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EFFECTS OF NATURAL ANTIOXIDANT EXTRACT SUPPLEMENTATION ON THE GROWTH PERFORMANCE AND MEAT QUALITY OF BROILER CHICKENS

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Abstract: The study examined the effect of dietary antioxidant supplementation on the performance and meat quality of broiler chickens. Namely, 300 one-day-old Arbor Acres broiler chicks were fed a starter diet from 1 to 4 weeks and a finisher diet for the last 4 weeks. Birds were randomly assigned to treatments based on antioxidant supplementation in drinking water at 0.02% butylated hydroxyanisole (BHA), ordinary water (OW), 0.02% sweet orange peel extract (SOPE), 0.02% shaddock peel extract (SHPE) and 0.02% lemon peel extract (LMPE) per litre of water in a completely randomized design experiment. Feed intake and body weight gain were recorded on a weekly basis. Three birds were selected in each treatment and slaughtered for meat quality determination. BHA and LMPE treatments had the best weight gain and feed conversion efficiency at the significance level ($p<0.05$). There were significant differences ($p<0.05$) in the shear force (force peak and yield) in the dietary antioxidants fed to the birds. Sensory parameters (taste, aroma and overall acceptability) show significant differences ($p<0.05$) amongst the treatments. However, there were no significant differences ($p>0.05$) in appearance and texture perception amongst treatments. Finally, significant differences ($p<0.05$) in the lightness (L*) and redness (a*) of the meat samples were observed amongst the treatments. There were no significant differences ($p>0.05$) in the yellowness (b*) amongst the treatments. It can be concluded that broiler birds fed SOPE, SHPE and LMPE treatments performed better and that these treatments enhanced the meat quality of the birds when compared to BHA and OW treatments.

Key words: synthetic antioxidant, natural antioxidants, feed intake, weight gain, sensory parameters.

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Introduction

Broiler meat has several desirable nutritional characteristics such as high protein, low lipid contents and high polyunsaturated fatty acids (Mothershaw et al., 2009). These make it preferable, health-wise when compared to red meat. Broiler meat is, however, highly susceptible to lipid oxidation during storage (Sahin et al., 2010). Lipid oxidation is reported to have adverse effects on meat quality parameters such as colour, juiciness, tenderness and flavour, thus leading to the reduction of the meat shelf-life (Min et al., 2008). Wood and Enser (1997) recommended the use of dietary antioxidant in preserving animal products by reducing lipid peroxidation. In recent years, the use of synthetic substances like antibiotics as feed additives has been discouraged. In response to this, there is an increased interest in the use of natural antioxidants from plants and these antioxidants have gained popularity because they are believed to be safer than synthetic antioxidants (Moyo et al., 2011).

Synthetic antioxidants have been widely used as food and feed preservatives, because of their effectiveness in delaying lipid oxidation. With relatively low cost, there is an increase in consumers' preference for natural ingredients over synthetic compounds (Ahn et al., 2002). This has resulted in a need for more information on the efficacy of different natural additives that can reduce lipid oxidation in meat and meat products. Some natural sources of antioxidants like rosemary, sage, ginger and grape seed are shown to contain large amounts of phytochemicals such as phenolic acids and flavonoids, glycosides and alkaloids (Abeysinghe et al., 2007), which, if used as dietary supplementation in feed and water, can reduce the lipid peroxidation and extend the shelf life of broiler meats under different storage conditions (Botsoglou et al., 2002; Jang et al., 2007; Rababah et al., 2004; Sahin et al., 2010). Fruits are an important source of many bioactive compounds such as phenolic acids, flavonoids and glycosides. Peels are the primary by-products during citrus juice processing, and if unused, they turn to be waste and represent a source of environmental pollution. However, research conducted on several fruits (citrus, apples and grapes) has shown that peels are the major source of natural antioxidants (Lucia et al., 2008, Rababah et al., 2004, Sallam et al., 2004).

Phenolic compounds in peels and fruit can be used in food products as a natural antioxidant and can serve as substitutes to synthetic preservatives (Ignat et al., 2011). Phenolic compounds are important components of many fruits (Miguel et al., 2004). As Robards et al. (1999) reported, there are approximately 5000 known plant phenolics and model studies have demonstrated that many of them have antioxidant activities. The antioxidant activity of phenolics is mainly due to their redox properties, which allow them to act as reducing agents, hydrogen donors, singlet oxygen quenchers, and metal chelators (Rice-Evans et al., 1995). The aim of this research work is to evaluate the dietary supplementation of natural antioxidant extracts and the effect it has on the growth performance and the meat quality of broiler chickens.

Materials and Methods

Broiler chicken managements and diets

The field experiment was conducted at the Kwara State University Teaching and Research Farm, Malete, on a geographical location of latitude 08^{o} 71′ N and longitude 04^{o} 44′ E at 365 m above sea level. The climate of Malete is characterised by distinct wet and dry seasons with the annual mean rainfall of about 1,150 mm and a mean annual temperature that ranges from 25 to 28.9^{o} C (Olaniyan, 2003). Three hundred (300) one-day-old Arbor Acres broilers were used in this study. The chicks were weighed and randomly allotted to five treatments in a completely randomised design and were replicated in three units with twenty birds per replicate. Birds were housed in a metabolic battery cage for birds. The treatments were based on the natural antioxidant supplementation in drinking water, as stated below (USFDA, 2009):

Extraction procedure

Fifty g of dried powdered samples of sweet orange, shaddock and lemon peels were extracted with ethanol organic solvents using the procedure described by VanAcker et al. (2011):

1. Treatment one – Positive control (drinking water with 200 ppm BHA/litre),
2. Treatment two – Negative control (drinking water with no antioxidant supplement),
3. Treatment three – Drinking water with 200 ppm of sweet orange peel extract (SOPE)/litre,
4. Treatment four – Drinking water with 200 ppm of shaddock peel extract (SHPE)/litre,
5. Treatment five – Drinking water with 200 ppm of lemon peel extract (LMPE)/litre.

Routine management and vaccination were followed (Ishola and Atteh 2018). Feed and water were given *ad libitum* for the 8-week trial. The birds were placed on a formulated broiler starter diet containing 23% CP and 2879Kcal/kg ME for the first four weeks and a broiler finisher diet containing 17% CP and 2700 kcal/kg ME for the second four weeks (Table 1).

Table 1. The composition of the diets (% DM).

Ingredients	Starter (%)	Finisher (%)
Maize	57.50	56.50
Wheat offal	0.00	8.00
Soybean meal	20.00	15.00
Groundnut cake	16.00	8.50
Fish meal	2.00	1.00
Bone meal	2.50	4.00
Limestone	1.00	6.00
Vitamin premix	0.25	0.25
Methionine	0.25	0.25
Lysine	0.25	0.25
Salt	0.25	0.25
Total	100.00	100.00
Calculated analysis		
Crude protein %	23	17
ME Kcal/kg	2879	2700
Crude fibre %	3.91	2.94
Ether extracts %	4.63	2.44
Methionine + Cysteine %	0.92	0.46
Lysine %	1.31	0.85
Calcium %	1.18	3.63
Phosphorus %	0.50	0.83

DM = Dry matter, kg = Kilogramme, CP = Crude protein, ME = Metabolisable energy, Kcal = Kilocalorie.

Data collection

Performance and physicochemical determination

Feed intake and body weight gain were recorded weekly and used to determine the feed to gain ratio. At the end of the feeding trial, three birds were selected per replicate in each treatment, fasted overnight and slaughtered by severing the jugular vein, defeathered and eviscerated. Breast meat parts were collected for meat quality (shear force, sensory evaluation and colour coordinates) determination using procedures described by Sazili et al. (2005), Meilgaard et al. (2006) and Sabow et al. (2015) respectively.

Shear force

The textural assessment of the broiler breast meat fed dietary antioxidant supplementation was conducted using the HD plus® texture analyser (Stable Micro System, Surrey, UK) equipped with a Volodkevitch bite jaw. The equipment was calibrated at 5 kg for weight, 10mm return distance for height and the blade speed was set at 10 mm/sec. The sample preparation was analysed following the procedure described by Sazili et al. (2005). From each sample, three replicate blocks (1 cm height × 1 cm width × 2 cm length) were cut parallel to the direction of the muscle fibres and each block was sheared in the centre perpendicular to the longitudinal direction of the fibres. Shear force was reported as the average peak positive force values for all blocks of each treatment sample.

Sensory evaluation

A consumer type sensory evaluation was conducted as described by Meilgaard et al. (2006). Twenty g of the breast meat for each treatment was trimmed free of fat, labelled and cooked in a water bath at 80°C for 10 mins. The meat samples were wrapped in aluminium foil and coded with numbers. A consumer type of sensory evaluation was conducted by thirty (30) assessors consisting of staff and students of the Kwara State University, Malete, Nigeria. Assessors were trained on the sensory protocol and instructed on the parameters (tenderness, juiciness, flavour, cooked colour and overall acceptability) to judge using a 9-point hedonic scale (Meilgaard et al., 2006). A value of nine indicated ‘like extremely’ and one indicated ‘dislike extremely’.

Colour coordinates

Meat colour coordinates of the breast meat samples from each treatment (BHA, OW, SOPE, SHPE and LMPE) were determined according to the method of AMSA (2012) as described by Sabow et al. (2015). A dimension of 1 x 1 x 2 cm^3 breast meat part of bird per replicate were cut and placed at the base of the colour flex cup of a Colour Flex spectrophotometer (Hunter Lab, Reston, VA, USA). Readings for lightness (L*), redness (a*) and yellowness (b*) were taken based on the International Commission on Illumination (CIE), with D65 illuminant and 10° standard observer, tristimulus values (X,Y,Z) and reflectance at specific wavelength (400–700 nm). For each sample, triplicate readings for L*, a* and b* values were recorded and then averaged.

Statistical analysis

Data obtained from the experimental trial were analysed and subjected to analysis of variance (ANOVA) using the PROC MIXED procedure of SAS (2014). Means were separated at the 5% significance level.

Results and Discussion

Performance

There were significant differences (P<0.05) in the weekly feed intake, weight gain and feed conversion ratio of broilers fed with the different treatments (Table 2). Birds on dietary ordinary water treatment (OW) had the highest feed intake (p<0.05) while birds on butylated hydroxyanisole (BHA) treatment had the lowest. The weight gain ranged from 354.17g to 418.75g in dietary treatments OW and LMPE. Birds fed BHA and LMPE treatments were not significantly different from each other (p>0.05) but were significantly different (p<0.05) from those on other diets. Birds fed on BHA and LMPE diets had the best feed to gain ratio.

Table 2. The effect of dietary antioxidant supplementation on the performance of broiler chicken.

Parameter	Treatments						
	BHA (0.02%)	OW	SOPE (0.02%)	SHPE (0.02%)	LMPE (0.02%)	SEM	P value
Initial body weight (g/b)	37.10^{e}	45.10^{a}	38.50^{d}	43.50^{b}	41.50^{c}	0.07	<0.0001
Final body weight (g/b)	3333.00^{ba}	2878.5^{c}	2888.5^{c}	3093.5^{bc}	3390.00^{a}	62.29	<.0003
Feed intake (g/b/w)	629.03^{e}	652.87^{a}	646.41^{b}	636.53^{c}	633.33^{d}	0.08	<0.0001
Weight gain (g/b/w)	412.50^{a}	354.17^{c}	356.25^{c}	381.25^{b}	418.75^{a}	7.79	0.0003
FCR	1.53^{c}	1.85^{a}	1.81^{a}	1.67^{b}	1.51^{c}	0.03	0.0001

$^{a, b, c, d, e}$ means having different superscripts along the same row are significantly different (p < 0.05), g = Gramme, b = Bird, w = Week; FCR = Feed conversion ratio, BHA = Butylated hydroxyanisole, OW = Ordinary water, SOPE = Sweet orange peel extract, SHPE = Shaddock peel extract, LMPE = Lemon peel extract.

Shear force analysis

The current study shows that there were significant differences (p<0.05) in the shear force (force peak and yield) and strain peak of the meat samples of birds fed dietary antioxidants. The synthetic antioxidant (BHA) treatment force peak was significantly different (p<0.05) from OW, SOPE, SHPE and LMPE treatment force peaks (Table 3). Moreover, more force was expended in cutting through the meat of birds fed dietary treatment (OW) than other treatments (BHA, SOPE, SHPE and LMPE). There were no significant differences (p>0.05) in the stress (yield and peak) of the meat samples when subjected to texture analysing across the treatments. Also, there were significant differences in the strain (peak and yield percentage) of the meat samples across the treatments, with treatment (SHPE) having the highest percentage of strain peak and treatment (OW) having the lowest percentage of strain yield.

Table 3. The effect of dietary antioxidant supplementation on meat quality (shear force) of broiler meat.

Parameters	Treatments						
	BHA (0.02%)	OW	SOPE (0.02%)	SHPE (0.02%)	LMPE (0.02%)	SEM	P value
Force peak (N)	15.90^{a}	12.00^{b}	7.20^{c}	3.50^{d}	10.40^{b}	0.469	<0.0001
Force yield (N)	3.20^{b}	11.60^{a}	1.50^{c}	1.20^{c}	3.90^{b}	0.184	<0.0001
Stress peak(N/mm^2)	0.06	0.05	0.03	0.01	0.04	0.017	0.4029
Stress yield (N/mm^2)	0.01	0.05	0.01	0.01	0.02	0.01	0.1297
Strain peak (%)	71.91^{b}	10.18^{e}	52.31^{d}	95.09^{a}	59.22^{c}	0.013	<0.0001
Strain yield (%)	11.97^{a}	0.04^{e}	3.83^{c}	5.49^{b}	0.92^{d}	0.019	<0.0001
Young’s modulus (N/mm^2)	0.1^{c}	2.13^{a}	0.05^{dc}	0.01^{d}	0.76^{b}	0.015	<0.0001
Width (mm)	25.00	25.00	25.00	25.00	25.00	1.0	1.0000
Thickness (mm)	10.00	10.00	10.00	10.00	10.00	1.0	1.0000

$^{a, b, c, d, e, dc}$ means having different superscripts along the same row are significantly different ($p < 0.05$); BHA = Butylated hydroxyanisole, OW = Ordinary water, SOPE = Sweet orange peel extract, SHPE = Shaddock peel extract, LMPE = Lemon peel extract.

Sensory evaluation

The effects of dietary antioxidant supplementation on meat sensory scores were presented in Table 4. There were no significant differences ($p>0.05$) in the assessor’s perception of the appearance and texture of the meat samples across the treatments (Table 4).

Table 4. The effect of dietary antioxidant supplementation on meat quality (sensory evaluation) of broiler meat.

Parameter	Treatments						
	BHA (0.02%)	OW	SOPE (0.02%)	SHPE (0.02%)	LMPE (0.02%)	SEM	P value
Appearance	7.50	7.95	7.05	7.20	7.55	0.30	0.27
Taste/flavour	7.40^{ab}	8.00^{a}	7.00^{ab}	6.50^{b}	7.75^{a}	0.30	0.01
Texture	7.80	7.25	6.50	6.55	7.60	0.35	0.30
Aroma	7.35^{abc}	7.80^{a}	6.50^{bc}	6.30^{c}	7.45^{ab}	0.29	0.001
Overall acceptability	7.95^{a}	7.95^{a}	7.15^{ab}	6.70^{b}	7.90^{a}	0.25	0.001

$^{a, b, c, ab, bc, abc}$ means having different superscripts along the same row are significantly different ($p < 0.05$);BHA = Butylated hydroxyanisole, OW = Ordinary water, SOPE = Sweet orange peel extract, SHPE = Shaddock peel extract, LMPE = Lemon peel extract.

The taste perception of broiler meat in BHA, SOPE and SHPE treatments was not significantly different ($p>0.05$), but different significantly ($p<0.05$) from LMPE and OW treatments. The aroma perception of the broiler meat in OW treatment was significantly different ($p<0.05$) from BHA, SOPE, SHPE and LMPE treatments. The overall acceptability perception of the broiler meat in BHA, OW and LMPE treatments was significantly different ($p<0.05$) from SOPE and SHPE treatments.

Colour coordinates

As shown in Table 5, post mortem dietary antioxidant supplementation had a significant effect on broiler meat colour. The lightness (L*) and redness (a*) of the broiler chicken breast colour were significantly different across the treatments used. On the other hand, yellowness (b*) of the pectoralis muscles of the broiler chicken as a result of the dietary antioxidants administered showed no significant differences ($p>0.05$) among the treatments.

Table 5. The effect of dietary antioxidant supplementation on meat quality (colour coordinates) of broiler meat.

Parameters	Treatments						
	BHA (0.02%)	OW	SOPE (0.02%)	SHPE (0.02%)	LMPE (0.02%)	SEM	P value
Lightness (L*)	20.03^{c}	38.23^{a}	18.47^{c}	34.62^{ba}	22.52^{bc}	2.733	0.0011
Redness (a*)	2.82^{b}	1.22^{b}	1.97^{b}	8.19^{a}	1.95^{b}	0.904	0.0017
Yellowness (b*)	5.33	4.67	3.12	5.11	2.33	0.827	0.1051

$^{a, b, c, ba, bc}$ means having different superscripts along the same row are significantly different ($p < 0.05$); BHA = Butylated hydroxyanisole, OW = Ordinary water, SOPE = Sweet orange peel extract, SHPE = Shaddock peel extract, LMPE = Lemon peel extract.

Performance

The feed intake observed in this study suggests that the dietary intake under OW diet may have aided nutrient digestion, especially energy. Weight gain was reported as a function of the appropriate nutrient intake by the bird (Ishola and Atteh, 2018). NRC (2004) has observed that the feed intake in birds is inversely proportional to the energy content of the diet. Through a feedback mechanism, energy requirement satisfaction can reduce voluntary feed intake by the birds.

Shear force analysis

Tenderness is the most significant component of meat quality that influences consumers' eating satisfaction (Hildrum et al., 2009). The different values of the shear force mean values obtained in this work correspond to the study conducted by Harris et al. (2001) who have affirmed that an increase in phenolic compounds and vitamin E has an impact on the tenderness of the broiler meat. Table 3 shows the effect of dietary antioxidant extract supplementation on shear force values of pectoralis muscles of the broiler chicken. The shear force values (force peak and yield) reduced significantly in SHPE treatment as compared to other treatments. Similar findings were found in other studies where post mortem ageing increased meat tenderness (Lomiwes et al., 2014; Marino et al., 2013; Sabow et al., 2015).

Sensory evaluation

Within the assessment of sensory parameters, assessors ranked the broiler meat samples based on the hedonic scale. The assessors were with a view that the taste, aroma and overall acceptability perceptions of treatment (OW) were the best, while treatment (SHPE) had a slightly liked taste and aroma perception. This could be due to the absence of phytochemicals in (OW) as compared with other treatments (BHA, SOPE, SHPE and LMPE) that contained some of the phytochemicals which could impact on or affect postmortem weakening of myofibrillar proteins in the course of ageing (Lawne and Ledward, 2006). Since the treatment (OW) did not contain any phytochemical compounds as compared to other treatments (BHA, SOPE, SHPE and LMPE), this could be the reason why the flavour and aroma perception of treatment (OW) was liked very much by the assessors. This agrees with the findings of Elmore et al., (2004a), who postulated that phytochemicals like phenolic compounds could impact negatively on the volatile compounds like butyric acid and 2-Ethylbenzaldehyde found in meat, which contributes to its flavour and aroma. The overall acceptability of the broiler meat fed dietary treatments (BHA, OW and LMPE) was rated higher by the assessors as compared to treatment (SHPE).

Colour coordinates

Redness of meat is a very important colour parameter for the assessment of meat oxidation (Traore et al., 2012). The customer first appraisal of meat quality is based on its colour and this could be linked to both perceived and actual values (Holman et al., 2015). The colour assessment of the meat is related to the oxidation of myoglobin and the decreased metmyoglobin reducing activity (MRA) which eventually leads to metmyoglobin accumulation in the meat (Xue et al., 2012). This change reduces the redness and makes the meat unpleasant for consumers (Filgueras et al., 2010). This current study suggests that broilers fed with SHPE treatment had greater accumulation of metmyoglobin at the pectoralis muscle part of the bird than other treatments (BHA, OW, SOPE and LMPE). This agrees with the results of Seydim et al., (2006), who have stated that a reduction in redness is due to myoglobin oxidation, especially when meat pH is above 6.

Conclusion

This study indicates that the growth performance and meat quality of broiler chickens subjected to dietary treatments (SOPE, SHPE and LMPE) are comparable and show better results than BHA and OW treatments. Hence, the results obtained from this study affirm that dietary treatments (SOPE, SHPE and LMPE) neither resulted in the poor growth performance nor negatively impacted on the meat quality of the broiler chickens.

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Ethical standards

All human and animal studies have been approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

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UTICAJI DODATAKA EKSTRAKTA PRIRODNIH ANTIOKSIDANASA NA PERFORMANSE PORASTA I KVALITET MESA BROJLERA

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R e z i m e

U istraživanju je ispitivan uticaj dodavanja antioksidanata u obroke, na performanse i kvalitet mesa brojlera. Naime, 300 jednodnevnih brojlera Arbor Acres hranjeni su početnom smešom od 1. do 4. nedelje i završnom smešom tokom poslednje 4 nedelje. Ptice su nasumično raspoređivane u tretmane zasnovane na dodavanju antioksidanata u vodi za piće u količini od 0,02% butiliranog hidroksianisola (BHA), obične vode (OV), 0,02% ekstrakta kore slatke pomorandže (EKSP), 0,02% ekstrakta kore pomela (EKS) i 0,02% ekstrakta kore limuna (EKL) po litru vode u ogledu sa potpuno slučajnim rasporedom. Konzumiranje hrane i prirast telesne mase beleženi su nedeljno. U svakom tretmanu po tri ptice su odabrane i zaklane radi utvrđivanja kvaliteta mesa. Tretmani sa BHA i EKL imali su najbolji prirast i efikasnost iskorišćavanja hrane na nivou značajnosti ($p<0,05$). Postojale su značajne razlike ($p<0,05$) u mekoći mesa (maksimalna snaga i prinos) pri korišćenju različitih antioksidanasa u ishrani brojlera. Senzorni parametri (ukus, aroma i ukupna prihvatljivost) pokazuju značajne razlike ($p<0,05$) među tretmanima. Međutim, nije bilo značajnih razlika ($p>0,05$) u percepciji izgleda i teksture među tretmanima. Konačno, među tretmanima su uočene značajne razlike ($p<0,05$) u svetlini (L*) i crveno-zelenoj komponenti (a*) boje mesa. Nije bilo značajnih razlika ($p>0,05$) u žuto-plavoj (b*) komponenti boje mesa među tretmanima. Može se zaključiti da su brojleri hranjeni u tretmanima sa EKSP, EKP i EKL imali bolje performanse i da su ovi tretmani poboljšali kvalitet mesa brojlera u poređenju sa tretmanima sa BHA i OV.

Ključne reči: sintetički antioksidans, prirodni antioksidansi, konzumiranje, prirast, senzorni parametri.

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