

EFFECT OF CRUDE HESPERIDIN AND ASORBIC ACID ON NUTRIENT INTAKE, NUTRIENT DIGESTIBILITY, GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF HEAT-STRESSED BROILER FINISHER CHICKENS

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Abstract

Two hundred and forty-day old un-sexed Arbor acre broilers' chicks were randomly divided into four treatment groups (T1 – T4) for the purpose of investigating the effect of crude hesperidin and ascorbic acid supplementation either singly or in combination on nutrient intake, nutrient digestibility, growth performance and carcass characteristics during stater phase of the experiment. The study was carried out between May and June, during hot dry season. Crude hesperidin was extracted from dried orange peel according to the protocol developed by Chaudhri (2016), while ascorbic acid was obtained commercially. The test materials were administered throughout the finishing stage of the broiler chickens at the rate of 20 mg/liter and 200 mg/ liter of water. There was improvement

Introduction

The increase demand in animal protein is due to surge in world population which makes poultry production very important source of protein. Broiler chickens are mainly raised for meat (Tona, 2018) the Production cycle of broiler chicken is between 5 to 8 weeks as they easily attained market weight during which these birds undergo a remarkable transformation (Apalowo *et al.*, 2024). Breakthroughs in breeding techniques in

($P < 0.05$) in feed utilization, nutrient digestibility, growth performance and carcass characteristics of the supplemented groups with enhanced performance ($P < 0.05$) obtained in T3 relative to other treated groups. The result shows that, crude hesperidin and ascorbic acid either singly or in combination can improve nutrient intake, digestibility and growth performance of heat-stressed broiler chickens.

Key words: Crude hesperidin, Ascorbic acid, Heat-stress, Broiler finisher

Response to the worldwide surge in demand for chicken meat lead to rapid improvement in maturity of broiler chickens and the enhanced weight within shortest possible time. Broiler chickens are prone to heat stress due to their fast-growing nature. The innovations in the production leads to alterations in the preexisting relationships with the environment. It is documented that broiler production of broiler chickens is greatly affected by environmental stresses, which have negative effects on their health, welfare, and performance (Al-Abdullatif and Azzam, 2023). Broiler chickens health is greatly affected by environmental factors such as excessive humidity, air flow, and temperature. The most serious of the existing stressors is heat stress caused by high temperatures, which is worsening due to global climate changes (Livingston *et al.*, 2022). It has negative effects on feed consumption, feed efficiency, body mass index, meat quality, and mortality rates. However, general well-being and proper development of broiler chickens depend on controlling these environmental stresses. (Livingston *et al.*, 2022). To maintain the advancements made in poultry production, it is crucial to make sure that broiler chicks can survive the fluctuating environmental circumstances. Proffering solutions to challenges that broiler chickens encounter is essential for a prosperous poultry farm. Broiler chickens delicate physiological equilibrium can be altered environmental, dietary, or even internal stresses (Elitok, and Bingüler, 2018). Despite advancements in housing and management systems chicken production sector is seriously affected by environmental stress (Ghanima *et al.*, 2020).

Hesperidin, a dihydroflavone glycoside compound obtained from hesperetin and the disaccharide rutinose, is a natural phenolic compound and a significant active flavonoid present in dried citrus peel (Pyrzynska, 2022). Report shows that hesperidin displays antioxidant properties and enhances the metabolism and the assimilation of nutrients (Buzdağlı *et al.*, 2023). Dietary supplementation with hesperidin has been documented to enhance both growth performance and the quality of the meat produced in chicken (Hager-Theodorides *et al.*, 2021). Furthermore, hesperidin could improve growth performance and relieve the impact of heat stress on broilers by decreasing the

expression of creatine kinase, lactate dehydrogenase, and heat shock protein 70 in elevated temperature environments (Kamboh *et al.*, 2013)

MATERIALS AND METHOD

Determination of Meteorological Condition of the Experimental Pen

The ambient temperature and relative humidity of the experimental site were measured daily using a hygrometer and mercury thermometer. Measurements were taken five times a day at four-hour intervals (08:00, 12:00, 16:00, 20:00, and 24:00 hours) for seven consecutive days prior to the start of the experiment. Also the same procedure measurement were subsequently repeated throughout the study period. THI was used to measure the thermal comfort of the broiler chickens. It was determined using the equation reported by Marai *et al.* (2001).

$$THI = Tdb - \{(0.31 - 0.31 RH) (Tdb - 14.4)\}$$

Where: THI = temperature humidity index, Tdb = dry bulb temperature (°C), RH = relative humidity (%) / 100.

Interpretations:- < 26 = comfort limit, 26-29 = heat stress, > 29 = severe heat stress

Management of experimental birds and treatment

Two hundred and forty unsexed day old broiler chicks (Arbo acre) were obtained from a commercial hatchery and transported to a poultry farm in Chikuku, Gwagwalada Local Government Area in Abuja. On arrival, the chicks were administered anti-stress (Vitalyte®) and glucose in drinking water to reduce the effect of stress due to transportation. The chicks were weighed individually at the beginning of the experiment using electronic scale. They were then divided into 4 treatment groups (T1-T4) and subsequently assigned to treatments in a completely randomised design. There were 60 chicks per treatment with 3 replicates comprising 20 chicks per replicate. The birds were randomly transferred into a brooder house based on the treatments and were brooded for two weeks in a deep liter. Thus, there were total of 4 brooders (equal to treatment groups) made of plywood board, with. Each brooder partitioned into three replicates to align with the treatments design. Broiler starter diet was fed to the chicks from day 0 to 28 day, while broiler finisher diet fed from 29 to 56 days. Birds were served the experimental diets twice a day, in the morning and in the evening and water provided *ad libitum*. The quantity of feed consumed by the birds were calculated on daily basis by subtracting the leftover of the feed from the quantity initially given. The quantity consumed weekly was calculated by addition of daily intake for seven days' period. The test materials, crude hesperidin and ascorbic acid, were administered in water to the chicks trough out their finishing phase according to experimental design, Daily dose of crude hesperidin and ascorbic acid were based on recommendations of Ahmadu *et al.*

(2015) and Kamboh *et al.* (2013) at the rate of 20mg and 200mg/kg respectively. Treatment 1 was the control group (T1), with no test ingredient administered. Treatment 2 was crude hesperidin only (T2) administered at 20 mg/litre of water. Treatment 3 was crude hesperidin + ascorbic acid (T3) at the dosage rate of 20mg and 200mg/litre respectively. Treatment 4 was ascorbic acid only at the dosage rate of 200 mg/litre. To ensure rapid consumption of the test material, water was withdrawn from the birds every evening of the experiment.. electric bulb of 100-Watt capacity was used as a source of lighting for the first 2 weeks of brooding. The lightening duration was 22 hours for the first week of brooding and was stepped down with advance in the age of the chicks. The temperature and relative humidity of the brooder were taken with mercury thermometer and hygrometer throughout brooding period. At the expiration of brooding, chicks were transferred to battery cage following distribution pattern of the brooding stage. Birds were kept under similar conditions of management throughout the experimental period. Strict biosecurity measures were followed throughout the experimental periods. Water troughs and other equipment used were cleaned daily. Birds were kept under close observation throughout the experimental period for abnormal signs. Sick birds were promptly isolated to a sick bay separated from main pen. Dead birds were disposed in an incinerator built at a distance from the poultry house.

Experimental diets

Birds were fed a basal diet formulated according to NRC (1994). Starter diet (0 – 28 days) containing a crude protein of 22.12 % and metabolisable energy (ME) of 30254 kcal/kg and finisher diet (29 – 56 days) containing 20.46 % crude protein and metabolisable energy of 31279 kcal/kg were given. Table 1 shows the chemical composition of the experimental basal diets.

Data collection

The following data were collected and determined over a period of four weeks:

Feed intake: Daily feed intake was calculated by subtracting the leftover feed from the quantity initially given.

Body weight gain: Body weight gain was calculated by subtracting the initial body weight from the final body weight.

Feed conversion ratio: Feed conversion ratio was calculated using the formula: $FCR = \text{Feed consumed (g)} / \text{Body weight gain (g)}$

Mortality: Mortality was recorded as encountered throughout the experimental period.

Nutrient digestibility: The nutrient digestibility test was carried out according to the method described by Bashar *et al.* (2010).

Statistical Analysis

Collected data were analysed by using General Linear Model of Statistical Analysis System (SAS) software version 9.2 (2009) and compared between groups by one way Analysis of Variance (ANOVA). Means were separated by Duncan Multiple Range Test of the same package. Probability values less than 0.05 ($p < 0.05$) were considered significant.

Table 1: Chemical composition of experimental diets (% DM)

Parameters	Starter mash	Finisher mash
Crude protein (%)	22.12	20.46
Crude fibre (%)	5.04	5.27
Ether extract (%)	4.09	3.12
Ash (%)	5.42	5.87
Nitrogen free extract (%)	52.08	57.11
Calcium (%)	1.42	1.33
Phosphorus (%)	0.75	0.82
Metabolizable energy (Kcal/kg)	30254	31279

RESULTS

Thermal environmental observation of experimental house

The ambient temperature and relative humidity of the experimental house is shown in Table 2. Results for ambient temperature (DBT), relative humidity (RH) and temperature humidity index (THI) shows fluctuations in obtained values at different time of the day. The observed difference in the obtained values were not significantly ($P > 0.05$) influence by the period of collection. Weekly results followed similar pattern for DBT, RH and THI which shows insignificant ($P > 0.05$) differences in the listed variable across the groups for the period which the recording took place.

Effect of feed and nutrient intake of heat-stressed broiler chickens administered crude hesperidin, ascorbic acid and the combination of both antioxidants

The feed and nutrient intake of heat stressed broiler chickens administered crude hesperidin, ascorbic acid and the combination for finisher phase is shown in Table 3. Intake of feed and ether extract was affected by the supplementation in the order: $T3 > T2 > T4 > T1$ ($P < 0.05$). Intake of crude protein and crude fibre was enhanced in ($P < 0.05$) in T3, followed by T2 and T4, and lowest in T1. Intake of ash, nitrogen free extract and calcium was higher ($P < 0.05$) in the treatment groups compared with the non-supplemented group. Phosphorus intake was not affected ($P > 0.05$) by the treatment.

Nutrient digestibility and mineral retention of heat-stressed broiler chickens administered crude hesperidin and ascorbic acid

It was observed from the results obtained for nutrient digestibility and mineral retention (Table 4) that, dry matter, crude protein, Nitrogen free extract and phosphorus was increased in T3 similar in T2 and T4 but reduced in T1 ($P<0.05$). Crude fibre digestibility was not affected by treatments. Ether extract was similar in T2, T3 and T4 but greater than T1 ($P<0.05$). Calcium was similar in T2 and T3 with highest value followed by T4 and lowest in T1 ($P<0.05$).

Table 2: Thermal environmental observation of experimental house

Week	8:00 hour			12:00 hour			16:00 hour			20:00 hour			24:00 hour		
	DBT (°C)	RH (%)	THI	DBT (°C)	RH (%)	THI	DBT (°C)	RH (%)	THI	DBT (°C)	RH (%)	THI	DBT (°C)	RH (%)	THI
1	27.43	57.53	25.62	39.14	62.27	36.24	39.42	62.23	36.49	31.29	62.20	29.21	27.00	63.47	25.57
2	27.08	57.08	25.39	35.28	61.96	32.82	39.00	61.39	36.06	31.42	62.73	29.45	28.02	61.62	29.45
3	26.33	56.33	24.71	37.86	63.96	35.24	39.11	63.01	36.28	30.85	61.01	28.86	24.85	63.08	23.65
4	25.50	59.01	24.09	35.33	60.73	32.78	40.03	65.22	37.27	27.83	64.14	26.34	22.66	64.37	21.75
5	25.91	55.93	24.32	35.02	62.09	32.60	39.72	61.73	36.77	28.01	62.40	26.42	23.07	62.17	22.05
6	24.17	59.45	22.94	38.28	62.11	35.47	40.12	60.97	37.01	29.15	63.05	27.46	24.30	63.92	23.19
7	27.14	60.03	25.56	36.04	63.04	33.55	40.73	63.28	37.73	25.16	60.94	23.86	23.28	60.84	22.20
8	26.02	56.75	24.46	38.11	62.75	35.37	38.41	62.45	35.61	27.13	62.18	25.63	24.62	62.17	23.42
Mean	26.19	57.77	24.64	36.88	62.36	34.26	39.57	63.54	36.65	28.86	62.33	27.15	24.73	62.71	23.91
SEM	0.38	0.54	0.32	0.58	0.33	0.52	0.26	0.43	0.24	0.79	0.37	0.69	0.67	0.43	0.90

DBT (°C) = Dry bulb temperature; RH (%) = Relative humidity; THI = Temperature humidity index

Table 3; Feed and nutrient intake of heat-stressed broiler chickens administered crude hesperidin, ascorbic acid and the combination of both antioxidants

Parameter	Treatment				SEM
	T1	T2	T3	T4	
Crude protein (%)	25.15 ^c	38.75 ^b	40.79 ^a	35.84 ^b	3.48
Ether extract (%)	3.84 ^d	5.91 ^b	6.22 ^a	5.45 ^c	0.53
Crude fiber (%)	6.48 ^c	9.98 ^b	10.51 ^a	9.72 ^b	0.91
Ash (%)	7.21 ^b	11.12 ^a	11.70 ^a	10.28 ^a	1.00
Nitrogen free extract (%)	7.02 ^b	10.82 ^a	11.38 ^a	10.00 ^a	0.97
Calcium (%)	1.63 ^b	2.53 ^a	2.65 ^a	2.33 ^a	0.22
Phosphorus (%)	1.01	1.55	1.63	1.44	0.13

^{abc} means within rows having different superscript differed significantly ($P < 0.05$)

Table 4: Nutrient digestibility and mineral retention of heat-stressed broiler chickens administered crude hesperidin and ascorbic acid

Parameter	Treatment				SEM
	T1	T2	T3	T4	
Dry matter (%)	70.16 ^c	75.89 ^b	82.70 ^a	77.08 ^b	2.57
Crude protein (%)	62.20 ^c	73.48 ^b	80.97 ^a	70.79 ^b	3.87
Crude fiber (%)	48.72	52.89	56.94	53.33	1.68
Ether extract (%)	55.90 ^b	70.87 ^a	77.27 ^a	72.38 ^a	4.61
Nitrogen free extract (%)	64.73 ^c	78.67 ^b	84.41 ^a	77.02 ^b	2.04
Mineral retention					
Calcium (%)	60.00 ^c	80.00 ^a	84.12 ^a	75.60 ^b	2.28
Phosphorus (%)	62.71 ^c	76.15 ^b	82.32 ^a	75.00 ^b	2.05

^{abc} means within rows having different superscript differed significantly ($P < 0.05$)

Feed utilisation and growth performance of heat-stressed broiler chickens administered crude hesperidin, ascorbic acid and the combination

The outcome of feed utilisation and growth performance of broiler chickens administered the test materials is shown below (Table 5). Initial body weight (IBW), final body weight (FBW), body weight gain (BWG), daily weight gain (DWG), daily feed intake (DFI), feed conversion ratio (FCR), protein efficiency (PER) ratio and mortality ranged values were displayed in the outcome. IBW was similar ($P > 0.05$) across the treated groups. FBW, BWG, DWG, DFI and PER were highest in T3 ($P < 0.05$), similar in T2 and T4 while lowest value was seen in T1. FCR was highest in T1 ($P < 0.05$), similar in T2 and T4, lowest value recorded in T3. Mortality was significantly ($P < 0.05$) affected by treatment in the order: T1 > T4 > T2 > T3.

Table 5: Feed utilization and growth performance of heat-stressed broiler chickens administered crude hesperidin, ascorbic acid and the combination

Parameter	Treatment				SEM
	T1	T2	T3	T4	
Initial body weight (g/bird)	40.15	40.32	40.20	40.08	0.05
Final body weight (g/bird)	2113.06 ^d	3410.82 ^b	3847.25 ^a	3197.09 ^c	368.25
Body weight gain (g/bird)	2074.91 ^d	3370.5 ^b	3807.05 ^a	3157.01 ^c	368.23
Daily weight gain (g/bird)	37.05 ^d	60.19 ^b	67.88 ^a	56.38 ^c	6.56
Daily feed intake (g/bird)	111.15 ^d	156.24 ^b	165.35 ^a	146.47 ^c	11.86
Feed conversion ratio	3.11 ^a	2.60 ^b	2.43 ^b	2.59 ^b	0.15
Protein efficiency ratio	1.71 ^c	1.97 ^b	2.11 ^a	1.98 ^b	0.08
Mortality ratio (%)	11.00 ^a	5.00 ^b	2.00 ^d	7.00 ^c	1.89

^{abc} means within rows having different superscript differed significantly ($P < 0.05$)

Effect of crude hesperidin, ascorbic acid and the combination on carcass characteristics and primal cut of heat-stressed broiler chickens

The table below (Table 6) displays effect of crude hesperidin, ascorbic acid and the combination on carcass characteristics and primal cut of heat stressed broiler chickens. Live weight was affected in the order: T3 > T2 > T4 > T1 ($P < 0.05$). Slaughter weight dressed weight, dressing percentage drumstick and thigh were higher in T3 ($P < 0.05$), similar in T2 and T4 but lowest in T1. Breast muscle, wing and back were similar ($P > 0.05$) among the supplemented group but higher when compared with control ($P < 0.05$). Head, neck and shank values were not affected by the treatment ($P > 0.05$).

Table 6: Effect of crude hesperidin, ascorbic acid and the combination on carcass characteristics and primal cut of heat-stressed broiler chickens

Parameter	Treatment				SEM
	T1	T2	T3	T4	
Live weight (g)	2115.06 ^a	3410.82 ^b	3847.25 ^a	3197.09 ^c	368.25
Slaughter weight (g)	1997.72 ^c	3280.75 ^b	3718.49 ^a	3072.21 ^b	365.56
Dressed weight (g)	1549.28 ^c	2764.86 ^b	3262.14 ^a	2521.84 ^b	359.74
Dressing percentage (%)	77.55 ^c	84.28 ^b	87.72 ^a	82.08 ^b	2.13
Drumstick (%)	14.47 ^c	16.0 ^b	19.64 ^a	17.93 ^b	1.12
Breast muscle (%)	17.57 ^b	23.15 ^a	27.85 ^a	22.64 ^a	2.10
Thigh (%)	12.22 ^c	15.12 ^b	18.79 ^a	14.51 ^b	1.36
Wing (%)	5.20 ^b	8.63 ^a	9.14 ^a	9.61 ^a	1.00
Head (%)	2.24	2.52	2.27	2.48	0.07
Neck (%)	3.81	4.05	3.62	4.13	0.11
Back (%)	14.52 ^b	18.04 ^a	19.79 ^a	17.58 ^a	1.10
Shank (%)	3.07	3.85	3.96	3.19	0.23

^{abc} means within rows having different superscript differed significantly ($P < 0.05$)

DISCUSSIONS

The higher intake of feed and nutrient of the treated groups compared to the untreated shows that supplementation of broiler chickens' diet with antioxidants reduced metabolic rate and heat stress in the birds and thus enhanced feed intake. Generally, birds eat to meet their energy requirements and reduce their feed intake during hot dry season in order to reduce heat increment and metabolic rate, which increase heat loss and consequently increase feed intake. It has been reported that heat stressed chickens lower their body temperature by reducing their feed intake (Lemme *et al.*, 2019; Wasti *et al.*, 2020), indicating that broiler chickens in the control group must have experienced more heat stress than the treated birds. Therefore, birds without antioxidant supplementation to ameliorate heat stress probably reduced their intake in order to

reduce metabolic rate, heat increment and body temperature. However, among the antioxidant supplemented groups, the higher feed and nutrient intake was seen in birds treated with combination of the test materials which indicates a positive association or synergy between the two antioxidants in ameliorating heat stress and enhancing feed intake. It was observed that either crude hesperidin or ascorbic acid supplementation enhanced feed and nutrient intake in similar manner, indicating that neither of the antioxidants was superior to the other in ameliorating heat stress and improving feed intake. This result, therefore, indicates that crude hesperidin could be another alternative to ascorbic acid, a well-known and over-used conventional antioxidant.

The experiment shows that supplementation affects nutrient digestibility and mineral retention in the treated birds. The outcome may be due to the fact that the antioxidants reduce metabolic rate and heat generation, which perhaps stimulate the optimum functionality of digestive enzymes. Enzymes are protein and can be denatured at a temperature above the thermo-neutral zone for the comfort and survivability of bird. Poultry limit feed consumption in hot weather, which results in nutrient deficiencies and decrease in the intake of essential nutrients, such as protein, essential amino acids, minerals and vitamins (Teyssier *et al.*, 2022). It is an established fact that ascorbic acid ameliorates deleterious effect of heat stress in poultry by prevention of free radical production. This mechanism reduces metabolic rate and heat increment, thereby boosting feed intake and digestibility. Similarly, crude hesperidin supplementation in this research improved digestibility and compared favourably with ascorbic acid, a standard antioxidant. Phytochemicals present in crude hesperidin might have promoted the performance of intestinal flora, thereby improving digestion and nutrient retention and enhances utilization of energy, which improves the growth of the birds. This findings is in consonance with the reports of Chowdhury *et al.* (2018), who stated that broilers fed diet supplemented with 200 mg/kg essential oil from peppermint led to the increase in crude protein digestibility. Reyer *et al.* (2017) reported that birds fed 700 ppm, 1400 ppm and 2100 ppm of herbal extract, consisting of mixtures of essential oils of thyme, clove, oregano, eugenol and carvacrol, improved nutrient digestibility. Conversely, Peng *et al.* (2016) observed that dietary inclusion of oregano oil at 800 mg/kg did not cause any significant change in nutrient absorption. The result for digestibility and mineral retention for each antioxidant was observed to have similar value which implied that, crude hesperidin may replace ascorbic acid in amelioration of heat stress in broiler chickens. However, synergy between both antioxidants was found more potent and effective than either of the antioxidant alone. Therefore, crude hesperidin may replace ascorbic acid in amelioration of heat stress in broiler chickens.

The improved daily feed intake, final body weight, body weight gain, daily weight gain, feed conversion ratio, protein efficiency ratio and reduced mortality of the treated group

relative to the control could be attributed to reduction in body temperature and bioavailability of nutrients and energy induced increased feed consumption as a result of enhanced gut clearance. On the contrary, lower weight gain observed in control birds may be due to the absence of antioxidant to ameliorate heat increment with the consequence of the reduced feed intake and digestibility. The lower feed conversion ratio of the treated groups indicates higher feed utilization, feed efficiency with improved body weight gain in term of meat. Also, the improved protein efficiency ratio of the supplemented birds suggests enhanced dietary protein utilisation and conversion to flesh. The most striking result is the reduced mortality rate in the treated groups compared with the control. One of the dangerous consequences of heat stress in poultry production is high mortality, which often times reduces profitability of the business. This suggests that supplements used in this study either singly or combined has anti-inflammatory and antioxidant properties which reduced mortality. The result of this study is similar to the findings of Kairalla *et al.* (2022) who found increase in body weight gain and feed conversion ratio of broiler chickens supplemented by 0.3 % garlic powder. Olafadehan *et al.* (2020) observed that the dietary inclusion of 0.8 % *Daniellia oliveri* extract, as a phytogenic feed additive, in broiler diets improved the bird's performance and lowered mortality. The reduced mortality seen in the crude hesperidin group suggests antimicrobial property of certain phytoconstituents of orange peel from which hesperidin was extracted possibly lowered the pathogenic organisms load of the birds and thus enhanced their health. The result of this study is in contrast with previous results of Simitzis *et al.* (2019), who observed no significant differences in performance traits and meat quality characteristics of lambs fed with dietary hesperidin, naringin or α -tocopheryl acetate. The results show crude hesperidin or ascorbic acid supplementation enhanced feed utilisation and growth performance in similar manner, indicating that neither of the antioxidant is superior to each other. Therefore, crude hesperidin can be used as a potent replacement or an alternative to ascorbic acid.

The antioxidants supplementation in this study had a profound, positive effects on slaughter weight, dressed weight, dressing percentage and primal cuts such as drumstick, breast muscle, thigh, wing and back relative to the control treatment. Dressing percentage is generally influenced by several factors particularly live weight and dressed weight. The higher dressing percentage of the supplemented groups could, therefore, be attributed to their higher slaughter and dressed weights, which are the two major determinants of dressing percentage. The result obtained is similar to the results of Khan *et al.* (2023), who showed enhanced body weight gain, better feed conversion ratio, increase breast muscle and thigh weight of naked neck chickens administered organic selenium diet.

CONCLUSION

The study shows that supplementation of broiler chickens with crude hesperidin and ascorbic acid, either singly or combined positively affect feed and nutrient intake, nutrient digestibility, growth performance and carcass characteristics. Synergy between crude hesperidin and ascorbic acid proves to be more efficacious than the use of the antioxidants independently. It was also concluded that crude hesperidin group had similar performance to the ascorbic group, which implied that, crude hesperidin can replace ascorbic acid as choice antioxidant in mitigating heat stress in broiler chickens.

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