

Effects of culinary treatments on lipids quality, proximate composition and mineral content of broilers meat fed with rations supplemented with powders of *Camellia sinensis*, *Annona muricata* and *Zingiber officinale*

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Abstract

This study aimed to evaluate the effects of feeding system and cooking treatments on the lipids quality, proximate composition and mineral content of broiler meat (thigh muscle) fed with powders of three natural plants. Hundred (100) twenty-one-day-old broiler chickens (*Cobb 500*) were randomly allocated to five (5) experimental diets with 10 replicates consisting of the basic ration (without antioxidant) from which four other feeds were obtained by adding 200 UI/kg of Vitamin E (VitE); 5 g/kg of tea leaves powder (CS); Ginger root powder (ZO) and Soursop flowers powder (AM). Feed and water were supplied *ad libitum* throughout the experimental period. On the 49th day, they were randomly slaughtered, and their carcasses were collected for culinary treatments. Thereafter, lipids were extracted from the meat using the method described by Bligh and Dyer. Their quality was assessed by the determination of peroxide value (PV), thiobarbituric acid reactive substances value (TBARS) and acid value (AV); while the proximate composition and mineral content were performed on meat flours. Results revealed that the treatments Raw+ZO; Fr+AM; Fr+ZO; Bo+CS; Bo+ZO and Bo+AM limited the formation of hydroperoxides. Except for the treatment Fr+AM, all the treatments significantly increased ($P<0.05$) the level of TBARS. Combined treatments increased AV. Plant supplementation enhances the nutritional value of broiler meat. Thus, the supplementation of broiler ration with natural powders might be a good alternative to maintain the lipids stability of broiler meat and enhance their nutritional value during cooking treatments.

1. Introduction

The production of meat is increasing highly and the sector of monogastric animals is more concerned where the production of poultry meat is most representatives. Consumption of poultry meat is constantly increasing and nutrition of meat quality depends mainly on poultry feed composition's (Schwartzkopf-Genswein *et al.*, 2012). Poultry meat is among the most popular meats in the world owing because of its low price, short production time and ease preparation (Chouliara *et al.*, 2007).

However, broiler meat possesses a higher amount of polyunsaturated fatty acids that are susceptible to oxidative degradation, leading to lower consumer acceptability for broiler meat products (Sohaib *et al.*,

2017). Besides these deteriorations, lipid oxidation also generates cytotoxic and genotoxic compounds which are deleterious to humans health (Botsoglou *et al.*, 2014). Some problems in meat and meat-based products such as tissues damaging, loss of nutrients, putrefaction, malonaldehydes production and enhancement of free radicals generation are caused by oxidative damage that reduce the antioxidant capacity of products (Ahn *et al.*, 2009).

The stability of meat lipids mainly depends on the balance of antioxidants, oxidation substrate and cholesterol content as well as heme pigment. Using antioxidant based formulation in animal feeding can be important to control oxidative process in meat and meat products. These help in disruption of the oxidation chain

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reaction that further progress with a passage of time which ultimately reduces the quality of meat-based products (Ennajar *et al.*, 2009). However, according to Altmann *et al.* (1986) synthetic antioxidants such as butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) that are generally used to slow or minimize oxidative deterioration of foods have been rejected because of their carcinogen effects.

Nowadays, the increasing preference for natural foods has obliged agrifood industries to incorporate natural antioxidants in various products in order to replace synthetic antioxidants, limit oxidative degradation of lipids and improve their nutritional values (Camo *et al.*, 2008). Dietary supplementation of α -tocopherol in poultry meat was found to be one of pragmatic choice to improve the oxidative stability of lipids and inhibiting oxidation of cholesterol in meat. Adding α -tocopherol in feed protects the broiler chicken against a stress-induced increase in thiobarbituric acid reactive substances (TBARS) by limiting oxidation as well as preserving animal health. It also enhances stability and quality of lipids in chicken muscles when added in the diet (Li *et al.*, 2009). According to Sohaib *et al.* (2012), incorporation of α -tocopherol at 200 IU/Kg level is considered effective to increase the oxidative stability of broiler meat. Including α -tocopherol in livestock diets presented significant effects on the oxidative activities of their tissues and stability of meat products (Boler *et al.*, 2009; Lahucky *et al.*, 2010). Extracts or essential oils from several herbal plants including rosemary, ginger and sage (Lopez-Bote *et al.*, 1998), tea (Tang *et al.*, 2001), and oregano (Botsoglou *et al.*, 2003; Giannenas *et al.*, 2005) have been shown to have the capacity to ameliorate growth performance and increase the antioxidant capacity of poultry meat when supplemented in feeds. Recently, a study revealed that methanolic extract of soursop flowers (*Annona muricata*) is rich in vanillic acid, caffeic acid, ferulic acid, ellagic acid, and quercetin. These compounds have shown a good lipid stability of palm olein during accelerated storage of 30 days at 70°C (Womeni, Djikeng, Anjaneyulu *et al.*, 2016). The quercetin is a type of flavonol belonging to the class of flavonoids, present in vegetables and fruits especially red onion, caper, apple, in some medicinal and aromatic plants (Bhagwat *et al.*, 2013). Quercetin is a powerful antioxidant capable of reducing lipid peroxidation in meat-based products by limiting the oxidation chain reaction. The antioxidant activity of quercetin is attributed to its ability to scavenge free radicals, chelate metal cations and donate hydrogen atoms or electrons. Also, various studies conducted *in vitro* and *in vivo* in experimental animals showed that quercetin has antioxidant and anti-inflammatory properties (Bodas *et al.*, 2011). Ginger

(*Zingiber officinale*), contains relatively large amounts of volatile oils camphene, alpha-terpineol, p-cineole, zingiberene, and pentadecanoic acid (El-Ghorab *et al.*, 2010) both in the fresh and dried form. Ginger extracts revealed antioxidant activity almost equal to that of synthetic antioxidants such as BHA and BHT (Rehman *et al.*, 2003).

This study aimed at evaluating the effects of dietary supplementation by natural sources of antioxidants (flowers of *Annona muricata*; roots of *Zingiber officinalis* and leaves of *Camellia sinensis*) and cooking treatments on lipids quality, proximate composition and mineral content in broiler meat in order to improve food security and consumers health.

2. Material and methods

2.1 Plants preparation

Fresh leaves of *Camellia sinensis* and flowers of *Annona muricata* were collected respectively at Bafou and Santchou Divisions, Cameroon; while the roots of *Zingiber officinale* were purchased at the local market of Dschang, Menoua Division, Cameroon. After collection, they were cleaned and dried at 45°C in an oven during 48 h. The dried plant samples were grounded to obtain fine powders which were kept in a desiccator for further use.

2.2 Animal's experimental design

One hundred 21-day-old broiler chicks (*Cobb 500*) with an average weight of 550 g were used, they were randomly assigned in cages of 50 cm (length) × 50 cm (width) × 50 cm (height) previously washed and disinfected. Each cage consisted of two broilers (male and female) receiving the 5 treatment groups, with 10 replicates per treatment. From a control diet without any supplement(CO), four other rations were obtained by adding to the 200 UI/kg of VitE (VitE); 5g/kg of tea leaves (*Camellia sinensis*) dried powder (CS); 5g/kg Ginger root (*Zingiber officinale*) dried powder (ZO) and 5g/kg soursop flowers (*Annona muricata*) dried powder (AM) (Table 1). Feed and water were supplied *ad libitum* throughout the experimental period and for sanitation, drinkers were washed every day. Chicks were vaccinated against Gumboro Disease, Newcastle Disease at day 8, 14 and day 21, respectively in the drinking water. On the 49th day, 8 broilers (per treatment) were randomly selected, fate for 24h and slaughtered by cervical dislocation. Feathers were plucked using boiling water and eviscerated manually. The carcass was collected and used for culinary treatments.

2.3 Culinary treatments of broiler meat

2.3.1 Cooking by boiling

Boiling was performed at $100\pm 5^{\circ}\text{C}$ and 200 g of sample (thigh without bone) were boiled in 1400 ml water for 30 min using a domestic stainless-steel pot on a hotplate.

2.3.2 Cooking by frying

For this treatment, 200 g (thigh without bone) of each ration were weighed, and placed in one liter of refined palm oil (Mayor) heated for 5 min in a deep fryer (HQ brand). Frying was done at 180°C minimum for 15 min and the meat was turned after every 3 min. The Mayor oil (purchased at the local market) was used because of its high saturated fatty acids content, thereby limiting oxidation reactions during the treatment. The oil was replaced after each frying.

2.3.3 Cooking by frying and boiling

The meat obtained after frying under the same conditions as stated above was introduced into 1400 ml of boiling water (initial boiling point of 95°C) and the treatment was carried out for 10 min on a hotplate.

Table 1. Feed ingredients and proximate nutrients composition of experimental diets

Ingredients (Kg)	Periods	
	Brooding (1 st – 21 st day)	Finisher (22 nd – 49 th day)
Corn	59	60
wheat bran	03	08
Soybean crab	23	13
Premix 5%	05	05
Shell	01	01
Cotton	03	05
Palm oil	01	1.5
Fish meal	05	6.5
Total (Kg)	100	100
Calculated proximate nutrients composition		
Metabolizable Energy (kcal/kg)	2961.71	3005.80
Crude Protein (%)	23.32	20.54
Energy/protein ratio	126.98	146.37
Lysine (%)	1.4	1.20
Methionine (%)	0.48	0.45
Calcium (%)	1.11	1.32
Phosphorus (%)	0.54	0.58
Crude fiber (%)	4.76	4.91

Premix 5%: crude proteins = 40%, Lys = 3.3%, Meth = 2.40%, Ca = 8%, P = 2.05%, Metabolizable energy=2078kcal/kg

2.4 Lipid extraction

Fat was extracted from raw and cooked broiler meat according to the method described by Bligh and Dyer (1959) using a combination of Chloroform and Methanol (2:1). The extracted oil samples were stored at -4°C for chemical analysis.

2.5 Lipids oxidation assessment

The peroxide value of oils extracted from the different samples was determined using the spectrophotometric IDF standard method, 74A (1991). Its acid value was determined according to the procedure of AOCS Official Method CD 3d-63 (AOCS, 2003). Secondary oxidation products were evaluated using thiobarbituric acid value as described by Draper and Hadley (1990).

2.6 Proximate composition analysis

For proximate composition, samples obtained for fresh and cooked meat was previously dried in an oven at 45°C during 12 hours and they were reduced to powder using a kitchen blender. Moisture, fat, ash, and protein content of fresh and cooked meat samples were determined using standard analytical methods described by AOAC procedures (AOAC, 1990). Moisture content was determined by drying meat sample in an oven at $105\pm 2^{\circ}\text{C}$ until a constant weight was achieved according to the AOAC procedures 925.40 (AOAC, 1990). For the cooked samples, the moisture content was determined on the meat flours. Ash content was determined by incineration of the sample for 20 h at 550°C according to the AOAC procedures 942.05 (AOAC, 1990). Nitrogen (N) content was determined using the micro-Kjeldahl method, according to AOAC procedures 984.13 (AOAC, 1990), the protein content was calculated as $\text{N} \times 6.25$. Lipid content was determined using Soxhlet apparatus with hexane, following AOAC 963.15 methodology (AOAC, 1990). The total percentage carbohydrate content was determined by the difference method as reported by Onyeike *et al.* (2015). This method involved adding the total values of crude protein, crude fat, moisture and ash constituents of the sample and subtracting it from 100. All samples were analyzed in triplicate.

2.7 Mineral analysis

Some main minerals (Ca, Na, K, P, and Mg) and some trace minerals (Fe and Zn) were analyzed in fresh and cooked meat sample. For mineral analysis accurately weighed ash samples were boiled with 10 ml of 20% HCl in a beaker and then filtered into a 100 ml standard flask to determine the mineral content. Mineral content of the digested samples was determined by flame atomic

absorption spectrophotometry using a Varian 220FS Spectra AA apparatus for calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), zinc (Zn) and iron (Fe), while phosphorus (P) was determined by spectrophotometric colorimetric method using UV spectrophotometer according to AOAC procedure 965.17 (AOAC, 1999). Mineral contents of the samples were determined from calibration curves of standards minerals. All samples were analyzed in triplicate.

2.8 Statistical analysis

Results obtained were subjected to analysis of variance (ANOVA) with Newman-Keuls Multiple Comparison Test, to evaluate the statistical significance of the data expressed as mean \pm standard deviations. A probability value of $p < 0.05$ was considered statistically significant using GraphPad Prism 5 software.

3. Results and discussion

3.1 Effects of treatments on the peroxide value

The peroxide value (PV) measures the number of hydroperoxide products and is used to evaluate the oxidative state of lipid-containing foods (Juntachote *et al.*, 2007). The PV data is presented in Figure 1. The treatments Raw+ZO (2.11 ± 0.04 meq O_2 /Kg); Fr+AM (2.51 ± 0.00 meq O_2 /Kg); Fr+ZO (2.65 ± 0.06 meq O_2 /Kg); Bo+CS (3.75 ± 0.44 meq O_2 /Kg); Bo+ZO (5.49 ± 0.39 meq O_2 /Kg) and Bo+AM (8.08 ± 0.45 meq O_2 /Kg) significantly decreased ($p < 0.05$) the PV in oil extracted on thigh meat than the other treatments. These observations could be due to the presence of natural antioxidant substances in broiler food that have limited the production of hydroperoxides in these treatments at that concentration. It was revealed that extract of *Annona muricata* is rich in vanillic acid, caffeic acid, ferulic acid, ellagic acid, and quercetin and extract of *Camellia sinensis* are rich in gallic acid, epicatechin gallate, galocatechin and epigallocatechin gallate (Womeni, Djikeng, Anjaneyulu *et al.*, 2016; Womeni, Tonfack, Prabhakar *et al.*, 2016). Also, it might also due to the transformation of hydroperoxides; which are unstable intermediate substances, to secondary oxidation products which are responsible for the changes in odor and flavor of rancid fats (Shermer, 1990). According to CODEX standards (2015), the maximum limit recommended for animal's fat is 10 millieq of active O_2 / kg; so, the above treatments had preserved this indicator. However, all the treatments supplemented with vitamin E as synthetic antioxidant presented a high PV than the above treatment. This might be due to the less integration during feeding. Also, high amounts of PV were generally observed in the both treatments and this might be due to the high temperature that had inhibited the activities of

antioxidants and allowed the formation of hydroperoxides. These results were in agreements with Song *et al.* (2010), which reported that PV of tallow reached a high level when heated at 140°C for 2 hours.

3.2 Effects of treatment on the thiobarbituric acid reactive substances

Peroxidation of lipids is one of the major mechanisms of quality modification in foods. It occurs when hydroxyl radicals attack fatty acid side chains of membrane phospholipids. Malondialdehyde (MDA) is a product of lipid peroxidation and TBARS, as indicated by the MDA concentration, serving as oxidative damage index. The changes in quality contribute to the deterioration of nutritive value, flavor, color, and texture of the food due to the production of toxic compounds (Mohamed *et al.*, 2008).

The results show that thiobarbituric acid reactive substances (TBARS) of the broiler thigh meat presented significant differences ($p < 0.05$) due to the cooking treatments (Figure 2). The lowest TBARS of thigh meat was recorded in the treatments: Fr+AM (2.457 ± 0.01 mg MDA/kg), followed by Bo+CS (3.58 ± 0.304 mg MDA/kg) and Fr+VitE (4.32 ± 0.027 mg MDA/kg); while the majority of highest TBARS values were obtained with Boiling and combination of treatments. Also, in these treatments, the TBARS values recorded were significantly lower ($p < 0.05$) than the raw sample. The lowest values observed in different treatments could be due to the action of compounds such as quercetin and α -tocopherol that have limited lipids deterioration. Indeed, quercetin is a powerful antioxidant capable of reducing lipid peroxidation in meat-based products by limiting oxidation chain reaction. The antioxidant activity is attributed to its ability to scavenge free radicals, chelate metal cations and donate hydrogen atoms or electrons (Bodas *et al.*, 2011). Also, it has been shown that α -tocopherol is a lipid-soluble antioxidant that belongs to tocopherol family which cannot be synthesized by the animal cells and plays a role in the protection of membrane against oxidation (D'Arrigo *et al.*, 2002). According to Barroeta (2007), feed supplementation with α -tocopherol in animals increased the deposition of lipoic acid as an increase in its concentration and the level of vitamin E in the muscle depends on its dietary level, the duration of the supplementing period, the fiber type distribution and on a metabolic characteristic. Previous studies revealed that quercetin and α -tocopherol were able to attenuate lipid peroxidation process in birds (Goliomytis *et al.*, 2014). Haak *et al.* (2009) showed that α -tocopherol alone or in combination with rosemary and green tea extract retarded retards lipid oxidation in meat.

However, according to Greene and Cumuze (1982),

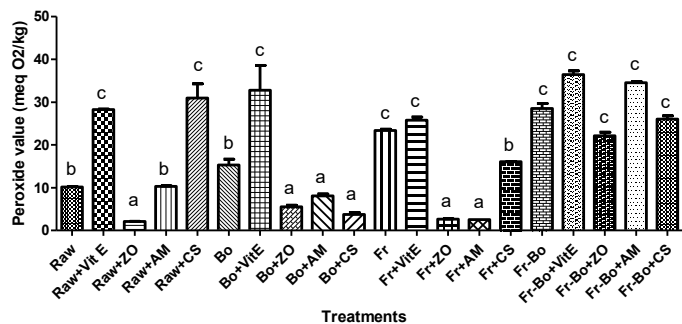


Figure 1. Peroxide value in thigh meat of broilers.

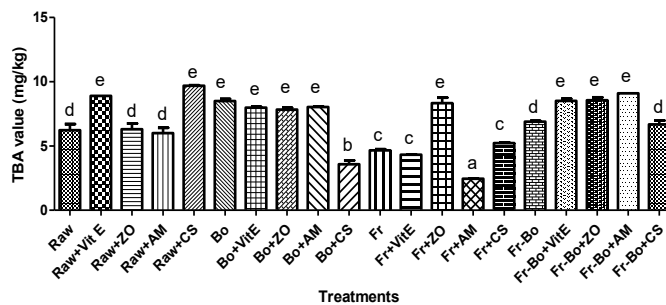


Figure 2. Thiobarbituric acid reactive substances in thigh meat of broilers

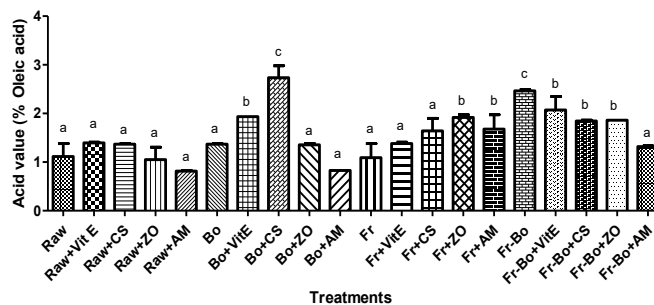


Figure 3. Acid value in thigh meat of broilers

Results are means ± standard error (n = 3). The column diagram with different letters differs significantly (p < 0.05). Raw = Raw meat; Raw+VitE = broiler reared with 200 UI of vitamin E, Raw+ZO = broiler reared with 5g/kg of *Zingiber officinale*, Raw+AM = broiler reared with 5g/kg of *Annona muricata*; Raw+CS = broiler reared with 5g/kg of *Camellia sinensis*, Bo = Boiled meat, Bo+VitE = Boiled meat reared with 200 UI of vitamin E; Bo+ZO = Boiled meat reared with 5g/kg of *Zingiber officinale*, Bo+AM = Boiled meat reared with 5g/kg of *Annona muricata*, Bo+CS = Boiled meat reared with 5 g of *Camellia sinensis*; Fr = Fried meat, Fr+ VitE = Fried meat reared with 200 UI of vitamin E, Fr+ZO = Fried meat reared with 5g/kg of *Zingiber officinale*; Fr+AM = Fried meat reared with 5g/kg of *Annona muricata*, Fr+CS = Fried meat reared with 5g/kg of *Camellia sinensis*, Fr-Bo = Fried and boiled meat, Fr-Bo+VitE = Fried and boiled meat reared with 200 UI of vitamin, Fr- Bo+ZO = Fried and boiled meat reared with 5g/kg of *Zingiber officinale*, Fr-Bo+AM = Fried and boiled meat reared with 5g/kg of *Annona muricata* and Fr-Bo+CS = Fried and boiled meat reared with 5g/kg of *Camellia sinensis*.

the maximum acceptable limit of TBARS in a dietary product is 2.0 mg MA/kg and this was due to its relation to off-odor appearance. The high levels of TBARS values obtained in our study could be due to the animal part used and the heat treatments applied. Chen *et al.* (2011) reported that MDA values found in leg meat were greater than those in breast meat because leg meat had a greater percentage of polyunsaturated fatty acids than breast meat. Also, Sohaib *et al.* (2015) observed that cooking process depleted quercetin in broiler meat after cooking during 30 min and this could lead to the increase of TBARS level in meat.

3.3 Effects of treatments on the acid value

Acid value (AV) allows the determination of free fatty acid (FFA) generally expressed as a percentage of oleic acid in oil samples. The increase in AV might be an important measure of rancidity of foods. Free fatty acids are formed due to hydrolysis of triglycerides and may get promoted by reaction of oil with moisture (Frega *et al.*, 1999). The changes in the acidity of broiler meat oil during culinary treatments are shown in Figure 3. FFA content of broiler meat increased significantly in the cooking methods evaluated, with a high value obtained

with the treatment: Bo+CS (2.73%); Fr-Bo (2.46%); Fr-Bo+VitE (2.07%); Bo+VitE (1.93%) and Fr+ZO (1.91%) while lower values were observed in the treatments Raw+AM (0.81%); Bo+AM (0.82%) and Raw+ZO (1.05%). This could be explained by the breakdown of ester bonds of triglycerides by the heating process. During frying, the very high temperature involves a further breakdown of ester bonds of triglycerides present in oil by thermolysis. These results were close to those of Labuza (1974), who revealed that a very high temperature could lead to a higher FFA content due to a strong hydrolysis of esters bonds of triglycerides. Also, Lin *et al.* (2011) showed that the percentage of acidity on minced pork increases with the temperature and the duration of cooking. During boiling, heating water catalyses the hydrolysis of ester bonds of triglycerides and releases free fatty acids in oil. Similar results have been obtained by Hernandez *et al.* (1999), they showed that the boiling of the pig meat increases its free fatty acid content and they allocated that to the hydrolysis of triglycerides. So, we observed that frying and frying followed by boiling increased AV of broiler meat oils and this was also observed with the PV and TBARS; and this can be explained by the transformation of FFA to second oxidation products such as peroxide and

Table 2. Changes in the proximate composition of broiler meat during culinary treatments

Samples	Moisture (%)	Protein (%)	Lipids (%)	Ash (%)	Carbohydrate (%)
Raw	59.44 ± 3.54 ^c	31.65 ± 0.63 ^b	54.17 ± 0.24 ^f	6.20 ± 0.60 ^c	7.97 ± 0.28 ^b
Raw + VitE	70.60 ± 0.39 ^d	41.69 ± 0.39 ^d	39.64 ± 0.55 ^c	13.70 ± 0.80 ^d	4.96 ± 1.75 ^b
Raw + CS	64.57 ± 0.25 ^d	43.77 ± 0.68 ^e	41.64 ± 0.21 ^c	15.25 ± 0.25 ^e	0.47 ± 0.00 ^a
Raw + ZO	68.80 ± 1.25 ^d	41.17 ± 0.66 ^d	35.63 ± 0.19 ^c	13.75 ± 0.75 ^d	9.44 ± 1.21 ^b
Raw + AM	74.66 ± 1.81 ^d	26.88 ± 0.32 ^a	55.24 ± 3.58 ^f	8.20 ± 0.30 ^c	9.67 ± 3.60 ^b
Bo	8.78 ± 0.98 ^a	41.21 ± 0.70 ^d	49.00 ± 2.38 ^d	1.25 ± 0.25 ^a	8.53 ± 3.33 ^b
Bo + VitE	10.78 ± 0.1 ^b	46.46 ± 1.13 ^f	35.32 ± 0.81 ^c	4.35 ± 0.15 ^b	13.86 ± 2.09 ^b
Bo + CS	8.18 ± 0.22 ^a	48.25 ± 1.00 ^f	34.93 ± 1.19 ^c	4.1 ± 0.10 ^b	12.71 ± 2.10 ^b
Bo + ZO	11.30 ± 0.42 ^b	36.18 ± 0.74 ^c	51.61 ± 0.73 ^c	0.70 ± 0.10 ^a	11.50 ± 1.57 ^b
Bo + AM	10.62 ± 0.11 ^b	48.60 ± 0.65 ^f	33.36 ± 0.42 ^c	8.20 ± 0.20 ^c	9.82 ± 1.28 ^b
Fr	11.44 ± 0.1 ^b	43.31 ± 0.61 ^c	34.74 ± 0.23 ^c	5.65 ± 0.25 ^c	16.29 ± 0.63 ^b
Fr + VitE	8.23 ± 0.44 ^a	39.68 ± 0.13 ^d	25.14 ± 0.09 ^a	6.45 ± 0.85 ^c	28.72 ± 0.62 ^c
Fr + CS	8.04 ± 0.04 ^a	40.31 ± 0.63 ^d	28.86 ± 1.05 ^b	4.40 ± 0.40 ^b	26.41 ± 0.02 ^c
Fr + ZO	13.09 ± 0.1 ^b	39.94 ± 1.00 ^d	27.51 ± 0.15 ^b	3.35 ± 0.25 ^b	29.18 ± 0.90 ^c
Fr + AM	8.81 ± 0.28 ^a	49.92 ± 0.66 ^f	38.14 ± 0.29 ^c	4.30 ± 0.10 ^b	7.63 ± 1.05 ^b
Fr-Bo	10.54 ± 0.82 ^b	57.95 ± 0.37 ^g	31.94 ± 0.26 ^c	6.45 ± 0.35 ^c	3.65 ± 0.28 ^b
Fr-Bo + VitE	6.24 ± 0.82 ^a	57.20 ± 0.46 ^g	28.37 ± 0.39 ^b	3.25 ± 0.25 ^b	11.17 ± 0.18 ^b
Fr-Bo + CS	9.69 ± 0.16 ^a	46.57 ± 0.65 ^f	28.83 ± 1.08 ^b	6.75 ± 0.15 ^c	17.83 ± 1.86 ^b
Fr-Bo + ZO	8.12 ± 0.53 ^a	47.66 ± 0.63 ^f	39.33 ± 0.43 ^c	7.60 ± 0.20 ^c	5.40 ± 1.26 ^b
Fr-Bo + AM	9.20 ± 0.52 ^a	45.48 ± 0.15 ^f	35.36 ± 0.13 ^c	7.70 ± 0.20 ^c	11.45 ± 0.08 ^b

Results are means ± standard error (n = 3). Means within each column with different superscripts differ significantly (p < 0.05). Raw = Raw meat; Raw+VitE = broiler reared with 200 UI of vitamin E, Raw+ZO = broiler reared with 5g/kg of *Zingiber officinale*, Raw+AM = broiler reared with 5g/kg of *Annona muricata*; Raw+CS = broiler reared with 5g/kg of *Camellia sinensis*, Bo = Boiled meat, Bo+VitE = Boiled meat reared with 200 UI of vitamin E; Bo+ZO = Boiled meat reared with 5g/kg of *Zingiber officinale*, Bo+AM = Boiled meat reared with 5g/kg of *Annona muricata*, Bo+CS = Boiled meat reared with 5 g of *Camellia sinensis*; Fr = Fried meat, Fr+ VitE= Fried meat reared with 200 UI of vitamin E, Fr+ZO = Fried meat reared with 5g/kg of *Zingiber officinale*; Fr+AM = Fried meat reared with 5g/kg of *Annona muricata*, Fr+CS = Fried meat reared with 5g/kg of *Camellia sinensis*, Fr-Bo = Fried and boiled meat, Fr-Bo+VitE = Fried and boiled meat reared with 200 UI of vitamin, Fr-Bo+ZO = Fried and boiled meat reared with 5g/kg of *Zingiber officinale*, Fr-Bo+AM = Fried and boiled meat reared with 5g/kg of *Annona muricata* and Fr-Bo+CS = Fried and boiled meat reared with 5g/kg of *Camellia sinensis*.

Malondialdehyde. However, all these acidities were lower than those recommended by FEDNA (1999) which was 8% for poultry fat and 4% for beef tallow and lard.

3.4 Effect of culinary treatments on the proximate composition of broiler meat

The effect of culinary treatments on the proximate composition of broiler thigh meat is presented in Table 2. There was a significant (p<0.05) reduction in moisture content between raw and cooked samples, in which a linear decrease (p<0.05) in moisture content was observed as the cooking time and the temperature increase. The lowest value was obtained with the treatment Fr-Bo + VitE (6.24%) and the highest value was by the treatment Raw+AM (74.66%). These results revealed that thermal treatments help in decreasing the water content in meat, water might be displaced due to heat-induced protein denaturation during cooking (Juárez et al., 2010). According to Latip et al. (2013), heating techniques applied to meat products enhance its hygienic quality by inactivation of pathogenic microorganisms and improve its taste, flavor and shelf life.

For the protein content, there was a significant

increased (p<0.05) in the protein content of broiler thigh meat after cooking treatments with high value observed in the combined treatments Fr-Bo (57.95%) and Fr-Bo+VitE (57.20%) while the lowest values were obtained in raw sample (31.6%) and raw sample supplied with powder of *Annona muricata* (26.88%)(Table 2). This could be due to thermal treatment releasing water during cooking treatments, increase the aggregation and concentration of protein in meat. Latif (2010), showed a significant increase in protein content in marinated chicken breast muscle during frying (29.50%), roasting (22.60%) compared with the control (18.65%). Also, for uncooked samples, we observed that rations supplemented with powders of *Camellia sinensis* and *Zingiber officinale* significantly increased (p<0.05) protein content of broiler meat. This was in agreement with findings of Kim et al. (2009), who showed that dietary supplementation with different levels of garlic bulb and garlic husk significantly increased the protein content of chicken thigh muscle compared with muscle from birds fed with non-supplemented diets. These values showed that broiler meat contained high levels of proteins, and can be used as an animal proteins source for human nutrition especially to enhance children

growth.

Lipids content of broiler thigh meat exhibited a significant difference ($p < 0.05$) among treatments (Table 2). Compared to raw samples, there was a considerable decrease in lipids content after cooking, in which a maximum decrease in fat was found in the treatment Fr + VitE (25.14%) and a maximum increase was found in the treatment Raw+AM (55.24%). High cooking temperature makes the meat juice run out leads to melted fat release from the surface. According to Braeckman *et al.* (2009), during thermal processing, water is usually lost either by evaporation through the crust or as drip, while fat is only lost exuded from the meat as a drip.

A similar finding has been showed by Gerber *et al.* (2009) when they studied the effect of cooking temperature and time on the fat content of meat. Also, Asmaa *et al.* (2015) showed a linear decreasing of the total fat content of sausage chicken with time at all investigated temperatures. Various investigations reported that longer cooking time at high temperature resulted in greater cooking, moisture and fat loss (Serrano *et al.*, 2007; Sanghoon, 2011). The higher lipid content observed in this study indicates that broiler thigh meat may be classified as fatty meat (Feinberg *et al.*, 1987) and this was due to the rations and to the fact that the skin was not removed in this study.

For the carbohydrates content (digestible and undigestible), there was a significant difference ($p < 0.05$) among cooked and uncooked treatments (Table 2). Fried treatments of broiler thigh meat revealed a high level of carbohydrate content (16.29-29.18%); while the lowest value was obtained with the treatment Raw+CS (0.47%). This might be due to thermal processing that released water and allowed concentration of carbohydrates in meat; also, it was also showed that broiler meat contained dietary fibers that are undigestible carbohydrate. These were in agreement with the findings of Tiwo *et al.* (2016) which showed an increase in carbohydrate content in cooked and fried freshwater fish produced in Cameroon compared to the raw sample.

Concerning the changes in ash content, there was a significant decrease ($p < 0.05$) after cooking treatment with the highest value obtained with the treatment Raw+CS (15.25%) and the lowest value obtained with the treatment Bo+ZO (0.70%)(Table 2). However, we observed that supplemented rations increased the ash content of broiler thigh meat compared to the raw sample. The values of ash content obtained in this study were greater than those obtained by Shirzadegan and Falahpour (2014) on thigh meat from broilers fed with dietary medicinal herb extract mixture that ranged from 2.69 to 4.94%. The high concentration of ash in broiler

thigh meat indicated a good source of minerals.

3.5 Effect of culinary treatments on the mineral content of broiler meat

The changes in the mineral composition of broiler thigh meat during processing are presented in Table 3. Broiler thigh meat contains important amount of macroelements, among which phosphorus, potassium, and calcium are the most represented and microelements among which there are iron and zinc. These mineral elements play important role in human health. They are implicated in several body functions such as enzymatic reactions, energy production, transmission of nerve impulses, and multiple biological reactions (Steinberg *et al.*, 2003). For the iron content, there was a significant difference ($p < 0.05$) among all the treatments. In general, the cooking treatments slightly decreased iron content of meat. It was showed that iron can be degraded if foods are cooked at a high temperature for too long (Hallberg *et al.*, 1993). However, the values obtained in this study are greater than those obtained by Tiwo *et al.* (2016) on freshwater fishes of Cameroon.

The level of zinc ranged between 23.42 to 29.70 mg/kg with high values obtained for the raw sample (Table 3). As observed above, cooking treatment decreased ($p < 0.05$) zinc content of broiler thigh meat compared to other treatments. These values were greater than those found by Njinkoue *et al.* (2016) on edible part of two Cameroonian marine fishes: *Pseudotolithus elongatus* (12.49 mg/kg) and *Pseudotolithus elongatus* (14.7 mg/kg).

Table 3 also revealed the level of macroelements of broiler thigh meat. It was observed that boiling significantly decreased ($p < 0.05$) the level of phosphorus and calcium in comparison to the other treatments with values ranging from 3531 to 6495 mg/kg for the treatments Bo and Fr+VitE and from 480 to 1920 mg/kg for Bo and Raw+VitE respectively for phosphorus and calcium levels. This was in agreement with findings of Tiwo *et al.* (2016) who showed that boiling decreased the level of phosphorus and calcium in two freshwater fish *Clarias gariepinus* and *Cyprinus carpio*. Due to the fact that calcium and phosphorus contents are not similar in all the samples, the Ca/P ratios showed different values. According to Belitz *et al.* (2009), the Ca/P ratio in food should be about 1 in order to enhance their absorption in the body. The results of our study were in agreement with findings of Njinkoue *et al.* (2016) on edible part of two Cameroonian marine fish.

The levels of sodium and potassium are presented in Table 3. Boiling significantly decreased ($p < 0.05$) the sodium and potassium levels compared to other

Table 3. Changes in the mineral content of broiler meat during culinary treatments

Samples	Fe (mg/Kg)	P (mg/Kg)	Na (mg/Kg)	K (mg/Kg)	Zn (mg/Kg)	Ca (mg/Kg)	Mg (mg/Kg)
Raw	356.50 ± 6.50 ^d	4956.00 ± 71.00 ^c	875.00 ± 0.00 ^d	6354.00 ± 0.00 ^d	29.70 ± 0.50 ^b	600.00 ± 40.00 ^a	182.50 ± 36.50 ^a
Raw + VitE	332.00 ± 6.00 ^b	5625.50 ± 28.50 ^g	1000.00 ± 0.00 ^f	7483.00 ± 2.00 ^c	27.69 ± 0.50 ^b	1920.00 ± 80.00 ^c	243.00 ± 0.00 ^b
Raw + CS	341.00 ± 0.00 ^c	4485.50 ± 28.50 ^d	750.00 ± 0.00 ^c	5227.00 ± 0.00 ^c	28.45 ± 0.25 ^b	700.00 ± 60.00 ^a	158.00 ± 12.00 ^a
Raw + ZO	281.00 ± 9.00 ^a	6138.50 ± 28.50 ⁱ	1000.00 ± 0.00 ^f	8604.00 ± 4.00 ^f	23.42 ± 0.75 ^a	680.00 ± 40.00 ^a	195.50 ± 1.50 ^a
Raw + AM	302.00 ± 6.00 ^b	5298.00 ± 14.00 ^f	747.50 ± 2.50 ^c	6354.00 ± 0.00 ^d	25.18 ± 0.50 ^b	2200.00 ± 120.00 ^d	449.50 ± 60.50 ^c
Bo	347.00 ± 9.00 ^c	3531.00 ± 71.00 ^a	500.00 ± 0.00 ^a	2974.00 ± 1.00 ^a	28.95 ± 0.75 ^b	1800.00 ± 40.00 ^c	437.50 ± 48.50 ^c
Bo + VitE	335.00 ± 9.00 ^c	4243.50 ± 71.50 ^c	500.00 ± 0.00 ^a	4100.00 ± 0.00 ^b	27.94 ± 0.75 ^b	480.00 ± 0.00 ^a	206.50 ± 12.50 ^a
Bo + CS	353.50 ± 9.50 ^c	4143.50 ± 28.50 ^c	505.00 ± 5.00 ^a	4100.00 ± 0.00 ^b	29.45 ± 0.75 ^b	480.00 ± 80.00 ^a	121.50 ± 24.50 ^a
Bo + ZO	329.00 ± 9.00 ^b	3858.50 ± 28.05 ^b	500.00 ± 0.00 ^a	2973.00 ± 0.00 ^a	27.44 ± 0.75 ^b	560.00 ± 0.00 ^a	218.50 ± 24.50 ^a
Bo + AM	359.50 ± 9.50 ^d	4685.00 ± 57.00 ^d	622.50 ± 2.50 ^b	5227.00 ± 0.00 ^c	29.95 ± 0.75 ^b	640.00 ± 0.00 ^a	97.00 ± 0.00 ^a
Fr	305.00 ± 3.00 ^b	5896.50 ± 14.50 ^h	750.00 ± 0.00 ^c	6354.00 ± 0.00 ^d	25.43 ± 0.25 ^b	1640.00 ± 120.00 ^c	705.00 ± 73.00 ^c
Fr + VitE	287.00 ± 3.00 ^a	6495.00 ± 43.00 ^j	1000.00 ± 0.00 ^f	7483.00 ± 2.00 ^e	23.92 ± 0.25 ^a	1160.00 ± 200.00 ^b	364.50 ± 72.50 ^c
Fr + CS	284.00 ± 6.00 ^a	5853.50 ± 28.50 ^h	875.00 ± 0.00 ^d	7481.00 ± 0.00 ^c	23.67 ± 0.50 ^a	1440.00 ± 80.00 ^c	121.50 ± 24.50 ^a
Fr + ZO	302.00 ± 6.00 ^b	6423.50 ± 28.05 ^j	987.50 ± 7.50 ^e	7482.00 ± 1.00 ^e	25.18 ± 0.50 ^b	1620.00 ± 60.00 ^c	498.00 ± 12.00 ^d
Fr + AM	317.00 ± 3.00 ^b	6210.00 ± 43.00 ⁱ	875.00 ± 0.00 ^d	7481.00 ± 0.00 ^e	26.44 ± 0.25 ^b	1340.00 ± 20.00 ^b	510.50 ± 24.50 ^d
Fr-Bo	323.00 ± 3.00 ^b	5797.00 ± 57.00 ^h	747.50 ± 2.50 ^c	5228.00 ± 1.00 ^c	26.94 ± 0.25 ^b	1360.00 ± 0.00 ^b	534.50 ± 48.50 ^d
Fr-Bo + VitE	314.00 ± 6.00 ^b	5668.50 ± 71.50 ^g	625.00 ± 0.00 ^b	5227.00 ± 0.00 ^c	26.18 ± 0.50 ^b	1800.00 ± 40.00 ^c	729.00 ± 49.00 ^d
Fr-Bo + CS	305.00 ± 3.00 ^b	5340.50 ± 28.05 ^f	750.00 ± 0.00 ^c	6354.00 ± 0.00 ^d	25.43 ± 0.25 ^b	1440.00 ± 80.00 ^c	668.00 ± 12.00 ^c
Fr-Bo + ZO	332.00 ± 6.00 ^b	5611.50 ± 14.50 ^g	625.00 ± 0.00 ^b	4100.00 ± 0.00 ^b	27.69 ± 0.50 ^b	1780.00 ± 60.00 ^c	413.00 ± 0.00 ^c
Fr-Bo + AM	311.00 ± 9.00 ^b	4243.50 ± 71.50 ^c	1375.00 ± 0.00 ^g	5227.00 ± 0.00 ^c	25.93 ± 0.75 ^b	1640.00 ± 120.00 ^c	340.50 ± 48.50 ^c

Results are means ± standard error (n = 3). Means within each column with different superscripts differ significantly (p < 0.05). Raw = Raw meat; Raw+VitE = broiler reared with 200 UI of vitamin E. Raw+ZO = broiler reared with 5g/kg of *Zingiber officinale*. Raw+AM = broiler reared with 5g/kg of *Annona muricata*; Raw+CS = broiler reared with 5g/kg of *Camellia sinensis*. Bo = Boiled meat. Bo+VitE = Boiled meat reared with 200 UI of vitamin E; Bo+ZO = Boiled meat reared with 5g/kg of *Zingiber officinale*. Bo+AM = Boiled meat reared with 5g/kg of *Annona muricata*. Bo+CS = Boiled meat reared with 5 g of *Camellia sinensis*; Fr = Fried meat. Fr+ VitE= Fried meat reared with 200 UI of vitamin E. Fr+ZO = Fried meat reared with 5g/kg of *Zingiber officinale*; Fr+AM = Fried meat reared with 5g/kg of *Annona muricata*. Fr+CS = Fried meat reared with 5g/kg of *Camellia sinensis*. Fr-Bo = Fried and boiled meat. Fr-Bo+VitE = Fried and boiled meat reared with 200 UI of vitamin. Fr-Bo+ZO = Fried and boiled meat reared with 5g/kg of *Zingiber officinale*. Fr-Bo+AM = Fried and boiled meat reared with 5g/kg of *Annona muricata* and Fr-Bo+CS = Fried and boiled meat reared with 5g/kg of *Camellia sinensis*.

treatments. Their values ranged from 500 to 1375 mg/kg respectively for the treatments Bo and Fr-Bo+AM for sodium level; while for potassium level, they ranged from 2973 to 8604 mg/kg for the treatments Bo+ZO and Raw+ZO respectively. These results were similar to those of Tiwo *et al.* (2016) who showed that boiling decreased the level of sodium and phosphorus in freshwater fish *Cyprinus carpio* produced in Batie, West-

Cameroon. Also, the sodium and potassium contents were not similar in all the samples and the Na/K ratios showed different values. According to Bu *et al.* (2012) and Perez *et al.* (2014), the Na/K ratio in food should be less than 1 as a good indicator for human health, especially in the case of cardiovascular disease prevention.

Concerning the level of magnesium in broiler thigh meat, there was a significant difference ($p < 0.05$) between the samples. The level of magnesium ranged between 97 mg/kg (Bo+AM) to 729 mg/kg (Fr-Bo+VitE) (Table 3). Overall, the values obtained in this study were lower than those shown by Tiwo *et al.* (2016) on cooked and uncooked freshwater fish produced in Batie, Cameroon.

4. Conclusion

The objective of this study was to evaluate the effects of feeding system and cooking treatments on the lipids quality, proximate composition and mineral content of broiler meat fed with powders of three natural plants. Results revealed that food supplementation with dry powder of *Annona muricata* flower at 0.5% limited the formation of hydroperoxide and malondialdehyde in oil extracted from broiler meat during frying. Also, all the treatments significantly reduced the iodine value of oils extracted from broiler meat. The combined treatments increased acid value of fat. Rations supplemented with powders of *Camellia sinensis*, *Annona muricata* and *Zingiber officinale* also enhanced the proximate composition and mineral content of uncooked and cooked broiler meat.

Conflict of interest

The authors declare that there are no conflicts of interest.

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