Evaluation of *Aloe vera* (*Aloe barbadensis linné*) and Ginger (*Zingiber officinale*) as phytogenic supplements for broilers

BY

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Declaration

I, **Masechaba Moalamedi, student number 16023576**, hereby declare that this dissertation, submitted in fulfilment of the requirements for Master of Science in Agriculture (Animal Science), submitted to the Department of Animal Science, Faculty of Science, Engineering & Agriculture, at the University of Venda, has not been submitted previously for a degree at this or any another university. It is original in design and execution, and all reference material contained herein has been duly acknowledged.

Signed (Moalamedi M): ___________________ Date: 27 February 2023

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Dedication

This dissertation is dedicated to my hardworking self.
To my courage and strength that kept me going.
To my parents, Mr MJ Moalamedi and Mrs NP Moalamedi, this is the first fruit which I have received because of your countless and arduous sacrifices.
To Letlotlo.

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Abstract

The study investigated the potential of Aloe vera (*Aloe barbadensis linné* - AVE) and Ginger (*Zingiber officinale* - GNE) extracts as phytogenic supplements for broilers, as indicated by the growth, slaughter performance, visceral organ sizes, and meat quality broilers. A total of 480 Ross 308 broilers were housed in a deep litter open-sided house, stocked at 15 birds per 150 cm length × 144 cm width mesh-wire pen. During the starter period (days 1-22), the chicks were fed a diet containing 220 g kg-1 CP and 17.8 MJ ME kg-1. For the grower (days 23-36) and finisher (days 37-50) phases, the chicks were assigned to pens in a 2 (sex) × 4 (additive) factorial design, with two diets used for each phase: an antibiotic-free negative control (NC) diet and a positive control (PC) diet containing zinc bacitracin 15% granular at 500g/tonne plus 12% valinomycin sodium at 500g/tonne. Birds on the PC diet had access to clean drinking water only, while those on the NC diet received water without or with 2 mL/L of AVE or GNE. Birds on the GNE had small livers (33.5±1.37g), which suggested liver damage or a lower metabolic load. Birds on AVE had low (17.0±0.15g) abdominal fat, which indicated leaner growth. Males consumed more feed (145.5 ±2.74g) than the females (136.4±2.74g) during the finisher phase, and by slaughter (54.3±1.77 versus 52.6±1.77 g, respectively). The treatments affected the mean feed intake (132.7±2.27 - 149.5±2.27 g), weight gain (46.7±2.50 -77.7±2.50 g/bird/day), and FCR (3.4±0.14 - 2.1±0.14) across all growth phases, with the best performance recorded in birds on the PC. Females had higher percentage wings (4.8±0.18 versus 4.4±0.18 %) and breasts (33.9±0.96 versus 29.8 ±0.96 %) on the PC, compared to the NC treatment. In conclusion, the plant extracts did not improve broiler growth performance, carcass characteristics, and meat quality parameters at the 2 ml/L dosage.

Keywords: *Aloe Vera*; ginger; therapeutics

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ABBREVIATIONS AND ACRONYMS

°C	Degrees Celsius
%	Percentage
a*	CIE red (+)/ green (-) colour attributes
AGPs	Antibiotic growth promoters
ALE	*Aloe vera* leaf extract
APEDA	Agricultural and processed food products export development authority
AV	*Aloe vera*
AVG	*Aloe vera* gel
AVLP	*Aloe vera* leaf powder
b*	CIE yellow (+) / blue (-) colour attributes
BW	Body weight
BWG	Body weight gain
BHA	Butylated Hydroxyanisole
BHT	Butylated hydroxytoluene
C*	Chroma
C_D	Colour difference
EDTA	Ethylenediaminetetraacetic
FBG	Fasting blood glucose
FCR	Feed conversion ratio
FFA	Free fatty acids
FI	Feed intake

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FRAP	Ferric-reducing antioxidant power.
g	Grams
g/b/d	Gram per bird per day
g/kg	Gram per kilogram
GE	Ginger extracts
GRAS	Generally recognized as safe
GSH	Glutathione serum
h*	Hue
HDLc	Density lipoprotein cholesterol
LDLc	Density lipoprotein cholesterol
L*	CIE lightness coordinate
M^2	Square meter
Mg	Milligram
ml	Millilitres
mm	Millimetres
kg/mm^2	Kilogram per millimeter squared.
MDA	Malondialdehyde
NO	Nitrogen oxide
NC	Negative control
PC	Positive control
PFA	Phytogenic feed additives
RNS	Reactive nitrogen species

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ROS	Reactive oxidant species
SEM	Standard error of mean
SOD	Superoxide dismutase
TC	Total cholesterol
WHC	Water holding capacity.
Wt.	Weight

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CHAPTER 1: INTRODUCTION

1.1 Background

The production of poultry is among the most thriving livestock sectors globally, providing people with the least expensive source of animal protein (DAFF, 2018). The agriculture sector of South Africa continues to be primarily supported by the poultry industry (SAPA, 2019). Broilers have a 5–7-week shorter production cycle than beef, mutton, and pork production, while modern commercial broilers are bred to attain a slaughter weight of 1.9 to 2 kg (Grain SA, 2021) in 35 to 42 days (Abougabal, 2020). Meat production, quality, and safety can be significantly impacted by the nutrition of broilers (Mir *et al*., 2017).

Antibiotics were successfully used as poultry growth promoters to reduce infectious diseases and boost feed efficiency (Engberg *et al*., 2000, Karangiya *et al*., 2016). However, the chicken industry has taken some steps to limit the consumption of antibiotics in diets, as growth promoters (Rathod *et al*., 2021). This has been achieved through increased controls or banning antibiotics use in most countries. This is because of their extensive use and as residues in feed and the environment (Carvalho and Santos, 2016, Ronquillo and Hernandez, 2017), which compromise human and animal health (Rathod *et al*., 2021). Furthermore, using antibiotics extensively as growth promoters in the poultry industry has led to the fast emergence of an antibiotic-resistant form of microorganisms, which is less sensitive to pathogens (Onimawo *et al*., 2021). Recently, research has focused on using naturally occurring probiotics, to replace chemically based feed. Modern substitutes for antibiotic growth promoters (AGP) include probiotics (Yadav, 1999, Santos and Ferket, 2006, Al-Kassie, 2010, Alagawany *et al*., 2021, El-Saadony *et al*., 2021, Khalafalla *et al*., 2022), prebiotics (Patterson and Burkholder, 2003, Mosoeunyane, 2006, Yaqoob *et al*., 2021) and phytogenic compounds (Tucker, 2001, Amber *et al*., 2021).

The use of phytogenic additives in boosting broiler growth has yet to be accepted, due to lack of information on the optimal inclusion levels and feeding duration (Abdelli *et al*., 2021, Peregrine *et al*., 2021). These plant-based additives' impact on the meat quality of broiler chickens has still not well-defined (Orlowski *et al*., 2018). Appearance, texture, juiciness, wateriness, firmness, tenderness, odour, and flavour are meat quality attributes that may be affected by phytogenic additives and are considered important in ensuring consumer satisfaction (Mir *et al*., 2017). Thus, there is a need for research on growth-promoting additives that are safe for chicken and human health (Mir *et al*., 2017). There is also a need for research on quantifiable characteristics that are necessary to investigate the factors that give value to meat products, including collagen content, protein solubility, cohesion, pH, cooking loss, drip loss, shear force, and water holding capacity (Mir *et al*., 2017).

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It has been established that natural growth promoters, including prebiotics, probiotics, symbiotics, enzymes, and plant extracts, can be used to replace antibiotics, without adversely affecting the performance of birds (Borazjanizadeh *et al*., 2011). The growth-promoting herbs contain a variety of secondary metabolites. The phytogenic chemicals seem to be mostly isoprene derivatives, mucilage, flavonoids, glycosides, alkaloids, and bitters (El-Saber Batiha *et al*., 2020, Arif *et al*., 2022, Islam *et al*., 2023). According to Mnisi *et al*., (2023) these active substances increase feed digestion, by producing phytases, lipases, amylases, and proteases, or by stimulating the gastro-intestinal tract (GIT), to secrete digestive enzymes. They also act as antibodies and antioxidants in feed and within the animals. By producing vitamins, exopolysaccharides and antioxidants, probiotics increase the nutritional value of feed (Neveling and Dicks, 2021). Furthermore, they exhibit a variety of activities, including the stimulation of endogenous secretions and feed intake, as well as antimicrobial, coccidiostat, or anthelmintic properties (Pandey *et al*., 2019).

Aloe sp., which is widely distributed throughout sub-Saharan Africa (Odukoya *et al*., 2022), is one of the most common therapeutic plant species (Kamba, 2014). The species include *Aloe ferox, Aloe barbadensis*, *Aloe marlotii* and *Aloe arborescens*. They are also regarded as multifunctional because they possess antibacterial, anti-inflammatory, anthelminthic, and anti-oxidative effects (Kamba, 2014). *Aloe vera* contains *Aloe* gel and latex. However, the gel expresses stronger therapeutic properties than latex. This is due to its 96% water content and 4% dry matter, which includes dietary fibre (18.8%), polysaccharides (8.8%), protein (4.7%), lipids (2.7%), and ashes, this is in addition to organic acids (22.8%) (Nicolau-Lapena *et al*., 2021). Vitamins, terpenoids, phenols and carotenoids are also contained in *Aloe vera,* as active compounds (Kamba, 2014). *Gingiber officinale*, a species of ginger, is a common and significant medicinal herb (Al-Nahain *et al*., 2014). It is an herbaceous plant with rhizomes, and its rhizome is utilized for medical purposes (Oleforuh-Okoleh *et al*., 2014). It includes a variety of substances and enzymes, such as shogaols, gingerol, gingerdiol, and gingerone (Zhao *et al*., 2011), compounds which are antioxidative, antimicrobial, and have other pharmacological effects (Al-Amin *et al*., 2006, Tapsell *et al*., 2006, Ali *et al*., 2008).

Aloe vera and ginger have distincive properties and both possess antibacterial activity against various pathogenic bacteria, particularly Gram-positive bacteria, as well as antiseptic, anti-inflammatory, and immune stimulant effects (Hassan *et al*., 2019 and Arif *et al*., 2022). They are both regarded as excellent alternatives to conventional medicine. Therefore, the study investigated the effects of *Aloe vera* (*Aloe barbedenis miller*) and Ginger (*Zingiber officinale*) on the growth, carcass and meat characteristics of broilers when supplemented in drinking water to replace commercial growth promoters.

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1.2 Research Problem

Commercial growth-promoting products, which are frequently utilized in the poultry industry, are expensive and unaffordable for many farmers, in addition to their potential health and metabolic hazards (Neveling and Dicks, 2021). The risk of using antibiotics for both poultry and human health is of major concern (Borazjanizadeh *et al*., 2011, Zeng and Zhang, 2015, Agyare *et al*., 2018, Aabed *et al*., 2021, Grakh *et al*., 2022, Binsker *et al*., 2022) because an increase in bacterial species that are resistant to antibiotics is due to the use of non-therapeutic antibiotics in poultry feed. According to Andremont, (2000), antibiotic use alters the gut microflora composition and leads to the development of drug-resistant strains that can become zoonotic (Wegener *et al*., 1999, Singer and Hofacre, 2006). These strains can accumulate in animal products and in the environment (Ghalamkari *et al*., 2012, Goodarzi *et al*., 2014).

1.2 Justification/Rationale of the Study

In African rural areas, chicken production is a key component of livestock production. By ensuring food security and generating income, it helps reduce poverty. Although the nutritional value of meat may be objectively measured, customers' perceptions of what constitutes high-quality meat are often subjective (Cassian *et al*., 2019). If alternative growth promoters of plant origin are easily accessible, readily available, less expensive, and biodegradable, then using naturally occurring herbs in diets to enhance animal development and meat quality of poultry would be a cheap and safe method that would be more likely to be adopted by many poultry farmers (Ifelayo *et al*., 2020, Kumsa and Hagos, 2020).

In poultry, metabolites of medicinal plants and their bioactive components offer a wide therapeutic spectrum which include; improvement of immune system parameters, intestinal microbiota, antioxidant effects and overall health (Alloui *et al*., 2014). Furthermore, metabolites are regarded as effective ethno-veterinary treatments to a variety of clinical problems. This is because they have a less negative side (Kumsa and Hagos, 2020). Plant-based herbs can also be used in a variety of processed forms, including liquid, ointment, powder, and incisions (Apata, 1979). Research continues to add new feed additives and feed supplements in the poultry industry, by determining their efficacy, in order to minimize expenditure and maintain better health (Carocho *et al*., 2014, Tona, 2018, Neveling and Dicks, 2021).

1.3 Research Objective

1.3.1 Main Objective(s)

To evaluate the phytogenic effects of *Aloe vera* (*Aloe barbadensis* Miller) and ginger (*Zingiber officinale*), as supplements, on growth performance, carcass components and meat quality of sexed Ross 308 broilers.

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1.3.2 Specific Objectives

To determine the effects of supplementary *Aloe vera* and ginger extract in drinking water for male and female Ross 308 broiler chickens on the following:

a) Growth performance (body weight, weight gain, feed intake, and feed conversion ratio)

b) Carcass characteristics (carcass components; breast, thigh, wing and selected internal viscera)

c) Meat quality (colour, dripping loss, pH, texture, and water holding capacity)

1.4 Research Hypothesis

Supplementing *Aloe vera* and ginger extracts in drinking water does not affect growth performance, carcass components and meat quality in male and female Ross broiler chickens.

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CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

One of the major sources of animal protein in South Africa is chicken. Chicken is also a good source of health-promoting polyunsaturated fatty acids (Popova, 2017). Compared to beef, mutton, pork, and lamb, chicken has the advantage of a faster production cycle. Within 5 to 6 weeks, modern broilers grow from 1.5 to 2.0 kg live weight (Islam *et al*., 2017, Abougabal, 2020). Furthermore, broilers can be raised intensively in large numbers, from hundreds or thousands to hundreds of thousands per farm per year.

Chickens are also a cheap source of protein that help ensure global food security (Saleh *et al*., 2020). However, birds farmed under standard intensive production systems, as well as super-intensive systems and areas that experience extreme weather conditions, tend to be susceptible to contagious diseases and are exposed to stress (Meseret, 2016). Tropical and sub-tropical climatic conditions are conducive to the reproduction of parasites, leading to high disease burden, mortality, and economic loss (Ebrahim *et al*., 2020). Antibiotics are still commonly used in poultry (Sahoo and Tamhankar, 2010, Landers *et al.,* 2012, Boamah and Agyare, 2016). The cost of supplementing with commercial antibiotics has been recognized by Mnisi *et al*., (2021) as one of the largest expenses in animal production. This is because indiscriminate use of antibiotics in animal production can lead to antibiotic resistance among pathogens, with the risk of genetic evolution and transmission of resistant strains to humans (Zeng and Zhang, 2015, Agyare *et al*., 2018, Aabed *et al*., 2021, Grakh *et al*., 2022, Binsker *et al*., 2022).

Antibiotics have been extensively used as subtherapeutic, growth-promoting additives in poultry (Miles *et al*., 2006, Landy *et al*., 2012, Yazdi *et al*., 2014, Wati *et al*., 2015). The gut comprises of bacteria, both probiotics or symbiotic and pathogenic bacteria (President, 2008, Haque and Haque, 2017). Probiotics are beneficial because they can fight against harmful pathogens, build the immune system response, and promote the assimilation and absorption of food, thereby supporting digestion (President, 2008, Haque and Haque, 2017). Pathogenic bacteria may cause infections, cause sickness and even death. The factors that enhance harmful bacteria are external forces such as feed, environmental toxins, as well as the effects of stress on broilers (Li *et al*., 2020). Probiotics also augment the ability of the host to resist infections. Therefore, adequate probiotic bacteria need to be present, to overcome the effects pathogenic bacteria may have on gut flora for the promotion of healthy wellbeing.

The risk of using antibiotics on both poultry and human health is of major concern (Borazjanizadeh *et al*., 2011). This is because antibiotics can lead to an imbalance of gut microflora (Andremont, 2000), and induce drug resistance, with proof of zoonotic resistant strains (Wegener *et al*., 1999,

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Singer and Hofacre, 2006). Antibiotic residues may also accumulate in animal products and the environment (Ghalamkari *et al*., 2012, Goodarzi *et al*., 2014). Consequently, producers increasingly strive to minimize using AGPs as growth promoters. Alternatives such as phytogenic additives present an opportunity for safer control of poultry gut health (Guarino *et al*., 2020, Khan *et al*., 2021) and metabolic modulation (Khan *et al*., 2022), to promote growth.

2.2 Phototherapy in livestock production

Phytotherapy is the study of using therapeutic plants that date back to the beginning of livestock domestication (Smith-Schalkwijk, 1999, Yasmin *et al*., 2020). Although they may have negative side effects, phytocherapy is made from medicinal plants, and their active compounds may be used to treat diseases and alleviate their effects (Trojan-Rodrigues *et al*., 2012). Many countries have pushed for the regulations to limit the use of these products, which require reliable empirical evidence (Brunetti *et al*., 2020). To optimize phytotherapy in poultry production, the use of plant extracts should ensure that postmortem enzymatic processes do not alter the composition of the product and ensure that microbiological stability of extracts is achieved.

Phytogenic feed additives (PFA) or phytobiotics are defined by Pandey *et al*., (2019) as plant products derived from plants. Phytobiotics are supplemented to animals through feed or drinking water, to promote efficient growth and improve the quality of end products (Jalal *et al*., 2019, Johnny *et al*., 2022). Phytobiotics originate from roots, tubers, leaves or fruits of herb spices, and other plants. Phytogenic feed additives may be processed into powdered forms, solid, dried, and/or as extract forms (Vidanarachchi *et al*., 2005). The potential of a probiotic to bind to receptor sites in the intestinal tract determines its efficacy (Hemaiswarya *et al*., 2013). Mechanisms of action include improved nutrient digestion and absorption, the elimination of gut pathogens and the promotion of good bacteria (De Wasch *et al*., 2001, Balunas and Kinghorn 2005, Semmler *et al*., 2009), to improve gut health. *Aloe vera* and ginger have received special attention as natural immunostimulants and antioxidants in poultry (Jalal *et al*., 2019). Oral administration through feed is the most effective technique (Upadhaya and Kim, 2017).

Aloe vera gel administered to broilers' drinking water, improved growth, and gut immunity, with improved resistance to infectious diseases (Shokraneh *et al*., 2016 and Amber *et al*., 2021). In addition, ginger extract administered to broilers' drinking water, improved growth, and gut immunity, with improved resistance to infectious disease (Sa'aci *et al*., 2018 and An *et al.,* 2019). Currently, research on the effects of medicinal plants on broiler chickens suggests that these chemicals might work well as an alternative to antibiotic growth boosters (Pliego *et al*., 2022).

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2.3 Botany and phytogenic potential of *Aloe vera* L. *(Aloe barbadensis Miller)*

Aloe vera is amongst the highly regarded therapeutic plants that have many bioactive compounds (Harshavardhan, 2021). It is the rhizome of the plant *Aloe* officinale. *Aloe vera* (*Aloe barbadensis Miller*) is phytogenic and a member of the Liliaceous family (Elbanna *et al*., 2013). There are more than 300 species of aloe. However, A. vera L. is the most popular and most utilized species for therapeutic, cosmetic, and nutraceutical uses (Tiwari and Upadhayay, 2018).

Aloe vera consists primarily of water (99.0-99.5 %) and solid matter (0.5-1.0 %). Furthermore, it contains almost 75 different chemicals (Radha and Laxmipriya, 2015). Aloe vera gel is composed of polysacchirides (55%), sugars (17%), proteins (7%), lipids (4%), and phenolic chemicals (1%), on a dry matter basis (Kumar *et al*., 2019). Pectins, hemicelluloses, glucomannans, and acetylated mannans, commonly known as acemannans and mannose derivatives, are among the polysaccharides found in *Aloe vera*. Mannose-6-phosphate is their main sugar component (Joseph and Raj, 2010, Hamza, 2022). These acemannan sugars are responsible for boosting immunity (Hamza, 2022). Supplementing chicks' water with *Aloe vera* reportedly improved gut health and gut growth (Zayed *et al*., 2020).

2.3.1 Uses of *Aloe vera* (*Aloe barbadensis miller*)

Aloe vera, a succulent, is a well-known therapeutic plant which has been used for centuries (Joseph and Raj, 2010, Sandeep and Yadav, 2014, Tiwari and Upadhayay, 2018). *Aloe vera* has a long history of being useful medication for the alleviation of numerous diseases, both human and animal diseases. However, its use has since increased markedly (Kumar *et al*., 2019). *Aloe* has about nineteen to twenty-two amino acids, all needed for healthy living (Tiwari and Upadhayay, 2018). Out of the eight essential amino acids required, *Aloe vera* has seven (Tiwari and Upadhayay, 2018).

Aloe vera contains *Aloe*-emodin and isobarbaloin, the two compounds which act as analgesics, antibacterial, and antivirals (Sandeep and Yadav, 2014). *Aloe* also contains a bradykinase enzyme that is responsible for slowing down inflammation (Cock, 2015). It also contains several other enzymes, such as alkaline phosphate, carboxypeptidase, superoxide dismutase catalase, cyclooxidase, cyclooxygenase, oxidase, phosphoenolpyruvate, amylase, carboxylase, and lipase, which are essential for breaking down or catalysing sugars and fats, as well as keeping the digestive system running smoothly (Cock, 2015). It has a collection of components, including compounds and lipids such as salicylic acid, which also possess anti-inflammatory and anti-bacterial benefits, and can treat excessive inflammation, by increasing the amount of moisture to the inflamed area and dissolving the substances that lead to the skin cells sticking together (Misir *et al*., 2014, Sandeep and Yadav, 2014).

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Choline, folic acid, and Vitamins A, B12, C, E are some of the nutrients of *Aloe vera*. Of these vitamins, Vit A and E show antioxidant properties and antioxidant-free radicals. Moreover, it contains the hormones gibberellins and auxins, which are good in anti-inflammatory and wound healing functions. *Aloe vera* is water-dense and therefore, an ideal remedy for dehydration. Hydration in animals is prominent because hydrated bodies can detoxify impurities, and liver and kidney functions are largely responsible for blood detoxification and urination. Studies by Zhang *et al*., (2021), and Shi *et al*., (2023) have shown that the relationship between intestinal water content increase and stimulation of peristalsis is good for stool excretion (Diebakate-Scordamaglia *et al*., 2022).

2.4 Botany and phytogenic potential of Ginger *(Zingiber Officinale)*

Ginger (ginger root) is a monocotyledonous plant for which many varieties are described. It is the rhizome of the herbaceous plant Zingiber officinale, a member of the Zingiberaceae family, which is widely used as a spice, medicine, and delicacy (Remans *et al*., 2011, Karangiya *et al*., 2016). The *Zingiberaceae* are well known for their strong aromatic properties and chemotherapy, with both tuberous and non-tuberous species (Chen *et al*., 2008). The plant family also includes the well-known herbs galangal, cardamom, and turmeric. There is evidence that suggests that using ginger formulations as feed additives helps poultry birds gain weight, consume more feed, live longer, and lower mortality (Oleforuh-Okoleh *et al*., 2014).

There are numerous types of monocotyledonous plants, known as ginger (ginger root). It is the rhizome of the herbaceous plant Zingiber officinale. They are a member of the Zingiberaceae family, which is widely used as a spice, medicine, and delicacy (Remans *et al*., 2011, Karangiya *et al*., 2016). Both tuberous and non-tuberous species of Zingiberaceae are well-known for their potent aromatic qualities and chemotherapy (Chen *et al*., 2008). The plant family also includes the well-known spices galangal, cardamom, and turmeric.

2.4.1 Uses of Ginger (Zingiber officinale)

Ginger is a very useful herb, used as the basis for most medicinal therapy. According to Aldebasi *et al*., (2013), Rahmani, (2014), and Ballester *et al*., (2022), ginger and its constituents, based on clinical trials and animal models, are important in the prevention of diseases, through the modulation of genetic and metabolic activities. The most active compounds in ginger, the rhizome of *zingiber* officinale, such as gingerols, are essential for healthy living.

Gingerols and gingerol compounds and a couple of other compounds that are constituted in ginger, such as ginger flavonoids, paradol, zingerone and shogaol, are responsible for antioxidant

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activity. Prakash, (2010) concluded that ginger was a good herb and a good source of antioxidant activity. Furthermore, most of its antioxidant components displayed very high activities in alcoholic media. Hence, except for its therapeutic properties, ginger can be used as a good source of antioxidant activity. Antioxidants are substances that can inhibit free radicals and potentially oxidizing agents in living organisms; thus, they are useful in preventing diseases (Neha *et al*., 2019).

Table 2. 1 (Thorat *et al*., 2013 and Embuscado, 2015): Botanical classification of *Aloe vera* (*Aloe barbadensis*) and ginger (*Zingiber officinale*)

	Aloe vera	**Ginger**
Domain	Eukaryotes	Eukaryotes
Kingdom	Plantae	Plantae
Phylum	Magnoliophyta	Magnoliopyta
Class	Liliopsida	Liliopsida
Order	Aspagales	Zingiberales
Family	Aloaceae	Zingiberaceae
Genus	*Aloe* L	Zingiber Mill
Species	*Aloe vera*	Zingiber officinale

Sources: (Thorat *et al*., 2013 and Embuscado, 2015).

2.5 Effect of *Aloe barbadensis* miller on growth performance of broiler chickens

Ghasemi-Sadabadi *et al*., (2020) reported increased body weight gain and an effect on feed intake and FCR in Japanese quails, supplemented with *Aloe vera* powder, in diets at 0.6% concentration, at 22-35 days and throughout the experimental period. In another study, Cobb-400 broiler chickens were subjected to four diets, which were Control (Feed without additive), Feed Containing Tulsi Leaf Powder, *Aloe vera* leaf powder, and both Tulsi and *Aloe vera* leaf powder, all at a concentration of 0.5% (Gohel *et al*., 2019). It was reported that the birds on a diet containing *Aloe vera* leaf powder had the highest feed intake, followed by birds on control (diet without additive), diet containing both Tulsi and *Aloe vera* leaves powder, and those on a diet

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containing Tulsi leaf powder, while *Aloe vera* alone at 0.5% in diet did not have a marked impact on body weight gain and FCR of Cobb-400 (Gohel *et al*., 2019).

Male broiler chickens of Cobb strain on Standard ration, standard ration plus 0.1%, 0.2 %, and 0.3 % Aloe vera, showed increased feed intake when the birds were supplemented with 0% and 0.3% Aloe vera in their standard ration, while increased body weight gain and higher FCR were observed in birds that received their standard ration with 0.1%, 0.2%, and 0.3% Aloe vera for a period of 6 weeks (Singh *et al*., 2017). Ross 308 broiler chickens were subjected to the following treatment control, the inclusion of 0.2 and 0.4% Aloe vera, as well as the inclusion of 0.2 and 0.4% liquorice extracts in drinking water. Increased feed consumption was observed in broiler chickens on 0.2% AV at 21 and 42 days of age, and increased FCR at 21 days of age, while at 42 days of age broiler birds on 0.2% AV had a higher body weight gain (Salary *et al*., 2014).

Broiler birds were fed a standard ration (Control) supplemented, with *Aloe vera* powder at the rate of 1.0, 1.5, and 2.0 g/kg. It was reported that *Aloe vera* powder in all treatment groups did not affect the body weight of birds, body weight gain and feed intake of broiler birds, while better FCR was reported for birds which fed on a diet with 2.0 g/kg AV powder, followed by FCR of birds which fed on a diet with 1.5g/kg and basal diet with poor FCR, reported for birds which fed on a diet with 1.0 g/kg AV powder (Lotha and Vidyarthi, 2020). Low mortality was reported in Aloe treated groups, especially the group which fed on a diet with 2.0 g/kg AV powder, as compared with birds in the control, for a period of 10 weeks. It was indicated that the mortality rate was within the standard limits (Lotha and Vidyarthi, 2020).

Arif *et al*., (2022) assessed the impact of *Aloe vera (AV)* and Clove powder (CV) supplementation on the growth performance of broiler chickens, subjected to the following treatments: standard diet with enramycin at 0.02% as control, diet supplemented with 0.5 % AV, 0.5 % CV powders, and 0.25 AV plus 0.25 % CV powders. It was observed that the body weight gain, feed intake, and FCR of birds on 0.5% AV powder diet were better than those of birds in the Control. Cobb-400 broiler birds were fed a standard diet (control), standard diets supplemented with *Aloe vera* Powder at 1.0, 1.5, 2.0 g/kg and reported no mortality in all treatment groups (Jamir *et al*., 2019).

2.6 Effect of Zingiber officinale on growth performance of broiler chickens

Broiler birds of Cobb-400 strain were subjected to four experimental diets (Rio *et al*., 2019). These consisted of ginger powder at 0; 0.25; 5.0; 7.5 g/kg. These had a significant effect on body weight, body weight gain, and FCE was reported in all birds on ginger powder diets, compared to a diet with a 0 g/kg ginger powder and feed intake. Mortality was reported to be not significantly different from each other across treatments (Rio *et al*., 2019). Sadeghi and Moghaddam, (2018) reported

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the highest overall body weight of Cobb 500 birds in birds on basal diet + 0.5 % ginger powder, as compared to the same birds on control basal diet and birds on basal diet + 0.5 % turmeric, basal diet + 0.5 % cinnamon, and basal diet + 0.5 % garlic, along the whole length of the experiment.

A multi-strain probiotic (Lactobacillus casei, Lactobacillus acidophilus, Enterococcus faecium, and Bifidobacterium thermophilum) or 0.15, 0.20, and 0.25% ginger powder were added to the basal diet of Ross-308 broiler birds (Qorbanpour *et al*., 2018). It was found that there was no mortality throughout the experimental period, while FCR, daily feed intake, and weight gain were not affected by experimental diets throughout the experimental period (Qorbanpour *et al*., 2018). In another study, it was concluded that broiler chickens could be supplemented with 0.5 % ginger meal in their diets, to increase their weight gain, in a study where Arbor-acres birds were fed diets containing ginger meal at levels of 0.0, 0.5, 1.0 and 1.5 % (Egenuka *et al*., 2021).

In another study, the effects of adding ginger root powder at graded levels of 0.0% ginger root powder diet (control), 0.5%, 0.75% and 1% dietary levels, as a natural feed additive on the growth performance of Ross, was targeted, and it was observed that when they were 4 and 5 weeks old, birds on a 0.5 % ginger powder diet had highest feed intake, compared to birds on the Control. On their 5th week, Ross broiler chickens reported the lowest body weight gain when given 0.5% ginger root powder in diets, compared to the control (0.0% ginger root powder), and diets with either 0.75% or 1% ginger root powder in diets. Furthermore, there was no significant difference in FCR across the treatment groups, although poor FCR was reported for birds on a diet with 0.5% ginger root powder (Ahmed and Abdel Atti, 2014). Overall, there was no significant difference in daily final weight, body weight gain, total feed intake, and FCR of birds. Finally, mortality was reported in all treatment groups (Ahmed and Abdel Atti, 2014).

Cobb 500 birds which received 0.75% ginger reported the highest feed intake, while the same birds receiving 0.5% ginger reported higher weight gain and a lower FCR for best performance, as compared to the same birds receiving either 0.5% or 0.75 % turmeric, as well as the Control group. On the other hand, birds receiving neither Ginger nor turmeric, in a study that assessed the effects of administering ginger, turmeric, and their combination to broiler chicken diets, as treatments control (neither turmeric nor ginger), 0.5 and 0.75% turmeric and 0.5 and 0.75% ginger in diets (Kafi *et al*., 2017). Fakhim *et al*., (2013) showed that the supplementation of ginger extracts in drinking water at the rates of 0, 0.25, and 0.5%, did not affect feed consumption, FCR, and the body weight gain of Cobb 500 at 11 to 21, 22 to 42 and 1 to 42 days of age, in a study where broilers were fed a wheat-soybean meal-based diet, with water supplemented with various doses of ginger extract (0, 0.25, 0.5, 0.75 and 1%).

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Eltazi, (2014b) evaluated the response of Ross 308 to diets with various mixture levels of ginger and garlic powder as natural feed additives and reported that treatments had no significant effect on the mortality of birds. Higher mean body weight, body weight gain, improved FCR, and lower feed intake by commercial Giriraja birds, were reported in a basal diet supplemented with 0.5% ginger powder, as compared to other treatment groups; namely, the control (basal diet) group, a basal diet supplemented with 0.5% thyme, and a basal diet supplemented with 0.5% ginger powder + 0.5% thyme powder, at week 8 of the experimental period (Rathod *et al*., 2021). Broiler birds of Cobb strain were fed diets containing air-dried ginger rhizome meal at levels 0; 0.1; 0.2; 0.4; and 0.6 %, and reported no effect of treatment on live weight, daily weight gain and daily feed intake, while FCR did not differ significantly across treatment groups thorough the experimental period (Agu *et al*., 2017).

2.7 Effect of *Aloe barbadensis miller* on carcass characteristics of broiler chickens

Japanese quails fed a diet containing *Aloe vera* leaf powder at the rate of 0.5% reported an improved carcass weight, fat percentage and breast yield, as compared to the control group (a diet containing Enramycin at the rate of 0.02% as an antibiotic growth promoter), and the mixture of both *Aloe vera leaf* powder and clove powder at the rate of 0.25 + 0.25% of feed. On the other hand, all treatment groups, including the diet supplemented with *Aloe vera* leaf powder at the rate 0.5%, did not affect the liver, heart, and gizzard weight significantly. This was observed in a study which was assessing the impacts of AV and clove powder supplementation on the carcass quality of Japanese quails from 7-42 days (Arif *et al*., 2022). Breast and dressing yields were reported to be affected by the supplementation of AV powder at the rate of 0.5% in Japanese quail diets, in a study where birds were on a control diet (no additive in feed), 0.5% AV leaf powder, 0.5% CV powder, and 0.25% AV powder + 0.25% CV powder (Tariq *et al*., 2015). Aloe vera treatment in broilers decreased the accumulation of fat, increased dressing %, spleen weight, liver weight and whole giblet weight, according to research by Eevuri and Putturu (2013).

In a study where the diets supplemented with 4% soybean oil had peroxidation values that varied in 2.06, 45.18, 101.99, and 146.03 (meq/kg) and an antioxidant treatment; including, no antioxidant, both Rosemary powder, Aloe Vera gel powder at 0.6%, and commercial antioxidant, the antioxidant Aloe vera powder at the concentration of 0.6%, it was found that the diet significantly improved carcass yield and abdominal fat in quails at 35 days (Ghasemi-Sadabadi *et al*., 2020). Minor increases in the relative weight of gizzards, the liver and spleen in broiler birds on *Aloe vera* treated diets, including birds treated with AV powder at 0.5 %, were observed, compared to gizzard, liver, and heart weights of birds on a basal diet (control) and birds on a diet with antibiotic enramycin. Furthermore, there were no improvements in the wing cut, drumsticks,

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thighs, and organs, among the treatment group basal diet (control), diets supplemented with *Aloe vera* and diets with enramycin. These were observed in a study where treatment groups included the Control group (basal diet) and basal diets mixed with Aloe *vera* powder at levels of 0.5; 1.0 and 1.5% (Amaechi and Iheanetu, 2014).

The current study was undertaken to evaluate the effects of *Aloe vera* (*Aloe barbadensis miller*) on carcass and visceral characteristics of Ross 308 broiler chickens.

2.8 Effect of *Gingiber officinale* on carcass characteristics of broiler chickens

A study assessed the effects of dietary supplementation of ginger powder on broilers of hybrid Cobb 400 at levels 0, 2.5, 5.0, and 7.5 g/kg feed and found that the values of dressing percentage were lower in birds which were supplemented with 2.5 and 5.0 g/kg ginger diet, compared to birds which received 7.5 g/kg ginger powder diet, while the best average gizzard and spleen weight were reported by Cobb 400 birds supplemented with ginger powder at a level of 5.0 g/kg and the best heart weight in birds which received 2.5 g/kg diet, compared to birds on a 0 g/kg ginger powder diet (Rio *et al*., 2019).

At the slaughter phase, the lowest abdominal fat was reported in Ross 308, fed a basal diet supplemented with 0.25% ginger, compared to Ross 308, fed on a basal diet, supplemented with no additive, multi-strain probiotic Lactobacillus acidophilus, or 0.15%, and 0.20% ginger powder, respectively (Qorbanpour *et al*., 2018). Improved percentages of wings and breasts were reported in Cobb 500 birds, fed diets with ginger at rates of 0.5 %, compared to birds receiving neither ginger nor turmeric and 0.5 and 0.75 % turmeric in their diets (Kafi *et al*., 2017). Similarly, the weight of gizzards also increased slightly in Cobb 500 birds receiving 0.5 % ginger, compared to those in the control group receiving neither ginger nor turmeric (Kafi *et al*., 2017). Fakhim *et al*., (2013) conducted a study on the effects of various ginger extract (Zingiber officinale) aqueous concentrations on performance and carcass characteristics of male broiler chickens in wheat-soybean meal-based diets. The results showed that between the treatments groups (0; 0.25; 0.5; 0.75 and 1%) ginger extracts in drinking water, from 1-42 days of age, there was no significant difference in the cut percentage, abdominal fat percentage, and liver percentage of live weight, whereas the carcass yield differed significantly.

Furthermore, Javed *et al*., (2009) found that when broiler chicks were exposed to an aqueous extract of a plant mixture containing ginger, dressing percentage, breast weight, and leg weights all increased significantly. Regarding ginger, the relative weight of broiler breasts increased when ginger was supplemented in the diets of broilers only (Elagib *et al*., 2013). In a study that evaluated the effect of different inclusion levels of ginger meal on arbour-acres broiler chickens, it was

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observed that all the carcass parameters measured (heart, thighs, drumsticks, wings, liver, gizzard, and breast) were similar across dietary treatments, except for abdominal fat, which was significantly higher in 0.5 % ginger level, in a study where birds were fed diets which contained ginger meal at levels of 0.0; 0.5; 1.0 and 1.5 %, respectively, with the 0.0 % ginger meal diet serving as the control diet in both starter and finisher phases (Egenuka *et al*., 2021).

Eltazi, (2014b) noted that -except for broilers fed 2.0 % ginger powder- all the carcass components measured (breast, drumstick, thigh, and dressing percentage) were significantly improved when ginger powder was added at 0.0 %; 0.5 %; 1.0 % and 1.5 % levels, as a feed additive in the diet of broilers for six weeks. On day 35, no significant differences were observed in percentages of visceral organs (heart, liver, and gizzard) in all treated groups, including the groups treated with ginger at 0.5 %, compared to the control (basal diet). For the same age, the dressing % of Giriraja birds was highest in ginger-powder-treated groups at 0.5 %, compared to the control (basal diet), basal diet containing 0.5% thyme powder, and ginger powder + thyme powder in the basal diet, both at 0.5% (Rathod *et al*., 2021).

From 1-42 days of age, there was an improvement in carcass characteristics in broilers supplemented with different levels of powder/aqueous extract of ginger (Ademola *et al*., 2009, Javed *et al*., 2009). When analysing two herbal spices as feed additives for finisher broilers, Onu, (2010) confirmed that the inclusion of 0.2% 5ginger in the basal diet of broiler chicks did not result in significantly different carcass characteristics.

The current study determined the phytogenic effects of ginger (*Gingiber officinale*) on carcass and visceral characteristics of sexed Ross 308 broiler chickens.

2.9 Effect of *Aloe barbadensis miller* on meat quality of broiler chickens

Biswas *et al*., (2014) evaluated the antioxidant activity of bioactive compounds in apple peels and aloe vera gel extracts and their effects on colour and oxidative stability of a turkey meat sample. They found that the ethanol extract of aloe vera gel significantly influenced the hue angles of the meat, as compared to the methanol, acetone, methanol, and methanol extracts of apple peels and aloe vera gel (Biswas *et al*., 2014). The current study investigated the effects of *Aloe vera* in drinking water on breast meat quality characteristics of Ross 308 broiler chickens. There is limited information on the effects of *Aloe vera* on the breast meat quality indices of broiler chickens. *Aloe vera* belongs to the lily family and therefore it is closely related to onions, garlic, and turnips, which also belong to the lily family (Tiwari and Upadhayay, 2018). Therefore, literature on the effects of onions, garlic, and turnips will be used in support of *Aloe vera* herbs on meat quality characteristics.

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In a study to determine the impact of onion and ginger supplementation in diets using Potchefstroom Koekoek allotted to basal diet as control, basal diet, plus either 15g/kg or 20g/kg onion; basal diet plus either 15g/kg or 20g/kg onion, it was reported that onions did not have any effect on the ultimate pH level of meat. In contrast, meat lightness (L*), redness (a*), and yellowness (b*) were influenced by a dietary onion extract in the diet, at 15g/kg and 20g/kg, as compared to the control group (0g/kg onion extract) in the diet (Mamonong, 2019).

Ross 308 broiler chickens were assigned to a basal diet without an additive, a basal diet with 0.5 g/kg oxytetracycline plus 0.13g/kg tert-butyl hydroxyanisole, a diet with 10 g/kg or 40g/kg onion skin waste, for 42 days. It was reported that that the treatment groups, including the diet containing 10g/kg or 40g/kg of onion skin waste, did not influence muscle pH, drip loss and colour coordinates (Adeyemi *et al*., 2021). The treatment groups, including the garlic extract in a diet at 0.02%, influenced the water holding capacity but did not affect the texture of broiler meat in a study where broiler chickens were offered dietary treatments basal diet without any supplementation, a basal diet with 0.015% bacitracin +2.485% filler, a basal diet with 2.50% turmeric extract, a basal diet with 2.00% Garlic extract plus 0.50% filler, as well as a basal diet with a combination of turmeric and garlic at 2.50% (Purwanti *et al*., 2019).

2.10 Effect of *Gingiber officinale* on meat quality of broiler chickens

In a study that evaluated the effects of ginger root powder and apple cider vinegar as natural feed additives in Ross broiler chickens assigned to the control group (normal diet), apple cider in drinking water at the rate of 1, 2, and 3 %, and ginger powder added to their diet at the rate of 0.25%, 0.50%, and 0.75% of ginger powder, it was reported that treatment groups, including the ginger supplemented diet, did not have any effect on the water holding capacity and colour coordinates (L*, a*,b*) of breast meat of Ross broiler chickens. However, ginger powder in a diet had a significant effect on the pH value of breast meat of broiler chickens (Hayajneh, 2019). Mamonong, (2019) determined the impact of onion and ginger supplementation on diets using Potchefstroom Koekoek, allotted to the basal diet as a Control, basal diet plus either 15g/kg or 20g/kg onion, basal diet plus either 15g/kg or 20g/kg onion. It was reported that ginger at 15g/kg or 20g/kg treatment group did not have any effect on the ultimate pH level of meat, while meat lightness (L*), redness (a*), and yellowness (b*) were influenced by dietary ginger in the diet, at 15g/kg and 20g/kg, as compared to the control group (0g/kg ginger extract) in the diet.

Eltazi, (2014a) fed Ross 308 broiler birds with a basal diet, supplemented with dietary ginger powder at levels 0.0, 1, 1.5 and 2.0% for six weeks. It was reported that colour parameters did not differ significantly with the addition of ginger powder at different levels in the diets. In one study, broiler birds were fed diets comprising ginger (*Zingiber officinale*) and garlic (*Allium*

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sativum) in concentrations of 0, as control, 1%, 2% and 3%, as well as Nigella (*Nigella sativa*), for 45 days. It was reported that the Control, ginger with a concentration level of 3%, and Nigella with a concentration level of 1%, did not significantly influence the redness values of the samples, whereas significant differences were observed in redness (a*) for the Control sample, sample fed on 2% of garlic, sample fed on 2% ginger, and sample fed on 3% of Nigella, while samples fed on the Control sample, followed by the sample treated with ginger in a concentration of 1% and sample treated with Nigella with a concentration of 3%, it was found that the highest value for the lightness (L*) of the meat (Aljabeili, 2015). Cobb strain broiler birds were fed experimental diets, supplemented with air-dried ginger rhizome meal, at either 0%; 0.2%; 0.4% and 0.6% levels, from 0 to 8 weeks and it was reported that meat samples of the group supplemented with air-dried ginger rhizome meal, at 0.4 and 0.6 %, were more tender than the samples from the Control, 0% treatment while air dried ginger rhizome meat did not affect the colour of meat samples when supplemented in diets of 0%; 0.2%; 0.4% and 0.6% levels (Agu *et al*., 2017). Herawati and Marjuki, (2011) observed that the pH level and tenderness of meat samples were higher, while the water holding capacity of broiler meat samples decreased with the addition of red ginger in the ration at 0.5; 1.0; 1.5 and 2.0% levels, compared to meat samples from the control group, ration without red ginger.

The current study investigated the effects of ginger on meat quality and meat colour parameters.

2.11 Importance of *Aloe vera* and Ginger on the meat quality

Meat quality can be defined as the compositional quality and the palatability attributes of meat, such as colour, water holding capacity and fatness, tenderness, juiciness, flavour, and aroma, which can be evaluated directly or indirectly, depending on which group of elements is being evaluated. These factors influence the suitability of the meat and consumers' rejection and acceptance (Barbin *et al*., 2012). Fatness or marbling has a close relationship with the other attributes of meat quality, and it can contribute negatively or positively to them. In a study which investigated the effect of increasing the efficiency of lean tissue composition in broiler chickens, it was found that modern broiler strains contain about 15% to 20% fat, and greater than 85% of that fat is not physiologically required for the body function of chickens (Choct *et al*., 2000).

Due to their monogastric nature, chickens use mostly the lipids and fatty acids in their diet to meet their physiological requirements for growth and muscle development (Saadoun and Leclercq, 1987). Chicken diet which contains corn, soya meal, sunflower meal, and other green foods, helps to produce meat with reasonably high levels of polyunsaturated fatty acids (PUFA) (Morrissey and Kiely, 2006; Betti *et al*., 2009). However, high PUFA levels in chicken meat make it more vulnerable to lipid oxidation, which in turn leads to unfavourable changes in a number of meat quality parameters, such as colour, texture loss, flavour loss, and water-holding capacity

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(Morrissey and Kiely, 2006, Betti *et al*., 2009), as well as changes in odour, taste, and nutritional value.

It is generally recommended to provide dietary antioxidants in poultry feed, to prevent this and maintain the lipid stability in meat (Surai, 2007). One of them, selenium, is a component of glutathione peroxidase, a crucial enzyme in the metabolism of nutrients and the body's first line of defense against oxidation (Perez *et al*., 2010). Vitamin E can also reduce oxidation. Conjugated linoleic acid (CLA), microelements, amino acids, vitamins, microalgae, and oils high in omega-3 PUFA (polyunsaturated fatty acids) are some additional bioactive ingredients added to chicken meat (Yan and Kim, 2013, Kralik *et al*., 2014). Selenium can be supplemented in diets in both organic or inorganic form, and thus far, it has been supplemented in inorganic form, as either selenite or selenate in farm animals (Lyons *et al*., 2007).

In chickens, organic selenium is more readily absorbed than inorganic selenium (Wang *et al*., 2011); hence it is present in both *Aloe vera* and ginger as organic selenium. In addition to its ability to protect against the oxidation process, the impact of selenium may be an intriguing strategy to alter the fatty acid composition of chicken meat. There is a relationship between heme-protein and lipid oxidation, which occurs concurrently and happens to enhance each other (Chaijan, 2008). Hemeprotein is responsible for meat colour. Heme-protein oxidation is mostly caused by the Fenton reaction (Banerjee *et al*., 2017). The process begins with the oxidation of ferrous (Fe^{+2}) to ferric form Fe^{+3}, after which the Fe^{+2} reacts with oxygen to create the ferric form (Fe^{+3}) and superoxide anion ($O_2\bullet^-$). As a result, the $O_2\bullet^-$ reacts with the fatty acids to form alkyl radicals, which start the oxidation of the lipids. Secondly, met hemeprotein and hydroperoxyl radical (OOH•) or $O_2\bullet^-$, which are transformed into hydrogen peroxide, are produced during the oxy heme-protein oxidation process (H_2O_2). Following this procedure, a highly reactive ferryl heme-protein radical is produced when the resulting met hem-protein combines with H_2O_2 or preformed lipid hydroperoxide (Banerjee *et al*., 2017, Domínguez *et al*., 2019).

Together with the ferryl radical, the oxygens produced when oxy heme-protein is oxidized (H_2O_2, OOH• or $O_2\bullet^-$) can abstract hydrogen from polyunsaturated fatty acids, thereby starting lipid oxidation (Chaijan, 2008). When all these occur, the oxidation of the heme-protein process results in the deterioration of meat and alteration of colour and aroma, which contributes highly to consumer acceptability (Chaijan, 2008). Fat is nonpolar. This means fat affects the water holding capacity of meat and decreases the amount of protein present to attract and hold water, since protein and water have a strong relationship. Water holding capacity is the ability of the muscle to retain water. It is also influenced by pH level, degree of contraction, ionic strength, osmotic pressure and whether the muscle is in pre- or post-rigour (Offer and Trinick, 1983). However,

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when WHC is affected due to fatness, simultaneously juiciness and tenderness of the meat get affected.

Meat tenderness is how hard or soft the meat is at chewing or cutting. It is one chief component of palatability. It is important because most people do not like having difficulty chewing meat (Kamba, 2014). It depends on the content, state of the connective tissue and the structure and state of the myofibrils. The aroma and flavour of the meat should always be normal for people to be interested. The smell and flavour create the sensation the consumer has during eating. There should not be any smell of rancidity on normal meat. Furthermore, fat plays multiple roles in the meat. Thus, fatness in meat must be available, but not excessively, because excessive fat is a product with low economic value and wasted dietary energy. In addition, it negatively impacts customer acceptance and decreases carcass yield, making it an unfavourable trait for both consumers and producers (Ahiwe *et al*., 2018). The current study evaluated the effects of supplemented *Aloe vera* and ginger in the drinking water of chickens on meat quality and colour components of breast meat. Furthermore, the current study investigated the effects of *Aloe vera* and ginger on meat quality parameters colour, pH, hardness, dripping loss, and WHC of breast meat.

2.12 Summary literature review

Extracts of an array of plant species are increasingly considered broiler growth promoters, similar in effects to antibiotics (Elamin *et al.,* 2015). Polysaccharides in *Aloe vera* have immunostimulatory and antibacterial effects that alter the intestinal morphology of birds, by improving their intestinal flora and reducing bacteriolysis, pathogenic and virulent diseases and preventing disease, through the modulation of various biological and genetic activities and thereby resulting in enhanced digestion and improved productive performance (Jalal *et al*., 2019, Ebrahim *et al*., 2020). Shogaols, gingerdione, gingerol, phenolic and gingerdiol are active compounds of ginger which improve the growth performance of broiler chickens, by stimulating feed intake and improving feed conversion ratio (George *et al*., 2013). The extent to which AV and G herbs have therapeutic properties or activity on broiler chickens, depends on the strain forms, and how the herbs are supplemented to broilers.

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CHAPTER 3 RESEARCH METHODOLOGY

3.1 Description of the Study Area

The study was conducted in the Poultry Unit of the University of Venda's experimental farm in South Africa, Limpopo Province, Thulamela Municipality, Vhembe District, Thohoyandou at 22°58'32"S, 30° 26' 45"E, altitude 596m above sea level. Summer temperatures range from 25°C to 40°C. An annual rainfall of 800 mm is seasonal, with 95% of it falling between October and March (Macil *et al*., 2020).

3.2 Source and processing of *Aloe vera* juice

Fresh *Aloe vera* leaves were sourced from the Wintervelde, Iphofolo Game Farm, Vivo, between latitude 34° 35' 0" S and longitude 19° 45' 0" E, Limpopo, South Africa, 72 km west of Louis Trichardt. On this farm, *Aloe vera* is cultivated under irrigation and its leaves are harvested for processing into commercial pharmaceuticals. This study used leaves of a mature, previously harvested crop of *Aloe vera*. Two-three bottommost leaves (≥ 25 cm) were randomly selected from Aloe plants along rows to a total of 25 kg fresh *Aloe* leaves. After collection, the leaves were rinsed thoroughly in clean and sterile water. *Aloe vera* leaves were left to secrete the *Aloe* latex for approximately 30 minutes. To maximize extraction of the juice, the apex, basal, pith, and thorny lateral leaf edges were removed utilizing manual filleting, to expose the inner jelly parenchyma, and the leaf was cut into approximately 30 mm x 30 mm sections and then ground into a slurry for cold mechanical extraction (Chandegara and Varshney, 2013). Before moving on to a de-pulping extractor, which removed the leftover pulp and rind particles produced by the original grinding operation, the resultant liquid was pumped into sterile stainless-steel holding bottles. Aloin and any microscopic fragments of leaf or phenolic particles were removed from the mixture, by passing it through a series of press filters with carbon-coated plates (Upton and Axentiev, 2012). The filter press was used repeatedly until 99.9% or more of the aloin had been extracted from the *Aloe vera* juice. Before the liquid was prepared for stabilization, filtration was performed out as a final purification step using 1% ascorbic acid (Ramachandra and Rao, 2008, Ahlawat and Khatkar, 2011). The extract was preserved with 1% potassium sorbate and stored at room temperature for 30 minutes, followed by refrigeration at 4 °C ± 1 °C (Kaithwas *et al*., 2011). The steps for processing *Aloe vera* juice are shown in Figure 3.1 below:

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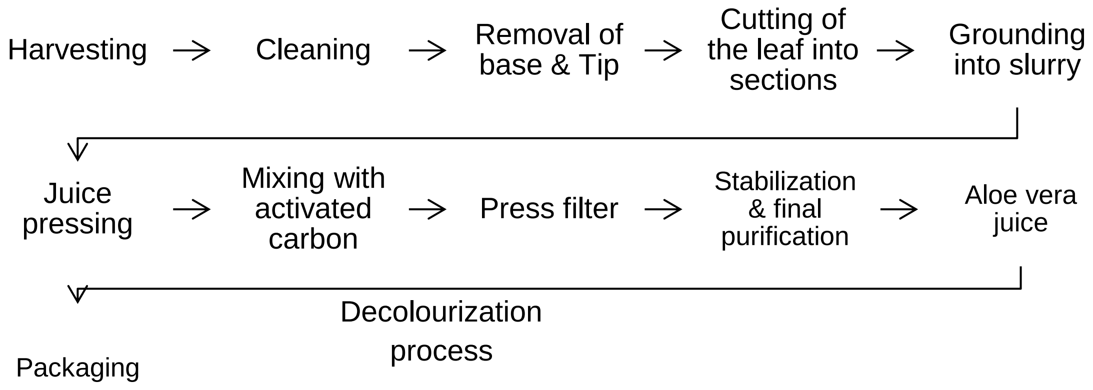

Figure 3. 1: Processing of *Aloe vera* juice
Source: (Ramachandra and Rao, 2008)

3.3 Source and processing of ginger

Fresh ginger roots were procured from Spar in Thohoyandou. The ginger extract was obtained following the procedures described by Wadikar and Premavalli (2012). The fresh ginger roots were rinsed thoroughly with water and cut into approximately 2 mm pieces. The ginger pieces were then blended into a ginger puree, which was then transferred to a Platinum centrifugal juicing machine (Model: KJ-1501, at 2 speed settings) for juice extraction. The ginger juice extract was stored in 1L plastic bottles and transferred into a refrigerator for preservation at 4^{0}C ± 1^{0}C (Kaithwas *et al*., 2011).

3.4 Diets, feeding and watering treatments

A three-phase *ad libitum* feeding regime was used: uniform starter (days 1 - 14), followed by experimental dietary and water additive treatments during the grower (Days 15-36) and finisher (days 37-50) phases. A poultry vitamin stress pack (Virbac Samrand Business Park, Centurion, Pretoria, South Africa) was given to all birds for the first six days following arrival. Feeds were delivered using adjustable height, 390mm diameter tube feeder per pen. Custom feeds with [Silgro feeds, Reg. No. V31122, Prod 2021/12/13] and without [Silgro feeds, Reg. No. V30556, Batch No. Prod 2021/12/13] antibiotics (500g/tonne zinc bacitracin, 15% granular; 500g/tonne valinomycin sodium (12%)) were supplied by Brennco Feeds Mills, Louis Trichardt, Limpopo, South Africa. The composition of the different diets is described in Tables 3.1, 3.2 and 3.3 below:

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Table 3. 1: Target composition of crumbled broiler starter diets[1], pelleted broiler grower and finisher diets[1]. Pellets with and without medication

Composition	Starter	Grower		Finisher	
		Non-medicated	Medicated	Non-medicated	Medicated
	Days 1-14	Days 23-36		Days 37-50	
Crude protein(g/kg)	220.0	180.0	180.0	160.0	160.0
ME (Mj/kg)	17.78	13.0	13.0	13.20	13.20
Moisture (g/kg)	120.0	120.0	120.0	120.0	120.0
Lysine(g/kg)	13.0	10.0	10.0	9.0	9.0
Fibre (g/kg)	50.0	50.0	50.0	70.0	70.0
Calcium min (g/kg)	8.0	8.0	8.0	6.0	6.0
Calcium max (g/kg)	12.0	12.0	12.0	12.0	12.0
Phosphorus (g/kg)	7.0	6.0	6.0	5.0	50
[1]Brennco feeds, Reg. No. V29376		[1]Silgro feeds, Reg. No. V31122		[1]Silgro feeds, Reg. No. V30556	
Prod 2021/08/21 08:45		Prod 2021/12/13 08:28	Prod 2021/12/10 10:56	Prod 2021/12/13 08:29	Prod 2021/12/22 04:05

A 0.2 per cent (v/v) water dosage of ginger (Onu, 2010, Herawati, 2011, Talukder *et al*., 2017) extract and *Aloe vera* (Olupona *et al*., 2010, Darabighane *et al*., 2011) juice were previously recommended to achieve the best performance in broilers. Accordingly, 0% and 0.002% extract dosage treatments were administered in water provided from 12L water founts with a diameter of 360mm and a height of 400 mm. One (1) 12L water fount was available at the starter to finisher stage per pen.

3.5 Birds, management, and experimental design

The study used a total of 480 sexed day-old Ross 308 chicks procured from Alpha company Pty Ltd (Alpha chicks, Pretoria, South Africa) and were housed in deep litter, and naturally ventilated open-sided 17.0 m × 9.0 m house. The house was partitioned by wire mesh into experimental pens of 150 cm length × 144 cm width for a stocking density of 2.3 m^2/15 birds per cage. Before the arrival of day-old chicks, the broiler production management equipment and the experimental house were cleaned and disinfected with ViroGon disinfectant. For bedding, fresh sawdust was provided. Wet sawdust was removed from the research house promptly for the birds' comfort and to prevent pathogenic bacteria from growing.

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At day 14, chickens were randomly assigned to sex*additive treatments in a 2 (sex) × 4 (additive) factorial experiment with 4 replicates denoted as follows.

T1: Ross (female) + medicated feed + normal drinking water (PC)
T2: Ross (female) – no feed medication + normal drinking water (NC)
T3: Ross (female) – no feed medication + AV water additive (AV)
T4: Ross (female) – no feed medication + GE water additive (GE)
T5: Ross (male) + medicated feed + normal drinking water (PC)
T6: Ross (male) – no feed medication + normal drinking water (NC)
T7: Ross (male) – no feed medication + AV water additive (AV)
T8: Ross (male) – no feed medication + GE water additive (GE)

3.6 Measurements

3.6.1 Growth Performance

Body weight and feed intake were recorded weekly. Body weight gain was computed in grams per day per bird. Mortality was collected daily, but mortality data was recorded throughout the experiment. Feed intake and FCR were calculated using the following formulas:

$$FI = TFO - LOF$$

Where:

FI = feed intake

TFO = total feed offered

LOF = left over feed

$$\text{FCR}=\frac{\text{AFI}}{\text{ABWG}}$$

Where:

FCR= feed conversion ratio

AFI = average feed intake per treatment

ABWG = average body weight gain per treatment

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3.6.2 Carcass components visceral organs and tissue

On the 50th day, birds were left for 12hrs without feed but with access to water for slaughter on day 51st. At slaughter, three (3) chickens from each replicate were randomly selected for analysis of carcass characteristics (carcass composition, live weight, and carcass yield) and meat quality. To determine the birds' live body weight, each bird was weighed separately. Thereafter, they were slaughtered (Netshipale, 2012), bled, scalded, and plucked. Using warm water, the birds were de-feathered and the carcasses were eviscerated, following methods by Brake *et al*., (1993). The thighs, breast meat and wing meat were carefully excised and left for 1 h to remove excess water and weighed using an electronic weighing balance. The weights were recorded. The dressed carcass, visceral organs and tissue (liver, spleen, heart, gizzard, spleen, and abdominal fat) were also weighed.

3.6.3 Meat Quality

The colour measurements of the meat were done following a procedure by Mohamed *et al*., (2008). To measure lightness (L*), redness (a*), and yellowness (b*) in breast meat samples, triplicates of each sample were placed on a cell glass that was positioned above the light source and covered with a black cover. A colorimeter (Lab Scan-XE model, Hunter Associates Laboratory Inc., USA) was used for this procedure.

Using a digital scale (Precision balance, J series RS323, South Africa), breast samples were weighed before being refrigerated for 3 days at 4˚C, according to a procedure by Bowker and Zhuang, (2015). Following this equation, all the samples were weighed once again, and drip loss was determined using the formula shown below:

$$Dripping\ loss\ (\%)\ = \frac{wf - wc}{wf} \times 100$$

Where:

wc = the weight of the breast before storage, and

wf = the weight of the chicken after storage.

Tissue slurries were used to assess the pH levels of meat samples. The stomacher (pbinternational. L7) was used to homogenize the mixture. 90 ml of distilled water and 10 g of the sample were blended (Zhang *et al.,* 2012). The pH value of the homogenate was measured using a pH meter (basic 20 pH meter, CRIMSON INSTRUMENTS, SA EU), which was calibrated using a standard 4.00; 7.00 and 9.00 pH buffer in triplicates (Jeacocke, 1977).

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Using the Texture TA-XT Plus Texture Analyzer (Stable Micro System Ltd, Surrey, England), the meat texture was determined. Meat samples were immobilized between stainless steel plates and squeezed using a cylindrical probe, with a 4 cm diameter in two consecutive cycles of 30% compression, with 5s between cycles, perpendicular to the direction of muscle fibers. A constant speed of 1 mm/s was set for the crosshead's movement in the programming. Hardness (g) was calculated, and the parameter was measured using computer software. Hardness (also known as toughness) was the highest force that could be measured during the initial compression cycle.

In a test tube, 12 ml of a 0.6 M sodium chloride solution was mixed with 8 g of breast meat. The sample was centrifuged at 5000 rpm for 30 minutes at 4 degrees Celsius, and the supernatant was collected afterwards. WHC was then calculated and expressed as a percentage (Wardlaw *et al.,* 1973).

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3.7 Statistical analysis

Data were subjected to analysis of variance (ANOVA) for a two-factor experiment, using Minitab 17 General Linear Models (GLM). Data for growth characteristics were analyzed, using model 1 and data for carcass components visceral organs and tissue and meat quality, were analyzed using model 2.

Model 1

$$\mathbf{Y}_{ijkl} = \mu + \boldsymbol{\alpha}_i + \mathbf{G}_j + W_k + (\boldsymbol{\alpha}\mathbf{G})_{ij} + (\boldsymbol{\alpha}\mathbf{W})_{ik} + (\mathbf{GW})_{jk} + (\boldsymbol{\alpha}\mathbf{GW})_{ijk} + e_{ijkl}$$

Where:

$\mathbf{Y}_{ijkl}$ = the l^{th} observation on birds on the i^{th} additive, of the j^{th} sex, during the k^{th} week

μ = the overall mean,

α_i = the effect of additive ($i_{1,2,3,4}$),

G_j = the effect of the j^{th} sex ($j_{1,2}$),

W_k = Effect of the k^{th} week ($k_{4,5,6,7}$),

$(\alpha G)_{ij}$ $(\alpha W)_{ik,}$ $(GW)_{jk}$,$(\alpha GW)_{ijk}$ = respective sex, additive and week interactions,

e_{ijkl} = the random error.

Model 2

$$\mathbf{Y}_{ijk} = \mu + \boldsymbol{\alpha}_i + \mathbf{G}_j + (\boldsymbol{\alpha}\mathbf{G})_{ij} + e_{ijk}$$

Where:

y_{ijk} = k^{th} observation of birds on the i^{th} additive and of the j^{th} sex

μ = the overall mean,

α_i = the effect of additive ($i_{1,2,3,4}$),

G_j = the effect of the j^{th} sex ($j=_{1,2}$),

$(\alpha G)_{ij}$ = respective additive and sex interaction,

e_{ijk} = the random error.

3.8 Ethical Considerations

Ethical approval was granted by the University of Venda, Research Ethics Committee (certificate number: FSEA/22/ANS/03/0909).

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3.9 Declaration of research error

The current study intended to supplement 2% Aloe vera extract (AVE) and 2% Ginger extract (GNE) in drinking water of broiler chickens. However, while preparing for the experiment, there was an error in converting the 2% to ml, which led to broiler chickens drinking water supplemented with 0.2% AVE and 0.2% GNE throughout the experiment. Therefore, there is little information on the effects of 0.2% AVE and 0.2% GNE on growth performance parameters of broiler chickens, which have affected the discussions of the results of the current study.

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CHAPTER 4: RESULTS

4.1 Effect of X and Y on broiler growth performance and bird mortality

The effect of additive and sex by week on growth performance parameters of Ross 308 broiler chickens during the grower, finisher, and full experimental period are presented in Table 4.1.

During the grower phase, there was a significant sex effect (*P<0.05*) on the initial (day 23) body weight of birds. Male birds were heavier (831 g ± 21.740) than the females (795 g ± 21.740). However, there was no significant additive and additive by sex interaction effect on the initial body weight of birds. Furthermore, birds on the PC had a significantly higher (*P<0.01*) live weight gain (84 g/b/d ± 4.240) than other additive groups (about 58 g ± 4.240), similar (*P>0.05*) FCR (1.8 ± 0.153) to that of birds on the AV of 2.3 ± 0.153 but better (*P<0.05*) compared to that of birds on the GE and NC of about 2.4 ± 0.153.

During the finisher phase, PC birds grew (71.23 g/b/d ± 2.660) significantly faster (*P<0.01*) at a similar (*P<0.01*) intake (165.66 g ± 3.870) to birds on other additives (30.0 g/b/d ± 2.660 (WG)) and (131.85 g ± 3.870 (FI)), to attain significantly low weight (*P<0.01*) FCR (2.39 ± 0.241). Male birds consumed significantly more (*P<0.05*) feed (145.54 g ± 2.740), but growth rate (43.02 g/b/d ± 1.880) and FCR (3.99 ± 0.170) were similar (*P>0.05*) among male and female (39.13 g/b/d ± 1.880) and (4.01 ± 0.170) birds.

Cumulatively, compared to other additives, PC (77.69 g/b/d ± 2.500) birds grew faster (*P<0.01*) and consumed more (149.52g ± 2.270) feed (*P<0.01*), with significantly lower (*P<0.01*) FCR (2.07 ± 0.143). The male birds consumed (54.34 g ± 1.770) significantly more (*P<0.05*), compared to female birds (52.58g ± 1.770).

No mortality occurred during the grower phase (0.00 % ± 0.000), with similar mortality across the treatments during the finisher phase (2.08 % ± 1.050). Across weeks, mortality was significantly (*P<0.05*) high during week 6 (2.92 % ± 0.521).

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Table 4. 1: Effect of additive and sex by week on production performance of Ross 308 broiler chickens during the grower (days 23-37) and finisher (days 38-50) phases.

		Growth parameters													
		Grower (23 to 37 days)					Finisher (38 to 50 days)					Cumulative			
Treatments		**Initial LW (day 23) (g)**	**Weight gain (g/b/d)**	**Feed intake (g)**	**FCR**	**Mort (%)**	**Final LW (day 50) (g)**	**Weight gain (g/b/d)**	**Feed intake (g)**	**FCR**	**Mort (%)**	**Weight gain (g/b/d)**	**Feed intake (g)**	**FCR**	**Mort (%)**
Additives															
	AV	794.68	60.98^{b}	134.21	2.29^{ab}	0.000	2098.13^{a}	32.43^{b}	131.85^{b}	4.47^{a}	0.830	46.71^{b}	132.69^{b}	3.382^{a}	0.417
	GE	835.88	56.94^{b}	135.11	2.47^{a}	0.000	2053.44^{a}	30.02^{b}	132.04^{b}	4.40^{a}	2.920	43.48^{b}	132.11^{b}	3.435^{a}	1.458
	NC	820.63	61.29^{b}	133.09	2.38^{a}	0.000	2107.50^{a}	30.62^{b}	134.39^{b}	4.75^{a}	0.000	45.96^{b}	133.74^{b}	3.568^{a}	0.000
	PC	766.81	84.15^{a}	136.76	1.75^{b}	0.000	2954.69^{b}	71.23^{a}	165.66^{a}	2.39^{b}	2.080	77.69^{a}	149.52^{a}	2.072^{b}	1.042
	SEM	21.740	4.240	2.800	0.153	0.000	83.773	2.660	3.870	0.241	1.050	2.500	2.270	0.143	0.521
Sex															
	F	778.06^{b}	66.03	132.55	2.19	0.000	2245.63	39.13	136.43^{b}	4.01	1.458	52.58	133.78^{b}	3.105	0.729
	M	830.94^{a}	65.66	136.76	2.25	0.000	2361.25	43.02	145.54^{a}	3.99	1.458	54.34	140.25^{a}	3.123	0.729
	SEM	15.373	3.000	1.980	1.108	0.000	459.273	1.880	2.740	0.170	0.744	1.770	1.610	0.101	0.369
Week															
	4	804.50	68.86	120.11^{b}	1.92^{b}	0.000						68.86^{a}	120.11^{c}	1.924^{c}	0.000^{b}
	5		62.82	149.20^{a}	2.52^{a}	0.000						62.82^{a}	149.20^{a}	2.522^{b}	0.000^{b}
	6							43.89^{a}	147.48^{a}	3.84	2.917^{a}	43.89^{b}	147.48^{a}	3.837^{a}	2.917^{a}
	7						2303.44	38.26^{b}	134.49^{b}	4.17	0.000^{b}	38.26^{b}	131.26^{b}	4.172^{a}	0.000^{b}
	SEM	10.870	3.000	1.980	0.108	0.000	41.887	1.880	2.740	0.170	0.744	2.500	2.270	0.143	0.521
Sex	**Additives**														
Significance															
Additives		NS	**	NS	**	NS	**	**	**	**	NS	**	**	**	NS
Sex		*	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	*	NS	NS
Week		**	NS	**	**	NS	**	*	*	NS	*	**	**	**	*
A x S		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

For each factor or combination of factors, means in the same column not sharing a common superscript are significantly different (*P<0.05*). **: (*P<0.01*); *: (*P<0.05*); (NS) Not Significant: (*P>0.05*). Additives; AV: *Aloe vera* juice (2ml/L of water); GE: Ginger extract (2ml/L of water); NC: Negative control=11L water; PC: Positive control=11L water; LW: Live Weight; Mort: Mortality; FCR: Feed Conversion Ratio; SEM: Standard Error of Means; A: Additives; S: Sex; %: Percentage

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4.2 Carcass components and visceral organs and tissue

The effect of additives and sex on carcass components, visceral organs and tissue of Ross 308 is presented in Table 4.2. Birds on the PC recorded higher (*P<0.01*) weights for all carcass components: breasts (885.0 g ± 21.600), thighs (324.58 g ± 8.620) and wings (112.92 g ± 4.150), visceral tissue and organs: hearts (15.22 g ± 0.547), spleen (3.59 g ± 0.098), gizzards (71.61 g ± 1.930), livers (56.33 g ± 1.370), and abdominal fat (20.52 g ± 0.152), compared to birds on other additives, where the breast was (535.8 g ± 21.600), thigh (201.25 g ± 8.620) and wing (82.50 g ± 4.150), heart (9.06 g ± 0.547), spleen (2.33 g ± 0.139), gizzard (55.26 g ± 1.930), liver (33.51 g ± 1.370), and abdominal fat (16.20 g ± 0.152). Male birds deposited significantly (*P<0.01*) lower (17.62 g ± 0.107) abdominal fat compared to female birds (18.11 g ± 0.107).

However, on a proportionate basis, at slaughter, the breast meat of birds on PC weighed significantly higher (33.89 % ± 0.962) than that of birds in other additive groups (29.84 % ± 0.962) (*P<0.05*). In addition, the wings of female birds were significantly bigger (4.83 % ± 0.125) than those of male birds (4.40 % ± 0.125) (*P<0.05*). The findings also showed that the birds on PC had significantly lower (0.79 % ± 0.026) abdominal fat, compared to birds on other treatment groups (0.96 % ± 0.026) (*P<0.01*). Finally, the females had significantly more abdominal fat percentage (0.93 % ± 0.019), compared to the males (0.87 % ± 0.019) (*P<0.05*).

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Table 4. 2: Effect of additive and sex on weight (grams) of carcass components, visceral organs, and tissue of Ross 308 broiler chickens.

Treatments		Carcass components, Visceral organs & tissue							
		Breast	**Thigh**	**Wing**	**Heart**	**Spleen**	**Gizzard**	**Liver**	**Abdominal fat**
		g							
Additives									
	AV	577.9[b]	223.75[b]	86.25[b]	10.236[b]	2.325[b]	55.26[b]	36.11[b]	17.024[c]
	GE	535.8[b]	201.25[b]	82.50[b]	9.060[b]	2.607[b]	55.66[b]	33.51[b]	16.203[d]
	NC	548.3[b]	212.50[b]	88.75[b]	10.318[b]	2.528[b]	56.40[b]	35.46[b]	17.722[b]
	PC	885.0[a]	324.58[a]	112.92[a]	15.214[a]	3.590[a]	71.61[a]	56.33[a]	20.517[a]
	SEM	21.600	8.620	4.150	0.547	0.139	1.930	1.370	0.152
Sex									
	F	626.2	234.17	95.42	11.121	2.734	59.91	39.269	18.110[a]
	M	647.3	246.87	89.79	11.306	2.791	59.55	41.433	17.623[b]
		15.300	6.100	2.940	0.387	0.098	1.370	0.972	0.107
Sex	**Additives**								
Significance									
Additives		**	**	**	**	**	**	**	**
Sex		NS	NS	NS	NS	NS	NS	NS	**
A x S		NS	NS	NS	NS	NS	NS	NS	NS

For each factor or combination of factors, means in the same column not sharing a common superscript are significantly different (*P<0.05*). **: (*P<0.01*); *: (*P<0.05*); (NS) Not Significant: (*P>0.05*). Additives; AV: *Aloe vera* juice (2ml/L of water); GE: Ginger extract (2ml/L of water); NC: Negative control=12L water; PC: Positive control=12L water; A: Additive: S: Sex.

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Treatments		Carcass components, Visceral organs & tissue								
		Dress weight	Breast	Thigh	Wing	Heart	Spleen	Gizzard	Liver	Abdominal fat
		%								
Additives										
	AV	87.74	31.447[ab]	12.166	4.677	0.559	0.127	3.019	1.959	0.933[a]
	GE	87.29	29.946[b]	11.224	4.638	0.510	0.147	3.140	1.887	0.916[a]
	NC	87.97	29.844[b]	11.572	4.833	0.562	0.137	3.078	1.934	0.965[a]
	PC	88.88	33.894[a]	12.415	4.315	0.584	0.137	2.745	2.160	0.787[b]
	SEM	1.900	0.962	0.328	0.177	0.032	0.007	0.124	0.076	0.026
Sex										
	F	88.58	31.256	11.718	4.830[a]	0.559	0.137	3.057	1.963	0.929[a]
	M	87.36	31.309	11.971	4.402[b]	0.550	0.137	2.934	2.008	0.871[b]
	SEM	1.350	0.680	0.232	0.125	0.022	0.005	0.087	0.054	0.019
Sex	**Additives**									
Significance										
Additives		NS	*	NS	NS	NS	NS	NS	NS	**
Sex		NS	NS	NS	*	NS	NS	NS	NS	*
A x S		NS	NS	NS	NS	NS	NS	NS	NS	NS

For each factor or combination of factors, means in the same column not sharing a common superscript are significantly different (*P<0.05*). **: (*P<0.01*); *: (*P<0.05*); (NS) Not Significant: (*P>0.05*). Additives; AV: *Aloe vera* juice (2ml/L of water); GE: Ginger extract (2ml/L of water); NC: Negative control=12L water; PC: Positive control=12L water; A: Additive: S: Sex.

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4.3 Effect of X and Y on meat quality attributes of broiler chickens

The effect of additives and sex on meat quality of breast meat of Ross 308 broiler chickens is presented in Table 4.3. Additives had a significant effect (*P<0.05*) on the pH of breast meat of birds. Furthermore, the pH of breast meat of birds on PC (6.01 ± 0.039) was higher (*P<0.05*), compared to that of birds using other additives (5.81 ± 0.039). Sex by additive interaction had a significant (*P<0.05*) effect on the pH of breast meat of birds, with increased means at PC by females (6.08 ± 0.055) and AV by males (6.02 ± 0.055).

There was also a significant (*P<0.05*) additive effect on the water holding capacity of breast meat, with the breast meat of birds on AV (10.16 ml ± 0.167) and NC (10.66 ml ± 0.167) holding more water than that of birds in using additives (9.16 ml ± 0.167). Finally, additive, sex, and additive by sex interaction did not have a significant (*P>0.05*) effect on drip loss and hardness of breast meat of birds.

4.4 Colour components

The effects of additive and sex on colour components of breast meat of Ross 308 broiler chickens are presented in Table 4.4. Meat lightness (L* coordinate) was significantly higher on PC (36.19 ± 0.631) than AV (33.85 ± 0.631). Finally, the additives, sex, and additive by sex interaction, did not have a significant (*P>0.05*) effect on all meat colour components of breast meat.

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Table 4. 3: Effect of additive and sex on quality of breast meat of Ross 308 broiler chickens

		Meat quality parameters			
Treatments		**pH**	**WHC (ml)**	**Drip Loss**	**Hardness (kg/mm^2)**
Additives					
	AV	5.91^{ab}	10.16^{a}	0.928	43.78
	GE	5.81^{b}	09.16^{b}	0.823	37.21
	NC	5.84^{b}	10.66^{a}	1.291	44.30
	PC	6.01^{a}	09.41^{b}	0.404	43.31
	SEM	0.039	0.167	0.449	3.060
Sex					
	F	5.87	09.96	1.129	39.80
	M	5.91	09.74	0.594	44.50
	SEM	0.027	0.118	0.318	2.160
Sex	**Additives**				
F	AV	5.81^{bc}	10.44	1.164	42.56
	GE	5.75^{c}	09.04	1.731	36.47
	NC	5.86^{abc}	10.62	1.040	38.95
	PC	6.08^{a}	09.72	0.581	41.20
	SEM	0.055	0.236	0.636	4.320
M	AV	6.02^{ab}	09.89	0.692	45.00
	GE	5.86^{abc}	09.27	-0.084	37.94
	NC	5.81^{bc}	10.69	1.541	49.66
	PC	5.96^{abc}	09.10	0.226	45.42
	SEM	0.055	0.236	0.636	4.320
Significance					
Additives		*	**	NS	NS
Sex		NS	NS	NS	NS
A x S		*	NS	NS	NS

For each factor or combination of factors, means in the same column not sharing a common superscript are significantly different (*P<0.05*). **: (*P<0.01*); *: (*P<0.05*); (NS) Not Significant: (*P>0.05*). Additives; AV: Aloe vera juice (2ml/L of water); GE: Ginger extract (2ml/L of water); NC: Negative control=12L water; PC: Positive control=12L water; SEM: Standard Error of Mean; WHC: Water Holding Capacity; ml: millilitres.

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Table 4. 4: Effect of additive and sex on colour components of breast meat of Ross 308 broiler chickens

Colour components		C_D	h*	C*	a*	b*	L*
Additives							
	AV	5.65	57.38	21.99	11.84	18.40	33.85^{b}
	GE	3.49	57.84	22.12	11.70	18.70	34.29^{ab}
	NC	5.19	59.20	22.48	11.49	19.24	35.70^{ab}
	PC	3.18	60.14	21.68	10.74	18.73	36.19^{a}
	SEM	0.765	1.270	0.404	0.448	0.449	0.631
Sex							
	F	4.23	59.60	22.15	11.17	19.01	35.47
	M	4.52	57.68	21.99	11.72	18.52	34.54
	SEM	0.541	0.895	0.286	0.317	0.317	0.446
Significance							
Additives		NS	NS	NS	NS	NS	*
Sex		NS	NS	NS	NS	NS	NS
A x S		NS	NS	NS	NS	NS	NS

For each factor or combination of factors, means in the same column not sharing a common superscript are significantly different (*P<0.05*). **: (*P<0.01*); *: (*P<0.05*); (NS) Not Significant: (*P>0.05*). Additives; AV: *Aloe vera* juice (2ml/L of water); GE: Ginger extract (2ml/L of water); NC: Negative control=12L water; PC: Positive control=12L water; SEM: Standard Error of Mean; C_D: Colour Difference; h*: Hue; C*: Chroma; a*: CIE red (+) / green (-) colour attributes; b*: CIE yellow (+) / blue (-) colour attributes; L*: CIE lightness coordinate.

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CHAPTER 5: DISCUSSION

5.1 Effects of additives and sex by week on production performance of Ross 308 broiler chickens

Birds on PC gained more weight during the grower phase, with the least growth by birds on the GE. Amaechi and Iheanetu, (2014) reported higher body weight in the antibiotic group (Enramycin antibiotic), with better FCR observed in both AV powder and antibiotic Enramycin-supplemented birds. Salary *et al*., (2014) reported similar findings on weight gain and FCR of Arbor Acres broilers which had been fed flavomycin or virginiamycin at 5 mg kg-1 in the diet during the grower phase. Similarly, Hassan *et al*., (2018) reported improved BWG and FCR in Cobb broilers, which were supplemented with antibiotic Bacitracin Methylene Disalicylate at 0.025% in diets from 26-35 days of age, while Murugesan *et al*., (2015) reported that antibiotic bacitracin methylene disalicylate, at the rate of 500 mg/kg of diet, improved the feed consumption and FCR of Ven Cobb broiler chickens at 1 to 39 days of age. Increased weight gain may be associated with the effects of AGP in improving feed utilization, which could have led to better nutrient absorption and improved growth performance, by controlling and reducing the opportunistic and subclinical infections growth in chicks' guts (Ashraf *et al*., 2019, Foroutankhah *et al*., 2019).

In the grower phase, AV and GE did not induce any discernible effects on growth performance parameters, except weight gain. These findings correlate with Jamir *et al*., (2019), who reported that supplementing with *Aloe vera* powder within the 1.0, 1.5 and 2.0 g/kg feed range did not affect the body weight of broilers, as compared to the standard diet at 3 and 4 weeks of age and contradict Mohamed *et al*., (2012), who reported that supplementing with 0.1 and 0.2 % ginger in diets did not affect the body weight of Ross broiler chickens for the first three weeks of the experiment. Researchers, including Agu *et al*., (2017), Egenuka *et al*., (2021), and Riswanda *et al*., (2021), reported similar findings. At 14 days of age, 0.5% AV gel, 0.75% AV gel, and 1% AV, gel in drinking water did not have any significant effect on the body weight of Ross 308 broiler chickens (Shokraneh *et al*., 2016), while at 28 days of age, AV gel increased the body weight of Ross 308 broiler birds (Shokraneh *et al*., 2016).

Poor growth, in this case, may be due to the low concentration of active compounds found in *Aloe vera* and ginger in the drinking water, as they were included at a dosage of 2ml/l.

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The results of the present study, depicted in Table 4.1, showed that male birds had higher initial body weight than females in initial body weight, at 23-day. Similarly, Benyi *et al*., (2015b), Siaga *et al*., (2017), Madilindi *et al*., (2018), and Gafar *et al*., (2022) reported a significant effect of sex on initial body weight, at 21-day. The superior weight of male birds over female birds could be attributed to physiological differences between the sexes (Madilindi *et al*., 2018, He *et al*., 2020) and other factors, including hormones for growth and fatness, greater competition for food and water, aggressive behaviour of males, such as social dominance, and differences in nutritional requirements (Benyi *et al*., 2015b, Siaga *et al*., 2017).

During the finisher phase, birds in the Treatment Group PC grew significantly faster, consumed more feed, and converted feed better than those in the Treatment Groups AV, GE, and NC. These results are consistent with Mohamed *et al*., (2017), who reported similar growth performance, slaughter performance and immune traits of broiler chickens, supplemented with 1 g/kg diet antibiotic (oxytetracycline), compared to birds on Aloe *vera* leaf powder at the rate of 0; 1.5; 2.0 and 2.5 % dietary levels. FCR was higher in birds supplemented with a 1 g/kg diet oxytetracycline antibiotic than that of birds on diets supplemented with AVLP at rates of 0, 1.5, 2.0 and 2.5 % (Mohamed *et al*., 2017). Islam *et al*., (2020) also reported improved FCR for both the supplemented groups (Aloe vera, 5ml/l and 10ml/l) and the antibiotic group (0.2g/l), as compared to the Control (drinking water without additives). Contrastingly, BW, BWG, FI, and FCR of Ross 308 broilers were not affected by the antibiotic Colistin as much as those on the Control, without any additive and birds on mentocin plus in drinking water (Alzawqari *et al*., 2021).

During the finisher phase, both AV and GE in drinking water at 2ml/l did not induce any discernible effects on the growth performance parameters, except weight gain. In another study, it was reported that Aloe *vera* alone, at 0.5% in the diet, did not have a marked impact on body weight gain and FCR of Cobb-400 broiler birds, compared to the same birds fed Tulsi alone and a combination of *Aloe vera* and Tulsi in diets (Gohel *et al*., 2019). Researchers, including Ahmed and Abdel Atti, (2014), and Rathod *et al*., (2021), contradicted the findings of the current study. According to Onyeji *et al*., (2021), the inclusion of 0.8l of Aloe vera gel extract + 4l of water and 1.2l Aloe vera gel extract + 4l of water reported the best values of the final body weight and FCR of broiler birds, compared to the final body weight of the same birds on normal water and vitamin vitalyte +4l of water during the finisher phase. The ineffectiveness of AV and GE on growth parameters might be due to the inclusion of a small amount of AV in the diet/drinking water, which was inadequate to affect growth (Arif *et al*., 2022) and due to the consumption of isocaloric and isonitrogenous feeds in all the Treatment Groups and Control throughout the experimental period (Amaechi and Iheanetu, 2014).

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In the current study, during the finisher phase, males grew faster, consumed more feeds, and converted feed better with similar FCR to the females. These findings correlate with Trocino *et al*., (2015), who reported that male birds were heavier, consumed more feeds, and had better FCR than female birds at day 46 of age. Similarly, males gained more weight, consumed more feed, and converted feed better than female birds at day 42 of age (Madilindi *et al*., 2018). Maiorano *et al*., (2017), Cygan-Szczegielniak and Bogucka, (2021) also concurs with the current study. The best performance by male birds might be due to their digestive tract being larger and heavier than the female birds. As a result, the males' absorptive capacity develops quicker than that of female birds (Miles *et al*., 2006).

Cumulatively to slaughter, compared to other additives, PC birds grew faster and consumed more feed with less FCR. These findings correlate with those by Bosetti *et al*., (2020), who reported that the live weight, weight gain, feed intake, and FCR parameters of Ross 308 birds on 30 mg/kg of virginiamycin, NC+100 mg/kg of essential oils at 1-41 day, were better than those of birds which received 100; 200 and 400 mg/kg of essential oils and birds fed just basal diet. Similarly, Foroutankhah *et al*., (2019) observed that Ross 308 birds which received a diet containing 4.5 mg/kg flavophospholipol were heavier than those on the Control, basal diet, and birds on basal diet, plus marigold at 5 or 10 g/kg. On the contrary, low feed intake, poor weight gain and FCR were reported in antibiotic (10% Zinc Bacitracin or 4% Enramycin) supplemented birds, compared to that of birds on prebiotic and basal diet during the whole experimental period (Ashraf *et al*., 2019). However, there was no improvement in the body weight, feed intake, and FCR of broiler chickens in all treatment groups, including zinc bacitracin antibiotic at 350 mg/kg in the diet in all production stages of the experiment, in a study where birds were assigned to a basal diet without additives and a diet of Ganoderma lucidum was included at the rate of 2.5 g/kg and zinc bacitracin antibiotic at the rate of 350 mg/kg (Martínez *et al*., 2022).

Aloe vera and ginger in drinking water did not have any effect on growth performance parameters for the whole experimental period in the current study. Fakhim *et al*.,(2013) also reported that ginger extracts with the range 0; 0.25; 0.5; 0.75, and 1% in drinking water of Cobb 500 broiler birds did not affect BWG, FI, and FCR at 22 to 42 days of age. These findings however contradict those that suggested that the feed consumption of Cobb 400 broiler birds increased in the group that was on a standard ration (control) and the one that was on a standard ration, fed 0.3 % *Aloe vera* for the entire experimental period, as compared to birds on a standard ration, fed either *Aloe vera* at 0.1 or 0.2%, while body weight gain and FCR of birds on a standard ration, fed *Aloe vera* at the rate of 0.1, 0.2, and 0.3% improved significantly, compared to birds on Standard ration fed 0% *Aloe vera* (Singh *et al*., 2017).

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In the current study, male birds consumed significantly more feed than females throughout the experimental period. Consistent with the present findings, Livingston *et al*., (2020) reported that male birds of the Ross strain consumed more feed than females of the Ross strain. Researchers, (Benyi *et al*., 2015a, Siaga *et al*., 2017, Madilindi *et al*., 2018) support the findings of the current study. The differences between males and females might be due to greater competition for feeds, aggressive behaviour of males, social dominance, the difference in nutritional requirements, and the impact of hormones for growth and fatness (Benyi *et al*., 2015a).

No mortality occurred during the grower phase, with similar mortality across the treatments during the finisher phase. Across treatments, mortality was significantly high during week 6 of the experimental period. In line with the current study, 0% mortality was reported (Nalge *et al*., 2017). Qorbanpour *et al*., (2018), Jamir *et al*., (2019), Rio *et al*., (2019), Darwish *et al*., 2021) also studied the effects of either Aloe vera or ginger on the growth performance of broiler birds. They reported 0 mortality in the grower, finisher, and whole experimental period. On the other hand, Lotha and Vidyarthi (2020) reported mortality in the finishing phase, while Amber *et al*., (2021) reported low mortality in birds receiving 1.5 % AV.

A study investigated the effects of supplementing three physical forms of *Aloe vera* (powder, gel and juice) in feeds and drinking water of Cobb 400 broiler chickens at treatment Control (Standard Broiler Ration), Control + *Aloe vera* powder in feed at 0.5 %, Control + *Aloe vera* gel in feed at 2 %, and Control + fresh *Aloe vera* juice in drinking water at 2 %. It reported mortality in all treatment groups and stated that the cause was pneumonia and ascites, due to seasonal effects during the experimental period (Yadav *et al*., 2017). Eltazi (2014b) assessed the response of Ross 308 to diets containing different mixture levefls of garlic and ginger powder, as natural feed additives. He reported that treatments had no significant effect on the mortality of birds. In the current study, the mortality reported during week six of the experiment was due to heavy rainfall (storm) and cold weather condition.

5.2 Effects of additives and sex on carcass characteristics of Ross 308 broiler chickens

The results in Table 4.2 showed that birds on the PC recorded quantitatively higher weights for all carcass components, visceral tissue, and organs, compared to those on other additives. On a proportionate basis, the breast meat of broiler birds on PC treatment was heavier than that of birds on AV, GE, and NC. These findings are consistent with those by Foroutankhah *et al*., (2019), who found that the AGP flavophospholipol, at the rate of 4.5 mg/kg diet, influenced the relative weight of the gizzard of Ross 308 broiler birds. Foroutankhah *et al*., (2019) also disagreed with

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the findings of the current study, when he found that the AGP flavophospholipol in the diet, at 4.5 mg/kg, did not influence the relative weights of the spleen, hearts, and liver, as compared to the control (basal diet). Similarly, Nguyen *et al*., (2018) concurred with the current study, by reporting that blends of organic acids and medium-chain fatty acids supplemented in diets at the rate of 0.02, 0.03, 0.04, 0.05, and 0.06% in matrix coating as antibiotic growth promoters did not affect the carcass % of liver, spleen, and gizzard of Ross 308 broilers. They contradicted with the current study, by reporting that they did not affect the abdominal fat and breast meat of Ross 308 broilers. In line with the current findings, Ashraf *et al*., (2019) reported a poor dressing % in birds supplemented with either 4% enramycin or 10% zinc bacitracin in diets, as compared to that of birds on a basal diet (Control).

Contrary to the current findings, supplementation of zinc bacitracin in diets at 2.5g/kg in diets of birds did not improve liver yield, heart, gizzard, and abdominal fat yield of Cobb 500 birds, as compared to birds that received *Ganoderma lucidum* mushroom powder (Martínez *et al*., 2022). Bosetti *et al*., (2020) also reported no significant differences in the liver, heart relative weight, and commercial cuts of breasts, thighs, and wings of Ross 308 broiler birds, among treatment groups, including birds on 30 mg/kg of virginiamycin. Similarly, Alzawqari *et al*., (2021) reported Colistin antibiotic in drinking water at the rate of 0.5 g/l did not have any influence on the liver, gizzard, heart, spleen, abdominal fat, breast, and thigh muscles of Cobb broiler chickens. Hassan *et al*., (2018) also reported that the gizzard, liver, and heart weights of broiler birds did not improve in all birds which received dietary treatments, including antibiotic Bacitracin Methylene Disalicylate at 0.025% in the diet. On the contrary, the dressing % of Cobb broiler chickens improved in birds that received bacitracin methylene disalicylate at the rate of 0.025%, as compared to birds on a basal diet (Hassan *et al*., 2018).

Male birds deposited lower abdominal fat, compared to female birds. These findings concur with those by Benyi et al., (2015a) who reported that male chickens deposited lower abdominal fat than female chickens. However, on a proportionate basis, at slaughter, the sex of broiler birds did not influence all carcasses' characteristics, visceral organs, and tissue, except the wings of female birds which were bigger than those of male birds, and abdominal fat percentage, where males deposited a lower percentage than the females. These findings contradicted reports which suggested that the sex of birds influenced the dressing, breast, thigh, liver, gizzard, and heart percentages and that female birds were heavier in all these traits than male birds (Madilindi *et al*., 2018). In correlation with the current findings, Madilindi *et al*., (2018) reported the effect of sex of broiler chickens on abdominal fat percentages, where female birds deposited heavier abdominal fat percentage than male birds.

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Higher abdominal fat deposition in female birds than males can be attributed to the greater impact of the hormones for fatness in females than males. Almasi *et al*., (2012) also suggested that it could be because females start to store fat earlier than males.

In the current study, the supplementing AV and GE in drinking water of broiler chickens resulted in poor weights of all carcass components, visceral tissue, and organs. These findings correlate with Arif *et al*., (2022), who reported that all treatment groups, including Aloe vera leaf powder at 0.5 % in the diet, did not improve the liver, heart, and gizzard weight and low fat deposition in Japanese quails that fed on a diet supplemented with *Aloe vera* leaf powder and Clove powder and their combination. Similarly, Aloe *vera* supplementation in broilers was reported to reduce fat accumulation (Eevuri and Putturu, 2013). Ghasemi-Sadabadi *et al*., (2020) also reported improved abdominal fat when Aloe vera powder, at the rate of 0.6 %, was supplemented in diets of birds. Aqueous extracts of ginger at 0, 0.25, 0.5, 0.75, and 1 % had no significant effects on abdominal fat percentage, cut percentage and liver percentage of live weight (Fakhim *et al*., 2013).

In a study that evaluated the effect of different inclusion levels of ginger meal on arbour-acres broiler chickens, it was observed that all the carcass parameters measured (heart, thighs, drumsticks, wings, liver, gizzard, and breast) were similar across dietary treatments, except for abdominal fat, which was significantly higher in 0.5 % ginger, treated in a study where birds were fed diets which contained ginger meal at levels of 0.0, 0.5, 1.0 and 1.5 %, respectively, with 0.0 % ginger meal diet serving as the Control diet in both starter and finisher phases (Egenuka *et al*., 2021). Furthermore, there were no improvements on wing cuts, drumsticks, thighs, and organs among treatment groups, basal diet (Control), diets supplemented with *Aloe vera* and diet with enramycin, in a study where treatment groups included the Control group (basal diet) and basal diets, mixed with Aloe *vera* powder, at 0.5, 1.0 and 1.5% levels (Amaechi and Iheanetu, 2014). No significant differences were observed in percentages of visceral organs: heart, liver, and gizzard, in all treated groups, including the ginger-powder-treated groups, at 0.5 %, compared to the Control (basal diet) (Rathod *et al*., 2021). Lower values of dressing % in Cobb 400 birds were observed, which were supplemented with 2.5 and 5.0 g/kg ginger diet, compared to birds which received 7.5 g/kg ginger powder diet, in a study where birds were supplemented with ginger powder at levels 0, 2.5, 5.0, and 7.5 g/kg feed (Rio *et al*., 2019). Qorbanpour *et al*., (2018) Ross 308 birds fed with a basal diet, supplemented with 0.25 % ginger, reported low abdominal fat.

On the other hand, supplementation of *Aloe vera* increased dressing percentage, liver weight, spleen weight and whole giblet weights (Eevuri and Putturu, 2013) while the breast and dressing yields of birds were reported to be affected by the supplementation of AV powder at the rate of 0.5% in Japanese quail diets, in a study where birds were the Control diet (no additives in feed),

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0.5% AV leaf powder, 0.5% CV powder, and 0.25% AV powder + 0.25% CV powder (Tariq *et al*., 2015). Amaechi and Iheanetu, (2014) also reported minor increases in the relative weight of the gizzard, liver, and spleen in broiler birds on *Aloe vera* treated diets, including birds treated with AV powder at 0.5 %, compared to the gizzard, liver, and heart weights of birds on a basal diet (Control) and those on a diet with antibiotic enramycin. The dressing % of Giriraja birds was highest in ginger-powder-treated groups, at 0.5%, compared to the control (basal diet), basal diet containing 0.5% thyme powder, and ginger powder + thyme powder in basal diet, both at 0.5% (Rathod *et al*., 2021), while the best average gizzard (Kafi *et al*., 2017) and spleen weight were reported by Cobb 400 birds, supplemented with ginger powder at 5.0 g/kg diet and the best heart weight in birds, which received 2.5 g/kg diet in comparison to birds on 0 g/kg ginger powder diet (Rio *et al*., 2019). Improved percentages of wings and breasts were reported in Cobb 500 birds fed diets with ginger at rates of 0.5%, compared to birds receiving neither ginger nor turmeric and 0.5 and 0.75 % turmeric in diets (Kafi *et al*., 2017). These findings contradict with those of the current study.

These findings may be explained by phytogenic activity, which may include altered nutrition fluxes to certain tissue, such as fat deposits or muscles, or affect visceral organ morphology or function, which may have implications for protein or energy efficiency.

5.3 Effects of additives and sex on meat quality parameters of breast meat of Ross 308 broiler chickens

The current study investigated the effects of phytogenic *Aloe vera* and ginger in drinking water on breast meat quality characteristics of Ross 308 broiler chickens. However, there is limited information on the effects of *Aloe vera* and ginger on breast meat quality indices of broiler chickens. *Aloe vera* belongs to the lily family and therefore it is closely related to onions, garlic, and turnips, which also belong to the lily family (Tiwari and Upadhayay, 2018), and ginger is from the ginger family, which is closely related to turmeric and Cardamom (Bode and Dong, 2011). Thus, literature on the effects of onions, garlic, and turnips will be used in support of *Aloe vera* herb, while literature on turmeric and cardamom will be used in support of ginger on meat quality characteristics.

The results in Table 4.3 for the current study show that the pH of breast meat of birds on PC was higher than that of breast meat of birds in other treatment groups. Sex by additive interaction has a significant effect on the pH of breast meat of birds, with increased means at PC by females and AV by males. These findings correlate with those of a study that reported that basal diet containing 30mg/kg of virginiamycin did not have an effect on the pH value of breast meat of broiler chickens (Bosetti *et al*., 2020). Similarly, Adeyemi *et al*., (2021) reported no effect on pH value of breast

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meat when birds were fed diets containing 0.5g/kg oxytetracycline plus 0013 g/kg tert-butyl Hydroxyanisole. On the other hand, the addition of red ginger in feeds at the rate of 0.5 % resulted in a high pH value of breast meat (Herawati, 2011). Hayajneh, (2019) reported similar results. In a study by Adeyemi *et al*., (2021), onion skin waste did not have any influence on the pH of muscle of broiler chickens and dietary onion, at the rate of 0.3% or 0.5%, did not have an effect on pH values of broiler meat (An *et al*., 2015).

The results of the current study showed a significant additive effect on the water holding capacity of breast meat on breast meat of birds on AV, and NC holding more water than breast meat of birds in other treatment groups. These findings correlate with Purwanti *et al*., (2019), who reported that garlic extract in diet at 0.02% influenced the water holding capacity of breast meat of broiler chickens. Similarly, Hayajneh, (2019) reported that ginger powder at the rate of 0.25% and 0.5% did not affect the water holding capacity of broiler birds. In the other study however, the addition of red ginger in diet at the rate of 0.5% resulted in decreased water holding capacity (Herawati and Marjuki, 2011). Concurrent with the present study, increasing levels of organic acids (AOs) and medium-chain fatty acids (MCFAs) in a matrix coating as antibiotic growth promoters supplemented in diets did not have an influence on the water holding capacity of breast meat of broiler chickens (Bosetti *et al*., 2020). Similarly, the water holding capacity of breast meat of broiler birds that received a basal diet with 0.05 bacitracin plus 2.485 % filler did not influence the water holding capacity (Purwanti, *et al*., 2019).

In addition, additives, sex, and additive by sex interaction did not have a significant effect on drip loss and hardness of the breast meat of birds. These findings correlate with Purwanti, *et al*., (2019), who reported that treatment groups, including ginger extract, in a diet at 0.02 % and 0.015 % bacitracin plus 2.485 % filler, did not have any effects on the texture of broiler birds. Consistent with the current study, drip loss of breast meat of Ross 308 broiler chickens were not significantly influenced by the increasing levels of blends of organic acids (OAs) and medium-chain fatty acids (MCFAs) in a matrix coating, as antibiotic growth promoters, supplemented in basal diets at the rates of 0.02, 0.03, 0.04, 0.05 each, and 0.06%, with a basal diet as Control (Nguyen *et al*., 2018).

5.4 Effects of additives and sex on colour parameters of breast meat of Ross 308 broiler chickens

In the current study, additives, sex, and additive by sex interaction did not have a significant effect on all meat colour components of breast meat. Consistent with the current study, ginger powder, added to their diet at the rate of 0.25%, 0.50%, and 0.75%, did not have any effect on the colour coordinates (L*, a*,b*) of breast meat of Ross broiler chickens (Hayajneh, 2019). Similarly, when Ross 308 broiler birds were fed a basal diet supplemented with dietary Ginger powder at levels

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0.0, 1, 1.5 and 2.0%, they reported no significant effects on colour parameters (Eltazi, 2014a). Agu, *et al*., (2017) reported similar results. Nguyen, *et al*., (2018) reported no significant effects on the lightness (L*), redness (a*), yellowness (b*) of breast meat of Ross 308 broiler chickens when the levels of blends of organic acids (OAs) and medium-chain fatty acids (MCFAs) were increased in a matrix coating as antibiotic growth promoters were increased in basal diets at each of the rates 0.02, 0.03, 0.04, 0.05, and 0.06%, with basal diet as control.

Contradicting the current study, it was reported that the ethanol extract of *Aloe vera* gel significantly influenced the hue angles of the meat, as compared to the ethanol extract of apple peels, methanol extract of apple peels, acetone extract of apple peels, methanol extract of *Aloe vera* gel, and acetone extract of *Aloe vera* gel (Biswas, *et al*., 2014). In a study that evaluated the use of a mixture of microencapsulated carvacrol and cinnamaldehyde as a replacement for growth-promoting antibiotics in Ross 308 broiler diets, assigned to Negative Control (NC) as basal diet, basal diet plus 30 mg/kg of virginiamycin, NC+100 mg/kg of essential oils, NC+200 mg/kg of essential oils and NC+400 mg/kg of essential oils, it was reported that the intensity of yellowness (b*) of breast meat was higher and there was no difference in intensity of lightness (L*) and redness (a*) of breast meat in birds fed a diet with 30 mg/kg of virginiamycin and NC+100 mg/kg essential oil groups than NC and NC+400 essential oil broiler groups (Bosetti, *et al*., 2020).

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CHAPTER 6: CONCLUSION AND RECOMMENDATION

Supplementary AV and GE at 2ml/l in drinking water did not express phytogenic effects in terms of body weight gain, feed intake, the FCR, carcass characteristics, and meat quality parameters of Ross 308 broiler chickens, which could be due to too low dosages of the plant extracts. Visceral organs were not affected, which would otherwise suggest toxic effects. Therefore, further research is recommended to investigate effects of plant extract supplements at higher dosages.

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APPENDICES

Appendix 1: Analysis of variance for production performance of Ross 308 broiler chickens during the grower (days 23-37) and finisher (days 38-50) phases using Adj MS.

		Grower (23 to 37 days)					Finisher (38 to 50 days)					Cumulative			
Source	**DF**	**LW$^{23-27}$**	**BWG (g/b/d)**	**FI (g)**	**FCR**	**MORT (%)**	**LW^{50}**	**BWG (g/b/d)**	**FI (g)**	**FCR**	**MORT (%)**	**BWG (g/b/d)**	**FI (g)**	**FCR**	**MORT (%)**
Additives	3	163701**	2446.51**	28.1	1.66191	ND	2058872**	6481.3**	4350.5**	18.8691**	26.851	8410.50**	2239.1**	15.6441**	13.4255
Sex	1	21664	2.17	283.4	0.04561	ND	90000	242.7	1325.8	0.0050	0.000	99.51	1337.4*	0.0102	0.0000
Week	1	3131794**	583.35	13533.4**	5.72818**	ND	1103813**	508.1*	2701.9*	1.7935	136.131	6906.09**	6151.5**	36.3445**	68.0653**
A x S	3	4164	168.33	346.8	0.65705	ND	17596	211.9	475.6*	0.6115	1.854	145.61	289.7	0.1888	0.9269
Error	55	24652	261.21	138.5	0.36410	ND	52597	117.8	258.1	1.2371	17.727	198.68	228.9	0.9060	8.7010

For each factor or combination of factors, means in the same column not sharing a common superscript are significantly different (*P<0.05*). **: (*P<0.01*); *: (*P<0.05*); (NS) Not Significant: (*P>0.05*). Additives; AV: *Aloe vera* juice (2ml/L of water); GE: Ginger extract (2ml/L of water); NC: Negative control=11L water; PC: Positive control=11L water; LW: Live Weight; Mort: Mortality; FCR: Feed Conversion Ratio; SEM: Standard Error of Means; A: Additives; S: Sex; %: Percentage; ND: Not Defined.

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Appendix 2: Analysis of variance for carcass components and visceral organs and tissue of Ross 308 broiler chickens using Adj MS.

Source	DF	Breast Wt	Thigh	Wing	Heart	Spleen	Gizzard	Liver	Abdominal fat
						G			
Additives	3	221576**	25800.3**	1519.8**	59.5990**	2.54610**	503.486**	917.852**	28.0707**
Sex	1	3542	1292.0	153.1	0.2738	0.02722	1.033	37.462	1.8948*
A x S	3	2627	391.1	150.3	1.1624	0.11141	25.851	1.677	0.1581
Error	24	3725	594.6	137.8	2.3903	0.15503	29.944	15.104	0.1840

For each factor or combination of factors, means in the same column not sharing a common superscript are significantly different ($P<0.05$). **: ($P<0.01$); *: ($P<0.05$); (NS) Not Significant: ($P>0.05$). Additives; AV: Aloe vera juice (2ml/L of water); GE: Ginger extract (2ml/L of water); NC: Negative control=12L water; PC: Positive control=12L water; A: Additive: S: Sex.

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Appendix 3: Analysis of variance for quality of breast meat of Ross 308 broiler chickens using Adj MS.

Source	DF	pH	WHC (ml)	Drip loss	Hardness (kg/mm^2)
Additives	3	0.07029*	3.7973**	1.066	88.23
Sex	1	0.01334	0.3852	2.292	177.38
A x S	3	0.04320*	0.3652	1.833	34.59
Error	24	0.01198	0.2231	1.616	74.73

For each factor or combination of factors, means in the same column not sharing a common superscript are significantly different (*P<0.05*). **: (*P<0.01*); *: (*P<0.05*); (NS) Not Significant: (*P>0.05*). Additives; AV: Aloe vera juice (2ml/L of water); GE: Ginger extract (2ml/L of water); NC: Negative control=12L water; PC: Positive control=12L water; SEM: Standard Error of Mean; WHC: Water Holding Capacity; ml: millilitres.

Appendix 4: Analysis of variance for breast meat colour parameters using Adj MS.

Source	DF	C_D	h*	C*	a*	b*	L*
Additives	3	11.9466	12.7433	0.8881	1.9292	0.9719	9.9651*
Sex	1	0.6910	29.3486	0.1954	2.3993	1.9208	6.9244
A x S	3	1.7003	0.9856	2.6995	0.7844	2.0525	0.2378
Error	24	4.6866	12.8100	1.3049	1.6056	1.6123	3.1820

For each factor or combination of factors, means in the same column not sharing a common superscript are significantly different (*P<0.05*). **: (*P<0.01*); *: (*P<0.05*); (NS) Not Significant: (*P>0.05*). Additives; AV: Aloe vera juice (2ml/L of water); GE: Ginger extract (2ml/L of water); NC: Negative control=12L water; PC: Positive control=12L water; SEM: Standard Error of Mean; C_D: Colour Difference; h*: Hue; C*: Chroma; a*: CIE red (+) / green (-) colour attributes; b*: CIE yellow (+) / blue (-) colour attributes; L*: CIE lightness coordinate.

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