Trop J Nat Prod Res, May 2025; 9(5): 1939 - 1944 **ISSN 2616-0684 (Print)**
ISSN 2616-0692 (Electronic)

Tropical Journal of Natural Product Research

Available online at https://www.tjnpr.org

Original Research Article

Effect of Orange (*Citrus sinensis*) Peels Enriched Feed on Meat Quality and Antioxidant Status of Fed Broiler Chicken

Tosin B. Oboh[1], Samuel Aro[1*], Idowu S. Oyeleye[2], Olajide R. Ojo[3], Ayokunle O. Ademosun[3], Olufemi O. Adu[1], Ganiyu Oboh[3]

[1]*Department of Animal Production and Health, Federal University of Technology, P.M.B. 704, Akure 340001, Nigeria*
[2]*Department of Biomedical Technology, Federal University of Technology, P.M.B. 704, Akure 340001, Nigeria*
[3]*Functional Food and Nutraceutical Unit, Department of Biochemistry, Federal University of Technology, P.M.B. 704, Akure 340001, Nigeria.*

ARTICLE INFO

Article history:
Received 07 August 2024
Revised 20 January 2025
Accepted 02 February 2025
Published online 01 June 2025

ABSTRACT

Orange peels are usually considered waste products and constitute an environmental menace. Interestingly, the peels are rich in bioactive compounds that could benefit humans and animals, including poultry. This study investigated the meat quality and antioxidant status of broiler chicken fed with orange peel-enriched feeds. In a completely randomized design, fifty-day-old birds were fed with 0%, 2.5%, 5%, 7.5%, and 10% orange peel inclusion feed for three weeks with twelve (12) chicks per group. Thereafter, the birds were sacrificed and the antioxidant status, meat quality, cooking and thaw losses, and water absorption power were assessed. The results revealed that feed with orange peel inclusion significantly ($p \leq 0.05$) improved the meat quality of the birds in terms of percentage water loss. The results also revealed that an increased percentage inclusion of the peels in the feed boosted ($p \leq 0.05$) antioxidant status by increasing the activities of superoxide dismutase, catalase, glutathione peroxidase, glutathione s-transferase, and reduced glutathione, and reduced thiobarbituric acid reactive species levels in the flesh of the breast, drumstick, and thigh of the birds. This study indicates that orange peels could be channeled to animal feed as they improve meat quality and antioxidant status, which could add value to poultry farmers and consumers.

Keywords: Antioxidants, Broiler chicken, Citrus peel, Feed, Meat quality.

Introduction

Citrus peels are regarded as waste materials in orange fruit processing companies and can be used as a source of antioxidants and nutraceuticals.[1,2] Consequently, much research is being conducted to channel citrus peels as waste to wealth-generated final products.[2,3] The continuous increase in chicken production and rising expenses for poultry feed necessitate the search for substitute materials for feed production. Using agri-food waste as a feed additive not only gives animals access to vital nutrients but also makes it possible to use low-cost nutritional supplements, which could cut feed costs and, in turn, production costs.[4]

Over 0.5 billion tons of waste are produced worldwide by the processing of orange fruits, unfortunately, the availability and potential worth of this raw material is still completely untapped.[5]. Recycling agri-food waste materials towards poultry production is an effective waste management technique, and it also contributes to environmental management by cutting pollution and garbage disposal expenses, among other things.[5]. The use of citrus peels in animal production has a pro-social component in addition to supporting the "zero waste" movement and proving to customers that the ingredients used in animal feeding are of natural origin.

***Corresponding author. E mail: soaro@futa.edu.ng
Tel: +2347062329254

Citation: Oboh TB, Aro S, Oyeleye IS, Ojo OR, Ademosun AO, Adu OO, Ganiyu Oboh G. Effect of Orange (*Citrus sinensis*) Peels Enriched Feed on Meat Quality and Antioxidant Status of Fed Broiler Chicken. Trop J Nat Prod Res. 2025; 9(2): 2025; 9(5): 1939 – 1944. https://doi.org/10.26538/tjnpr/v9i5.8

Official Journal of Natural Product Research Group, Faculty of Pharmacy, University of Benin, Benin City, Nigeria

Another rationale in waste management is using agricultural byproducts in animal nutrition, which enables cost reduction of feed ingredients like cereals and their utilisation in human products [3]. Orange peel (*Citrus sinensis*) is one of the most common by-products of the juice business. [6]. After the pulp is physically removed and the juice is taken, the orange peel, which comprises one-fourth of the fruit, is created [7]. A study by Ademosun et al.[4] discovered that citrus peels are rich in phenolic compounds and can control cholesterol synthesis. Additionally, it has been shown that citrus peels boost antioxidant status and fortify the immune system.[4,8] This study investigates the impact of broiler feed formulations containing dried citrus peels on broiler chickens' antioxidant indices and meat quality. Materials and Methods

Materials and Methods

Sigma–Aldrich chemicals and reagents, including trichloroacetic acid (TCA), Ellman's reagent, sodium dodecyl sulfate (SDS), Thiobarbituric acid (TBA), acetylthiocholine iodide, adenosine, and L-arginine, were used. The reagents were prepared with distilled water (DW). All other chemicals employed in this experiment were of the analytical variety.

Plant Collection and Identification

Ripe sweet citrus peels were collected freshly from fruit vendors in October 2021 within the FUTA campus (latitudes 7°17′-7°19′N and longitudes 5°7′-5°9′E), and identified by Mr. Omomoh (Plant Taxonomist) at the Centre for Research and Development (CERAD) of the Institution, while the samples were deposited to the University herbarium (FUTA herbarium: 0263). The peels were washed, drained, air-dried, and ground into fine powder.

Experimental Diet

The sample was weighed, pooled, and sun-dried to contain 10–13% moisture content. It was designated as "sun-dried formulated sweet orange peels" (FSOP) and kept in 4˚C airtight storage containers.

Experiment location

The experiment was conducted at the poultry Unit of the Teaching and Farm. The Federal University of Technology, Akure. The Functional Food and Nutraceutical Laboratory, FUTA, conducted the laboratory analysis. Akure.[13]

Experimental design, Procurement, brooding, and rearing of day-old broiler chicks.

Fifty (50) day-old Ross 308 broiler chicks were purchased from a reputable source, weighed, and randomly allotted to four treatment diets as follows: control without citrus peel, 2.5% citrus peel, 5% citrus peel, 7.5% citrus peel diets, and 10% citrus peel diet for both the starter and finisher phases of the experiment according to NRC 1998.[9] requirements for broiler chickens. The randomisation was to reduce bias in terms of body weight and morphometry of the chicks across their treatment and replicate groups. The starter and finisher phase diets (Table 1) were fed to the birds in the four treatment groups, replicated at ten (10) chicks per replicate in a completely randomised design. The broiler starter diets were fed during the first three weeks of brooding, while the broiler finisher diets were fed to the birds for the last three weeks of rearing/finishing. The ethical approval number (FUTA/ETH/006) for the use of poultry birds was obtained from the Center for Research and Development, FUTA. The vaccination and Medication Schedule for the Experimental broiler chicken is located in Table 2.

Table 1: Composition of Starter diet and finisher diet

Starter diet	**Finisher diet**	
Feed ingredient	**Percentage (%)**	**Percentage (%)**
Maize	52.35	59.35
Maize bran	7	6
Soybean meal	30	24
Fish meal 72	3	3
Soya oil	3	3
Bone meal	3	3
Limestone	0.5	0.5
Lysine	0.25	0.25
Methionine	0.3	0.5
Salt	0.3	0.3
Broiler Premix	0.3	0.3
Total	100	100

Table 2: Vaccination and Medication Schedule for the Experimental Broiler Chicken

1-5	**Antibiotics and Vitamin**	**oral**
7	First (NDV) Lasota	oral
11	First Gumboro	oral
14-19	Anticoccidia (3day)	oral
21	Second (NDV) Lasota	oral
28	Second Gumboro	oral

Poultry Unit: Teaching and Research Farm, FUTA

Preparation of Breast, Drumstick, and Thigh Tissue homogenate and biochemical assays

The birds were allowed to fast overnight and then slaughtered; the blood was collected into a plain sample bottle under cold conditions, and then centrifuged, where the serum supernatant was kept for serum lipid profile assay. So also, breast meat, drumstick meat, and thigh meat were isolated, weighed, rinsed with cold saline solution, homogenized with phosphate buffer (0.1 M pH 7.4), and centrifuged at 5000 × g for 10 min to collect the supernatant that was kept in the -80 deep freezer, and later used for the determination of lipid profile assays.

Meat quality evaluation

Calculation of the hydrogen index: The hydrogen index of the chest muscle was calculated using a digital-tipped meat pH probe (Meat pH Tester HI9981O36, Hanna, USA). The intact muscle was pierced with a sharp, pointed knife to a depth of around 2.5 cm, and the pH meter was inserted immediately to measure the pH.

Determination of cooking loss (CL)

At 24-hour postmortem, 2 g samples from the breast muscles of the carcass representing each of the dietary groups were taken and boiled in a water bath at 85 °C. The samples were then allowed to chill and then weighed again. Cooking loss (in %) was calculated as follows.[10]

$$\% \text{ CL} = \frac{\text{IW - FW}}{\text{IW}} \text{ X } 100\%$$

Where:

IW = Weight before cooking

FW = Weight after cooking

Determination of Thaw Loss

Thawing After being frozen at 20 °C for four weeks, the muscles were removed for the thawing treatments. The five thawing methods were accomplished using two thawing media and various temperatures. Thawing rates (TR) of 24 h and 48 h were achieved by placing the vacuum-packaged frozen muscles in a water bath set to 10 °C and 5 °C, respectively. Thawing was considered complete once the insoluble protein was no longer visibly frozen.[12]

Determination of Water Absorption Power

The water absorption power of the broiler meat samples was determined by the method of Szmanko et al [25]

Determination of Superoxide Dismutase (SOD) Activity

Superoxide dismutase activity in the tissue homogenates was determined according to the method of Misra and Fridovich [14]. About 40 µL of homogenate was pipetted into clean-sterilised test tubes containing 160 µL of distilled water to make a 1:4 (5-fold) dilution, followed by adding 2.5 ml of 0.05 M carbonate buffer (ph 10.2). The reaction was initiated by the addition of 300 µL of 0.3 mM adrenaline (freshly prepared) and was quickly mixed by inversion. The absorbance was read at 480 nm for 150 sec at 30-sec intervals against the reagent blank (prepared by replacing the homogenate with distilled water). The SOD activity was expressed as a percentage inhibition of adrenaline oxidation. 1 unit of SOD activity was defined as the amount of SOD necessary to cause 50% inhibition of the oxidation of adrenaline.

Determination of Catalase Activity
The activity of catalase in the tissue homogenates was assayed according to a procedure that was based on the method of Clairborne[7]. The method was based on catalase decomposing hydrogen peroxide to form water. Typically, clean-sterilized test tubes containing 1.25 ml of 10 mM sodium phosphate buffer (pH 7.0) were pipetted 1 ml of 0.2 M H_2O_2, 0.5 ml of tissue aliquot (0.1 ml of 1000 mg/kg but (w/v) homogenate and 0.4 ml of distilled water). The reaction was terminated at varying times (15, 30, 45, and 60 s) by the addition of 1 ml of 5% dichromate-glacial acetic acid (1:3). The reaction mixture was heated at 100°C for 10 min and allowed to cool down in running water. The absorbance was read at 570 nm against the reagent blank (prepared by replacing the tissue homogenates with distilled water). The catalase activity was calculated.

Determination of Glutathione peroxidase Activity (GPx)
To determine the activity of glutathione peroxidase, phosphate buffer (pH 6.9), 200 uL of sample supernatant, 200 uL of 100 mM GSH, and 100 uL of 0.2 mM H2O2 were combined. After incubating at 27°C for 10 minutes, 10% TCA was added to the mixture and centrifuged at 3200-x g for 2 minutes. The absorbance was measured at 412 nm after 1 mL of the supernatant was combined with 0.5 mL of Ellman's reagent and phosphate buffer (pH 8.0) [21].

Determination of Glutathione-S-Transferase Activity (GST)
Using 1-chloro-2,4-dinitrobenzene (CDNB) as a substrate, the GST activity was measured using the Habig and Jakoby [10] method with little modification[2]. 1.0 mL of phosphate buffer, pH 6.5, was added along with CDNB and distilled water. At 37°C, the mixture was incubated for 5 min. Then, 100 uL of tissue supernatant and 100 uL of GSH (300 mM) were added. After that, the absorbance was measured at 340 nm.

Determination of Glutathione Level
Reduced glutathione (GSH) content of the tissue homogenates was assayed according to the procedure that was based on the method of Moron *et al.* [15]

Lipid Peroxidation Assay
Malondialdehyde levels produced were determined using the method of Ohkawa et al.[18] A reaction mixture containing tissue homogenates (0.2 mL) or 0.03 mM lipid peroxidation assay (MDA), sodium dodecyl sulfate (SDS) (8.1%, 200 µl) 0.8% TBA (500 µl) and acetic acid (2.5 M HCl, pH 3.4, 500 µl) was prepared and incubated at 1 h at 95°C in a water bath. The absorbance of the solution was measured at 532 nm, and MDA produced was expressed as µmol MDA/mg of protein.

Determination of Total Protein
The total Protein content of homogenates was measured by the Coomassie blue method according to [6] using bovine serum albumin (BSA) as standard.

Statistical analysis
The mean and standard error of the mean were used to express all of the data (S.E.M.). Graph Pad Prism 8.2 software was used to assess the differences between the groups using a one-way analysis of variance (ANOVA).

Results and Discussion

A key element in determining consumer happiness and general market demand is the quality of broiler chicken meat. The quality of broiler chicken meat is determined by factors, including cooking loss (%), thawing loss after 24 hours, thawing loss after 48 hours, palatability, and water absorption capacity as represented in Table 1. These qualities significantly influence consumer tastes and perceptions of meat. According to [17], the muscle holds about 88–95% of its water between the myofibrils and the space between actin and myosin filaments. An increase improves the quality and economic worth of meat in the water content of the muscles, which also improves the meat's tenderness, juiciness, firmness, and appearance. The results of this study in Table 1 are related to those of [22]. Table 1 shows that cooking loss (CL) decreased as FSOP levels increased. The amount of meat that is reduced while cooking is known as cooking loss. Both the volatile loss (water evaporation) and the dripping loss are included in the overall loss. Because less protein was lost in the water after boiling, FSOP D (10% citrus peel inclusion) appears to have the best meat quality[19]. This is because it had the lowest percentage of cooking loss. According to [16], lower cooking loss results in better meat quality. As a result, the palatability of meat with higher levels of FSOP may improve meat quality.
According to [11], freezing is a widely used technique for food preservation to guarantee the security of beef products in the international meat export market. The quality of frozen chicken meat is affected by several physical and biochemical changes during frozen storage, including water loss, colour change, lipid and protein oxidation, and colour change[24]. Differences in standing duration, freezing rate, and thawing rate lead to different impacts of freezing. If the right temperature (20 °C) is maintained, freezing stops practically all biological reactions by occupying the available enzyme systems; as a result, vitamin retention is great in frozen foods [12]. It is possible that the freezing and thawing of meat disturbs cell membranes and alters the internal structure of biological components, resulting in drip losses that result in vitamin B losses during thawing and subsequent cooking[13]. (Table 3)

Table 3: Effect of Formulated Sweet Orange Peels-Based (FSOP) Feed on the Meat Quality of Broiler Chicken meat.

	Normal A	B	C	D	P -value	
Cooking loss (%)	28.78	30.10	28.88	26.22	24.10	0.71
Thaw loss after 24 hrs (%)	1.81[a]	1.34 [b]	1.40 [b]	1.44[b]	1.46[b]	0.02
Thaw loss after 48 hrs (%)	2.17 [a]	1.52 [b]	1.53 [b]	1.58[b]	1.58[b]	0.03
Palatability	2.50 [b]	2.80 [a]	2.83 [b]	2.85[b]	2.88[b]	0.01
Water absorption power	3.10	3.33	3.20	3.12	3.05	0.47

Palatability Scale: 1: Highly palatable, 2: Acceptable, 3: Moderate, 4: Slightly, 5: Not Acceptable

Figures 1 - 3 show the effect of FSOP Feed on the (a) Catalase, (b) Superoxide dismutase, (c) Glutathione Peroxidase, (d) Glutathione S-transferase, and (e) Reduced Glutathione in Breast, Drumstick, and Thigh meat of Broiler Chicken, respectively. Where there is a significant difference (*p<0.05, **p<0.01 and ***p<0.001) in samples 2.5%, 5%, 7.5%, and 10% compared to normal control (without citrus peel) in the antioxidant's enzymes in the Breast, Drumstick, and Thigh meat of broiler chicken. These project findings relate to the findings of Petru et al [20]. Although Figures 1f, 2b, and 3f, revealed thiobarbituric acid results showed a significant difference of (*p<0.05, **p<0.01, ***p<0.001, and ****p<0.0001) compared to normal control, all these were as a result of the influence of citrus peel inclusion [27,26]. In comparison to the control group, the broiler feed enriched with citrus peel all showed low levels of TBARS values. In addition, compared to the normal control, which lacked citrus peel, the broiler feed supplemented with 10% had the lowest amount of TBARS values. Citrus peel is on the rise, and its addition causes the level of TBARS in broiler chicken breast meat to decline. Petru et al [20] claims that this diet has beneficial impacts on the quality of conserved broiler meat. The reduction or postponement of lipid oxidation in breast, drumstick, and

thigh meat is related to their antioxidant qualities. It is well-accepted that adding natural photogenic compounds to broilers' diets will improve the functionality, safety, and quality of the food when it is stored either raw or cooked [23,1]. The inclusion of citrus waste reduces TBARS levels and enhances the activity of antioxidant enzymes in broiler chicken muscle. In line with our findings, citrus peels reduce the development of TBARS, by employing diets rich in natural antioxidants, [9] were able to attain comparable values. This finding allows us to conclude that the antioxidants (Catalase, Superoxide dismutase, Glutathione Peroxidase, Glutathione S-transferase, and Reduced Glutathione) biomolecules in the broiler chicken feed inhibit the growth of TBARS in the meat (Breast, Drumstick, and Thigh) and halt the lipid oxidation process.

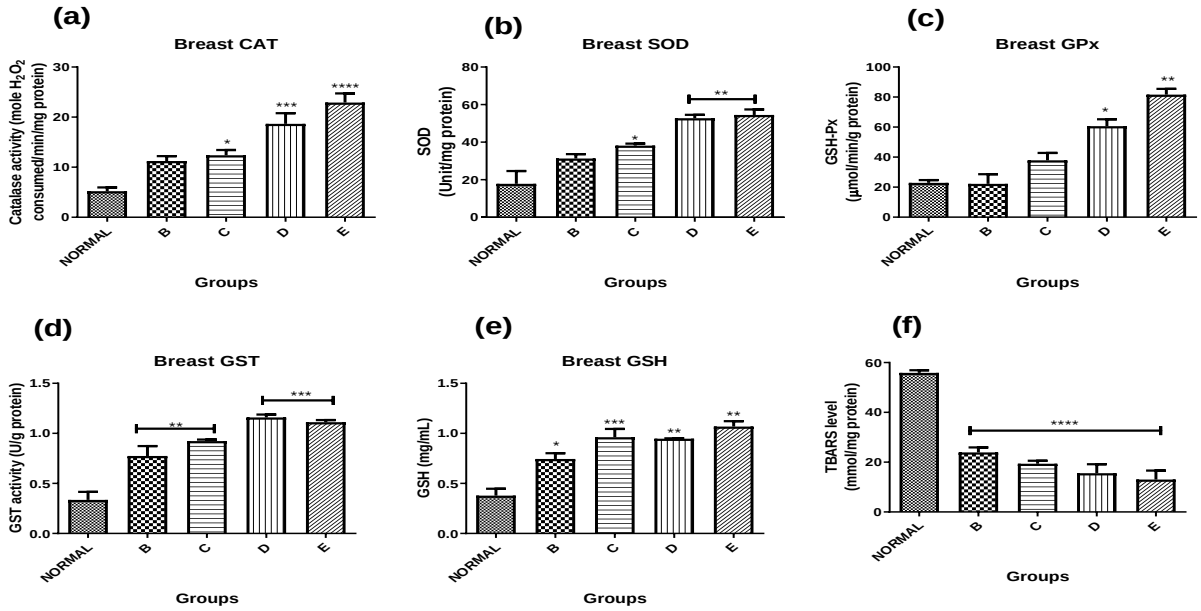

Figure 1: Effect of Formulated Sweet Orange Peels-Based (FSOP) Feed on the (a) Catalase, (b) Superoxide dismutase, (c) Glutathione Peroxidase, (d) Glutathione S-transferase, (e) Reduced Glutathione, and (f) Thiobarbituric acid in breast meat of Broiler Chicken. Bars are significantly different from normal (*p<0.05; **p<0.01; ***p<0.001; ****p<0.0001). Normal: Feed without citrus peel; B: Feed with 2.5% citrus peel; C: Feed with 5% citrus peel; D: Feed with 7% citrus peel; E: Feed with 10% citrus peel.

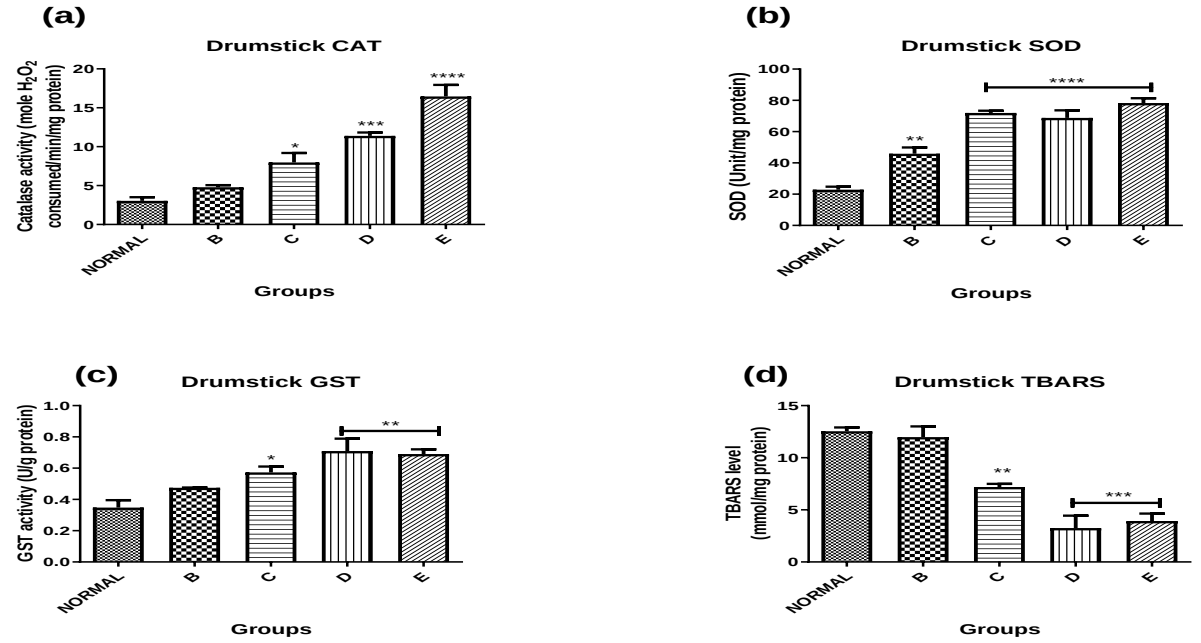

Figure 2: Effect of Formulated Sweet Orange Peels-Based (FSOP) Feed on the (a) Catalase, (b) Superoxide dismutase, (c) Glutathione S-transferase, (d) Thiobabituric acid in drumstick meat of Broiler Chicken. Bars are significantly different from normal (*p<0.05; **p<0.01; ***p<0.001; ****p<0.0001). Normal: Feed without citrus peel; B: Feed with 2.5% citrus peel; C: Feed with 5% citrus peel; D: Feed with 7% citrus peel; E: Feed with 10% citrus peel

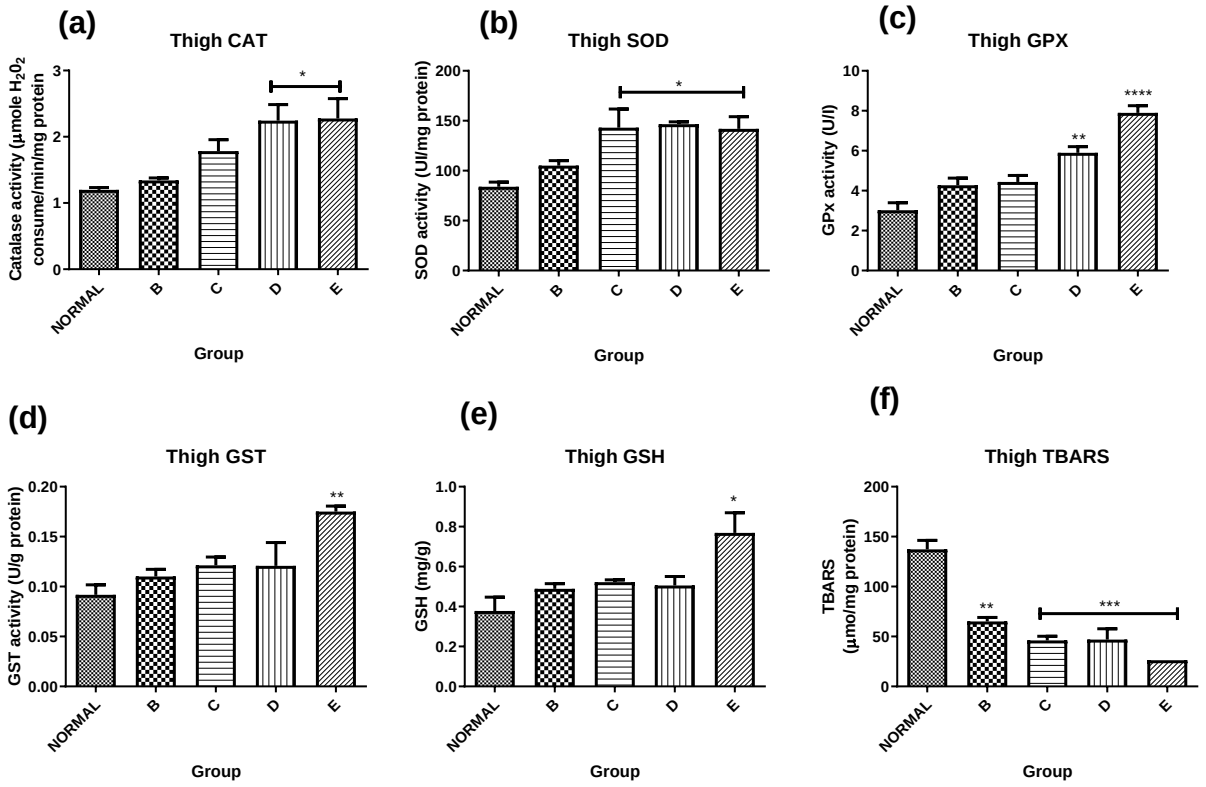

Figure 3: Effect of Formulated Sweet Orange Peels-Based (FSOP) Feeds on the (a) Catalase, (b) Superoxide dismutase, (c) Glutathione Peroxidase, (d) Glutathione S-transferase, (e) Reduced Glutathione, and (f) Thiobarbituric acid in thigh meat of Broiler Chicken. Bars are significantly different from normal (*p<0.05; **p<0.01; ***p<0.001; ****p<0.0001). Normal: Feed without citrus peel; B: Feed with 2.5% citrus peel; C: Feed with 5% citrus peel; D: Feed with 7% citrus peel; E: Feed with 10% citrus peel

Conclusion

Citrus peel-inclusive diets enhance meat quality by preventing lipid peroxidation in all the tissues tested. This could be attributed to the antioxidant composition of the feed from citrus peel, which shows an increasing effect as the peel increases in percentage inclusion. To thoroughly study the impacts on the physiology of broiler chickens, additional research is necessary, particularly on the active component of citrus peels.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that they will bear any liability for claims relating to the content of this article.

Acknowledgment

The authors are grateful for the TETFUND-NRF, grant number: TETF/ES/DR&D-CE/NRF2020/SETI/02/VOL1 of 2020 midwives by the Federal Republic of Nigeria and the Centre for Research and Development (CERAD) of the Federal University of Technology, Akure, Nigeria.

Funding

Funding was provided by the generous intervention of the TETFUND-NRF 2020 Research Grant of the Federal Republic of Nigeria.

References

1. Abbasi H, Seidavi A, Liu W, Asadpour L. Investigation on the effect of different levels of dried sweet orange (*Citrus sinensis*) pulp on performance, carcass characteristics, and physiological and biochemical parameters in broiler chicken. Saudí J Biol Sci. 2015; 22(2):139–146.
2. Abolaji OA., Adebayo AH., Odesanmi OS. Nutritional qualities of three medicinal plant parts *(Xylopia aethiopica, Blighia sapida,* and *Parinari polyandra*) commonly used by pregnant women in the western part of Nigeria. Pak J Nutr 2007; 6(6), 665–668.
3. Ademosun AO, Oboh G, Olasehinde TA., Adeoyo OO. From folk medicine to functional food: A review on the bioactive components and pharmacological properties of citrus peels. Orient Pharm Exp Med. 2018; 18, 9–20.
4. Ademosun, A.O, Oboh G, Passamonti S, Tramer F, Ziberna L, Boligon AA. Inhibition of metalloproteinase and proteasome activities in colon cancer cells by citrus peel extracts. J Basic Clin Physiol Pharmacol. 2015; 26 (5), 471–477.
5. Animashahun RA., Aro SO, Onibi GE, Alabi OO, Okeniyi FA, Olawoye SO, Falana MB. Carcass Indices And Meat Quality Of Broiler Chickens Fed Diets Containing Fortified Fermented Cassava Stump. Chil. J Agric Anim Sci. 2022; 38 (1) Chillánhttp://dx.doi.org/10.29393/chjaas38-12cirm70012
6. Bradford MM. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. Anal Biochem. 1976; 72:248-54. doi: 10.1006/abio.1976.9999.

7. Clairborne A. Catalase activity. In A.R., Greenwald (Ed.), Handbook of methods for oxygen radical research (pp. 237–242). Boca Raton, FL: CRC Press.1995
8. Ellman GL. Tissue sulfhydryl groups. Arch Biochem Biophys. 1959; 82 (1), 70–77.
9. Faiz F, Khan MI, Sadiq M, Nawaz H. Effects of dietary natural antioxidants from citrus waste on growth and blood antioxidants status of the broilers. Sarhad J Agric. 2017; 33(3): 371-376.
10. Habig WH, Jakoby WB. Glutathione S-transferases (rat and human). Methods Enzymol. 1981; 77 (pp. 218–231). Academic Press.
11. Leygonie C, Britz TJ, Hoffman LC. Impact of freezing and thawing on the quality of meat: review. Meat Sci. 2012; 91:93–98. doi: 10.1016/j.meatsci.2012.01.013.
12. Leygonie C., Hoffman LC. Effect of Different Combinations of Freezing and Thawing Rates on the Shelf-Life and Oxidative Stability of Ostrich Moon Steaks (*M. Femorotibialis medius*) under Retail Display Conditions. Foods (Basel, Switzerland). 2020; 9(11), 1624. https://doi.org/10.3390/foods9111624
13. Mir NA, Rafiq, A, Kumar F, Singh V, Shukla V. Determinants of broiler chicken meat quality and factors affecting them: a review. J Food Sci Technol. 2017; 54(10), 2997–3009. https://doi.org/10.1007/s13197-017-2789-z
14. Misra HP, Fridovich I. The Role of Superoxide Anion in the Autoxidation of Epinephrine and a Simple Assay for Superoxide Dismutase. J Biol Chem. 1972; 244(10):6049-6055 DOI: 10.1016/S0021-9258(19)45228-9
15. Moron MS, Dipierre JW, Mannervik B. Levels of glutathione, glutathione reductase and glutathione *S*-transferase activities in rat lung and liver. Biochimica et Biophysica Acta (BBA) - General Subjects, 1979. 582(1): 67-78
16. Navid S, Hilmi M, Sazili AQ, Sheikhlar A. Effect of papaya leaf meal and vitamin D3 supplementation on meat quality of spent layer hen. J Anim Vet Adv. 2010; 9(22):2873-2876. doi:10.3923/ javaa.2010.2873.2876
17. Liu J, Arner A, Puolanne E, Ertbjerg P. On the water-holding of myofibrils: Effect of sarcoplasmic protein denaturation. Meat Science. 2016, 119:32-40. https://doi.org/10.1016/j.meatsci.2016.04.020
18. Ohkawa H, Ohishi N, Yagi K. Assay for lipid peroxides in animal tissues by thiobarbituric acid reaction. Anal Biochem. 1979, 95(2):351-8. doi: 10.1016/0003-2697(79)90738-3
19. Oko AO, Nwoba ST, Idenyi JN, Ogah O, Ugwu OO, Ehihia LU. Effects of substituting some components of broilers' feed with aqueous extract of fresh leaves of *Mucuna poggei*. Int J Biol Sci. 2012; 3(1):243-253.
20. Petru AV, Arabela EU, Tatiana DP, Raluca PT. Effect of dietary orange and grapefruit peel on growth performance, health status, meat quality and intestinal microflora of broiler chickens. Ital J Anim Sci. 2020; 19:1, 1394-1405, DOI: 10.1080/1828051X.2020.1845576
21. Rotruck JT, Pope AL, Ganther HE, Swanson AB, Hafeman DG, Hoekstra WG. Selenium: biochemical role as a component of glutathione peroxidase. Sci. 1973; 179, 588–590.
22. Sang-Oh PR, Chae-Min P, Byung- Sung B Jong H. The meat quality and growth performance in broiler chickens fed diet with cinnamon powder. J Environ Biol. 2013; 34(1):127-133. PMID: 24006819
23. Soltan MA, Shewita RS, El-Katcha MI. Effect of dietary anise seeds supplementation on growth performance, immune response, carcass traits and some blood parameters of broiler chickens. Int J Poult Sci 2008; 7 (11): 1078–1088.
24. Soyer A, Ozalp B, Dalmis U, Bilgin V. Effects of freezing temperature and duration of frozen storage on lipid and protein oxidation in chicken meat. Food Chem. 2010; 120:1025–1030. doi: 10.1016/j.foodchem.2009.11.042.
25. Szmanko T, Lesiow T, Gorecka, J. The water-holding capacity of meat: A reference analytical method. Food Chem. 2021; 357, 129727
26. Vlaicu PA, Turcu RP, Mironeasa S, Panaite TD. Meat quality of breast from broilers fed a diet supplemented with orange and red grapefruit dried peel. Sci Papers Series D Anim Sci. 2020; 63(1):161–169.
27. Wang YC, Chuang YC, Hsu HW. The flavonoid, carotenoid, and pectin content in peels of citrus cultivated in Taiwan. Food Chem. 2008; 106(1):277–284.