NIGERIAN AGRICULTURAL JOURNAL
ISSN: 0300-368X
Volume 53 Number 1, April 2022 Pg. 103-112
Available online at: http://www.ajol.info/index.php/naj
https://www.naj.asn.org.ng

Oxidative Stability and Quality of Meat from Broiler Chickens Fed Diets Supplemented with Plant Based Antioxidants

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Abstract
Usage of synthetic antioxidants in meat quality preservation is discouraged due to associated risks; this has made utilization of natural alternatives paramount. Five diets were formulated such that diet 1 had no supplementation, while diets 2, 3, 4, and 5 were each supplemented with 1% of dried garlic, ginger, roselle, and 200mg/kg Vitamin E. A total of 150 day-old broiler chicks were procured and randomly divided into five groups of thirty birds each, in a Completely Randomized Design and assigned to a dietary treatment. They were fed *ad libitum* with the diets for eight weeks; thereafter nine birds per treatment were purposively selected and sacrificed for meat quality evaluation over eight weeks of cold storage. Significant differences ($P<0.05$) were observed for Cooking loss (%), which ranged from 33.93 (Diet 5) to 47.62 (Diet 1). Water-Holding-Capacity, and pH were also different ($P<0.05$) across diets, with birds on Diet 1 recording the least values for those parameters. Meat from birds raised on Diet 1 had higher microbial loads (10^2cfu/g); 34.67, 24.00, 20.33, 13.66, and 10.33. Meat from birds fed Diet 1 had significantly higher Thiobarbituric acid (mgMDA/kg) and lower acceptability. Roselle gave the best results among all the plant supplements used in this study.

Keywords: Dietary antioxidants, Chicken meat, Garlic, Ginger, Lipid oxidation, Roselle

Introduction

Lipid peroxidation is a major problem in the meat industry, because it leads to quality deterioration, rancidity, and accumulation of potentially toxic compounds in foods, particularly meat and its products due to their considerable lipid components (Gorelik *et al.*, 2008; Dominguez *et al.,* 2019). Lipid oxidation reduces meat quality in a number of ways, including off-flavour formation, increased drip loss, and colour changes. Poultry meat is considered to be more prone to the development of oxidative rancidity than red meat; this is explained by its higher content of unsaturated fatty acids. During lipid oxidation, the Polyunsaturated fatty acids (PUFAs) are degraded to volatile short chain oxidation products, which lead to off-odour and off-flavour formation. The oxidation process is strongly enhanced during the cooking and storage of meat. The formation of volatile lipid oxidation products strongly reduces consumer acceptability of the product (Jensen *et al.,* 1998).

It has been demonstrated that the development of rancidity in meat can be minimized with the use of dietary antioxidants (Sheldon *et al.*, 1997). However, apart from alpha tocopherol which is sometimes utilized as a dietary supplement in livestock to mitigate lipid oxidation in the carcasses of animals after slaughter, virtually all the other substances being used for the same purpose which includes butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA), ethoxyquin, among others have been implicated in the onset of some human illnesses. As a result of this observation, there is a global paradigm shift towards the use of more natural and biodegradable products that are less likely to have hazardous effects on humans when consumed, to enhance livestock production and products (Schleicher *et al.,* 1998, Onibi *et al.,* 2000 and Gardzielewska *et al.,* 2003).

A variety of herbs, including but not limited to Aloe vera, garlic (*Allium sativum*), ginger(*Zingiber officinale*), onions (*Allium cepa*), roselle (*Hibiscus sabdariffa*), thyme (*Thymus vulgaris*) have been widely utilized by humans in the diet and for maintenance of good health because of their medicinal values (Freeman and Kodera, 1995). Garlic supplements in broiler chicken have been recognized for their strong stimulating effect on the immune system and its very rich aromatic oils enhance digestion of birds

(Gardzielewska *et al.,* 2003). The main active ingredient in garlic is a compound called 'allicin' which rapidly decomposes to several volatile organosulphur compounds with bioactivities (Chang and Cheong, 2008). Garlic is used as condiment, medicament, antioxidant, anticoagulant, hypolipidaemic, antihypertensive, anti-ageing, and heavy metal detoxifier (Agarwal, 1996 and Marilynn, 2001).

Ginger contains phenolic compounds among other substances. Phenolic compounds in ginger are made up of the shogaols and gingerols. Sesquiterpenes are the major active ingredients in ginger oils that include zingiberene and zingiberol. Ginger is both used as a spice and herb, it has been reported to have antioxidant, analgesic, sedative, antipyretic, hypocholesterolemic and antibacterial effects against both gram positive and gram negative bacteria. When fed as a dietary supplement to chickens, ginger increased digestion and also improved sensory properties of meat from chicken (Gardzielewska *et al*., 2003).

Roselle (*Hibiscus sabdariffa*) is widely grown in different parts of Nigeria. It has been reported to have a high content on ascorbic acid (Akanya *et al*., 1997) which makes it an excellent source of natural antioxidant in livestock feed and meat (Onibi and Osho., 2007). The objective of this study was to determine the effect of dietary supplementation with dried raw garlic, ginger and roselle; all of which have been reputed to possess medicinal and antioxidant properties on the lipid oxidation, physicochemical properties and general quality of broiler chicken meat.

Materials and Methods

Experimental site

This study was conducted at the Department of Animal Science, University of Ibadan, Nigeria.

Experimental diets and animals

Diets offered to all birds were formulated to meet birds' requirement as recommended by NRC (1994). Five identical diets were formulated such that diet 1(Negative control) had no antioxidant supplementation while diets 2, 3, 4, and 5 (positive control) were each supplemented with 1% of dried garlic, ginger, roselle, and 200mg/kg vitamin E. The experimental starter diet as shown in Table 1 was fed to the chicks for the first four weeks of life.

Diet 1- Control diet (Negative control)
Diet 2- Control diet+1% dried Garlic (*Allium sativum)*
Diet 3- Control diet+1% dried Ginger (*Zingiber officinale)*
Diet 4- Control diet+1% dried Roselle (*Hibiscus sabdariffa*)
Diet 5- Control diet+200mg/kg Vitamin E (Positive control)

The experimental finisher diet as shown in Table 2 was fed to the birds for the last four weeks of life. The Vitamin E used as an additive in Diet 5 was manufactured by Adisseo Limited, France. A total of 150 day old Arbor acres broiler chicks were obtained from a commercial hatchery in Ibadan. Prior to arrival of the day old chicks, the brooder house, feeders, and drinkers were properly cleaned and disinfected. Brooding was carried out for two weeks, following which the starter and finisher experimental diets were fed. Fresh cool water and feed were provided *ad libitum* and routine medication administered as at when due. The chicks were randomly divided into fifteen groups of ten birds each in a Completely Randomized Design. Each group was randomly assigned to one of the three replicates of each dietary treatment, making a total of 30 chicks per treatment and ten birds per replicate.

Experimental design

The experimental design was completely randomized design (CRD).
Statistical model is specified thus;

$Y_{ij} = U + T_j + E_{ij}$

Where, Y_{ij} = Independent variable, assumed to be randomly distributed, U= Overall mean, T_j = The effect of treatment, E_{ij} = Experimental error containing all uncontrolled sources of variation.

Data collection

Carcass evaluation

At the end of the feeding trial (8 weeks) a total of forty-five birds (Nine per treatment) were purposively selected for meat quality evaluation. The birds were euthanized and then immediately exsanguinated by manually severing the jugular vein at the neck region with a knife, after which they were allowed to bleed thoroughly. After bleeding, the birds were scalded in hot water (85°C), which was followed by defeathering.

Primal cuts excision and storage study

The carcasses were cut into different primal cuts and the breast cuts were selected for this experiment. Part of the meat harvested was frozen stored at -4°C for eight weeks, during which some quality parameters were evaluated fortnightly.

Meat quality appraisals

Physical properties

Water holding capacity (WHC)

It was determined by the press method described by Wierbicki and Deatherage, (1958) and modified by Tsai and Ockerman (1981). 1g of fresh meat sample was cut from the breast muscle onto a 9 cm Whatman No 1 filter paper. The meat samples were duplicated. The meat sample was pressed between two 10.2 x 10.2cm plexi glasses at approximately 35.2kg/km^3 for 1 minute. The area of free meat was traced on a tracing paper and then on graph. The percentage water was calculated based on sample weight and moisture content.

$$\text{Water holding capacity} = 100 - \frac{(\text{Ar} - \text{Am x } 9.47)}{\text{Wm x Wo}}$$

Where, Ar = Area of water released from meat cm^2, Am = Area of meat sample cm^2, Wm = Weight of meat samples in mg, Wo =Moisture content of meat, 9.47 =

constant factor.

Cooking loss

Approximately 30 grams of meat samples from breast muscle was taken and tied in a cellophane nylon, and cooked. After 20 minutes, samples were removed, drained, equilibrated to room temperature and weighed. The weight of the cooked samples was recorded.

Cooking loss (%) was calculated thus;

$$= 100 \text{ X } \frac{\text{Weight of sample before cooking} - \text{Weight of sample after cooking}}{\text{Weight of sample before cooking}}$$

Organoleptic properties evaluation

A total of fifteen (15) trained individuals were employed as panelists. These panelists were randomly allocated to the control and other treatments. The panelists were asked to rate each piece of the cooked meat sample. Meat was served in odourless plastic containers. The panelists rated the samples on a 9-point hedonic scale for juiciness, flavour, aroma, tenderness, colour, overall acceptability and off-flavour score.

Chemical Properties

Proximate composition

The diets and meat samples were analysed for dry matter, crude protein, crude fibre, total fat, and ash using methods of A.O.A.C, (1990).

Microbial analysis of chicken meat samples

The chicken meat (Breast muscle) samples were collected and transported to the Laboratory for microbial analysis in sterile sample bottles kept in an ice packed container. The samples were immediately analysed on getting into the laboratory for the Total Heterotrophic Count (THC), *Escherichia coli*, *Staphylococcus* spp., and *Coliforms/ Enteric bacteria*. One gram of the samples was weighed, macerated aseptically and dropped into 10 ml sterile peptone water to serve as the stock from which the ten-fold serial dilutions were carried out. Appropriate dilutions were inoculated onto the different culture media (Nutrient Agar, for the Total Heterotrophic Count (THC); Mannitol Salt Agar, for the *Staphylococcus* sp.; Eosin Methylene Blue, for *Escherichia coli;* and MacConkey Agar, for the coliforms and other enteric bacteria); using the pour plate technique. The cultures were then incubated at 37^0C for 24 - 48 hours inside the incubator. The inoculated plates were observed for growth after the period of incubation and readings of the count were recorded against each sample.

Thiobarbituric Acid reactive substances (TBARS) evaluation

This was determined using the thiobarbituric acid method as described by by Pikul *et al*. (1989), at intervals of 0, 10, 20, and 30 days of storage. Five grams of sample was weighed into 50 ml test tube, homogenized with 15 ml of deionized distilled water using a laboratory mortar and pestle. 1ml of homogenized sample was transferred into a disposable test tube 13 x 100mm butylated hydroxyanisole (50µl, 10%). Tricholoroacetic acid (TBA) 2ml was added. The mixture was vortexed and then incubated in a boiling water bath for 15min to develop colour. The sample was then cooled in cold water for 10min, vortexed again and centrifuged for 15 minutes. The absorbance of the resulting supernatant solution was determined at 535nm against a blank containing 1ml of deionized distilled water and 2ml of TBA/Trichloroacetic acid solution. The amount of TBARS was expressed as milligrams of malondialdehyde (MDA) per kilogram of sample.

pH evaluation

5grams of meat samples from breast muscle from each treatment were blended with a mortar and pestle for homogenization. The blended meat was poured into a beaker and 45ml of distilled water was added. The pH meter was rinsed in distilled water and then in a buffer solution and dried with soft tissue paper before putting it into the homogenized meat sample, and the value of pH was recorded.

Statistical analysis

The data obtained were subjected to analysis of variance (ANOVA). The analysis was conducted using the general linear modelling procedure (SAS, 1999) while Duncan Multiple Range Test was used to separate means where significant differences occurred (Duncan, 1955).

Results and Discussion

Results

Table 3 shows the physical properties of broiler chicken meat as affected by garlic, ginger and roselle supplemented diets. Cooking loss showed significant differences ($P<0.05$) and values from 47.62% in meat in birds fed on negative control diet to 33.93% in the meat of birds fed positive control diet. Water Holding Capacity (WHC) differed significantly ($P<0.05$) among the treatments with meat from birds fed positive control diet recording the highest WHC value of 60.44 and meat to birds fed negative control diet recording the lowest WHC of 51.15. pH also showed significant differences among the treatments and the values recorded were from 5.89 in meat from birds fed the ginger supplemented diet to 5.50 in meat from the birds fed negative control diet.

Table 4 shows the microbial count of breast muscles from broiler chickens fed garlic. Ginger and roselle supplemented diets at fortnightly intervals during the experimental period. Significant differences ($P<0.05$) were observed among the different treatments throughout the duration of the experiment. At week 0 microbial count values were from 34.67 (x 10^2cfu/g) in meat from treatment 1 to 18.67 (x 10^2cfu/g) in meat from treatment 2. At 2 weeks, microbial count was 24.0 (x 10^2cfu/g) in meat from treatment 1 to 17.66 (x 10^2cfu/g) in meat from treatment 2. At 4 weeks, microbial count was 20.33 (x 10^2cfu/g) in meat from treatment 1 to 7.33 (x 10^2cfu/g) in meat from treatment 2. At 6 weeks, microbial count was 13.66 (x 10^2cfu/g) for meat in treatment 1 to 6.67 (x 10^2cfu/g) for meat in treatment 2. While, at 8 weeks, microbial count was 10.33 (x

10^2cfu/g) for meat in treatment 1 to 5.33 (x 10^2cfu/g) for meat in treatment 2.

Table 5 shows the types of bacteria observed in meat (breast muscle) from broiler chickens fed garlic, ginger and roselle supplemented diets. *Bacillus spp., Enterobacter spp.*, and *Staphylococcus spp.,* of bacteria were observed in all the treatments throughout the duration of the study, while *Actinomycetes spp* was observed in addition to *Bacillus spp. Enterobacter spp.* and *Staphylococcus spp* at weeks 0, 2, and 4. *Flavobacterium spp* was observed along with the other observed bacteria only at week 2.

Table 6 shows the proximate composition of breast muscle meat from broiler chickens fed garlic, ginger, and roselle supplemented diets. There were no significant differences (P>0.05) for the parameters across the treatments. Dry Matter values were from 36.40% for breast muscles from treatment 4 to 34.83% for breast muscles from treatment 3. Crude protein was from 20.11% for breast muscles in treatment 4 to 18.31% for breast muscles from treatment 3. Ether extract was from 3.08% in breast muscles from treatment 1 to 2.73% in breast muscles from treatment 2. Ash was from 1.01% in breast muscles from treatment 5 to 0.94% for breast muscles in treatment 1. While, Nitrogen-free Extract (NFE) was from 77.81% for breast muscles in treatment 3 to 75.90% for breast muscles in treatment 4.

Table 7 shows the Thiobarbituric acid reactive substance (TBA) value (mg malondialdehyde(MDA)/kg) of broiler chicken meat as influenced by garlic, ginger, and roselle supplemented diets. Significant differences (P<0.05) were recorded for the TBA values at only 0 and 2 weeks of storage. At 0 weeks of storage the TBA values observed were from 2.08 mgMDA/kg in meat from birds on the negative control diet to 1.73 mgMDA/kg in meat from birds fed the positive control diet. At 2 weeks of storage TBA values were from 2.08 mgMDA/kg in meat from birds fed the negative control diet to 1.61mgMDA/kg in meat from birds fed the positive control diet. Beyond the second week of storage, no significant differences were observed in the TBA values among the treatments.

Table 8 shows the Organoleptic properties of broiler chicken breast muscle as influenced by Garlic, Ginger, and Roselle supplemented diets. Significant differences (P<0.05) were observed across all treatments for all the various parameters determined. Aroma values were from 4.60 in meat from the broilers fed the Roselle supplemented diet to 3.10 in meat from broilers fed the positive control diet. Flavour was from 4.40 in meat from the broilers fed roselle supplemented diet to 3.10 in meat from broilers fed on garlic supplemented diet. Tenderness from 6.90 in meat from the broilers fed roselle supplemented diet to 6.00 in meat from the broilers fed garlic supplemented diet to. Juiciness from 7.00 in meat from the broilers fed roselle supplemented diet 3.60 in meat from the broilers fed garlic supplemented diet. Colour from 7.20 in meat from the broilers fed roselle supplemented diet to 5.30 in meat from the broilers fed ginger supplemented diet. Overall acceptability from 7.00 in both the ginger and roselle supplemented diets to 5.30 in meat from the broilers fed on the negative control diet.

Discussion

The lower the water released from meat after cooking the better the meat and this water, is influenced by factors like protein denaturation in meat, as some of the water (bound water) in muscle cells are closely bound to protein and are resistant to freezing and to being driven off by conventional heating (Fennema, 1996); and some are free water, whose flow from the tissue is unimpeded. Maintaining as much of this water as possible in meat is the goal of many processors, and in this study the meat from the birds on the negative control diets had significantly higher cooking loss than all the other treatments thus suggesting that supplementation of broiler diets with garlic, ginger, roselle, and Vitamin E elicits a positive effect on the cooking loss of meat from such animals. This is in agreement with the observation of Verleyen *et al.* (2005) who reported that feeding Vitamin E supplemented to pigs led to lower cooking losses in pork, which was linked to the ability of Vitamin E to reduce the rate of lipid oxidation and thereby preserve the structural integrity of meat membranes leading to lower drip loss. The Water Holding Capacity (WHC) which is the ability of meat to retain its moisture through processing (especially cooking) and is inversely related to cooking loss followed a similar trend to the cooking loss observed in this study with meat from the birds on the Negative control diet having the least desirable WHC which corresponds to the high cooking loss observed for meat from birds in the same treatment.

pH is also important for the storage life of meat. The lower the pH, the less favourable conditions for the growth of harmful bacteria. The lowering of pH in muscle is due to the accumulation of lactic acid and is one of the most crucial changes that occur in muscle during its conversion to meat (Forrest *et al.,* 1975). The pH values recorded in this study was from 5.50 to 5.89 with the lowest value was observed in birds on the negative control diet, these values differ from the values of 6.2 to 6.5 (at 15minutes post mortem) reported by Fletcher (1999) but comparable to that reported by Gardzielewska *et al.* (2003) and Saláková *et al*. (2009). High ultimate pH (pHu) meat is dark, firm and dry. These types of meats can occur in poultry, however all the values recorded for pH in this study are mainly within normal ranges where excessive degeneration of muscle components do not occur (Forrest *et al*., 1975).

The microbial counts observed for the breast muscles harvested from the experimental birds showed obvious variation. The microbial counts obtained in this experiment were comparable to, but higher than the values reported by Onibi and Osho (2007) for the meat from broiler chickens fed roselle supplemented diets. It was observed that the breast muscles harvested from the birds fed the unsupplemented negative control diets had higher microbial counts throughout the duration of the experiment, while breast muscles from the birds fed garlic supplemented diet (Treatment 2) and those fed ginger supplemented diet (Treatment 3) had lower microbial counts than all the other treatments, throughout the duration of the experiment, this occurrence might not be unconnected to the much reported antimicrobial properties of garlic and ginger (Gardzielewska *et al.,* 2003; Gernot, 2005). It was also noted that the microbial count were higher at week 0 and as the storage time increased there was a general decline in the microbial count, which could be as a result of the inability of some of the bacteria to withstand low temperature for extended periods, this observation is in agreement with observations reported by Forrest *et al.* (1975) and Kelly *et al.* (2003).

Contamination of meat usually occurs during slaughter and subsequent processing of carcass. Bergdoll (1980) reported that handlers of food products are the most likely source of contamination which could result from coughing, sneezing and talking over food. The use of contaminated water and equipment for processing is a likely source of bacteria too (Adams and Moss, 1999). For food to be entirely safe from the microbiological viewpoint it would need to be free from all pathogenic organisms, however, this is not a realistic goal for poultry meat. Therefore some level of contamination must be tolerated (Mead, 2004) which varies from country to country. It was noted that the microbial counts observed for the breast muscles were below the maximum limit for poultry prescribed by the Food Standards Australia New Zealand [FSANZ] (2001) of 10^5 for Total heterotrophic count, which is also acceptable by the European Union.

Five species of bacteria were isolated on the raw breast muscles harvested from the carcasses of the experimental birds viz *Bacillus spp,. Enterobacter spp., Staphylococcus spp., Actinomycetes spp,* and *Flavobacterium spp.* Of the observed bacteria *Bacillus spp., Staphylococcus spp.,* and and *Actinomycetes spp,* are gram positive bacteria species, while, *Enterobacter spp.,* and *Flavobacterium spp.* are gram negative species. The observed bacteria are generally opportunistic microorganisms that are generally found in soil, water, plants and can also be carried by humans. However, they can be easily and are generally curbed by common food safety practices which include regular hand washing during processing of food for consumption, exposure to temperatures of at least 100°C for 15 to 30 minutes and for meats cooking till a minimum internal temperature of 72°C is achieved (Hart, 2006).

No significant (P>0.05) difference were observed for any of the proximate composition parameters of the breast muscles across all the treatments. However, the values recorded were all within the range observed by Gardzielewska *et al.* (2003). The most common chemical measurement of lipid oxidation in muscle foods is the thiobarbituric acid (TBA) assay based on the reaction of malonaldehyde (MA) and TBA generating TBA-MA complex (Patton and Kurtz, 1951), the results of this measurement are generally expressed as thiobarbituric acid reactive substances (TBARS). The lower the TBA (mgMA/Kg), the better the keeping quality. In this study the TBA values of the evaluated meat samples increased throughout the storage/evaluation period. Initial measurement (Day 0) and measurement at two (2) weeks post mortem showed significantly (P<0.05) lower TBA for the Garlic, Ginger, Roselle and Vitamin E (positive control) supplemented diets, dietary ginger showed a stronger ability to minimize lipid oxidation in the experimental samples at the first and second week than either garlic or ginger. However, the various dietary supplements did not elicit any significant differences (P<0.05) in the meat from the different treatments beyond two weeks of storage. These observations are in agreement with the findings of Onibi *et al.* (2009) who reported that supplementation of broiler diets with graded levels of garlic resulted in lower TBA values in broiler chicken meat. They are also in agreement with findings by Choi *et al*. (2010) who used garlic bulbs and husks as dietary supplements in broiler chickens. These findings support the fact that the development of rancidity in meat can be minimized with the use of dietary antioxidants, since monogastric animals are able to incorporate dietary components with beneficial effects directly into their tissues (Onibi *et al*., 2000; Verleyen *et al*., 2005), which would later impact on meat quality. Dietary Vitamin E is absorbed in the small intestine and deposited in the membranes of muscle. Vitamin E reduces lipid oxidation in meat by protecting polyunsaturated fatty acids of meat membranes against oxidation (De Winne and Dirinic, 1997). The antioxidant effect of herbs and spices is primarily linked to their polyphenol content; as polyphenols are considered the most significant group of natural antioxidants after Vitamin A, C and E, and when deposited in muscle membranes they are thought to minimise lipid oxidation in a process similar to that of Vitamin E (El-Alim *et al*., 1999).

The organoleptic properties are the meat quality attributes associated with meat palatability and acceptability; showing whether the consumers are repeat buyers or not. Meat quality describes how much the meat is attractive to consumers. Meat must look good to consumers before satisfying their palate when they decide to buy it. Once the meat is bought, cooked, and served, the aroma, tenderness, juiciness, and flavor must meet the expectations (Aberle *et al*., 2001). The highest aroma value was recorded for meat from the birds fed the roselle supplemented diet, though it did not significantly differ for meat from the birds on the ginger supplemented diet and the birds on the negative control,. These observations are similar to reports by Gardzielewska *et al*. (2003) who reported that supplementation of broiler diets with ginger improved the aroma of meat from the experimental birds due to the aromatic nature of ginger. The meat from the birds on the garlic supplemented diet had significantly lower aroma and flavour scores, and this could be as a residual effect of garlic odour which most people are not comfortable with, this observation is similar to reports by other researchers that supplementation of chicken diets with garlic did not lead to carcasses with lower aroma scores (Choi *et al*., 2010; Onibi *et al*., 2009).

The meat from the birds fed roselle supplemented diets also had the highest scores for tenderness, juiciness, colour, and overall acceptability. This suggests that roselle supplemented diets best improved the organoleptic properties of chicken meat, especially colour which is one of the primary attractants of the consumer (Van Oeckel *et al*., 1999), this effect is most probably due to anthocyanin a pigment in roselle which helps to impart an attractive colour to the meat. These observations are also in agreement with reports by other researchers that supplementation of broiler diets with natural herbs/spices noticeably improved the qualities of the meat derived from such animals (Gardzielewska *et al*., 2003; Onibi and Osho, 2007).

Conclusion

The results of this study showed that supplementing broiler chicken diets, with garlic, ginger and roselle led to lower levels of lipid oxidation in chicken meat and higher overall acceptability. And roselle supplementation had the overall best performance. Further studies to determine optimal inclusion level are advisable.

Table 1: Composition of Starter Diets

Ingredients (%)	**1 (Control)**	**2 (+1% Garlic)**	**3 (+1% Ginger)**	**4 (+1% Roselle)**	**5 (+0.02% Vit. E)**
Maize	56.90	56.49	56.49	56.49	56.88
SBM	14.60	14.60	14.60	14.60	14.60
GNC	19.00	18.50	18.50	18.50	19.00
Wheat Bran	4.00	4.00	4.00	4.00	4.00
Fishmeal(72%)	2.00	2.00	2.00	2.00	2.00
DCP	2.40	2.40	2.40	2.40	2.40
Salt(NaCl)	0.30	0.30	0.30	0.30	0.30
Vit. Premix	0.30	0.30	0.30	0.30	0.30
Methionine	0.20	0.20	0.20	0.20	0.20
Lysine	0.30	0.30	0.30	0.30	0.30
Garlic	-	1.00	-	-	-
Ginger	-	-	1.00	-	-
Roselle	-	-	-	1.00	-
Vit.E supplement	-	-	-	-	0.02
Total	100	100	100	100	100
Calculated Composition					
ME(kcal/kg)	2985.18	2954.81	2954.81	2954.81	2985.18
Calculated crude protein (%)	22.50	22.14	22.14	22.14	22.50
Calorie: Protein	132.67	133.50	133.50	133.50	132.67
Lysine (%)	1.24	1.16	1.16	1.16	1.24
Methionine (%)	0.42	0.41	0.41	0.41	0.42
Crude fibre (%)	3.29	3.22	3.22	3.22	3.29
Calcium (%)	1.02	1.01	1.01	1.01	1.02
Phosphorus (%)	0.69	0.69	0.69	0.69	0.69
Analysed Composition (%)					
Dry matter	90.10	89.04	88.72	89.57	90.04
Crude Protein	22.56	22.18	22.21	22.10	22.57
Ash	6.13	5.97	6.46	7.01	6.11
Crude Fibre	7.04	6.83	7.14	6.92	7.05
Ether Extract	9.21	8.46	7.88	8.26	9.22
NFE	55.06	56.56	56.31	55.71	55.05

Source: Adediran and Omojola (2021)

Vitamin Premix supplies the following per Kg of diet: Vit . A 7812.50IU, Vit .D3 1562.50IU, Vit K 1.25mg, Vit E 25mg, Vit . B1 1.88mg, Vit B2 3.44mg, Niacin 34.38mg, Calcium pantothenate 7.19mg, Vit B6 3.13mg, Vit B12 0.016mg, Choline chloride 312.50mg, Folic acid 0.62mg, Biotin 0.05mg, Mn 75mg, Fe 62.5mg, Zn 50mg, Cu 5.31mg, Iodine 0.94mg, Cobalt 0.19mg, Se 0.075mg, DCP=Dicalcium Phosphate

Table 2: Composition of Finisher Diets

Ingredients (%)	1 (Control)	2 (+1% Garlic)	3 (+1% Ginger)	4 (+1% Roselle)	5 (+0.02% Vit. E)
Maize	58.00	58.00	58.00	58.00	58.00
GNC	13.50	13.50	13.50	13.50	13.50
Wheat Bran	7.15	6.15	6.15	6.15	7.13
SBM	15.00	15.00	15.00	15.00	15.00
Fishmeal (72%)	1.50	1.50	1.50	1.50	1.50
DCP	3.00	3.00	3.00	3.00	3.00
Oyster shell	1.00	1.00	1.00	1.00	1.00
Vit. Premix	0.25	0.25	0.25	0.25	0.25
Methionine	0.20	0.20	0.20	0.20	0.20
Lysine	0.20	0.20	0.20	0.20	0.20
Salt(NaCl)	0.20	0.20	0.20	0.20	0.20
Garlic	-	1.00	-	-	-
Ginger	-	-	1.00	-	-
Roselle	-	-	-	1.00	-
Vit.E supplement	-	-	-	-	0.02
Total	100	100	100	100	100
Calculated Composition					
ME(kcal/kg)	2929.73	2910.63	2910.63	2910.63	2929.73
Crude protein(%)	20.50	20.30	20.30	20.30	20.50
Calorie: Protein	142.87	143.38	143.38	143.38	142.87
Lysine (%)	1.02	1.01	1.01	1.01	1.02
Methionine (%)	0.40	0.40	0.40	0.40	0.40
Crude Fibre (%)	3.09	3.02	3.02	3.02	3.09
Calcium (%)	1.53	1.51	1.51	1.51	1.53
Phosphorus (%)	0.84	0.82	0.82	0.82	0.82
Analysed Composition (%)					
Dry matter	89.38	90.01	91.52	91.07	90.83
Crude Protein	21.03	21.05	22.05	21.80	21.24
Ash	6.02	4.01	6.88	5.10	6.02
Crude Fibre	5.87	7.13	6.04	5.26	5.88
Ether Extract	8.00	7.21	9.11	8.04	8.00
NFE	59.08	60.6	55.92	59.80	58.86

Source: Adediran and Omojola (2021)

Vitamin Premix supplies the following per Kg of diet: Vit . A 7812.50IU, Vit .D3 1562.50IU, Vit K 1.25mg, Vit E 25mg, Vit . B1 1.88mg, Vit B2 3.44mg, Niacin 34.38mg, Calcium pantothenate 7.19mg, Vit B6 3.13mg, Vit B12 0.016mg, Choline chloride 312.50mg, Folic acid 0.62mg, Biotin 0.05mg, Mn 75mg, Fe 62.5mg, Zn 50mg, Cu 5.31mg, Iodine 0.94mg, Cobalt 0.19mg, Se 0.075mg, DCP=Dicalcium Phosphate

Table 3: Effect of Garlic, Ginger, and Roselle supplemented diets on the physical properties of broiler chicken meat (Breast muscle)

Parameter	1 (Control)	2 (+1% Garlic)	3 (+1% Ginger)	4 (+1% Roselle)	5 (+0.02% Vit. E)	SEM
Cooking loss (%)	47.62^{a}	37.95^{b}	38.14^{b}	35.16^{b}	33.93^{b}	1.62
WHC	51.15^{c}	57.38^{ab}	53.39^{bc}	54.93^{bc}	60.44^{a}	1.43
pH	5.50^{b}	5.74^{a}	5.89^{a}	5.59^{ab}	5.59^{ab}	0.07

Determined at 6 hours post mortem

$^{a\,b}$ Means on the same row with similar superscripts are not significantly different (P<0.05)

WHC- Water Holding Capacity SEM-Standard Error of the Mean

Table 4: Microbial count of breast muscles from broiler chickens fed Garlic, Ginger and Roselle supplemented diets (x 10^2cfu/g) stored at -4°C

Treatment/Weeks	1 (Control)	2 (+1% Garlic)	3 (+1% Ginger)	4 (+1% Roselle)	5 (+0.02% Vit. E)	SEM
0	34.67^{a}	18.67^{d}	19.67^{d}	24.00^{c}	29.33^{b}	2.41
2	24.00^{a}	17.66^{b}	18.00^{b}	18.67^{b}	22.67^{a}	1.83
4	20.33^{a}	7.33^{d}	10.33^{c}	11.33^{c}	18.33^{b}	2.71
6	13.66^{a}	6.67^{d}	7.67^{c}	9.67^{b}	9.00^{c}	1.40
8	10.33^{a}	5.33^{c}	5.66^{c}	9.00^{b}	9.00^{b}	1.16

***a b** Means on the same row with similar superscripts are not significantly different (P<0.05)*
WHC- Water Holding Capacity SEM-Standard Error of the Mean

Table 5: Bacteria observed in meat from broiler chickens fed Garlic, Ginger and Roselle supplemented diets

Storage Length(Weeks)	Bacteria isolated
0	*Bacillus spp.* *Enterobacter spp.* *Staphylococcus spp.* *Actinomycetes spp*
2	*Bacillus spp.* *Enterobacter spp.* *Staphylococcus spp.* *Actinomycetes spp* *Flavobacterium spp*
4	*Bacillus spp.* *Enterobacter spp.* *Staphylococcus spp.* *Actinomycetes spp*
6	*Bacillus spp.* *Flavobacterium spp.* *Enterobacter spp.*
8	*Bacillus spp.* *Flavobacterium spp.* *Enterobacter spp.*

Table 6: Proximate composition of breast muscle meat from broiler chickens fed Garlic, Ginger, and Roselle supplemented diets

Parameter\Treatment	1 (Control)	2 (+1% Garlic)	3 (+1% Ginger)	4 (+1% Roselle)	5 (+0.02% Vit. E)	SEM
Dry Matter (%)	36.07	35.21	34.89	36.40	35.13	3.41
Crude Protein (%)	18.93	19.04	18.31	20.11	19.25	1.73
Ether Extract (%)	3.08	2.73	2.88	3.02	2.91	0.39
Ash (%)	0.94	0.96	1.00	0.97	1.01	0.08
NFE (%)	76.85	77.27	77.81	75.90	76.83	4.27

***a b** Means on the same row with similar superscripts are not significantly different (P<0.05) NFE-Nitrogen-free Extract SEM-Standard Error of the Mean*

Table 7: Effect of Garlic, Ginger and Roselle supplemented diets on the Thiobarbituric acid (TBA) value (mgMDA/kg) of broiler chicken meat stored at -4°C

Storage period (Weeks)	1 (Control)	2(+1% Garlic)	3(+1% Ginger)	4(+1% Roselle)	5(+0.02% Vit. E)	SEM
0	2.04^{a}	1.83^{b}	1.78^{b}	1.93^{b}	1.73^{c}	0.10
2	2.08^{a}	1.84^{b}	1.42^{c}	1.88^{b}	1.61^{b}	0.21
4	2.20	2.15	2.37	2.42	2.39	0.16
6	2.88	2.10	2.59	2.68	2.66	0.22
8	2.71	2.68	2.83	3.03	2.63	0.24

a b** **Means on the same row with similar superscripts are not significantly different (P<0.05)

SEM-Standard Error of the Mean

Table 8: Organoleptic properties of broiler chicken breast muscle as influenced by Garlic, Ginger, and Roselle supplemented diets

Parameters	1 (Control)	2(+1% Garlic)	3(+1% Ginger)	4(+1% Roselle)	5(+0.02% Vit. E)	SEM
Aroma	4.20^{a}	2.90^{c}	4.40^{a}	4.60^{a}	3.10^{b}	0.01
Flavour	3.90^{b}	3.10^{c}	3.90^{b}	4.40^{a}	3.30^{c}	0.01
Tenderness	6.60^{b}	6.00^{c}	6.20^{c}	6.90^{a}	6.70^{a}	0.01
Juiciness	5.10^{b}	3.60^{c}	5.20^{b}	7.00^{a}	4.40^{c}	0.01
Colour	6.20^{b}	5.80^{b}	5.30^{c}	7.20^{a}	6.00^{b}	0.01
Overall acceptability	5.30^{d}	5.90^{c}	7.00^{a}	7.00^{a}	6.80^{b}	0.01

a b Means on the same row with similar superscripts are not significantly different (P<0.05)

SEM-Standard Error of the Mean

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