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REGULAR ARTICLES

The impact of breed, *Ficus exasperata* leaf powder and vitamin C on carcass traits, brain and meat oxidative enzymes of broiler chickens raised under the tropical condition

Olufemi Clement Osowe[1] · Olufemi Adesanya Adu[1] · Olugbenga David Oloruntola[2] · Clifford Adinma Chineke[1] · Adewale Johnson Atansuyi[1] · Imoleayo Sarah Olateju[1]

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Abstract

This study aims to see how supplementing broiler chickens with *Ficus exasperata* leaf powder (FELP) and vitamin C affects carcass characteristics, brain and meat oxidative enzymes and cholesterol levels in tropical conditions. Three hundred thirty-six-day-old chicks (comprising of 168 Cobb 500 breed chicks and 168 Arbor Acre breed chicks) of broiler chicks weighing 37.40 ± 0.45 g were assigned to 8 experimental diets of 7 replicates (6 birds/replicate; 42 birds/treatment). Diets 1 and 2 were not supplemented, while diets 3 and 4 had vitamin C (200 mg/kg of basal diet) supplementation. Then, diets 5 and 6 received 1 g FELP/kg of basal diet supplementation each while diets 7 and 8 had 1 g FELP/kg of basal diet + 200 mg of vitamin C. The breed and FELP affected ($P < 0.05$) the dressing percentage. The relative weights of the gizzard and heart were affected ($P < 0.05$) by the vitamin c and FELP, while the lung weight was affected by vitamin C. The proventriculus was affected by the breed, FELP and vitamin c. The brain catalase and glutathione peroxidase increased with vitamin c and FELP supplementation while catalase and glutathione peroxidases were higher in CO. Vitamin c and FELP reduced the meat lipid oxidation but increased the glutathione peroxidase and catalase. Conclusively, dietary supplementation with 200 mg/kg of vitamin C and 1% FELP could increase the brain's antioxidant capacity and improve the meat quality of broiler chickens.

Keywords Antioxidant status · Carcass · Brain · Ficus · Meat · Supplementation

Introduction

Due to the rise in demand for animal protein, there has been an unheard-of boom in animal production, particularly broiler production in the tropics and subtropics. However, there are several restrictions on broiler production, making it nearly impossible for broiler chickens to reach their genetic potential (Kpomasse et al. 2021).

Heat stress is one of the key factors limiting poultry production in the tropics and subtropics. Due to increased global warming, heat stress impacts on poultry production are projected to be amplified, posing more risks (Salah et al. 2021). Because of their rapid development rate and high metabolic heat output, broiler chickens are particularly vulnerable to heat stress. Furthermore, heat stress has been shown to reduce broiler chicken survival rates, feed consumption, performance attributes and meat quality (Gous 2010; Salah et al. 2021).

Heat stress promotes several processes which affect the membrane's structure and cellular organelles, and activates the lipid peroxidation process in tissues by amplifying the reactive oxygen species (ROS) production in the mitochondria and disturbing energy mitochondria and ATP synthesis (Akbarian et al. 2016). Previous reports alarm the increased oxidative skeletal muscle damage in broiler chickens, acceleration of lipid oxidation, protein denaturation and deterioration of broiler chickens' meat quality and nutritional value due to thermal stress (Shakeri et al. 2019). Antioxidant enzymes such as superoxide dismutase, glutathione peroxidase and catalase protect cells from the detrimental effects of reactive oxygen species, hence preventing oxidative damage and degradation in meat and extending its shelf life (Gbore et al. 2021).

✉ Olugbenga David Oloruntola
olugbenga.oloruntola@aaua.edu.ng

[1] Department of Animal Production and Health, The Federal University of Technology, Akure, Nigeria

[2] Department of Animal Science, Adekunle Ajasin University, Akungba-Akoko, Nigeria

To mitigate the effects of heat stress in poultry production, strategies such as housing design, nutrition and the provision of cooling systems have been considered previously; however, the use of phytochemicals or phytogens as dietary supplements or additives is gaining wider consideration in broiler production (Gbore et al. 2021; Oloruntola et al. 2021, 2022). This could be because phytochemicals inhibit enzymes involved in the oxidative process indirectly by enhancing the activity of known antioxidant enzymes such as superoxide dismutase and catalase (Kocyigit et al. 2017). In addition, free radical production is inhibited by glutathione, flavonoids, phenols and carotenoids, among others (Engwa 2018).

Natural antioxidant compounds can be found in *Ficus exasperata* leaf. As reported by Osowe et al. (2021), alkaloids, flavonoids and phenols are prominent phytochemicals in *Ficus exasperata* leaf powder (FELP). Alkaloids were reported to demonstrate scavenging activity in vitro and behave as an antioxidant (Macáková et al. 2019). Flavonoids have been shown to have antiviral, anti-inflammatory and antioxidant properties (Pietta, 2000), while by interacting with free radicals, phenolic substances act as antioxidants (Zeb 2020). Osowe et al. (2021) reported that the leaf powder of *Ficus exasperata* contains a significant number of important minerals and phytochemicals with high antioxidant activity and thus could be employed as a natural feed supplement in animal nutrition.

By having synergistic effects, vitamin C can work as a co-antioxidant with other antioxidants. For example, vitamin C can increase the antioxidant activity of vitamin E by converting tocopheroxy radicals back into vitamin E's active form (Shakeri et al. 2020). Additionally, vitamin C has been shown to control body temperature and strengthen the immune system by increasing phagocyte proliferation, cytokine production, lymphocyte production and the number of cell adhesion molecules in monocytes (Sorice et al. 2014). Synthetic vitamin c is a conventional dietary supplement used in poultry production to salvage cases of heat stress, oxidative stress, inflammation and infection (El-Senousey et al. 2018; Adebayo et al. 2022).

Specifically, there is a paucity of information on the effects of FELP supplementation on broiler chicks raised in tropical heat stress. As a result, the goal of this study is to see how supplementing broiler chickens with FELP and vitamin C affects carcass characteristics, brain and meat oxidative enzymes and cholesterol levels in tropical conditions.

Materials and methods

Ethical approval: collection, processing and analysis of phytogens

The Research and Ethics Committee of the Department of Animal Production and Health, Federal University of Technology, Akure, Nigeria, approved the animal and animal protocol requirements (FUTA/APH/2021/12). Osowe et al. (2021) described and published the techniques for collecting *Ficus exasperata* leaf, turning it into FELP, and analysing FELP for phytochemical content, proximate components, antioxidant and mineral composition.

Management and arrangement of experimental birds

The feeding trial took place at the Teaching and Research Farm of the Federal University of Technology in Akure, Nigeria, between February and March 2021. The temperature-humidity index (THI), as described by Jimoh et al. (2017), was calculated using the thermo-hygrometer. $THI = t_a - [(0.31 - 0.31 \times RH)(t_a - 14.4)]$, where T_a = ambient temperature and RH = relative humidity/100. The THI for the temperate and tropical regions are no heat stress (< 27.8 °C), middling heat stress (27.8–28.9 °C), severe heat stress (28.9–30 °C) and very severe heat stress (> 30 °C). The average temperature and average relative humidity were 29.79 °C and 74.5%, respectively, while the THI was computed as 28.57.

The experimental design was a completely randomised one in a 2 × 2 × 2 factorial arrangement comprising 2 breeds (Cobb 500 (CO) and Arbor Acre (AB); 2 vitamin c levels (0 and 200 mg/kg) and 2 levels of FELP (0 and 1%).

A baseline diet was developed and divided into 8 equal portions for the starter and finisher periods of broiler chicken rearing (Table 1). Each portion was supplemented with its respective supplements. Diets 1 and 2 were not supplemented, while diets 3 and 4 had vitamin C (200 mg/kg of basal diet) supplementation. Then, diets 5 and 6 received 1 g FELP/kg of basal diet supplementation each while diets 7 and 8 had 1 g FELP/kg of basal diet + 200 mg of vitamin C. In total, 336-day-old chicks (168 CO and 168 AB breeds) of broiler chicks with an initial weight of 37.40 ± 0.45 g were assigned to 8 experimental diets of 7 replicates (42 birds/treatment; 6 birds/replicate). Arbore acre was distributed to dies 1, 3, 5 and 7, while CO was distributed to diets 2, 4, 6 and 8. The birds were housed in experimental pens (2 m × 2 m) covered with dry wood shaving to a depth of 3 cm. Management practices such as adequate stocking density, proper pen ventilation and maintenance of dry litter by avoiding water spillage were adopted to prevent the building up of litter moisture and ammonia levels. The experimental house temperature was stabilised at 31 ± 2 °C for the first week and then reduced by 2 °C during the subsequent 2 weeks after which the birds were raised under natural ambient temperature for the rest of the rearing period (week 4 to 6). The lighting was turned on for 24 h on the first day and 23 h on days 1 to 7. The lighting was provided for 18 h

Table 1 Dietary composition

Ingredients (%)	Starter phase	Finisher phase
Maize	50.35	58.37
Rice bran	0	3.01
Maize bran	3.01	0
Soy oil	1	1
Fish meal	3	3
Soybean meal	38	30
Bone meal	3	3
Limestone	0.49	0.47
Premix	0.31	0.31
Salt	0.31	0.31
Lysine	0.24	0.24
Methionine	0.29	0.29
Nutrient composition (%)		
Metabolizable energy (Kcal/kg)	3018.1	3108.2
Available phosphorus	0.48	0.43
Calcium	1.03	1.04
*Crude fibre	3.52	3.58
*Crude fat	4.23	2.38
*Crude protein	22.17	20.04

*Determined/analysed composition

for the rest of the rearing period. For the 6 weeks of the experiment, all birds were fed ad libitum.

Carcass traits

To analyse carcass traits, 14 birds were randomly selected from each treatment group (2 birds/replicate) on the 42nd day of the experiment, weighed and slaughtered according to the EU guideline on animal protection during slaughter and killing (Uijttenboogaart 1999). Carcasses were eviscerated, spray-washed and chilled for 30 min at 2 °C. The dressing percentage was estimated as the percentage ratio of the carcass weight relative to the final body weight. The relative weights (% final weight) of the liver, gizzard, spleen, pancreas, heart, bile, lung and proventriculus were also calculated.

Total protein and antioxidant enzymes of the brain and lipid oxidation, antioxidant enzymes and cholesterol level of the meat

After slaughtering, a total of 7 birds were selected from each treatment group (1 bird/replicate) for the determination of brain total protein and antioxidant and meat lipid oxidation, antioxidant enzymes and cholesterol level determination. The complete brains of broiler chickens were extracted and homogenised in cold saline 0.9% in a 1:10 (w/v) proportion using a high-speed homogeniser. The homogenate samples were centrifuged at 2000 revolutions per minute for 20 min before being separated into 1.0 ml aliquots and kept at − 18 °C until use. The ultraviolet method was used to determine the total protein (Zaia et al. 2000). The catalase activity (Khan et al. 2012) and glutathione peroxidase activities (Khan et al. 2012) were also determined.

After dressing, a sample of breast meat was taken from the slaughtered birds, packaged aerobically in an oxygen-permeable bag and frozen for 20 days at − 18 °C. Following that, the thiobarbituric acid (TBA) assay method was used to determine the degree of lipid oxidation in the meat (Tokur et al. 2006). The glutathione peroxidase (Cichoski et al. 2012) and catalase (Muhlisin et al. 2016) activities were also determined. As indicated by de Almeida et al. (2006), the concentration of meat cholesterol was measured spectrophotometrically using commercial kits (Asan Pharm. Co., Ltd. Seoul).

Statistical data evaluation

The SPSS, version 20, was used to conduct the statistical analysis. Data were analysed in a 2 × 2 × 2 factorial arrangement with 2 levels of FELP, 2 levels of vitamin c and 2 breeds using the general linear model: $Yijk = \mu + Fi + Vj + B_K + eijk$, where μ = mean, Fi = effect of FELP, Vj = effect of vitamin C, B_K = effect of breed and eijk = random error. Duncan's multiple range analysis at $P < 0.05$ was used to assess the differences between the diets' means.

Results

Relative internal organs and carcass characteristics of broiler chickens

Table 2 shows the effects of breed, FELP supplementation and vitamin C supplementation on the relative internal organs and carcass characteristics of broiler chickens. The broiler chicks in treatment groups 1 and 3 had the highest ($P < 0.05$) dressed percentages. In addition, the breed effect and FELP supplementation had an impact ($P < 0.05$) on the dressing percentage of the broiler chickens, with the dressing % being higher ($P < 0.05$) in AB than in CO and lower ($P < 0.05$) with FELP supplementation.

In treatment groups 4 (CO + vitamin C) and 7 (AB + vitamin C + FELP), the relative weight of the gizzard was considerably ($P < 0.05$) higher. The weight of the gizzard increased significantly ($P < 0.05$) as a result of the addition of vitamin C and FELP and significantly ($P < 0.05$) as a result of breed × FELP and breed × vitamin C × FELP.

Treatment groups 7 (AB + vitamin C + FELP) and 3 (AB + vitamin C) had the largest ($P < 0.05$) heart weights. With vitamin C and FELP administration, the heart weight

Table 2 Effects of different breeds, *Ficus exasperata* leaf powder and vitamin c on the carcass trait and relative organ weight (% dressed weight) of broiler chickens

Diet	Breed	Vitamin C mg/kg	FELP %	Dressed percentage	Liver	Gizzard	Spleen	Pancreas	Heart	Bile	Lung	Proventriculus
1	AB	0	0	78.79^{a}	2.52	1.97^{cd}	0.12	0.23	0.53^{c}	0.11	0.52^{b}	0.44^{bc}
2	CO	0	0	75.14^{b}	2.79	1.88^{d}	0.15	0.29	0.59^{c}	0.15	0.43^{b}	0.53^{a}
3	AB	200	0	76.94^{ab}	2.78	2.05^{bcd}	0.13	0.27	0.71^{ab}	0.16	0.49^{b}	0.48^{ab}
4	CO	200	0	75.38^{b}	2.64	2.52^{a}	0.16	0.30	0.54^{c}	0.15	0.63^{a}	0.48^{ab}
5	AB	0	1	74.25^{bc}	2.39	2.16^{bc}	0.23	0.29	0.60^{c}	0.16	0.51^{b}	0.38^{d}
6	CO	0	1	73.48^{bc}	2.40	2.25^{b}	0.11	0.29	0.63^{bc}	0.15	0.48^{b}	0.41^{cd}
7	AB	200	1	74.12^{bc}	2.83	2.53^{a}	0.12	0.29	0.77^{a}	0.13	0.62^{a}	0.46^{bc}
8	CO	200	1	71.51^{c}	2.57	2.20^{bc}	0.13	0.26	0.60^{c}	0.16	0.63^{a}	0.50^{ab}
SEM				0.52	0.06	0.05	0.01	0.01	0.01	0.01	0.01	0.01
P-value				0.01	0.45	0.01	0.06	0.29	0.01	0.44	0.01	0.01
AB				76.52^{a}	2.45	2.06	0.18	0.26	0.56	0.13	0.51	0.41^{b}
CO				75.53^{b}	2.80	2.29	0.12	0.28	0.74	0.14	0.55	0.47^{a}
SEM				0.73	0.12	0.05	0.01	0.01	0.02	0.01	0.02	0.01
P-value				0.01	0.79	0.47	0.49	0.28	0.22	0.39	0.64	0.01
0				77.86	2.65	2.01^{b}	0.15	0.25	0.56^{b}	0.13	0.53^{b}	0.46^{a}
200				74.19	2.61	2.34^{a}	0.12	0.29	0.61^{a}	0.14	0.58^{a}	0.42^{b}
SEM				0.73	0.12	0.05	0.01	0.01	0.02	0.01	0.02	0.01
P value				0.22	0.16	0.01	0.26	0.74	0.01	0.48	0.01	0.01
0				76.96^{a}	2.65	1.92^{b}	0.14	0.26	0.56^{b}	0.13	0.47	0.48^{a}
1				73.86^{b}	2.39	2.20^{a}	0.12	0.29	0.61^{a}	0.15	0.49	0.39^{b}
SEM				0.73	0.12	0.05	0.01	0.01	0.02	0.01	0.02	0.01
P value				0.01	0.28	0.01	0.61	0.45	0.04	0.48	0.08	0.01
Interactions *P-value*												
Breed × vitamin C				0.93	0.18	0.52	0.06	0.45	0.01	0.81	0.01	0.25
Breed × FELP				0.54	0.44	0.01	0.08	0.05	0.74	0.81	0.46	0.76
Vitamin C × FELP				0.87	0.33	0.06	0.16	0.14	0.89	0.19	0.31	0.01
Breed × vitamin C × FELP				0.20	0.75	0.01	0.07	1.00	0.69	0.08	0.06	0.11

Means with a different superscript in the same column are significantly ($P<0.05$) different; *AB*, Arbor acre; *CO*, Cobb 500; *FELP*, *Ficus exasperata* leaf powder; *SEM*, standard error of the means

increased ($P<0.05$). Vitamin C × breed was significant ($P<0.05$).

Treatment groups 4 (CO + vitamin C), 7 (AB + vitamin C + FELP) and 8 (CO + vitamin C + FELP) all had significantly ($P<0.05$) greater lung weights. The weight of the lung rose ($P<0.05$) with vitamin C treatment, and the interaction between breed and vitamin C was significant ($P<0.05$). Treatment groups 2, 3, 4 and 8 all had greater ($P<0.05$) proventriculus weights. In comparison to AB, CO had a heavier ($P<0.05$) proventriculus. The relative weight of the proventriculus was decreased ($P<0.05$) by the vitamin C and FELP, while the vitamin C × FELP interaction was significant ($P<0.05$).

Brain total protein and antioxidant enzymes

Brain total protein and antioxidant enzymes of two breeds of broiler chickens fed FELP and vitamin C-supplemented diets are shown in Table 3. The treatment groups 6, 7 and 8 significantly ($P<0.05$) increased catalase and glutathione peroxidase concentrations. Breed, vitamin C and FELP had no ($P>0.05$) effect on the total protein. However, the breed had a significant ($P<0.05$) impact on the levels of brain catalase and glutathione peroxidase, with higher levels found in CO. The brain catalase and glutathione peroxidase were also considerably ($P<0.05$) elevated by vitamin C and FELP. There were no significant ($P>0.05$) interactions between the breed, vitamin c and FELP.

Meat lipid oxidation, antioxidant enzymes and cholesterol

Table 4 displays the meat lipid oxidation, antioxidant enzymes and cholesterol of two breeds of broiler chickens fed diets supplemented with vitamin C and FELP. The treatment groups that received vitamin C, FELP or a combination of vitamin C

Table 3 Effects of different breeds, *Ficus exasperata* leaf powder and vitamin c on the brain total protein and antioxidant enzymes of broiler chickens

Diet	Breed	Vitamin C mg/kg	FELP %	Total protein (mg/g)	Catalase (Ku)	Glutathione peroxidase (µmol/mg)
1	AB	0	0	0.60	24.98[d]	20.93 [g]
2	CO	0	0	0.51	38.82[c]	39.36[f]
3	AB	200	0	0.62	45.24[bc]	41.89[ef]
4	CO	200	0	0.62	51.39[b]	50.33[de]
5	AB	0	1	0.61	49.72[b]	53.37 [cd]
6	CO	0	1	0.57	61.33[a]	60.96[ab]
7	AB	200	1	0.62	65.49[a]	67.44[ab]
8	CO	200	1	0.54	69.71[a]	71.19[a]
SEM				0.01	3.01	3.34
P-value				0.57	0.01	0.01
AB				0.61	46.36[b]	45.91[b]
CO				0.56	55.31[a]	55.47[a]
SEM				0.02	1.52	1.57
P-value				0.13	0.01	0.01
0				0.57	43.71[b]	43.65[b]
200				0.60	57.96[a]	57.72[a]
SEM				0.02	1.52	1.57
P value				0.41	0.01	0.01
0				0.59	40.11[b]	38.13[b]
1				0.58	61.56[a]	63.24[a]
SEM				0.02	1.52	1.57
P value				0.94	0.01	0.01
Interactions P-value						
Breed × vitamin C				0.57	0.10	0.14
Breed × FELP				0.82	0.63	0.09
Vitamin C × FELP				0.27	0.32	0.40
Breed x Vitamin C x FELP				0.34	0.97	0.50

Means with a different superscript in the same column are significantly ($P < 0.05$) different; *FELP*, *Ficus exasperata* leaf powder; *AB*, Arbor acre; *CO*, Cobb 500; *SEM*, standard error of the means

and FELP had a substantial ($P < 0.05$) reduction in lipid oxidation (treatment groups 3, 4, 5, 6, 7 and 8). The broiler chicken meat's lipid oxidation activities were decreased ($P < 0.05$) by vitamin C and FELP supplementation. The breed × vitamin c, breed × FELP and vitamin C × FELP were significant ($P < 0.05$).

In all of the treatment groups that received vitamin C and FELP supplements, 3, 4, 5, 6, 7 and 8, the quantity of meat glutathione peroxidase and catalase increased ($P < 0.05$). The levels of glutathione peroxidase and catalase in the meat were elevated ($P < 0.05$) by the addition of vitamin C and FELP. Vitamin C and FELP had significant interaction ($P < 0.05$).

Discussions

Several factors, including genetic influences and nutritional pathways, have an impact on carcass quality, and more specifically dressing percentage (Kareem-Ibrahim et al. 2021; Marcinčák et al. 2011). The observed difference in the percentage of dressing between AB and CO may be caused by genetic differences between the two breeds. This finding is consistent with that of Kareem-Ibrahim et al. (2021), who discovered higher dressing percentages in some broiler chicken breeds than in others under investigation. Additionally, the lower dressing % that was seen as a result of the FELP supplementation was consistent with an earlier study by Marcinčák et al. (2011) that detailed inferior broiler chicken performance as a result of the addition of Camellia leaves. This study's finding that FELP harms dressing percentage suggests that the bioactive compound profiles of FELP support the development of the visceral organs, blood, head and gastrointestinal system more than the edible parts of broiler chickens. Sometimes phyto-supplements have antioxidant effects that modify how some tissues or target tissues develop (Valenzuela-Grijalva et al. 2017). Additionally, the components of animals' diets can occasionally cause changes in the weight of their internal organs (Oloruntola

Table 4 Effects of different breeds, *Ficus exasperata* leaf powder and vitamin c on meat lipid oxidation, antioxidant enzymes and cholesterol of broiler chickens

Diet	Breed	Vitamin C mg/kg	FELP %	Lipid oxidation (mgMDA/g)	Glutathione peroxidase (µmol/m)	Catalase (Ku)	Cholesterol (mg/dl)
1	AB	0	0	3.21^{a}	25.71^{e}	31.19^{d}	117.30
2	CO	0	0	2.27^{b}	27.15^{e}	35.15^{d}	110.73
3	AB	200	0	1.45^{c}	46.64^{cd}	49.66^{bc}	114.34
4	CO	200	0	1.26^{e}	50.06^{bc}	50.17^{ab}	109.93
5	AB	0	1	1.31^{d}	49.16^{bc}	48.98^{bc}	108.11
6	CO	0	1	1.39^{d}	56.62^{a}	50.76^{ab}	106.78
7	AB	200	1	1.10^{f}	57.41^{a}	49.76^{bc}	108.37
8	CO	200	1	1.35^{d}	52.36^{ab}	52.77^{a}	107.98
SEM				0.14	2.82	2.07	3.03
P-value				0.01	0.01	0.02	0.99
AB				1.77	44.73	44.91	112.03
CO				1.57	46.55	47.21	108.85
SEM				0.07	2.47	2.28	5.00
P-value				0.06	0.61	0.48	0.65
0				2.04^{a}	39.66^{b}	41.52^{b}	110.73
200				1.29^{b}	51.61^{a}	50.60^{a}	110.15
SEM				0.07	2.47	2.28	5.00
P value				0.01	0.01	0.01	0.93
0				2.05^{a}	37.39^{b}	41.54^{b}	113.07
1				1.29^{b}	53.88^{a}	50.58^{a}	107.81
SEM				0.07	2.47	2.28	5.00
P value				0.01	0.01	0.01	0.46
Interactions *P*-value							
Breed × vitamin C				0.04	0.46	0.86	0.91
Breed × FELP				0.01	0.86	0.98	0.74
Vitamin C × FELP				0.01	0.01	0.03	0.85
Breed × vitamin C × FELP				0.18	0.31	0.72	0.96

Means with a different superscript in the same column are significantly ($P < 0.05$) different; *FELP*, *Ficus exasperata leaf powder*; *AB*, Arbor acre; *CO*, Cobb 500; *SEM*, standard error of the means

et al. 2021). This could account for the variations in the relative weights of the broiler chickens' gizzard, heart, lungs and proventriculus that are caused by nutritional interventions.

The brain is vulnerable to oxidative stress because it discharges a variety of signalling mechanisms using chemically varied reactive molecules (Salim 2017). The improved brain catalase and glutathione peroxidase concentrations recorded in this study as a result of breed effects, vitamin c and FELP supplementation are of great benefit because antioxidants serve as the first line of defence against oxidative damage, removing the damaged biomolecules before their aggregation results in changes to cell metabolism, blocking and capturing the produced radicals and preventing the production of ROS (Lee et al. 2020). For instance, catalase detoxifies generated H_2O_2 to preserve brain cells, and catalase deficiency or dysfunction is associated with the aetiology of neurodegenerative diseases. Additionally, glutathione peroxidase uses glutathione to catalyse the conversion of a variety of hydroperoxides to matching alcohols or water, protecting mammalian cells from oxidative damage (Usui et al. 2009; Lee et al. 2020). The enhanced brain antioxidant enzymes concentration observed in this study supports the reports of neuroprotective potential of phytochemicals by Kumar and Khanum (2012) and brain antioxidant enzymes concentration enhancing capacity by vitamin C supplementation by Coşkun et al. (2005) and variation of brain antioxidant capacity caused by breed effects (Ren et al. 2013).

Stages of lipid oxidation result in a variety of by-products that have an impact on the nutritive values, functional properties and sensory properties of meat (Sottero et al. 2019). Based on the decreased meat lipid oxidation seen in this study as a result of vitamin C and FELP ingestion, it indicates that supplements have inhibitory effects on the oxidation of lipids in meat. Additionally, broiler meat from vitamin C-supplemented diets might include electron donors to fend against free radicals and stop the oxidation of lipids (Yoo et al. 2016). By limiting the generation of free radicals and lipid oxidation, the phenolic component in FELP may also stimulate antioxidant defence (Yesilbag et al. 2011).

Due to increased cellular antioxidant enzymatic activity, there is a correlation between dietary antioxidants and a decrease in the oxidative instability of proteins and lipids (Delles et al. 2014). Since catalase, superoxide dismutase and glutathione peroxidase are enzymatic antioxidants that are part of the first line of defence, the observed increased catalase and glutathione peroxidase concentration in broiler meat in this study as a result of vitamin c and FELP supplementation could be beneficial by inhibiting lipid oxidation and improving the meat quality (Delles et al. 2014).

The fact that vitamin C and FELP administration resulted in higher concentrations of catalase and glutathione peroxidase in broiler meat in this investigation demonstrates these supplements' ability to activate antioxidant enzymes. The observed increased meat antioxidant concentration may prevent lipid oxidation and enhance the meat quality since the enzymatic antioxidants are a part of the first line of defence antioxidants (Ray and Husain 2002).

Conclusion

The FELP and breeds influence the dressing % of broiler chickens. Vitamin C and FELP boosted the catalase and glutathione peroxidase in the brain and meat of broiler chickens while lowering the lipid oxidation in the meat. Therefore, broiler chickens' meat quality and antioxidant capacity may both be improved by diet supplementation with 200 mg/kg vitamin C and 1% FELP.

Author contribution O. C. C., O. A. A., C. A. C. and O. D. O. designed the experiment; All authors carried out the fieldwork supervision with O. C. C., O. A. A. and O. D. O. handling the data recording; O. D. O. prepares the manuscript with proofreading from all other authors. O. C. C., O. D. O. and O. A. A. performed the statistical analyses with figure representation carried out by O. C. C. and O. D. O. O. A. A. and C. A. C. proofread and approved the final manuscript.

Data availability The datasets used and/or analysed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethical approval The study was undertaken with approval from the institutional ethics committee for the care and use of animals for research at the host institution.

Conflict of interest The authors declare no competing interests.

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