar et al. (2004) using a cholesterol test kit (Coral), except that lipid extract was utilized instead of blood serum. One grams of minced meat was mixed with 10 ml of freshly prepared 2:1 chloroform: methanol solution and homogenized to make lipid extract. Whatman No. 42 filter paper was used to filter the homogenate. To 5 ml of filtrate an equal volume of distilled water was added, mixed, and centrifuged at 3,000 rpm for 7 minutes. The top layer (methanol) was removed using suction. The bottom (chloroform) layer containing cholesterol was measured in volume. 25 µL of the sample was pipetted into a test tube and dried for 2-3 minutes in a water bath. To develop the color, 5 ml of cholesterol reagent (cholesterol single reagent kit – oxidase peroxidase method) was added, mixed, and heated in a boiling water bath for 90 seconds (about 1 and a half minutes). The optical density of the standard and test versus the blank was measured at 505 nm. The cholesterol level (mg%) was calculated as follows:

Total cholesterol (mg%) = (O.D. of sample × volume of chloroform layer in ml × concentration of standard) / (O.D. of standard × weight of sample taken)

3.8 Collection and analysis of blood samples

3.8.1 Collection of blood

On the 42nd day of experimental experiment, blood samples were obtained from twelve experimental birds of each group, i.e., four broiler chicks from each replicate. Using sterile syringes and needles (24 gauze), blood samples were obtained aseptically from the jugular vein. Blood samples were collected and transferred to EDTA vials for examination of hematological parameters and plasma preparation.

3.8.2 Preparation of plasma and serum

The blood was transferred to EDTA vials and centrifuged at 2000 rpm for 15 minutes to extract plasma. The plasma was transferred into clean polypropylene tubes with

a Pasteur pipette and kept at −20ºC with the date and sample number for subsequent analysis.

For separation of serum, blood samples were obtained aseptically from the jugular vein in syringes and left to stand at room temperature in a slanting posture for 3 to 4 hours to facilitate clot formation. After the blood had clotted, the plungers were withdrawn from the syringes, and the serum was collected in clean polypropylene tubes and kept at -20ºC with the date and sample number for subsequent analysis.

3.8.3 Hematological parameters

Hematological parameters such as hemoglobin (g/dl), packed cell volume (%), WBC ($\times 10^9$/L), RBC ($\times 10^{12}$/L), MCV (FL), MCH (Pg.) and MCHC (g/dl) were analyzed using a semiautomatic CBC analyzer (BC – 2800Vet).

3.8.4 Blood Biochemical analysis

The estimate of different biochemicals was performed in the laboratory of Department of Animal Nutrition, COVAS, Palampur, Himachal Pradesh, utilizing Agape diagnostic kits and an Erba Mannheim CHEM 5 X plasma analyzer.

Various blood biochemical parameters estimated were as under:

Plasma protein profile – Total protein, albumin, and globulin

Plasma lipid profile - Total cholesterol, HDL cholesterol and LDL cholesterol

Plasma creatinine and plasma uric acid

Plasma enzyme profile - Alanine aminotransferase (ALT/SGPT) and Aspartate aminotransferase (AST/SGOT)

Blood minerals - Calcium and phosphorus levels were determined in the serum samples in the laboratory of Department of Animal Nutrition, COVAS, Palampur (Himachal Pradesh), using an Erba Mannheim CHEM 5 X plasma analyzer and Agape diagnostic kits.

3.9 Collection and analysis of cecal contents

At the time of slaughter, the caecum was removed from the birds in each treatment group, and the cecal contents were collected in sterile petri plates. The samples were subsequently processed by preparing dilutions. The dilutions were made by thoroughly mixing the sample with the diluent.

3.9.1 Preparation of dilutions

a. Eight sterilized glass tubes were obtained, and 9 ml of sterile diluent was added to each tube
b. 1 gram of cecal content was added to the first tube and well mixed using a pipette. This was the initial dilution (10^{-1})
c. 1 ml of the first dilution was added to the second tube to produce the second dilution 10^{-2}
d. In this manner, additional dilutions were prepared until a 10^{-8} dilution was obtained

3.9.2 Plate inoculation and incubation

a. 1 ml of diluted sample (10^{-6} to 10^{-8} dilutions) was transferred to sterile petri dishes
b. To each plate 15-20 ml of molten agar (at 45-50ºC temperature) was added
c. On a levelled surface, the contents were gently mixed by rotating the plates clockwise and anticlockwise
d. For 15-20 minutes, agar was allowed to cool and harden in petri dishes at room temperature
e. Petri plates were inverted and incubated at 37ºC for 24-48 hours (about 1 to 2 days)
f. After incubation, the colonies were counted using a Quebec colony counter at the Department of Veterinary Public Health, COVAS, CSKHPKV, Palampur

Number of cfu /gm = Number of cfu × dilution factor

3.10 Analysis of tibial bone

The tibial bone of three birds from each replication was collected individually in sample bags at the time of slaughter. The sample bags were maintained in a deep freezer until further analysis was conducted.

Bone preparation was done prior to mineral estimation using the method described by Hall et al (2003). The tibial bone was first de fleshed and then immersed in ethanol overnight. To remove fat from the bones, they were extracted with ether in a Soxhlet extractor (Pelican socs plus). Following that, the bones were dried in a hot air oven. The length and diameter of the bones were measured using a vernier caliper.

Digestion of bone samples was done by wet digestion method (as described earlier for digestion of feed and faeces) in which organic substances are oxidized by using strong acids and oxidizing agents or their combination, and minerals are solubilized without volatilization.

200 mg bone ground bone sample was taken in a quartz crucible and moistened with 2 ml water. 5 ml Aqua regia (Nitric acid: Hydrochloric acid - 1: 3) and few glass beads were added. The mixture was then gently heated on hot plate. Initially it was heated at a temperature of 80°C which was gradually increased to 100°C. Thereafter, 5 ml more Aqua regia and 0.5 ml Perchloric acid was added. Heating was restored at 100°C. When the solution begun to become clear, 2 ml hydrogen peroxide was added. Temperature was increased to 115°C, to ensure the removal of the last traces of organic matter. This complete process took about 4 hours to complete. When solution became clear, it was cooled and final volume (after sample was filtered) was made in volumetric flask.

The atomic absorption spectrophotometer (AAS) technique (LABINDIA AA8000 AAS) was used to estimate the mineral calcium (Ca). The concentration of phosphorus (P) was measured spectrophotometrically (Spectronic 200 spectrophotometer) using the Parks and Dunn technique (1963).

3.12 Cost benefit ratio

European economic factor (EEF) and cost of producing per kilogram of chicken was computed under different treatments Viability, economic factors including the European efficiency factor (EEF), were calculated using the following formulae (Bera et al. 2010; Lup et al. 2012):

$$\text{Viability} = \{1-(\text{n of dead birds/total birds})\} \times 100$$

$$\text{EEF} = \{\text{BW} \times \text{viability} \times 100 / (\text{FCR} \times \text{age})\}$$

Where EEF is the European efficiency factor and BW is the average body weight (kg). Age was measured in days.

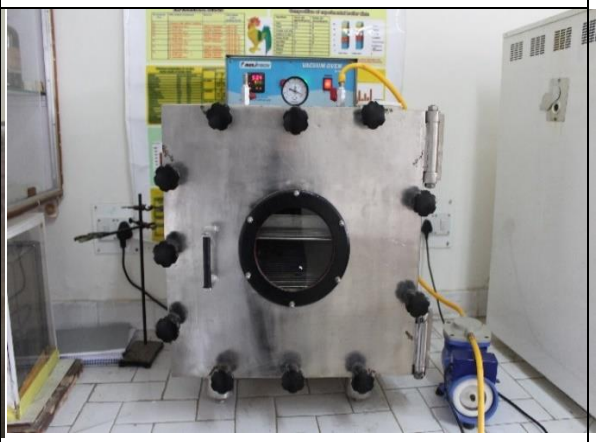
3.11 Statistical analysis

All recorded and computed data were subjected to analysis of variance (ANOVA) using the randomized block design (RBD) as described by Snedecor and Cochran (1968). The results were assessed at a 5% level of significance.

Raw garlic

Garlic bulbs

Garlic bulbs loaded into vacuum oven



Drying bulbs in vacuum oven at 55º C

Dry garlic bulbs

Dry garlic powder

Plate 1: Preparation of Garlic Powder

Cinnamon bark	Cinnamon bark powder
Extracting cinnamon in ethanol:water (50:50)	Drying cinnamon extract
Lyophylising cinnamon extract	Dry chocolaty brown cinnamon extract

Plate 2: Preparation of Cinnamon Extract

Plate 3: Arrival of Chicks

Plate 4: Weighing of Day-old Chicks

Plate 5: Electric Battery Brooder

Plate 6: Feeding and Watering during Starter Phase

Plate 7: Humidifier for maintaining Relative Humidity

Plate 8: Rearing of Chicks in Deep litter System

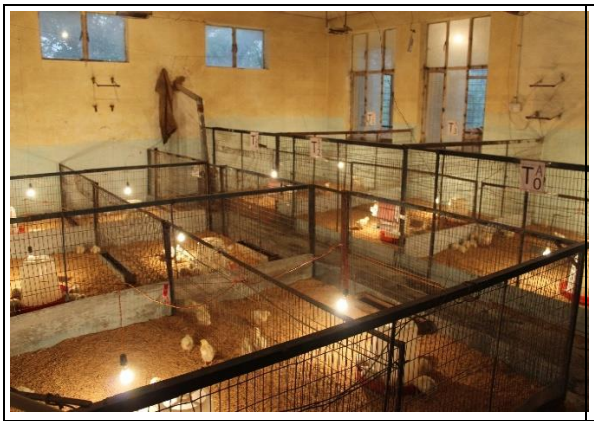


Plate 9: Completely Randomized Block Design

Plate 10: Feeding of Broiler during Finisher phase

Plate 11: Birds kept in cages for Metabolic Trial

Plate 12: Collected Faecal Samples

Plate 13: Pelican Kelplus KES 12L R Digestion Assembly

Plate 14: Pelican Socs Plus 08AS DLS instrument

Plate 15: LABINDIA AA8000 Atomic Absorption Spectrophotometer

Plate 16: Erba Mannheim CHEM 5 X Plasma Analyzer.

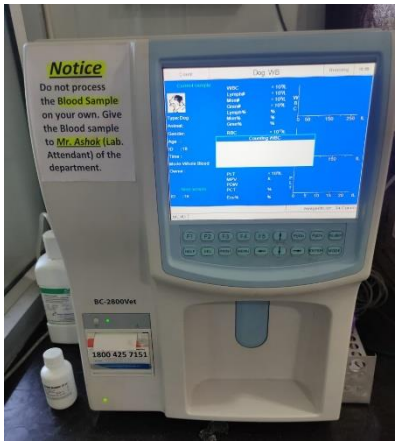


Plate 17: Semiautomatic CBC Analyzer (BC – 2800Vet)

Plate 18: Digital pH meter (eco test pH 1)

Plate 19: Spectronic 200 Spectrophotometer

Plate 20: Blood Collection from Jugular Vein

Plate 21: Dressed Broiler Chicken

Plate 22: Different Cuts and Internal Organs of Dressed Broiler Chicken

Heart

Liver

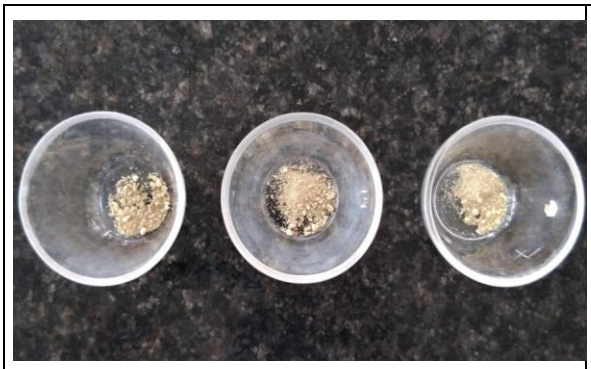
Spleen

Gizzard

Plate 23: Weighing of Internal Organs

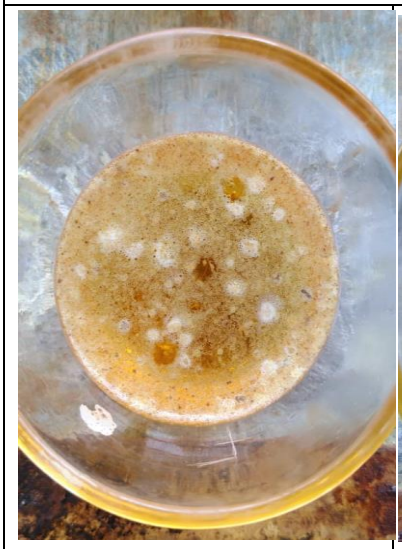
Plate 24: Weighing of Thigh and Drumstick

Plate 25: Weighing of Breast Minor and Breast Major



Tibial bone sample

Bone sample digestion with aqua regia on hot plate



Undigested bone sample

Partly digested bone sample

Completely digested bone sample

Plate 26: Wet Digestion of Tibial Bone

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Chemical composition of feed ingredients and test feed

Laboratory analysis of various feed ingredients for proximate principles like yellow maize, soya flakes, DCP and LSP which were used for formulating poultry diets, under different feeding experiments, was done for their proximate composition and the data has been presented in Table 4.1.

Table 4.1 Chemical composition of feed ingredients on dry matter basis (d.m.b)

	CP	EE	CF	NFE	TA	Ca	P	ME
Ingredients	%	%	%	%	%	%	%	Kcal/Kg
Yellow maize	10	3.2	0.55	84.92	1.33	0.09	0.26	3300
Soya flakes	42.5	0.6	10	39.3	7.6	0.41	0.51	2663
Dicalcium Phosphate (DCP)	0	0	0	0	100	26	18	0
Lime Stone Powder (LSP)	0	0	0	0	100	40	0	0

CP: Crude protein; EE: Ether extract; CF: Crude fibre; NFE: Nitrogen free extract; TA: Total ash; Ca: Calcium; P: Phosphorus; ME: Metabolizable energy

The per cent crude protein value for maize and soya flakes was found to be 10 and 42.5 respectively whereas Minhas (2017) reported 10.11 and 39 per cent, Koundal (2019) reported 11.20 and 45 per cent and Sharma (2019) reported 11.20 and 43.22 per cent.

The per cent ether extract value for maize and soya flakes was found to be 3.2 and 0.60 respectively whereas Minhas (2017) reported 2.26 and 0.10 per cent, Koundal (2019) reported 3.50 and 0.58 per cent and Sharma (2019) reported 3.51 and 0.58 per cent.

The per cent total ash value for maize and soya flakes was found to be 1.33 and 7.60 respectively whereas Thakur (2018) reported 1.40 and 7.95 per cent, Koundal (2019) reported 1.61 and 8.38 per cent and Sharma (2019) reported 1.61and 8.38 per cent.

The per cent crude fibre value for maize and soya flakes was found to be 0.55 and 10 respectively whereas Minhas (2017) reported 3.10 and 3.11 per cent, Thakur (2018) reported 2.50 and 8.33 per cent, Koundal (2019) reported 2.30 and 6.10 per cent and Sharma (2019) reported 2.30 and 6.10 per cent.

The per cent calcium value for maize, soya flakes, Di-Calcium Phosphate (DCP) and Lime-Stone Powder (LSP) was found to be 0.09, 0.41, 26 and 40 per cent respectively whereas Minhas (2017) reported 0.01, 0.10, 21 and 38 per cent, Koundal (2019) reported 0.01, 0.10, 21 and 38 per cent and Sharma (2019) reported 0.01, 0.10, 33 and 38 per cent.

The per cent phosphorus value for maize, soya flakes and DCP was found to be 0.26, 0.51 and 18 per cent respectively whereas Minhas (2017) reported 0.12, 0.42 and 18 per cent, Thakur (2018) reported 0.26, 0.54 and 18.50 per cent, Koundal (2019) reported 0.31, 0.61and 18 per cent and Sharma (2019) reported 0.13, 0.43 and 18 per cent.

The ME (Kcal/kg) value for maize and soya flakes was found to be 3300 and 2663respectively whereas Koundal (2019) reported 3300 and 2788 Kcal/Kg.

The variation in season, variety and quality of ingredients received at separate times of the year might be the reason for slight variation in the proximate composition of different ingredients.

4.1.1 Chemical composition of experimental broiler starter diets

The data regarding the composition of broiler starter diets has been presented in table 4.2. The crude protein content of the experimental starter feeds viz. T_0, T_1, T_2, T_3 and T_4 was found to be 21.95 per cent which signify that the test feeds were iso nitrogenous. The ether extract content of the experimental starter feeds viz. T_0, T_1, T_2, T_3 and T_4 was found to be 1.70 per cent. The crude fibre content of the experimental starter feeds viz. T_0, T_1, T_2, T_3 and T_4 was found to be 4.34 per cent. The total ash content of the experimental starter feeds viz. T_0, T_1, T_2, T_3 and T_4 was found to be 3.72 per cent. The calcium and phosphorus concentration in the experimental starter feeds T_0, T_1, T_2, T_3 and T_4 were found to be 0.99 per cent and 0.87 per cent, respectively. The amino acid concentrations of DL – Methionine and L – Lysine were found to be 0.97 per cent and 1.41 per cent, respectively. Metabolizable energy (ME) value for the positive control (T_0) group was calculated to be 2875 Kcal/Kg whereas for negative control (T_1) group and other supplemented groups (T_2, T_3 and T_4) it was calculated to be 2593 Kcal/Kg which was about 10 per cent less than the positive control (T_0) group. ME/CP ratio for the positive control (T_0) group was 131 whereas for negative control (T_1) group and other supplemented groups (T_2, T_3 and T_4) it was 118.

Table 4.2 Chemical composition of starter diets (% d.m.b)

Treatment Nutrient	T_0 (%)	T_1 (%)	T_2 (%)	T_3 (%)	T_4 (%)
Crude protein	21.95	21.95	21.95	21.95	21.95
Ether extract	1.70	1.70	1.70	1.70	1.70
Crude fibre	4.34	4.34	4.34	4.34	4.34
Total ash	3.72	3.72	3.72	3.72	3.72
Calcium	0.99	0.99	0.99	0.99	0.99
Total phosphorus	0.87	0.87	0.87	0.87	0.87
NFE	57.75	57.75	57.75	57.75	57.75
ME (Kcal/Kg)	2875	2593	2593	2593	2593
DL – Methionine	0.97	0.97	0.97	0.97	0.97
L – Lysine	1.41	1.41	1.41	1.41	1.41
ME/CP ratio	131	118	118	118	118

NFE: Nitrogen free extract; ME: Metabolizable energy; CP: Crude protein

4.1.2 Chemical composition of experimental broiler finisher diets

The data regarding the composition of broiler finisher diets has been presented in Table 4.3. The crude protein content of the experimental starter feeds viz. T_0, T_1, T_2, T_3 and T_4 was 19.82 per cent which signify that the test feeds were iso nitrogenous. The ether extract content of the experimental starter feeds viz. T_0, T_1, T_2, T_3 and T_4 was 1.87 per cent. The crude fibre content of the experimental starter feeds viz. T_0, T_1, T_2, T_3 and T_4 was 3.73 per cent. The total ash content of the experimental starter feeds viz. T_0, T_1, T_2, T_3 and T_4 was 3.31 per cent. The Calcium and phosphorus concentration in the experimental starter feeds T_0, T_1, T_2, T_3 and T_4 were 1.14 per cent and 0.58 per cent, respectively. The amino acid concentrations of DL – Methionine and L – Lysine were 1 per cent and 1.32 per cent, respectively. Metabolizable energy (ME) value for the positive control (T_0) group was found to be 2914 Kcal/Kg whereas for negative control (T_1) group and other supplemented groups (T_2, T_3 and T_4) it was found to be 2631 Kcal/Kg which was about 10 per cent less than the positive control (T_0) group. ME/CP ratio for the positive control (T_0) group was found to be 147 whereas for negative control (T_1) group and other supplemented groups (T_2, T_3 and T_4) it was found to be 133.

Table 4.3 Chemical composition of finisher diets (% d.m.b.)

Treatment Nutrient	T_0 (%)	T_1 (%)	T_2 (%)	T_3 (%)	T_4 (%)
Crude protein	19.82	19.82	19.82	19.82	19.82
Ether extract	1.87	1.87	1.87	1.87	1.87
Crude fibre	3.73	3.73	3.73	3.73	3.73
Total ash	3.31	3.31	3.31	3.31	3.31
Calcium	1.14	1.14	1.14	1.14	1.14
Total phosphorus	0.58	0.58	0.58	0.58	0.58
NFE	60.56	60.56	60.56	60.56	60.56
ME (Kcal/Kg)	2914	2631	2631	2631	2631
DL – Methionine	1	1	1	1	1
L – Lysine	1.32	1.32	1.32	1.32	1.32
ME/CP ratio	147	133	133	133	133

NFE: Nitrogen free extract; ME: Metabolizable energy; CP: Crude protein

4.2 Effects of supplementation of garlic powder and cinnamon extract in the feed

4.2.1 Growth performance of broiler birds during starter phase (0 to 21st day)

Results for initial body weight, final body weight, gain in weight, feed intake, feed conversion ratio, feed intake per day, gain in weight per day and mortality per cent for positive control T_0, negative control T_1 and supplemented treatments with garlic powder T_2, cinnamon extract T_3 and cinnamon extract + garlic powder T_4 has been presented in Table 4.4

Perusal of results revealed that the gain in live body weight of broiler birds at the end of the starter phase was T_0 (585.51) g, T_1 (508.84) g, T_2 (530.44) g, T_3 (557.86) g and T_4 (536.47) g, respectively which was significantly ($P<0.05$) high in positive control T_0 compared to negative control T_1. The difference for gain in live body weight among various phyto additive supplemented treatments offered low density energy feed did not exhibit any significant difference amongst each other and compared to negative control T_1 but the cinnamon extract supplemented treatment T_3 exhibited highest gain in weight compared to negative control T_1 and low energy treatments T_2 and T_4. Gain in live weight per day in positive control T_0 was recorded to be (27.88) g, in negative control T_1 was (24.23) g and in treatment T_2, T_3 and T_4 was (25.26) g, (26.56) g and

(25.55) g, respectively. Perusal of the results revealed significant difference ($P<0.05$) amongst positive control T_0, negative control T_1 and the phyto-additive supplemented (garlic powder and cinnamon extract) treatments T_2, T_3 and T_4 for gain in weight per day. Significantly ($P<0.05$) highest value for gain in live body weight per day was recorded in positive control T_0 (26.62g) compared to negative control T_1 (24.23) g. Feed Intake (FI) of broiler birds at the end of the starter phase in positive control T_0 was (999.67) g, negative control T_1 (1002.46) g, and treatment groups T_2 (987.13) g, T_3 (963.10) g and T_4 (987.41) g, respectively. No significant ($P>0.05$) difference was recorded amongst positive control T_0, negative control T_1 and the phyto-additive supplemented treatments T_2, T_3 and T_4 for feed intake. Numerically the highest value of feed intake was recorded in negative control T_1 (1002.46g) and the lowest feed intake was recorded in cinnamon extract supplemented treatment T_3 (963.10g). Feed intake per day in positive control T_0 was recorded to be (47.60) g, in negative control T_1 was (47.74) g and in treatment T_2, T_3 and T_4 was (47.01) g, (45.86) g and (47.02) g, respectively. Perusal of the results revealed no significant difference ($P>0.05$) amongst positive control T_0, negative control T_1 and the phyto-additive supplemented (garlic powder and cinnamon extract) treatments T_2, T_3 and T_4 for feed intake per day. Numerically highest FI per day was recorded in negative control T_1 (47.74) g and lowest feed intake was recorded in cinnamon extract supplemented treatment T_3 (45.86). Feed to live weight gain ratio (FCR) of broiler birds at the end of the starter phase in positive control T_0 was (1.71), negative control T_1 (1.97), and treatment groups T_2 (1.87), T_3 (1.73) and T_4 (1.84), respectively which was significantly ($P<0.05$) low in positive control T_0 compared to negative control T_1 but exhibited non-significant difference with treatment groups T_2, T_3 and T_4. The difference for FCR among various phyto additive supplemented treatments offered low density energy feed did not exhibit any significant difference amongst each other and compared to negative control T_1 but the cinnamon extract supplemented treatment T_3 exhibited better feed to gain ratio compared to negative control T_1 and low energy treatments T_2 and T_4. The recorded mortality per cent in T_0, T_1, T_2, T_3 and T_4 was 0.00, 0.00, 0.00, 2.56 and 0.00 respectively which was well within the normal managemental accepted norms.

At the end of starter phase (0-21 days), the birds of control group T_0 offered standard feed, exhibited higher live body weight gain, lower feed intake on weekly and per day basis, better feed to live weight gain ratio (FCR) which exhibited significant ($P<0.05$)

difference compared to negative control T_1 but did not exhibit any significant ($P>0.05$) difference compared to treatment groups T_2, T_3 and T_4. Mortality per cent was as per the standard management norms with treatment group T_3 exhibiting marginal (2.56) mortality per cent whereas no mortality was recorded in other treatments. Higher feed intake and subsequently higher FCR exhibited in negative control T_1 seems to be the result of compensatory mechanism for meeting the energy requirements when low energy density feed was offered. Energy calories ratio was narrow in case of negative control group T_1 which led to increased feed intake compared to positive control T_0 whereas treatment groups offered phyto additives viz. garlic powder and cinnamon extract exhibited weight gain, feed intake, FCR comparable to positive control group, though offered low energy density feed. The results obtained reveal better utilization of nutrients with the supplementation. Compared to negative control T_1 and treatment groups T_2 and T_4, treatment T_3 offered cinnamon extract at 0.1 per cent exhibited numerically higher gain in live body weight, lower feed intake and lower feed to live weight gain ratio (FCR).

Table 4.4 Growth performance of broiler birds during starter phase (0 to 21st day)

Particulars	IBW	FBW	GIW	FI	FCR	GIW/day	FI/day	Mortality
T_0	58.56±0.86	644.07±2.41	585.51±1.91^{b}	999.67±1.19	1.71±0.01^{a}	27.88±0.09^{b}	47.60±0.06	NIL
T_1	56.56±1.96	565.40±13.95	508.84±12.58^{a}	1002.46±4.17	1.97±0.04^{b}	24.23±0.60^{a}	47.74±0.20	NIL
T_2	54.56±0.45	585.00±24.12	530.44±23.67^{ab}	987.13±10.15	1.87±0.09^{ab}	25.26±1.13^{ab}	47.01±0.48	NIL
T_3	53.22±0.75	611.8±14.58	557.86±13.92^{ab}	963.10±13.64	1.73±0.02^{ab}	26.56±0.66^{ab}	45.86±0.65	2.56
T_4	52.97±2.33	589.44±16.01	536.47±14.76^{ab}	987.41±7.71	1.84±0.06^{ab}	25.55±0.70^{ab}	47.02±0.37	NIL
PSE	0.38	4.85	6.73	3.83	0.02	0.32	0.18	
P value	<0.0001	<0.0001	0.041	0.058	0.040	0.041	0.058	

Average means with different superscripts are significantly (P<0.05) different from each other

IBW: initial body weight; FBW: final body weight; GIW: gain in weight; FI: feed intake; FCR: feed conversion ratio.

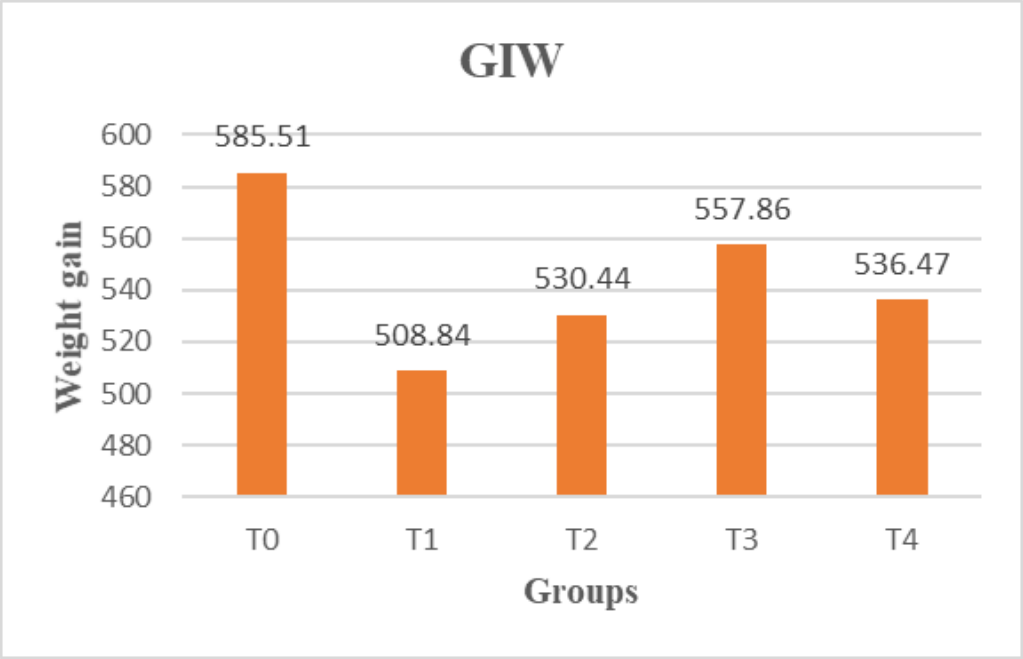


Fig. 4.1 Gain in weight (g) during starter phase

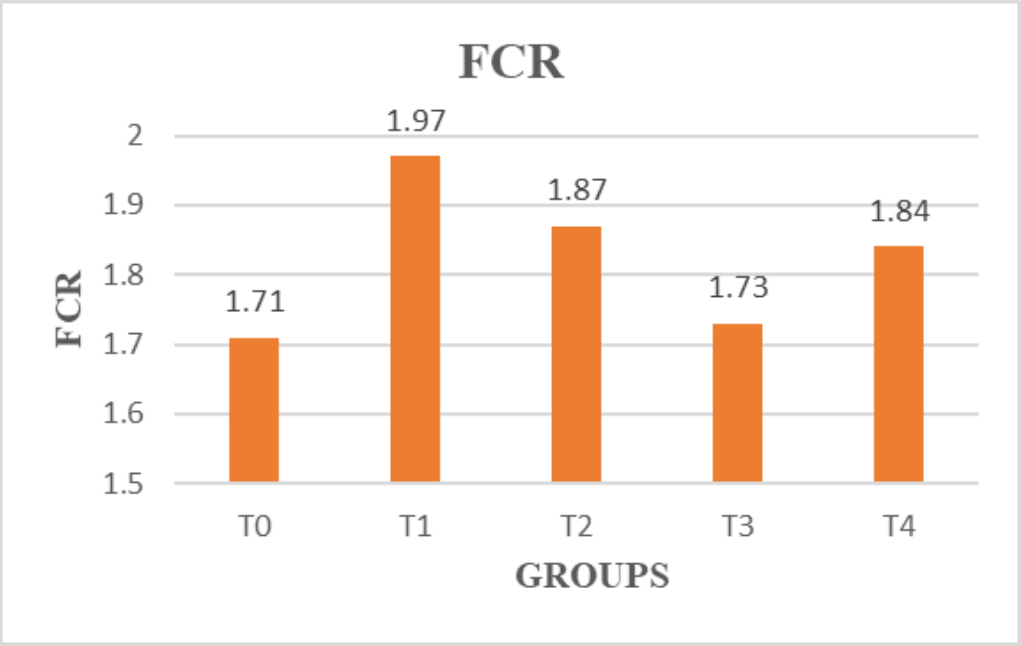


Fig. 4.2 FCR during starter phase

4.2.2 Growth performance of broiler birds during finisher phase (22nd to 42nd day)

Results for initial body weight, final body weight, gain in weight, feed intake, feed conversion ratio, feed intake per day, gain in weight per day and mortality per cent for positive control T_0, negative control T_1 and supplemented treatments with garlic

powder T_2, cinnamon extract T_3 and cinnamon extract + garlic powder T_4 has been presented in Table 4.5

Perusal of results revealed that the gain in live body weight of broiler birds at the end of the finisher phase was T_0 (1445.46) g, T_1 (1241.46) g, T_2 (1338.67) g, T_3 (1381.55) g and T_4 (1348.22) g, respectively which was significantly ($P<0.05$) high in positive control T_0 compared to negative control T_1. The difference for gain in live body weight among various phyto additive supplemented treatments viz. T_2, T_3 and T_4 offered low density energy feed did not exhibit any significant difference amongst each other and compared to negative control T_1 but the cinnamon extract supplemented treatment T_3 exhibited highest gain in live weight compared to negative control T_1 and low energy treatments T_2 and T_4. Gain in live weight per day in positive control T_0 was recorded to be (68.83) g, in negative control T_1 was (59.12) g and in treatment T_2, T_3 and T_4 was (63.75) g, (65.79) g and (64.20) g, respectively. Perusal of the results revealed significant difference ($P<0.05$) amongst positive control T_0, negative control T_1 and the phyto-additive supplemented (garlic powder and cinnamon extract) treatments T_2, T_3 and T_4 for gain in weight per day. Significantly ($P<0.05$) highest value for gain in live body weight per day was recorded in positive control T_0 (68.83) g compared to negative control T_1 (59.12) g. Feed intake (FI) of broiler birds at the end of the finisher phase in positive control T_0 was (2649.60) g, negative control T_1 (2756.92) g, and treatment groups T_2 (2618.91) g, T_3 (2701.94) g and T_4 (2619.72) g, respectively. No significant ($P>0.05$) difference was recorded amongst positive control T_0, negative control T_1 and the phyto-additive supplemented treatments T_2, T_3 and T_4 for feed intake. Numerically the highest feed intake was recorded in negative control T_1 (2756.92) and the lowest feed intake was recorded in garlic powder supplemented treatment T_2 (2618.91). Feed intake per day in positive control T_0 was recorded to be (126.17) g, in negative control T_1 was (131.28) g and in treatment T_2, T_3 and T_4 was (124.71) g, (128.66) g and (124.75) g, respectively. Perusal of the results revealed no significant difference ($P>0.05$) amongst positive control T_0, negative control T_1 and the phyto-additive supplemented (garlic powder and cinnamon extract) treatments T_2, T_3 and T_4 for feed intake per day. Numerically highest FI per day was recorded in negative control T_1 (131.28) g and lowest feed intake was recorded in garlic powder supplemented treatment T_2 (124.71) g. Feed to live weight gain ratio (FCR) of broiler birds at the end of the finisher phase in positive control T_0 was (1.83), negative control T_1 (2.22), and treatment groups T_2 (1.96), T_3 (1.96) and T_4 (1.95), respectively which was significantly ($P<0.05$) low in positive control T_0 and

phyto additive supplemented treatments T_2, T_3 and T_4 compared to negative control T_1. The difference for FCR among various phyto additive supplemented treatments offered low density energy feed did not exhibit any significant difference amongst each other and compared to positive control T_0. The recorded mortality per cent in T_0, T_1, T_2, T_3 and T_4 was 0.00, 2.56, 0.00, 0.00 and 0.00 respectively and was well within the normal managemental accepted norms.

Trend of growth and feed conversion was similar as was exhibited during starter phase. At the end of the finisher phase (22-42 days) the broiler birds of control group T_0 offered standard feed exhibited higher live body weight gain, lower feed intake on weekly and per day basis, better feed to live weight gain ratio (FCR) which exhibited significant ($P<0.05$) difference compared to negative control T_1 but did not exhibit any significant ($P>0.05$) difference compared to treatment groups T_2, T_3 and T_4. Mortality per cent was as per the standard management norms with negative control T_1 exhibiting marginal (2.56) mortality per cent whereas no mortality was recorded in other treatments. Higher feed intake and subsequently higher FCR exhibited in negative control seem to be the result of compensatory mechanism for meeting the energy requirements when low energy density feed was offered. Energy calories ratio was narrow in case of negative control group T_1 which led to increased feed intake compared to positive control T_0 whereas treatment groups offered phyto additives viz. garlic powder and cinnamon extract exhibited weight gain, feed intake, FCR comparable to positive control group, though offered low energy density feed. The results obtained reveal better utilization of nutrients with the supplementation of phyto additives. Compared to negative control T_1 and treatment groups T_2 and T_4, treatment T_3 offered cinnamon extract at 0.1 per cent exhibited numerically higher gain in live body weight and lower feed to live weight gain ratio (FCR).

Table 4.5 Growth performance of broiler birds during finisher phase (22nd to 42nd day)

Particulars	IBW	FBW	GIW	FI	FCR	GIW/day	FI/day	Mortality
T0	644.07±2.41	2089.52±16.91	1445.46±14.83^{b}	2649.60±6.86	1.83±0.02^{a}	68.83±0.71^{b}	126.17±0.33	NIL
T1	565.40±13.95	1806.86±36.51	1241.46±22.65^{a}	2756.92±87.93	2.22±0.08^{b}	59.12±1.08^{a}	131.28±4.19	2.56
T2	585.00±24.12	1923.67±20.54	1338.67±28.61^{ab}	2618.91±49.93	1.96±0.02^{a}	63.75±1.36^{ab}	124.71±2.38	NIL
T3	611.8±14.58	1992.63±78.05	1381.55±67.52^{ab}	2701.94±55.36	1.96±0.06^{a}	65.79±3.22^{ab}	128.66±2.64	NIL
T4	589.44±16.01	1937.67±39.54	1348.22±42.09^{ab}	2619.72±31.14	1.95±0.04^{a}	64.20±2.00^{ab}	124.75±1.48	NIL
PSE	4.85	15.51	17.76	23.92	0.02	0.85	1.14	
p-Value	<0.0001	<0.0001	0.050	0.357	0.003	0.050	0.357	

Average means with different superscripts are significantly (P<0.05) different from each other

IBW: initial body weight; FBW: final body weight; GIW: gain in weight; FI: feed intake; FCR: feed conversion ratio.

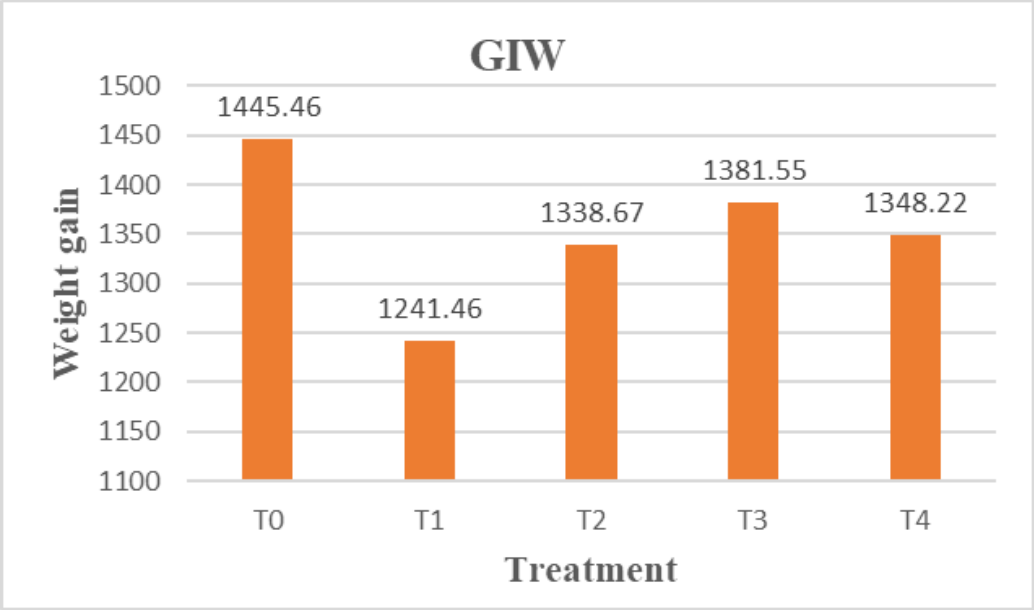


Fig. 4.3 Gain in weight (g) during finisher phase

Fig. 4.4 FCR during finisher phase

4.2.3 Growth performance of broiler birds for overall period (0 to 42nd day)

Results for initial body weight, final body weight, gain in weight, feed intake, feed conversion ratio, feed intake per day, gain in weight per day and mortality per cent for positive control T_0, negative control T_1 and supplemented treatments with garlic powder T_2, cinnamon extract T_3 and cinnamon extract + garlic powder T_4 for the overall period (0 to 42 days) has been presented in Table 4.6

Perusal of results revealed that the gain in live body weight of broiler birds at the end of the overall period was T_0 (2030.97) g, T_1 (1750.30) g, T_2 (1869.10) g, T_3 (1939.41) g and T_4 (1884.69) g, respectively which was significantly ($P<0.05$) high in positive control T_0 compared to negative control T_1. The difference for gain in live body weight among various phyto additive supplemented treatments offered low density energy feed did not exhibit any significant difference amongst each other and compared to negative control T_1 but the cinnamon extract supplemented treatment T_3 exhibited highest gain in weight compared to negative control T_1 and low energy treatments T_2 and T_4. Gain in live weight per day in positive control T_0 was recorded to be (48.36) g, in negative control T_1 was (41.67) g and in treatment T_2, T_3 and T_4 was (44.50) g, (46.18) g and (44.87) g, respectively. Perusal of the results revealed significant difference ($P<0.05$) amongst positive control T_0, negative control T_1 and the phyto-additive supplemented (garlic powder and cinnamon extract) treatments T_2, T_3 and T_4 for gain in weight per day. Significantly ($P<0.05$) highest value for gain in live body weight per day was recorded in positive control T_0 (48.36) g compared to negative control T_1 (41.67) g. Karim et al. (2017) reported that garlic powder supplementation at the rate of 0.25%, 0.50% and 0.75% had no significant effect on weight gain in broilers. Issa and Omar (2012) reported that supplementation of garlic powder (at the rate of 0.2% and 0.4%) had no significant effect on the weight gain of broilers as compared to the control group. Milosevic et al. (2013) supplemented the diet of broiler chicks with 1.5% and 3% garlic powder and found that there was no significant difference in body weight of supplemented groups when compared to control group. Karim et al. (2017) reported that garlic powder supplemented at the rate of 0.25%, 0.50% and 0.75% in the diet had no significant effect on body weight and body weight gain in broilers. Sampath and Atapattu (2013) reported that supplementation of cinnamon powder at the rate of 0.1%, 0.2%, 0.3%, 0.4% and 0.5% had no significant effect on weight gain in broilers. Khafaji (2018) also reported that cinnamon powder supplementation (500 and 1000 mg/kg) had no significant effect on broiler weight gain. Barreto et al. (2008) reported that broiler diet supplemented with 1000 ppm cinnamon extract had no effect on live weight of broiler chicks between 1-21 days and 1-42 days.

The quoted research reports were based on addition of phyto additives in standard diet whereas in the present study, dietary energy was lowered in treatment groups, despite that, the birds could match the growth performance of the positive control group T_0 and better than negative control group T_1, indicating better nutrient utilization thus eliciting its beneficial effects on growth. Effect of low energy density feed offered to negative control

group T_1 was clearly visible in the significantly ($P<0.05$) lowered live weight gain whereas the results for gain in live weight were more pronounced in cinnamon extract supplemented treatment T_3. Many of the research works have quoted that cinnamaldehyde increases the activity of intestinal and pancreatic enzymes by provoking the secretion of salivary glands which improves the digestion in broiler chickens such as Chowdhury et al. (2018). Similarly increased growth performance in broiler due to garlic powder supplementation is due to allicin, which promotes the performance of intestinal flora, thereby improving digestion and utilization of nutrient by increasing villi length and width leading to improved growth performance, Lewis et al. (2003). Feed intake of broiler birds during the overall phase in positive control T_0 was (3649.27) g, negative control T_1 (3759.39) g, and treatment groups T_2 (2606.03) g, T_3 (3665.04) g and T_4 (3607.13) g, respectively. No significant ($P>0.05$) difference was recorded amongst positive control T_0, negative control T_1 and the phyto-additive supplemented treatments T_2, T_3 and T_4 for feed intake. Numerically the highest feed intake was recorded in negative control T_1 (3759.39) g and the lowest feed intake was recorded in garlic powder supplemented treatment T_2 (2606.03) g. Feed intake (FI) per day in positive control T_0 was recorded to be (86.89) g, in negative control T_1 was (89.51) g and in treatment T_2, T_3 and T_4 was (85.86) g, (87.26) g and (85.88) g, respectively. Perusal of the results revealed no significant difference ($P>0.05$) amongst positive control T_0, negative control T_1 and the phyto-additive supplemented (garlic powder and cinnamon extract) treatments T_2, T_3 and T_4 for feed intake per day. Numerically highest FI per day was recorded in negative control T_1 (89.51) g and lowest feed intake was recorded in garlic powder supplemented treatment T_2 (85.86) g. Issa and Omar (2012) reported that supplementation of garlic powder (at the rate of 0.2% and 0.4%) had no significant effect on feed intake of broilers as compared to the control group. Kumar et al. (2016) also reported that supplementation of garlic powder (0.5 and 1%) had no significant effect on feed intake in broilers. Toghyani et al. (2011) reported that supplementation of cinnamon powder (2 and 4 g/kg), garlic powder (2 and 4 g/kg) and their combination in broilers has no effect on feed intake. Chowdhury et al. (2018) concluded that cinnamon oil supplementation in broiler chicks has no effect on feed intake. Barreto et al. (2008) reported that broiler diet supplemented with 1000 ppm cinnamon extract had no effect on feed intake in broiler chicks between 1-21 days and 1-42 days. Higher feed intake in negative control T_1 was in response to lower energy density and the feed intake was increased to compensate for the energy requirements whereas treatment diets T_2, T_3 and T_4 did not exhibit any such response as is evident by feed intake comparable

to positive control T_0. Feed to live weight gain ratio (FCR) of broiler birds at the end of the overall phase in positive control T_0 was (1.80), negative control T_1 (2.15), and treatment group T_2 (1.93), T_3 (1.89) and T_4 (1.92), respectively which was significantly ($P<0.05$) low in positive control T_0 and phyto additive supplemented treatments (T_2, T_3 and T_4) compared to negative control T_1. The difference for FCR among various phyto additive supplemented treatments offered low density energy feed did not exhibit any significant difference amongst each other and compared to positive control T_0. Significantly ($P<0.05$) higher FCR in negative control group T_1 compared to treatment T_2, T_3 and T_4 can be attributed to higher feed intake and lowered weight gain. Results of the experiment for FCR demonstrated the ability of the phyto additive viz. garlic powder and cinnamon extract to support tissue gain through better utilization of the nutrients. Comparatively birds offered cinnamon extract (T_3) demonstrated better ability for FCR and tissue gain compared to garlic powder (T_2) and combination of garlic powder and cinnamon extract (T_4). Kansal et al. (2017) conducted an experiment to investigate the effect of dietary supplementation of garlic (0.25%, 0.50% and 0.75%) on the performance of broiler chicken. Improved FCR was observed with garlic supplementation. Eid and Iraqi (2014) conducted a study to investigate the effect of garlic powder on performance of broilers and concluded that garlic supplementation increased feed conversation rate (FCR). Zekic et al. (2014) conducted a study to examine the effect of 2% of garlic powder addition in the broiler chicken diet on broilers chicken production and reported better feed conversion ratio in garlic supplemented group. Al-Massad et al. (2018) conducted a study to evaluate the beneficial effects of garlic powder (2.5 Kg/ton, 5 Kg/ton and 7.5 Kg/ton) as a phytogenic supplement on broilers chicken performance and concluded that the garlic powder supplementation improved feed conversion ratio compared with control group birds. Sampath and Atapattu (2013) conducted a study to determine the effects of dietary cinnamon bark powder (0%, 0.1%, 0.2%, 0.3%, 0.4% and 0.5%) on growth performance of broiler chicken and concluded that dietary cinnamon bark powder tends ($p=0.09$) to increase the feed conversion ratio (FCR). Chowdhury et al. (2018) also concluded that cinnamon oil supplementation in broiler chicks significantly lowered the feed conversion ratio (FCR). The recorded mortality per cent in T_0, T_1, T_2, T_3 and T_4 was 0.00, 2.56, 0.00, 2.56 and 0.00 respectively and was well within the normal managemental accepted norms.

Table 4.6 Growth performance of broiler birds for overall period (0 to 42nd day)

Particulars	IBW	FBW	GIW	FI	FCR	GIW/day	FI/day	Mortality
T0	58.56±0.86	2089.52±16.91	2030.97±16.69^{b}	3649.27±6.00	1.80±0.02^{a}	48.36±0.40^{b}	86.89±0.14	NIL
T1	56.56±1.96	1806.86±36.51	1750.30±34.98^{a}	3759.39±86.31	2.15±0.05^{b}	41.67±0.83^{a}	89.51±2.06	2.56
T2	54.56±0.45	1923.67±20.54	1869.10±20.40^{ab}	3606.03±58.98	1.93±0.04^{a}	44.50±0.49^{ab}	85.86±1.40	NIL
T3	53.22±0.75	1992.63±78.05	1939.41±77.76^{ab}	3665.04±57.66	1.89±0.05^{a}	46.18±1.85^{ab}	87.26±1.37	2.56
T4	52.97±2.33	1937.67±39.54	1884.69±41.40^{ab}	3607.13±33.16	1.92±0.03^{a}	44.87±0.99^{ab}	85.88±0.79	NIL
PSE	0.38	15.51	19.68	24.81	0.02	0.94	0.59	
p-Value	<0.0001	<0.0001	0.014	0.343	0.001	0.014	0.343	

Average means with different superscripts are significantly (P<0.05) different from each other

IBW: initial body weight; FBW: final body weight; GIW: gain in weight; FI: feed intake; FCR: feed conversion ratio.

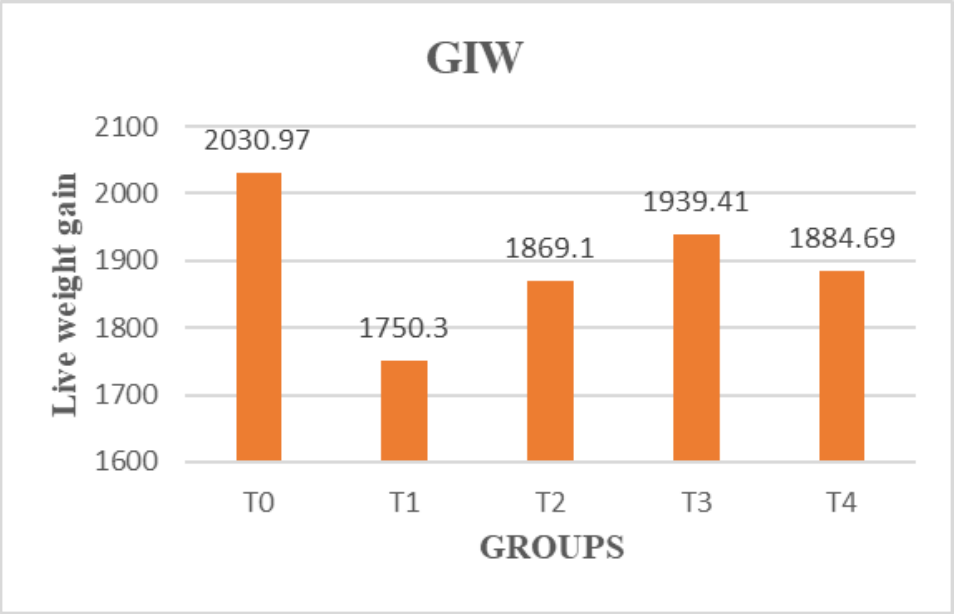


Fig. 4.5 Gain in live weight (g) during overall phase

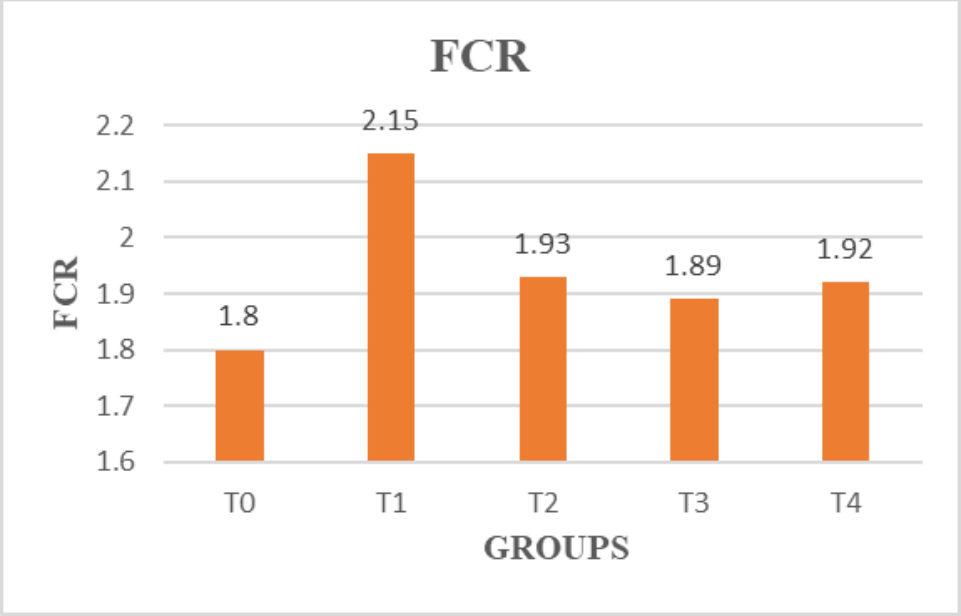


Fig. 4.6 FCR during overall phase

4.3 Digestibility coefficient of different nutrients during metabolism studies and microbial count of caeca

A metabolic trial was conducted on the 35thday of the experiment for five days. Results for digestibility coefficient of dry matter, crude protein, crude fibre, and ether extract for positive control T_0, negative control T_1 and supplemented

treatments with garlic powder T_2, cinnamon extract T_3 and cinnamon extract + garlic powder T_4 has been presented in Table 4.7.

Digestibility coefficient (per cent) for dry matter estimated in positive control T_0 (69.27), negative control T_1 (71.11), and treatment T_2 (61.77), T_3 (62.12) and T_4 (65.61), is presented in Table 4.7. Dry matter digestibility was lowest in treatment T_2 (61.77) and highest in positive control T_0 (69.27) but the results exhibited no significant ($P>0.05$) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4 for dry matter digestibility. Digestibility coefficient (per cent) for crude protein estimated in positive control T_0 (78.93), negative control T_1 (78.57), and treatments T_2 (79.30), T_3 (90.21) and T_4 (80.99), is presented in Table 4.7. Highest nitrogen retention was recorded in cinnamon supplemented treatment T_3 (90.21) and lowest in negative control T_1 (78.57). Statistical analysis of the results exhibited no significant ($P>0.05$) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4 for crude protein digestibility, though numerically, cinnamon extract supplemented treatment T_3 exhibited 12.90 and 12.50 per cent higher nitrogen retention compared to control group T_1 and T_0. The results are not without precedence. Mountzouris et al. (2011) also reported that inclusion of cinnamon in broiler diet improves protein digestion via increasing secretion of hydrochloric acid and pepsin in the gut. Digestibility coefficient (percent) for crude fibre estimated in positive control T_0 (17.60), negative control T_1 (24.49), and treatment T_2 (20.88), T_3 (16.71) and T_4 (24.59), is presented in Table 4.7. Statistical analysis of the results exhibited no significant ($P>0.05$) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4 for crude fibre digestibility, though numerically, negative control T_1 and treatment T_4 exhibited higher crude fibre digestibility. Digestibility coefficient (percent) for ether extract estimated in positive control T_0 (85.39), negative control T_1 (92.55), and treatment T_2 (86.76), T_3 (84.70) and T_4 (89.14), is presented in Table 4.7. Experimental birds offered low energy feed of negative control group (T_1) exhibited highest digestibility of ether extract as exhibited by significantly ($P<0.05$) high value of 92.55 percent compared to other treatments. Digestibility studies based on total faecal collection method exhibited significantly highest ether extract digestibility in negative control T_1, whereas crude protein digestibility was numerically highest in treatment group T_3 and T_4. Similarly, dry matter and crude fibre digestibility did not exhibit any significant difference but was numerically higher in negative control T_1.

Results were contrary to that reported by Sampath and Atapattu (2013) who concluded that supplementation of cinnamon powder (0.1, 0.2, 0.3, 0.4 and 0.5%) had no significant positive effect on nutrient digestion. Conclusion was drawn on the basis of experimental model with standard feed supplemented with cinnamon powder. Further, Issa and Omar (2012) concluded that supplementation of garlic (0.2 and 0.4%) has significantly positive effect on apparent digestibility of nutrients. Whereas the experiment design in our study created nutritional stress by offering low energy diets and to further alleviate the stress, cinnamon and garlic powder alone and in combination was added. Higher digestibility of crude fibre and ether extract and nutrient utilization in negative control T_1 revealed the compensatory mechanism of digestive system to extract maximum nutrients when offered low energy density feed. Weight of inedible offal was numerically high in negative control T_1 (Table 4.13), similarly weight of liver was also significantly ($P<0.05$) high in negative control T_1 (Table 4.12) compared to positive control T_0. To adapt to low energy changes, secretion activity of the intestine may increase, which, in turn may lead to increase in weight and size of gastrointestinal tract, liver and pancreas. Increased size of the gastrointestinal tract could be adaptive response to an increased need for enzymes (Brenes et al. 1993). Similar pattern was recorded in treatment T_2 and T_4 but the digestibility co-efficient in positive control T_0 and cinnamon supplemented treatment T_3 revealed lesser stress on digestive system for energy extraction. Further, higher nitrogen retention in cinnamon supplemented treatment T_3 was recorded.

Table 4.7 Digestibility coefficient of different nutrients and microbial count of caeca

Particulars	DM	CP	CF	EE	SPC (Cfu/gm) $\times 10^9$
T_0	69.27±1.11	78.93±2.95	17.60±2.34	85.39 ± 0.54^{ab}	6.34±5.20
T_1	71.11±3.83	78.57±4.80	24.49±11.44	92.55 ± 0.83^{c}	5.50±2.51
T_2	61.77±2.93	79.30±2.24	20.88±2.63	86.76 ± 1.32^{ab}	4.77±0.79
T_3	62.12±1.08	90.21±2.56	16.71±1.90	84.70 ± 0.34^{a}	5.12±0.43
T_4	65.61±1.77	80.99±3.50	24.59±5.51	89.14 ± 0.72^{bc}	4.13±0.91
PSE	1.07	1.39	2.66	0.37	
p-Value	0.070	0.110	0.813	<0.0001	

Average means with different subscripts are significantly (P<0.05) different from each other

4.3.1 Effect on total microbial count in caecal content of broiler chicks

Results for count of microbial cells in caeca at the end of the trial in positive control T_0, negative control T_1 and supplemented treatments with garlic powder T_2, cinnamon extract T_3 and cinnamon extract + garlic powder T_4 has been presented in Table 4.7. Total microbial count in caeca contents (cfu/g$\times 10^9$) in positive control T_0 was (6.34), negative control T_1 (5.50), and treatment T_2 (4.77), T_3 (5.12) and T_4 (4.13), respectively. Results exhibited no significant ($P>0.05$) difference amongst positive control T_0, negative control T_1 and the phyto-additive supplemented treatments T_2, T_3 and T_4. Although there was no significant difference in total microbial count, but phyto additive viz. garlic and cinnamon supplementation in treatment T_2, T_3 and T_4 led to numerical decrease in total microbial count in comparison to control T_0 and T_1. Results obtained are similar to those reported by Peinado et al. (2013) that supplementation of garlic derivative PTS-O (propyl propane thiosulfonate) decreases the cecal content of *E. coli* and bacteriodes and help in modulating intestinal microbiota. Rashid et al. (2020) in their study concluded that dietary cinnamon reduced the pathogenic bacteria in the ileum and cecum of poultry and have anti-bacterial properties. Although in our study we did not find any significant effect on total microbial count but the results were similar as reported in above studies.

4.4 Blood analysis

4.4.1 Evaluation of Complete Blood Count (CBC)

Results for CBC at the end of the trial in positive control T_0, negative control T_1 and supplemented treatments with garlic powder T_2, cinnamon extract T_3 and cinnamon extract + garlic powder T_4 has been presented in Table 4.8.

Recorded value of haemoglobin (g/dL) in positive control T_0 (12.88±0.28), negative control T_1 (11.00±0.60), and treatments T_2 (11.83±0.34), T_3 (11.83±0.28) and T_4 (11.82±0.26), is presented in Table 4.8. Lowest value of haemoglobin content was recorded in negative control T_1 compared to treatment diets and was significantly ($P<0.05$) low compared to positive control T_0. Recorded value of WBC'S ($\times 10^9$/L) in positive control T_0 (236.36±2.17), negative control T_1 (211.45±10.60), and treatment T_2 (225.74±2.70), T_3 (218.20±4.77) and T_4 (224.22±3.21), is presented in Table 4.8. Lowest value of WBC count was recorded in negative control T_1 compared to treatment diets and was significantly ($P<0.05$) low compared to positive control. Recorded value of RBC's

($\times 10^{12}$/L) in positive control T_0 (3.24±0.07), negative control T_1 (2.75±0.15), and treatment T_2 (2.94±0.08), T_3 (2.89±0.08) and T_4 (2.93±0.08), is presented in Table 4.8. Lowest value of RBC count was recorded in negative control T_1 compared to treatment diets and was significantly ($P<0.05$) low compared to positive control.

Recorded value of PCV (%) in positive control T_0 (38.79±0.88), negative control T_1 (33.35±1.81), and treatment T_2 (36.34±1.07), T_3 (35.76±0.83) and T_4 (35.76±0.76), is presented in Table 4.8. Lowest value of PCV count was recorded in negative control T_1 compared to treatment diets and was significantly ($P<0.05$) low compared to positive control T_0. Recorded value of MCV (fL) in positive control T_0 (119.69±0.62), negative control T_1 (122.00±1.31), and treatment T_2 (123.53±0.94), T_3 (123.94±1.22) and T_4 (122.45±1.68), is presented in Table 4.8. Results exhibited no significant ($P>0.05$) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4. Recorded value of MCH (pg) in positive control T_0 (39.69±0.22), negative control T_1 (39.98±0.38), and treatment T_2 (40.11±0.45), T_3 (40.83±0.30) and T_4 (40.35±0.64), is presented in Table 4.8. Results exhibited no significant ($P>0.05$) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4. Recorded value of MCHC (g/dL) in positive control T_0 (33.17±0.14), negative control T_1 (32.86±0.45), and treatment T_2 (32.53±0.53), T_3 (33.04±0.21) and T_4 (33.01±0.16), is presented in Table 4.8. Results exhibited no significant ($P>0.05$) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4.

Table 4.8 Complete Blood Count (CBC)

Particulars	WBC ($\times 10^9$/L)	RBC ($\times 10^{12}$/L)	HGB (g/dL)	PCV (%)	MCV (FL)	MCH (pg)	MCHC (g/dL)
T_0	236.36±2.17^{b}	3.24±0.07^{b}	12.88±0.28^{b}	38.79±0.88^{b}	119.69±0.62	39.69±0.22	33.17±0.14
T_1	211.45±10.60^{a}	2.75±0.15^{a}	11.00±0.60^{a}	33.35±1.81^{a}	122.00±1.31	39.98±0.38	32.86±0.45
T_2	225.74±2.70^{ab}	2.94±0.08^{ab}	11.83±0.34^{ab}	36.34±1.07^{ab}	123.53±0.94	40.11±0.45	32.53±0.53
T_3	218.20±4.77^{ab}	2.89±0.08^{ab}	11.83±0.28^{ab}	35.76±0.83^{ab}	123.94±1.22	40.83±0.30	33.04±0.21
T_4	224.22±3.21^{ab}	2.93±0.08^{ab}	11.82±0.26^{ab}	35.76±0.76^{ab}	122.45±1.68	40.35±0.64	33.01±0.16
PSE	2.54	0.04	0.17	0.51	0.53	0.18	0.15
p-Value	0.040	0.015	0.021	0.030	0.108	0.346	0.720

Average means with different sub scripts in a column are significantly (P<0.05) different from each other

Haematological parameters namely WBC, RBC, Hb and PCV were significantly ($P<0.05$) higher in positive control T_0 and lowest in negative control T_1, whereas treatment groups with phyto-additive supplementation viz. garlic powder, cinnamon extract, garlic powder + cinnamon extract, T_2, T_3 and T_4 recorded numerically higher values in comparison to negative control T_1. Obtained results were contrary to the results of Eid and Iraqi (2014), Kansal et al. (2017) and Onunkwo et al. (2019) who reported significant increase in value of WBC, RBC, Hb and PCV with the supplementation of garlic in the diet. These results were based on the supplementation of garlic with standard feed whereas, our experimental design was based on garlic and cinnamon supplementation with low energy density feed. Further, supplementation in T_2, T_3 and T_4 led to numerical increase in WBC, RBC, Hb and PCV compared to negative control T_1. Ismail et al. (2021) reported no significant alteration in PCV and WBC with supplementation of garlic powder (0.25, 0.50 and 0.75 g/kg diet) in broiler chickens. Toghyani et al. (2011) reported that supplementation with cinnamon powder and garlic powder in broiler chicks had no significant influence on WBC. Khafaji (2018) who also reported no significant increase in value of WBC, RBC, Hb and PCV with the supplementation of cinnamon. There was no significant difference in values of MCV, MCH and MCHC among various treatments and they were within normal range. The results agreed with those of Toghyani et al. (2011) who reported that supplementation with cinnamon powder and garlic powder in broiler chicks had no significant influence on MCV, MCH and MCHC.

4.4.2 Estimation of blood biochemical parameters

Results for blood biochemical parameters at the end of the trial in positive control T_0, negative control T_1 and supplemented treatments with garlic powder T_2, cinnamon extract T_3 and cinnamon extract + garlic powder T_4 has been presented in Table 4.9.

Table 4.9 Blood Biochemical Parameters

Particulars	Plasma Protein profile			Plasma enzyme profile		Plasma		Plasma lipid profile			
	Total Protein (g/dL)	Albumin (g/dL)	Globulin (g/dL)	ALT (U/L)	AST (U/L)	Creatinine (mg/dL)	Uric acid (mg/dL)	Total cholesterol (mg/dL)	HDL cholesterol (mg/dL)	LDL cholesterol (mg/dL)	Triglyceride(mg/dL)
T_0	3.22±0.11	1.75±0.04	1.47±0.11	3.82±0.20	191.74±18.55	0.32±0.01	7.58±0.68^{c}	132.91±7.54^{ab}	47.14±4.90	53.15±3.41	117.28±9.24
T_1	3.34±0.12	1.77±0.04	1.58±0.13	4.11±0.23	209.71±10.98	0.31±0.01	5.82±0.48^{b}	109.58±3.90^{a}	46.93±2.67	46.13±4.07	144.87±11.95
T_2	3.26±0.10	1.70±0.05	1.55±0.10	3.36±0.36	254.92±18.86	0.34±0.01	5.36±0.58^{ab}	125.54±4.06^{ab}	57.01±4.01	50.16±3.94	121.28±6.66
T_3	3.41±0.19	1.59±0.06	1.83±0.15	3.12±0.34	227.88±18.85	0.32±0.02	4.21±0.48^{ab}	131.53±7.67^{ab}	53.26±3.88	42.96±3.19	129.34±10.36
T_4	3.01±0.13	1.63±0.07	1.38±0.13	3.71±0.16	233.78±13.05	0.28±0.01	3.71±0.23^{a}	140.89±8.25^{b}	44.69±4.05	47.01±4.07	140.60±10.25
PSE	0.06	0.02	0.06	0.12	7.34	0.01	0.23	2.94	1.79	1.68	4.40
p-Value	0.291	0.087	0.156	0.101	0.093	0.028	<0.0001	0.020	0.174	0.374	0.224

Average means with different sub scripts in a column are significantly (P<0.05) different from each other

Recorded value of total protein (g/dL) in positive control T_0 (3.22±0.1), negative control T_1 (3.34±0.12), and treatment T_2 (3.26±0.10), T_3 (3.41±0.19) and T_4 (3.01±0.13), respectively are presented in Table 4.9. Results exhibited no significant (P>0.05) difference amongst positive control T_0, negative control T_1 and the phyto-additive supplemented treatments T_2, T_3 and T_4. Total protein (g/dL) in blood was within the normal physiological range. Recorded value of albumin (g/dL) in positive control T_0 (1.75±0.04), negative control T_1 (1.77±0.04), and treatment T_2 (1.70±0.05), T_3 (1.59±0.06) and T_4 (1.63±0.07) respectively are presented in table 4.9. Results exhibited no significant (P>0.05) difference amongst positive control T_0, negative control T_1 and the phyto-additive supplemented treatments T_2, T_3 and T_4. Recorded value of globulin (g/dL) in positive control T_0 (1.47±0.11), negative control T_1 (1.58±0.13), and treatment T_2 (1.55±0.10), T_3 (1.83±0.15) and T_4 (1.38±0.13), is presented in Table 4.9. Results exhibited no significant (P>0.05) difference amongst positive control T_0, negative control T_1 and the phyto-additive supplemented treatments T_2, T_3 and T_4. Recorded value of ALT (U/L) in positive control T_0 (3.82±0.20), negative control T_1 (4.11±0.23), and treatment T_2 (3.36±0.36), T_3 (3.12±0.34) and T_4 (3.71±0.16), is presented in Table 4.9. Results exhibited no significant (P>0.05) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4. Recorded value of AST (U/L) in positive control T_0 (191.74±18.55), negative control T_1 (209.71±10.98), and treatment T_2 (254.92±18.86), T_3 (227.88±18.85) and T_4 (233.78±13.05), is presented in Table 4.9. Results exhibited no significant (P>0.05) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4. Recorded value of creatinine (mg/dL) in positive control T_0 (0.32±0.01), negative control T_1 (0.31±0.01), and treatment T_2 (0.34±0.01), T_3 (0.32±0.02) and T_4 (0.28±0.01), is presented in Table 4.9. Results exhibited no significant (P>0.05) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4. Recorded value of uric acid (mg/dL) in positive control T_0 (7.58±0.68), negative control T_1 (5.82±0.48), and treatment T_2 (5.36±0.58), T_3 (4.21±0.48) and T_4 (3.71±0.23), is presented in Table 4.9. Results exhibited significant (P<0.05) difference. Positive control T_0 had significantly (P<0.05) highest value whereas cinnamon supplemented T_4 had significantly (P<0.05) lowest value. Recorded value of total cholesterol (mg/dL) in positive control T_0 (132.91±7.54), negative control T_1 (109.58±3.90), and treatment T_2 (125.54±4.06), T_3 (131.53±7.67) and T_4 (140.89±8.25), is presented in Table 4.9. Results exhibited significant (P<0.05) lowest

cholesterol level in negative control T_1. It may be due to low energy feed given to T_1. Recorded value of HDL cholesterol (mg/dL) in positive control T_0 (47.14±4.90), negative control T_1 (46.93±2.67), and treatment T_2 (57.01±4.01), T_3 (53.26±3.88) and T_4 (44.69±4.05), is presented in Table 4.9. Results exhibited no significant ($P>0.05$) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4. Recorded value of LDL cholesterol (mg/dL) in positive control T_0 (53.15±3.41), negative control T_1 (46.13±4.07), and treatment T_2 (50.16±3.94), T_3 (42.96±3.19) and T_4 (47.01±4.07), is presented in Table 4.9. Results exhibited no significant ($P>0.05$) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4. Recorded value of triglyceride (mg/dL) in positive control T_0 (117.28±9.24), negative control T_1 (144.87±11.95), and treatment T_2 (121.28±6.66), T_3 (129.34±10.36) and T_4 (140.60±10.25), is presented in Table 4.0. Results exhibited no significant ($P>0.05$) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4.

Results for the blood biochemical parameters namely total protein, albumin, globulin, ALT, AST, creatinine, uric acid, total cholesterol, HDL and LDL cholesterol and triglycerides in treatment diets T_2, T_3 and T_4 offered low energy diets supplemented with garlic powder, cinnamon extract, garlic powder + cinnamon extract, were within normal range and exhibited non-significant difference. These results agreed with those of Toghyani et al. (2011) who reported that supplementation with cinnamon powder and garlic powder in broiler chicks had no significant influence on total protein, albumin, total cholesterol, triglyceride, and ALT values. Ismail et al. (2021) who reported that garlic powder supplementation has no significant effect on albumin, triglyceride, and ALT values. Onunkwo et al. (2019) reported that inclusion of garlic powder (0.5%, 1% and 1.5%) in broiler feed had no significant effect ($P>0.05$) on the creatinine level. Koochaksaraie et al. (2011) who reported that cinnamon powder supplementation has no significant effect on blood cholesterol, ALT and AST levels. Sampath and Atapattu (2013) concluded that dietary cinnamon bark powder supplementation (0%, 0.1%, 0.2%, 0.3%, 0.4% and 0.5%) in broiler chicken had no effect on serum cholesterol levels. Shirzadegan (2014) reported that the addiction of cinnamon powder (0.25%, 0.50%, 0.75% and 1.0%) to the diets of broiler chicks had no significant effects ($P>0.05$) on cholesterol, triglyceride, and low-density lipoproteins (LDL) levels. Khafaji (2018) also reported no significant effect on serum albumin concentration with the supplementation of cinnamon powder in broiler chicks. Results obtained were contrary to those of Issa and

Omar (2012) who reported significant variation in cholesterol, triglyceride, LDL and HDL values with supplementation of garlic powder in broiler diet. Al-Massad et al., (2018) who reported that garlic powder (2.5 Kg/ton, 5 Kg/ton and 7.5 Kg/ton) supplementation in broiler diet reduced the blood cholesterol, Albumin, Triglyceride, and HDL levels as compared to the standard levels. Onunkwo et al. (2019) who reported that inclusion of garlic powder (0.5%, 1% and 1.5%) in broiler feed significantly ($P<0.05$) decreased serum cholesterol levels. Byung-Sung (2008) who concluded that supplementation with cinnamon powder causes signification variation in triglycerides, HDL, LDL, and total cholesterol values. Khafaji (2018) concluded that the cinnamon powder supplementation (500 mg/kg and 1000 mg/kg) in the broiler diet significantly increased ($P<0.05$) total protein and globulin concentration. Total cholesterol was not significantly affected by phyto-additive supplementation in treatment T_2, T_3 and T_4 and was at par with positive control T_0 but higher then negative control T_1.

4.4.3 Blood mineral contents

Results for blood mineral contents at the end of the trial in positive control T_0, negative control T_1 and supplemented treatments with garlic powder T_2, cinnamon extract T_3 and cinnamon extract + garlic powder T_4 has been presented in Table 4.10.

Table 4.10 Blood Mineral profile

Particulars	Calcium (mg/dL)	Phosphorus (mg/dL)
T_0	11.03 ± 0.58^{ab}	5.45 ± 0.22^{ab}
T_1	12.29 ± 0.57^{b}	5.81 ± 0.17^{b}
T_2	11.01 ± 0.52^{ab}	5.45 ± 0.19^{ab}
T_3	10.08 ± 0.50^{a}	4.72 ± 0.21^{a}
T_4	9.31 ± 0.41^{a}	5.22 ± 0.27^{ab}
PSE	0.23	0.10
p-Value	0.004	0.015

Average means with different sub scripts in a column are significantly ($P<0.05$) different from each other

Recorded value of serum calcium (mg/dL) in positive control T_0 (11.03±0.58), negative control T_1 (12.29±0.57), and treatment T_2 (11.01±0.52), T_3 (10.08±0.50) and T_4 (9.31±0.41), is presented in Table 4.10. Results exhibited

significantly (P<0.05) highest value of calcium in negative control T_1 and significantly (P<0.05) lowest values in supplemented treatments T_3 and T_4. In the study serum calcium ranged from 9.31 to 12.29 mg/dL which was within normal range of 8.00 to 13.00 mg/dL (Sakas 2002). Recorded value of plasma phosphorus (mg/dL) in positive control T_0 (5.45±0.22), negative control T_1 (5.81±0.17), and treatment T_2 (5.45±0.19), T_3 (4.72±0.21) and T_4 (5.22±0.27), is presented in Table 4.10. Results recorded were similar to that of calcium. Results exhibited significantly (P<0.05) highest value of phosphorus in negative control T_1 and significantly (P<0.05) lowest values in supplemented treatment T_3.

4.5 Tibial bone analysis

4.5.1 Physical parameters of tibial bone

Results for physical parameters of tibial bone at the end of the trial in positive control T_0, negative control T_1 and supplemented treatments with garlic powder T_2, cinnamon extract T_3 and cinnamon extract + garlic powder T_4 has been presented in Table 4.11.

Table 4.11 Physical parameters and Mineral Content of Tibial bone

Particulars	Physical parameters		Total ash (%)	Calcium (%)	Phosphorus (%)
	Bone length (cm)	Bone diameter (cm)			
T_0	9.57±0.06^{a}	0.84±0.02	50.31±0.45^{b}	1.39±0.24^{a}	1.86±0.10^{ab}
T_1	9.66±0.10^{ab}	0.89±0.03	48.27±0.43^{ab}	1.24±0.25^{a}	1.10±0.21^{a}
T_2	9.67±0.05^{ab}	0.90±0.02	48.72±0.41^{ab}	1.09±0.27^{a}	2.48±0.33^{b}
T_3	9.84±0.09^{ab}	0.91±0.03	46.46±0.65^{a}	2.74±0.47^{b}	2.50±0.25^{b}
T_4	9.90±0.08^{b}	0.94±0.04	49.10±0.81^{b}	4.13±0.16^{c}	3.79±0.14^{c}
PSE	0.04	0.01	0.26	0.13	0.10
p-Value	0.025	0.145	0.001	<0.0001	<0.0001

Average means with different sub scripts in a column are significantly (P<0.05) different from each other

Recorded value of bone length (cm) in positive control T_0 (9.57±0.06), negative control T_1 (9.66±0.10), and treatment T_2 (9.67±0.05), T_3 (9.84±0.09) and T_4 (9.90±0.08), is presented in Table 4.11. Perusal of the results revealed significant (P<0.05) difference between positive control T_0 and T_4. Bone length numerically increased in all phyto-additive

supplemented treatment groups T_2, T_3 and T_4. Recorded value of tibial bone diameter (cm) in positive control T_0 (0.84±0.02), negative control T_1 (0.89±0.03), and treatment T_2 (0.90±0.02), T_3 (0.91±0.03) and T_4 (0.94±0.04), is presented in Table 4.11. Results exhibited no significant ($P>0.05$) difference between positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4

4.5.2 Tibial bone mineral deposition

Results for tibial bone mineral deposition at the end of the trial in positive control T_0, negative control T_1 and supplemented treatments with garlic powder T_2, cinnamon extract T_3 and cinnamon extract + garlic powder T_4 has been presented in Table 4.11. The recorded value of total ash (%) in positive control T_0 (50.31±0.45), negative control T_1 (48.27±0.43), and treatment T_2 (48.72±0.41), T_3 (46.46±0.65) and T_4 (49.10±0.81), is presented in Table 4.11. Results revealed significantly ($P<0.05$) higher ash per cent in positive control T_0 Recorded value of calcium (%) of tibial bone in positive control T_0 (1.39±0.24), negative control T_1 (1.24±0.25), and treatment T_2 (1.09±0.27), T_3 (2.74±0.47) and T_4 (4.13±0.16), is presented in Table: 4.11. Results obtained revealed significantly ($P<0.05$) higher calcium content in tibial bone in treatment T_3 and T_4 compared to positive control T_0, negative control T_1 and treatment T_2. Recorded value of phosphorus (%) in positive control T_0 (1.86±0.10), negative control T_1 (1.10±0.21), and treatment T_2 (2.48±0.33), T_3 (2.50±0.25) and T_4 (3.79±0.14), is presented in Table 4.11. Results obtained revealed significantly ($P<0.05$) higher phosphorus content in tibial bone in phyto additive supplemented treatment T_2, T_3 and T_4 compared to control T_0 and T_1. Tibial bone is the storage organ for macro minerals Ca and P and there is a constant interaction and movement between bones, tissue and blood for various metabolic and structural functions. Supplementation of phyto-additive viz. garlic and cinnamon seem to influence the storage of these macro minerals.

4.6 Carcass characteristics and weight of important by products of broiler chicken supplemented with garlic powder and cinnamon extract

4.6.1 Carcass characteristics and weight (% of live weight) of important edible by products

Results for carcass characteristics and weight (% of live weight) of important edible by products at the end of the trial in positive control T_0, negative control

T_1 and supplemented treatments with garlic powder T_2, cinnamon extract T_3 and cinnamon extract + garlic powder T_4 has been presented in Table 4.12.

Table 4.12 Carcass characteristics and weight (% of live weight) of important edible by products

Particulars	Dressing percent (%)	Blood (%)	Giblet		
			Heart (%)	Liver (%)	Gizzard (%)
T_0	62.81±0.52^{a}	3.81±0.17	0.49±0.02	1.87±0.10^{ab}	1.81±0.04
T_1	61.88±0.71^{a}	3.97±0.15	0.47±0.01	2.35±0.06^{cd}	1.76±0.06
T_2	62.85±0.56^{ab}	3.79±0.16	0.46±0.02	2.48±0.07^{d}	1.68±0.05
T_3	66.24±1.10^{b}	3.50±0.16	0.49±0.03	2.15±0.10^{bc}	1.76±0.09
T_4	65.43±0.62^{b}	4.01±0.19	0.47±0.01	1.75±0.03^{a}	1.79±0.06
PSE	0.33	0.07	0.01	0.03	0.03
p- Value	<0.0001	0.237	0.742	<0.0001	0.624

Average means with different sub scripts in a column are significantly (P<0.05) different from each other

Broiler chicken dressing percent in positive control T_0 (62.81±0.52), negative control T_1 (61.88±0.71), and treatment T_2 (62.85±0.56), T_3 (66.24±1.10) and T_4 (65.43±0.62), is presented in Table 4.12. Perusal of the results revealed that dressing per cent was significantly (P<0.05) higher in the supplemented treatments T_3 and T_4 with highest value obtained in treatment T_3 (66.24%), supplemented with cinnamon extract and lowest in negative control T_1 (61.88%). Broiler chicken blood weight (% of live weight) in positive control T_0 (3.81±0.17), negative control T_1 (3.97±0.15), and treatment T_2 (3.79±0.16), T_3 (3.50±0.16) and T_4 (4.01±0.19), is presented in Table 4.12. Results exhibited no significant (P>0.05) difference between positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4. Broiler chicken heart weight (% of live weight) in positive control T_0 (0.49±0.02), negative control T_1 (0.47±0.01), and treatment T_2 (0.46±0.02), T_3 (0.49±0.03) and T_4 (0.47±0.01), is presented in Table 4.12. Results exhibited no significant (P>0.05) difference between positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4. Broiler chicken liver weight (% of live weight) in positive control T_0 (1.87±0.10), negative control T_1 (2.35±0.06), and treatment T_2 (2.48±0.07), T_3 (2.15±0.10) and T_4 (1.75±0.03), is presented in Table 4.12. Values were significantly (P<0.05) higher in garlic supplemented

treatment T_2 and negative control T_1. Broiler chicken gizzard weight (% of live weight) in positive control T_0 (1.81±0.04), negative control T_1 (1.76±0.06), and treatment T_2 (1.68±0.05), T_3 (1.76±0.09) and T_4 (1.79±0.06), is presented in Table 4.12. Results exhibited no significant ($P>0.05$) difference between positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4. Significantly ($P<0.05$) highest dressing per cent was recorded in cinnamon extract supplemented treatment T_3 followed by T_4 supplemented with garlic powder and cinnamon extract compared to positive and negative control T_0, T_1. Weight of liver as per cent of live weight was significantly ($P<0.05$) highest in garlic powder supplemented treatment T_2. The results are not without precedence. Kumar et al. (2016) reported that supplementation of broiler diet with garlic and tulsi powder increases dressing percentage but there is no effect on the percent weight of heart, liver, and gizzard. Issa and Omar (2012) reported that supplementation of garlic powder (0.2% and 0.4%) in broiler had no effect on heart and gizzard weight. Sang-Oh et al. (2013) and Gaikwad et al. (2019) reported that cinnamon powder supplementation significantly increases dressing percentage in broiler chicks. Shirzadegan (2014) reported that addition of cinnamon powder to broiler diet has no effect on heart and gizzard weight.

4.6.2 Gizzard thickness and weight (% of live weight) of important in-edible by products

Results for gizzard thickness and weight (% of live weight) of important in-edible by products at the end of the trial in positive control T_0, negative control T_1 and supplemented treatments with garlic powder T_2, cinnamon extract T_3 and cinnamon extract + garlic powder T_4 has been presented in Table 4.13.

Table 4.13 Gizzard thickness and Weight (% of live weight) of important in-edible by products

Particulars	Gizzard thickness (mm)	Spleen (%)	Bursa (%)	Abdominal fat (%)	Skin (%)	Head (%)	Feet (%)	Inedible offals (%)
T_0	21.17±0.85^{a}	0.10±0.01^{b}	0.22±0.01	2.21±0.14^{b}	9.19±0.37^{b}	2.87±0.13	4.44±0.07^{ab}	6.19±0.27^{ab}
T_1	21.91±0.52^{ab}	0.08±0.01^{ab}	0.25±0.02	1.46±0.11^{a}	8.20±0.64^{ab}	2.93±0.08	4.22±0.12^{a}	7.12±0.24^{b}
T_2	22.68±0.75^{ab}	0.07±0.00^{a}	0.26±0.02	1.56±0.12^{a}	7.51±0.36^{a}	2.64±0.07	4.50±0.08^{ab}	6.74±0.18^{ab}
T_3	23.34±1.16^{ab}	0.09±0.01^{ab}	0.28±0.02	1.58±0.21^{a}	7.79±0.23^{ab}	3.05±0.11	4.78±0.12^{b}	6.43±0.31^{ab}
T_4	24.43±0.32^{b}	0.09±0.01^{ab}	0.26±0.02	1.52±0.12^{a}	7.77±0.28^{ab}	2.80±0.09	4.53±0.15^{ab}	5.87±0.28^{a}
PSE	0.35	0.00	0.01	0.06	0.18	0.04	0.05	
p-Value	0.047	0.027	0.300	0.004	0.045	0.073	0.021	

Average means with different sub scripts in a column are significantly (P<0.05) different from each other

Broiler chicken gizzard thickness (mm) in positive control T_0 (21.17±0.85), negative control T_1 (21.91±0.52), and treatment T_2 (22.68±0.75), T_3 (23.34±1.16) and T_4 (24.43±0.32), is presented in Table 4.13. Thickness of gizzard (mm) was recorded to be significantly ($P<0.05$) highest in treatment T_4 supplemented with garlic powder and cinnamon extract compared to positive and negative control T_0 and T_1 followed by treatment T_3 supplemented with cinnamon extract and T_2 supplemented with garlic powder. Broiler chicken spleen weight (% of live weight) in positive control T_0 (0.10±0.01), negative control T_1 (0.08±0.01), and treatment T_2 (0.07±0.00), T_3 (0.09±0.01) and T_4 (0.09±0.01), is presented in Table 4.13. Results exhibited significant ($P<0.05$) difference between positive control T_0 and treatment T_2. Broiler chicken bursa weight (% of live weight) in positive control T_0 (0.22±0.01), negative control T_1 (0.25±0.02), and treatment T_2 (0.26±0.02), T_3 (0.28±0.02) and T_4 (0.26±0.02), is presented in Table 4.13. Results exhibited no significant ($P>0.05$) difference amongst positive control T_0, negative control T_1 and the phyto-additive supplemented treatments T_2, T_3 and T_4. Broiler chicken abdominal fat weight (% of live weight) in positive control T_0 (2.21±0.14), negative control T_1 (1.46±0.11), and treatment T_2 (1.56±0.12), T_3 (1.58±0.21) and T_4 (1.52±0.12), is presented in Table 4.13. Values were significantly ($P<0.05$) lower in all the supplemented treatments T_2, T_3 and T_4 as compared to positive control T_0. Results for deposition of abdominal fat deposition was indicative of low energy density feed offered to negative control T_1 and phyto additive supplemented treatments T_2, T_3 and T_4 which affected the carcass composition leading to leaner carcass. Broiler chicken skin weight (% of live weight) in positive control T_0 (9.19±0.37), negative control T_1 (8.20±0.64), and treatment T_2 (7.51±0.36), T_3 (7.79±0.23) and T_4 (7.77±0.28), is presented in Table 4.13. Values was significantly ($P<0.05$) higher in treatments T_0 and T_1. Broiler chicken head weight (% of live weight) in positive control T_0 (2.87±0.13), negative control T_1 (2.93±0.08), and treatment T_2 (2.64±0.07), T_3 (3.05±0.11) and T_4 (2.80±0.09), is presented in Table 4.13. Results exhibited no significant ($P>0.05$) difference amongst positive control T_0, negative control T_1 and the phyto-additive supplemented treatments T_2, T_3 and T_4. Broiler chicken feet weight (% of live weight) in positive control T_0 (4.44±0.07), negative control T_1 (4.22±0.12), and treatment T_2 (4.50±0.08), T_3 (4.78±0.12) and T_4 (4.53±0.15), is presented in Table 4.13. Values were significantly ($P<0.05$) higher in supplemented treatments T_2, T_3 and T_4 with highest value in cinnamon supplemented T_3. Gizzard thickness was significantly high in all phyto-additive supplemented treatment groups compared to positive and negative control T_0 & T_1.

Similarly, significantly lower abdominal fat deposition was recorded in all treatment groups compared to positive control T_0.

Results obtained agreed with those of Karim et al. (2017) who concluded that supplementation of garlic powder has no significant effect on skin, head, shank, spleen, heart, and gizzard weight in relation to body weight whereas the results were contrary to those reported by Chowdhury et al. (2018) who concluded that cinnamon supplementation in broilers has no effect on abdominal fat, heart, and gizzard weights. Similar results were reported by Toghyani et al. (2011) that cinnamon and garlic supplementation in broilers do not significantly affect abdominal fat and internal organ weights. Shirzadegan (2014) also reported that addition of cinnamon powder to broiler diet had no effect on abdominal fat content. Significantly low abdominal fat deposition seems to be a consequence of low energy density feed offered to negative control T_1 and supplemented treatments T_2, T_3 and T_4 compared to standard diet offered to positive control T_0

4.6.3 Yield of breast (pectoralis major and pectoralis minor) muscles (percent of dressed weight) in broiler chicken

Results for the yield of breast (percent of dressed weight) at the end of the trial in positive control T_0, negative control T_1 and supplemented treatments with garlic powder T_2, cinnamon extract T_3 and cinnamon extract + garlic powder T_4 has been presented in Table 4.14.

Table 4.14 Yield of Breast (pectoralis major and pectoralis minor) muscles (percent of dressed weight) in broiler chicken

Particulars	With bone (%)	Deboned (%)		Total deboned (%)
		Pectoralis major	Pectoralis minor	
T_0	31.77±0.56	19.89±0.51	5.43±0.09	25.32±0.53
T_1	33.15±0.69	21.63±0.68	5.39±0.25	27.02±0.87
T_2	33.11±0.69	21.56±0.58	5.62±0.10	27.18±0.63
T_3	33.13±0.78	21.14±0.73	5.56±0.12	26.71±0.78
T_4	33.27±0.68	21.38±0.60	5.50±0.08	26.88±0.65
p-Value	0.510	0.283	0.777	0.349
PSE	0.31	0.28	0.06	0.31

Average means with different sub scripts in a column are significantly (P<0.05) different from each other

Broiler chicken breast weight with bone (per cent of dressed weight) in positive control T_0 (31.77±0.56), negative control T_1 (33.15±0.69), and treatment T_2 (33.11±0.69), T_3 (33.13±0.78) and T_4 (33.27±0.68), is presented in Table 4.14. Results exhibited no significant (P>0.05) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4. Broiler chicken pectoralis major weight (per cent of dressed weight) in positive control T_0 (19.89±0.51), negative control T_1 (21.63±0.68), and treatment T_2 (21.56±0.58), T_3 (21.14±0.73) and T_4 (21.38±0.60), is presented in Table 4.14. Results exhibited no significant (P>0.05) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4. Broiler chicken Pectoralis minor weight (percent of dressed weight) in positive control T_0 (5.43±0.09), negative control T_1 (5.39±0.25), and treatment T_2 (5.62±0.10), T_3 (5.56±0.12) and T_4 (5.50±0.08), is presented in Table 4.14. Results exhibited no significant (P>0.05) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4. Broiler chicken deboned breast weight (percent of dressed weight) in positive control T_0 (25.32±0.53), negative control T_1 (27.02±0.87), and treatment T_2 (27.18±0.63), T_3 (26.71±0.78) and T_4 (26.88±0.65), is presented in Table 4.14. Results exhibited no significant (P>0.05) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4. Although the results were non-significant but numerically phyto-additive supplementation in T_2, T_3 and T_4 helped to increase the breast muscle yield (both boned and deboned). It may be due to active principles of herbal additives which promotes utilization of cellular lipids and fatty acids and in turn results in accumulation of protein (Ji et al. 2007) and thus increased yield.

4.6.4 Yield of leg muscle (boned) as percent of dressed weight in broiler chicken

Results for the yield of leg (per cent of dressed weight) at the end of the trial in positive control T_0, negative control T_1 and supplemented treatments with garlic powder T_2, cinnamon extract T_3 and cinnamon extract + garlic powder T_4 has been presented in Table 4.15.

Table 4.15 Yield of Leg Muscle (boned) as percent of dressed weight in broiler chicken

Particulars	Thigh (%)	Drumstick (%)	Total yield (%)
T_0	8.00 ± 0.20^{ab}	7.70±0.16	15.71±0.22
T_1	7.83 ± 0.20^{a}	7.54±0.06	15.36±0.21
T_2	8.15 ± 0.09^{ab}	7.47±0.11	15.62±0.17
T_3	8.56 ± 0.08^{b}	7.58±0.18	16.14±0.19
T_4	8.61 ± 0.20^{b}	7.17±0.13	15.78±0.32
PSE	0.07	0.06	0.10
p-Value	0.005	0.082	0.204

Average means with different sub scripts in a column are significantly (P<0.05) different from each other

Broiler chicken thigh weight (percent of dressed weight) in positive control T_0 (8.00±0.20), negative control T_1 (7.83±0.20), and treatment T_2 (8.15±0.09), T_3 (8.56±0.08) and T_4 (8.61±0.20) is presented in Table 4.15. Significantly (P<0.05) higher thigh weight was recorded in supplemented treatments T_3 and T_4. It may be due to active principles of herbal additives which promotes utilization of cellular lipids and fatty acids and in turn results in accumulation of protein (Ji et al. 2007) and thus increased yield. Broiler chicken drumstick weight (percent of dressed weight) in positive control T_0 (7.70±0.16), negative control T_1 (7.54±0.06), and treatment T_2 (7.47±0.11), T_3 (7.58±0.18) and T_4 (7.17±0.13), is presented in Table 4.15. Results exhibited no significant (P>0.05) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4. Broiler chicken total leg yield (percent of dressed weight) in positive control T_0 (15.71±0.22), negative control T_1 (15.36±0.21), and treatment T_2 (15.62±0.17), T_3 (16.14±0.19) and T_4 (15.78±0.32), is presented in Table 4.15. Results exhibited no significant (P>0.05) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4. Total thigh per cent was significantly (P<0.05) highest in T_3 & T_4. Phyto-additive supplementation alone (Cinnamon) and in combination (Cinnamon+ Garlic) increased thigh (significantly) and drumstick (non-significantly) yield offered low energy density feed.

Obtained results when compared with the results of Milosevic et al. (2013), Karim et al. (2017) and Odunowo and Olumide (2019) for garlic powder supplementation, we found

out that our results for breast muscle and drumstick yield agreed with them but contrary for the thigh muscle yield. Borgohain et al. (2019) also reported that garlic powder supplementation (0.5%, 1% and 1.5%) in broiler chicks had no significant (P>0.05) effect on breast weight and drumstick weight. Similarly results of Sang-Oh et al. (2013) for the effect of cinnamon supplementation on thigh yield agreed with the recorded findings. Singh et al. (2014) concluded that cinnamon supplementation does not influences carcass characteristics significantly.

4.7 Proximate composition, Ph, and cholesterol level of breast meat

Results for the proximate composition viz. dry matter, crude protein, ether extract, total ash, acid insoluble ash, Ph and cholesterol levels of broiler meat at the end of the trial in positive control T_0, negative control T_1 and supplemented treatments with garlic powder T_2, cinnamon extract T_3 and cinnamon extract + garlic powder T_4 has been presented in Table 4.16.

Broiler chicken dry matter (%) in positive control T_0 (29.91±0.52), negative control T_1 (29.16±0.36), and treatment T_2 (29.08±0.18), T_3 (28.90±0.27) and T_4 (30.53±0.37), is presented in Table 4.16. Significantly (P<0.05) lower value was observed in cinnamon extract supplemented treatment T_3. Broiler chicken crude protein (%) in positive control T_0 (73.69±1.09), negative controlT_1 (76.00±3.50), and treatment T_2 (74.54±3.07), T_3 (78.35±0.62) and T_4 (79.87±0.82), is presented in Table 4.16. Results exhibited no significant (P>0.05) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4. Meat CP percentage was numerically higher in T_3 and T_4. Shirzadegan (2014) also reported that cinnamon powder supplementation had no significant effect on breast protein percentage as compared to control group. Broiler chicken ether extract (%) in positive control T_0 (5.89±0.96), negative control T_1 (2.56±0.29), and treatment T_2 (3.83±0.54), T_3 (5.56±0.94) and T_4 (4.11±0.29), is presented in Table 4.16. Significantly (P<0.05) higher value of ether extract was recorded in positive control T_0 and cinnamon extract supplemented treatment diet T_3 and lowest in negative control T_1. Low energy density feed offered to negative control T_1 seemed to influence the body fat composition which is influenced by energy intake. Higher energy intake spares more energy for fat deposition in the body and vice versa. But treatment diets T_2, T_3 and T_4 offered phyto additives overcame the deficit of low energy intake and was able to accumulate more fat comparable to positive control T_0.

Table 4.16 Proximate Composition, Ph, and cholesterol level of breast meat

Particulars	DM (%)	CP (%)	EE (%)	TA (%)	AIA (%)	Ph(fresh)	Cholesterol (mg%)
T_0	29.91±0.52^{ab}	73.69±1.09	5.89±0.96^{b}	5.26±0.09	0.37±0.02	6.20±0.06^{a}	78.24±8.50
T_1	29.16±0.36^{ab}	76.00±3.50	2.56±0.29^{a}	5.18±0.12	0.48±0.03	6.39±0.03^{b}	86.39±4.56
T_2	29.08±0.18^{ab}	74.54±3.07	3.83±0.54^{ab}	5.37±0.08	0.43±0.06	6.27±0.03^{ab}	94.96±3.67
T_3	28.90±0.27^{a}	78.35±0.62	5.56±0.94^{b}	5.43±0.12	0.50±0.06	6.32±0.03^{ab}	86.58±12.30
T_4	30.53±0.37^{b}	79.87±0.82	4.11±0.29^{ab}	5.32±0.16	0.45±0.06	6.27±0.03^{ab}	80.63±9.73
PSE	0.16	0.98	0.30	0.05	0.15	0.02	3.27
p-Value	0.013	0.252	0.007	0.626	0.422	0.027	0.400

Average means with different sub scripts in a column are significantly (P<0.05) different from each other

Broiler chicken total ash (%) in positive control T_0 (5.26±0.09), negative control T_1 (5.18±0.12), and treatment T_2 (5.37±0.08), T_3 (5.43±0.12) and T_4 (5.32±0.16), is presented in Table 4.16. Results exhibited no significant (P>0.05) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4. Zekic et al. (2014) also reported that supplementation of garlic powder (2%) in broilers had no significant (P>0.05) effect on breast muscle total ash content. Broiler chicken AIA (%) in positive control T_0 (0.37±0.02), negative control T_1 (0.48±0.03), and treatment T_2 (0.43±0.06), T_3 (0.50±0.06) and T_4 (0.45±0.06), is presented in Table 4.16. Results exhibited no significant (P>0.05) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4.

Broiler chicken meat pH in positive control T_0 (6.20±0.06), negative control T_1 (6.39±0.03), and treatment T_2 (6.27±0.03), T_3 (6.32±0.03) and T_4 (6.27±0.03), is presented in Table 4.16. Significantly (P<0.05) lowest value of meat pH was recorded in positive control T_0 and highest value was recorded in negative control T_1, whereas pH in treatments supplemented with phyto-additives were comparable to T_0. The pH of broiler meat is attributable to the glycogen level in the muscles which is converted to lactic acid after slaughter. In our experiments the response of birds offered low energy diets T_1 revealed significantly (P<0.05) higher pH indicating low glycogen storage whereas treatment diets offered low energy diets but supplemented with garlic powder, cinnamon extract and combination of garlic powder and cinnamon extract viz. T_2, T_3 and T_4 exhibited non-significant (P>0.05) difference in pH compared to control group offered standard diet T_0. Better nutrient utilization was thus attributable to phyto additive supplementation as is evident in the results. Choi et al. (2010) reported reduction in meat pH with the supplementation of garlic in broiler diet contrary to our study where meat pH was similar to standard diet. Probable reason could be our experiment based on low energy diets offered to phyto additive supplemented treatments.

Broiler chicken meat cholesterol (mg/100gm) in positive control T_0 (78.24), negative control T_1 (86.39), and treatment T_2 (94.96), T_3 (86.58) and T_4 (80.63), is presented in Table 4.16. Results exhibited no significant (P>0.05) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4. Results recorded for meat cholesterol were contrary to Dzinic et al. (2013) and Zekic et al. (2014) who reported significant reduction in meat cholesterol levels with the supplementation of garlic.

4.8 Sensory attributes of broiler meat

Results for the sensory attributes of broiler meat at the end of the trial in positive control T_0, negative control T_1 and supplemented treatments with garlic powder T_2, cinnamon extract T_3 and cinnamon extract + garlic powder T_4 has been presented in Table 4.17.

Table 4.17 Sensory Attributes of Broiler Meat

Particulars	Appearance/Color	Flavor	Texture/Tenderness	Juiciness	Overall acceptability
T_0	6.33±0.22	$6.25±0.22^{ab}$	6.63±0.25	5.92±0.26	$6.25±0.22^{a}$
T_1	6.42±0.24	$6.00±0.21^{a}$	6.17±0.27	5.88±0.21	$6.27±0.19^{a}$
T_2	6.63±0.21	$6.17±0.32^{a}$	6.29±0.32	6.08±0.32	$6.60±0.32^{ab}$
T_3	6.54±0.24	$6.33±0.22^{ab}$	6.54±0.19	6.00±0.16	$6.73±0.19^{ab}$
T_4	6.71±0.21	$7.13±0.20^{b}$	6.42±0.27	6.46±0.27	$7.21±0.14^{b}$
PSE	0.10	0.11	0.12	0.11	0.10
p-Value	0.759	0.016	0.739	0.493	0.019

Average means with different sub scripts in a column are significantly (P<0.05) different from each other

Recorded value for appearance/colour of the cooked broiler meat in positive control T_0 (6.33), negative control T_1 (6.42), and treatment T_2 (6.63), T_3 (6.54) and T_4 (6.71), is presented in Table 4.17. Results exhibited no significant (P>0.05) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4. Panellists agreed that samples in all treatments have good appearance. Recorded value for the flavour of the cooked broiler meat in positive control T_0 (6.25), negative control T_1 (6.00), and treatment T_2 (6.17), T_3 (6.33) and T_4 (7.13), is presented in Table 4.17. Flavour perception was found to be significantly (P<0.05) higher in T_3 and T_4. But best in flavour was the one supplemented with combination of garlic powder and cinnamon extract i.e., T_4. Recorded value for texture/tenderness of the cooked broiler meat in positive control T_0 (6.63), negative control T_1 (6.17), and treatment T_2 (6.29), T_3 (6.54) and T_4 (6.42), is presented in Table 4.17. Results exhibited no significant (P>0.05) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4. Based on the scores obtained, the tenderness ranged from very desirable to moderately desirable. Recorded value for the juiciness of the cooked broiler meat in positive control T_0 (5.92), negative control T_1 (5.88), and treatment T_2 (6.08), T_3 (6.00) and

T_4 (6.46), is presented in Table 4.17. Results exhibited no significant (P>0.05) difference amongst positive control T_0, negative control T_1 and the supplemented treatments T_2, T_3 and T_4. Recorded value for the overall acceptability of the cooked broiler meat in positive control T_0 (6.25), negative control T_1 (6.27), and treatment T_2 (6.60), T_3 (6.73) and T_4 (7.21), is presented in Table 4.17. Overall acceptability was found to be significantly (P<0.05) higher in phyto-additive supplemented treatments T_2, T_3 and T_4. But the one supplemented with combination of garlic powder and cinnamon extract i.e., T_4 scored significantly (P<0.05) highest for overall acceptability. Results obtained agreed with Fadlalla et al. (2010) who reported that garlic supplementation has no significant effect on colour, tenderness, and juiciness of broiler meat. Singh et al. (2014) who reported that cinnamon supplementation improves flavour and overall acceptability of broiler meat, but some of the sensory attributes recorded like colour, appearance and juiciness were contrary to their findings. Byung-Sung (2008) concluded that the sensory evaluation of the taste and flavor related to cinnamon in fried or boiled chicken meat were significantly better from the broiler chicken fed diets containing cinnamon powder than the control group. The results were contrary to Toghyani et al. (2011) who reported that dietary supplementation of cinnamon powder (2 and 4 g/kg) and garlic powder (2 and 4 g/kg) in broilers had no difference in taste and flavor attributes of broiler meat.

4.9 Economics of broiler production

Results for the European economic factor (EEF) and cost of producing per kilogram of broiler meat during starter, finisher and overall period of rearing at the end of the trial in positive control T_0, negative control T_1 and supplemented treatments with garlic powder T_2, cinnamon extract T_3 and cinnamon extract + garlic powder T_4 has been presented in Table 4.18.

Recorded value of European economic factor (EEF) in positive control T_0 (234), negative control T_1 (211), and treatment T_2 (232), T_3 (233) and T_4 (233), is presented in Table 4.18. Results indicate that best value of EEF was in positive control T_0. Among the low energy treatments, phyto-additive supplemented treatments were better performers as compared to the negative control T_1. Recorded value for cost of producing 1 kg meat in starter phase in positive control T_0 (62.36), negative control T_1 (59.35), and treatment T_2 (61.40), T_3 (57.53) and T_4 (66.16), is presented in Table 4.18. Results indicates that most cost-efficient treatment was the one supplemented with cinnamon extract alone i.e., T_3. And most expensive was the one which was supplemented with combination of

garlic powder and cinnamon extract i.e., T_4. Cinnamon extract (alone) supplementation helped to reduce the cost of production by 7.75 percent as compared to positive control T_0. Recorded value for cost of producing 1 kg meat in finisher phase in positive control T_0 (63.51), negative control T_1 (60.94), and treatment T_2 (59.85), T_3 (60.45) and T_4 (63.53), is presented in Table 4.18. Results indicates that most cost-efficient treatment was the one supplemented with garlic powder i.e., T_2. And most expensive was the one which was supplemented with combination of garlic powder and cinnamon extract i.e., T_4. Garlic powder (alone) supplementation helped to reduce the cost of production by 5.76 percent as compared to positive control T_0

Table 4.18 Economics of Broiler Production

Treatments	EEF	Cost of producing 1 Kg meat (1 to 21 days)	Cost of producing 1 Kg meat (21 to 42 days)	Cost of producing 1 Kg meat (1 to 42 days)
T_0	243	62.36	63.51	64.24
T_1	211	59.35	60.94	61.80
T_2	232	61.40	59.85	61.34
T_3	233	57.53	60.45	60.73
T_4	233	66.16	63.53	65.24

Recorded value for cost of producing 1 kg meat in overall period in positive control T_0 (64.24), negative control T_1 (61.80), and treatment T_2 (61.34), T_3 (60.73) and T_4 (65.24), is presented in Table 4.18. Results indicates that most cost-efficient treatment was the one supplemented with cinnamon extract i.e., T_3. And most expensive was the one which was supplemented with combination of garlic powder and cinnamon extract i.e., T_4. Cinnamon extract (alone) supplementation helped to reduce the cost of production by 5.46 percent as compared to positive control T_0. Results obtained agreed with the results of Singh et al. (2014) who reported high benefit: cost ratio with cinnamon powder supplementation (0.5%) in broiler diet and Gaikwad et al. (2019) who also reported that supplementation of broiler diet with cinnamon powder provided better economic returns as compared to control group. Molla et al. (2012) supplemented broilers with polyherbal extract (extract of nishyinda (Vitex negundo) leaves, black pepper (Piper nigrum) and cinnamon (Cinnamomum verum)) @ 1 mL/liter in drinking water and concluded that supplementation with polyherbal extract containing cinnamon was more profitable than control group.

CHAPTER 5

SUMMARY AND CONCLUSION

In India, the poultry business has transitioned from a backyard pastime to a significant commercial agri-based enterprise. Owing to a competitive price offered by poultry which is the cheapest source of superior quality protein, Indian agriculture has witnessed poultry sector growing at the fastest rate. While agricultural crop output has been increasing at a pace of 1.5 to 2% per year, egg and broiler production has been increasing at a rate of 8 to 10% per year (Chatterjee and Rajkumar, 2015). Chicken meat is in high demand, and producers are looking for innovative ways to enhance output.

Antibiotics and chemotherapeutics in preventive dosages have been utilised in chicken diets for several decades to enhance animal welfare and provide economic benefits in the form of increased animal performance and lower treatment expenses. Antibiotic Growth Promoters (AGP) are drugs that are used to boost weight gain and feed conversion. However, because AGP has a lingering effect and contributes to antibiotic resistance, there is a push to reduce the use of antibiotics to avoid severe consequences for human health (Dibner and Richards, 2005).

Researchers are seeking for feasible alternatives to minimise or replace the use of antibiotics in chicken production due to the unfavourable effects of antibiotics as growth enhancers. Phyto biotics, often known as phyto additives, are being investigated as an alternative to AGP. Phyto biotics are plant-derived natural bioactive substances that may be introduced into the diet to improve animal performance and well-being. Turmeric, oregano, rosemary, garlic, ginger, green tea, black cumin, coriander, and cinnamon are just a few of the herbs and spices that have been tested in chicken for their prospective use as AGP replacements (Gadde et al. 2017)

In the study conducted, low energy density diets were formulated (10 percent less energy) and then they were supplemented with garlic powder and cinnamon extract to see the effect on broiler bird performance.

The present study thus will be undertaken with the following objective –

OBJECTIVES: -

1. Evaluate the biological growth performance and economic of broiler birds offered low nutrient density than standard feed supplemented with phyto additives viz. garlic and cinnamon.

2. Estimating the digestibility of nutrients, gut health and economics of broiler production.

The study was carried out in Department of Animal Nutrition, DGCN COVAS, CSKHPKV, Palampur, Himachal Pradesh, India. The experiment was carried out on broiler chickens from day old to 42 days of age.

A total of 195-day old broiler chicks (Ven cobb) were procured. Individually, chicks were weighed at the start of the experiment, then marked and randomly allocated into five feeding groups, T_0, T_1, T_2, T_3, and T_4, according to the experimental plan in the electric battery brooder. Each group comprised of three replicates, 13 chicks in each replicate. Thus, each treatment included 39 birds.

Positive control group T_0 was offered standard feed, negative control group T_1 was offered low energy density feed (10 percent less ME Kcal/Kg), treatment group T_2 was offered low energy density feed (10 percent less ME Kcal/Kg) with inclusion of 0.5 per cent garlic powder, treatment group T_3 was offered low energy density feed (10 percent less ME Kcal/Kg) with inclusion of 0.1 per cent cinnamon extract and treatment group T_4 was offered low energy density feed (10 percent less ME Kcal/Kg) with inclusion of combination of garlic powder (0.5 per cent) and cinnamon extract (0.1 per cent).

At the end of starter phase (0-21 days), the birds of control group T_0 offered standard feed, exhibited higher live body weight gain, lower feed intake on weekly and per day basis, better feed to live weight gain ratio (FCR) which exhibited significant ($P<0.05$) difference compared to negative control T_1 but did not exhibit any significant ($P>0.05$) difference compared to treatment groups T_2, T_3 and T_4. Mortality per cent was as per the standard management norms with treatment group T_3 exhibiting marginal (2.56) mortality per cent whereas no mortality was recorded in other treatments. Higher feed intake and subsequently higher FCR exhibited in negative control T_1 seems to be the result of compensatory mechanism for meeting the energy requirements when low energy density feed was offered. Energy calories ratio was narrow in case of negative control group T_1 which led to increased feed intake compared to positive control T_0 whereas treatment groups offered phyto additives viz. garlic powder and cinnamon extract exhibited weight gain, feed intake, FCR comparable to positive control group, though offered low energy density feed. The results obtained reveal better utilization of nutrients with the supplementation. Compared to negative control T_1 and treatment groups T_2 and T_4, treatment T_3 offered cinnamon extract at 0.1 per cent exhibited

numerically higher gain in live body weight, lower feed intake and lower feed to live weight gain ratio (FCR).

Trend of growth and feed conversion was similar as was exhibited during starter phase. At the end of the finisher phase (22-42 days) the broiler birds of control group T_0 offered standard feed exhibited higher live body weight gain, lower feed intake on weekly and per day basis, better feed to live weight gain ratio (FCR) which exhibited significant ($P<0.05$) difference compared to negative control T_1 but did not exhibit any significant ($P>0.05$) difference compared to treatment groups T_2, T_3 and T_4. Mortality per cent was as per the standard management norms with negative control T_1 exhibiting marginal (2.56) mortality per cent whereas no mortality was recorded in other treatments. Higher feed intake and subsequently higher FCR exhibited in negative control seem to be the result of compensatory mechanism for meeting the energy requirements when low energy density feed was offered. Energy calories ratio was narrow in case of negative control group T_1 which led to increased feed intake compared to positive control T_0 whereas treatment groups offered phyto additives viz. garlic powder and cinnamon extract exhibited weight gain, feed intake, FCR comparable to positive control group, though offered low energy density feed. The results obtained reveal better utilization of nutrients with the supplementation of phyto additives. Compared to negative control T_1 and treatment groups T_2 and T_4, treatment T_3 offered cinnamon extract at 0.1 per cent exhibited numerically higher gain in live body weight and lower feed to live weight gain ratio (FCR).

Trend of growth and feed conversion during overall phase was similar as was exhibited during finisher phase. At the end of the overall phase (0-42 days) the broiler birds of control group T_0 offered standard feed exhibited higher live body weight gain, lower feed intake on weekly and per day basis, better feed to live weight gain ratio (FCR) which exhibited significant ($P<0.05$) difference compared to negative control T_1 but did not exhibit any significant ($P>0.05$) difference compared to treatment groups T_2, T_3 and T_4. Mortality per cent was as per the standard management norms with negative control T_1 and treatment group T_3 exhibiting marginal (2.56) mortality per cent, whereas no mortality was recorded in other treatments. Higher feed intake and subsequently higher FCR exhibited in negative control seem to be the result of compensatory mechanism for meeting the energy requirements when low energy density feed was offered. Energy calories ratio was narrow in case of negative control group T_1 which led to increased feed intake compared to positive control T_0 whereas treatment groups offered phyto additives viz. garlic powder and cinnamon extract exhibited weight gain, feed intake, FCR comparable to positive control

group, though offered low energy density feed. The results obtained reveal better utilization of nutrients with the supplementation of phyto additives. Compared to negative control T_1 and treatment groups T_2 and T_4, treatment T_3 offered cinnamon extract at 0.1 per cent exhibited numerically higher gain in live body weight and lower feed to live weight gain ratio (FCR).

Digestibility studies based on total faecal collection method exhibited significantly ($P<0.05$) highest ether extract digestibility in negative control T_1. Similarly, dry matter and crude fibre digestibility did not exhibit any significant difference but was numerically higher in negative control T_1. Higher digestibility of crude fibre and ether extract and nutrient utilization in negative control T_1 revealed the compensatory mechanism of digestive system to extract maximum nutrients when offered low energy density feed without any phyto additive supplementation. Similarly, treatment group T_3 numerically exhibited 12.90 and 12.50 per cent higher nitrogen retention compared to control group T_1 and T_0.

Recorded value of microbial count in cecum did not exhibit significant ($P>0.05$) difference among various treatments. But phyto-additive supplementation in treatment T_2, T_3 and T_4 showed numerical decrease in total viable count in comparison to T_0 and T_1.

Recorded values of haematological parameters namely WBC, RBC, Hb and PCV were significantly ($P<0.05$) higher in positive control T_0 and lowest in negative control T_1. Whereas treatments groups with phyto-additive supplementation T_2, T_3 and T_4 recorded numerically higher values in comparison to negative control T_1. There was no significant ($P>0.05$) difference in values of MCV, MCH and MCHC among various treatments and they were within normal range.

Recorded values of biochemical parameters namely total protein, albumin, globulin, ALT, AST, creatinine, HDL and LDL cholesterol and triglycerides were within normal range and exhibited non-significant ($P>0.05$) difference. Total cholesterol was significantly ($P<0.05$) lower in negative control T_1 but not significantly ($P>0.05$) affected by phyto-additive supplementation in treatment T_2, T_3 and T_4 and was at par with positive control T_0 but higher then negative control.

Data obtained from the tibial bone analysis indicated good tibiae bone growth in phyto-additive supplemented treatments T_2, T_3 and T_4. Tibial calcium content was significantly ($P<0.05$) higher in treatment T_3 and T_4 with highest content being obtained in treatment T_4 which was supplemented with combination of garlic powder and cinnamon extract. Tibiae phosphorus content was significantly ($P<0.05$) higher in all the phyto-additive supplemented treatments T_2, T_3 and T_4 with highest content obtained in

treatment T_4 which was supplemented with combination of garlic powder and cinnamon extract.

Evaluation of carcass parameters revealed significantly ($P<0.05$) highest dressing percentage in treatment diets T_3 followed by T_4 compared to positive control T_0 and negative control T_1. Gizzard thickness was significantly ($P<0.05$) high in all phyto-additive supplemented treatment groups T_2, T_3 and T_4 compared to positive control T_0 and negative control T_1. Similarly, significantly ($P<0.05$) lower abdominal fat deposition was recorded in all supplemented groups compared to positive control T_0 and negative control T_1. No effect of supplementation on heart, gizzard, spleen, bursa, head, and skin weight was observed.

Although the results were non-significant ($P>0.05$) but numerically phyto-additive supplementation in T_2, T_3 and T_4 helped to increase the breast muscle yield (both boned and deboned). Total thigh percent was significantly ($P<0.05$) highest in T_3 and T_4. Phyto-additive supplementation alone T_3 (Cinnamon) and in combination T_4 (Cinnamon + Garlic) significantly ($P<0.05$) increased thigh yield. Drumstick yield was not significantly ($P>0.05$) affected by any of the dietary supplementations i.e., garlic and cinnamon. Numerically the total leg yield was 2.74 per cent higher in low energy cinnamon extract supplemented T_3 group as compared to standard energy positive control T_0.

Results of meat analysis indicated that there was no significant ($P>0.05$) effect of supplementation (garlic powder and cinnamon extract) on crude protein levels but numerically the increase in crude protein was recorded. Numerically decrease in pH was observed with the supplementation in T_2, T_3 and T_4. Meat cholesterol levels were not affected significantly ($P>0.05$) by different dietary treatments.

Results of sensory attributes of broiler meat indicated that significantly, there was no difference ($P>0.05$) in the appearance, texture and juiciness among the treatments (positive control T_0, negative control T_1, garlic powder supplemented T_2, cinnamon extract supplemented T_3 and garlic powder + cinnamon extract supplemented T_4) i.e., neither positive nor negative effect of garlic and cinnamon supplementation. But garlic and cinnamon has significantly ($P<0.05$) positive effect on flavour and overall acceptability of the broiler meat.

Economics of broiler production was studied by calculating the European economic factor and cost of producing per kg meat. Results indicate that best value of EEF was in positive control T_0. Among the low energy treatments, phyto-additive supplemented treatments T_2, T_3 and T_4 were better performers as compared to the negative control T_1. The most cost-efficient treatment was the one supplemented with cinnamon extract i.e., T_3. And

most expensive was the one which was supplemented with combination of garlic powder and cinnamon extract i.e., T_4. Cinnamon extract (alone) supplementation helped to reduce the cost of production by 5.46 percent as compared to positive control T_0.

Conclusion

Based on the results of the study conducted it can be concluded that:

- Phyto-additive supplementation namely garlic powder, cinnamon extract and combination of cinnamon extract and garlic powder in low energy density feed positively influenced the growth, nutrient utilization with better feed to gain ratio, both during starter and finisher phase. Overall cinnamon extract supplementation at 0.1 per cent in low energy feed exhibited higher nitrogen retention exhibiting higher live weight gain and feed to gain ratio compared to garlic powder and combination of garlic + cinnamon supplementation.
- Highest dressing percentage, thigh yield and low abdominal fat with leaner meat was recorded by cinnamon extract (0.1%) addition and garlic powder (0.5%) + cinnamon extract (0.1%) combination supplemented to low energy density feed.
- The organoleptic factors viz. flavor and overall acceptability of the meat was significantly ($P<0.05$) influenced by addition of cinnamon (0.1%) and combination of garlic powder (0.5%) + cinnamon extract (0.1%) supplementation
- Economics of broiler production revealed lowest cost of producing 1 Kg meat by cinnamon extract (0.1%) supplementation whereas it was highest in garlic powder (0.5%) + cinnamon extract (0.1%) supplementation. Cinnamon extract at 0.1 per cent supplementation helped to reduce the cost of production by 5.46 percent as compared to positive control T_0

Therefore, it is concluded that compared to garlic powder (0.5%) and combination of garlic powder (0.5%) + cinnamon extract (0.1%), cinnamon extract (0.1%) supplementation alone in low energy density feed offered to broiler birds positively compensate the low energy by lowering bacterial count thus leading to better nitrogen retention and growth. Cinnamon extract supplementation at 0.1 per cent increases broiler dressing percentage, positively influences the organoleptic values of the meat and reduce the cost of broiler meat production by 5.46% leading to good economic return to the farmers.

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APPENDIX

Sr. No.	Ingredients	Cost (per kg)
1	Yellow corn	18.77
2	Soya flakes	43
3	Palm oil	120
4	DCP	37.15
5	DL-Methionine	280
6	Lysine	172
7	LSP	5.4
8	Salt	6.4
9	Premix	200
10	Cinnamon	1350
11	Garlic	80

Brief Biodata of the student

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Academic Qualifications

Examination	Year	School/ Institute	Board/ University	Marks (%)	Division
Secondary (Class 10th)	2011	Mount Carmel School, Thakurdwara, Palampur (H.P.)	ICSE	87%	1st
Senior Secondary (Class 12th)	2013	-----do-----	ISC	77.4%	1st
B.V.Sc & A.H.	2019	DGCNCOVAS, Palampur (H.P.)	CSKHPKV, Palampur (H.P.)	77.0	1st
M.V.Sc		DGCNCOVAS, Palampur (H.P.)	CSKHPKV, Palampur (H.P.)	85.9	1st