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GROWTH PERFORMANCE AND CARCASS TRAITS OF BROILER CHICKENS FED DIETARY *CITRUS SINENSIS* PEEL-BASED DIET

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ABSTRACT

A total of one hundred and ninety- two Cobb 500 day -old broiler chicks were randomly distributed to four experimental diets: control diet (0.00 % dried *Citrus sinensis* peel (DCSP)), diet B (2.50 % DCSP), diet C (5.00 % DCSP), and diet D (7.50 % DCSP). The birds were fed *ad libitum* throughout the experiment which lasted for 8 weeks. The inclusion of DCSP (2.50 – 7.50 %) as a replacement for wheat offal in the diet of broiler chickens did not have any significant effect (P > 0.05 %) on the feed intake (FI), body weight gain (BWG), final weight (FWT), and feed conversion ratio (FCR) at the starter phase. However, at the finisher phase and overall period of the experiment, DCSP inclusion into the broiler diet reduced (P < 0.05%) the BWG, FWT, and FCR of the birds at a 7.50 % inclusion level. As the inclusion of DCSP in the diet increased, the growth response criteria (BWG, FWT, FCR) were affected negatively in a progressive trend at a 7.50 % level except for feed intake. Internal organs such as the heart, lung, gizzard, and proventriculus were unaffected (P > 0.05 %) by the varied levels of DCSP inclusions. DCSP inclusion at 2.50 % and 7.50 % levels had a similar impact on the weight of the liver as the control except for birds on diet C whose organ weights were unusually high. There was a gradual reduction in the weight of the pancreas as the dietary inclusion of DCSP increased. However, the dietary DCSP caused an increase in the weight of the spleen which is an indication of immune immune-boosting property of the peel. Judging from the comparable body weight gain and FCR between the control diet and birds fed with diets B and C, dietary inclusion of DCSP could be used up to 5.00 % in broilers diets without any deleterious effects on growth and carcass parameters of broiler chickens.

Key words: *Citrus* peel; animal nutrition; broilers; husbandry; organ

INTRODUCTION

The poultry industry is one of the crucial sectors of the livestock industry as it does not suffer social infringements on consumer acceptability like other livestock species. In Nigeria, poultry products have made protein sources more affordable for consumers and the demand for poultry products (eggs and meat) has continued to increase not only in Nigeria but across the African Continent (Ewubare and Ozar, 2018). However, the poultry industry has been faced with numerous challenges lately particularly due to the exorbitant price of feedstuffs such as maize, soybean meal, etc. used in the formulation of poultry diet (Ahmed and Mohammed, 2015; Heise *et al.*, 2015). Hence, there is a need to explore agricultural by-products that have medicinal and nutritional benefits which could help reduce feed costs and improve the quality of poultry products.

Citrus sinensis (sweet orange) peel is a common by-product of extracting juice from citrus (Abassi *et al.*, 2015). It is obtained from *citrus sinensis* fruits, and it constitutes approximately one-fourth of the whole fruit mass after the extraction of the juice and removal of the pulp mechanically (Akbarian *et al.*, 2013). The peels are waste products that oftentimes constitute environ-

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mental pollutants due to the lack of an effective waste disposal system by orange retailers and the Nigerian Government (Hegazy and Ibrahim, 2012; Ani *et al.*, 2015). The peels are a rich source of bioactive compounds. It contains lipase that hydrolyzes triglycerides, diglycerides, and monoglycerides into free fatty acids and glycerol (Budyghifari *et al.*, 2019). It also contains high concentrations of antioxidants such as phenols, and flavonoids (Vlaicu *et al.*, 2020), essential oils such as terpenes and aliphatic sesquiterpene, and dietary fiber (Ebrahimi *et al.*, 2014). Nutritionally, it is also a good source of calories and protein comparable with maize (Oluremi *et al.*, 2006) and also rich in vitamins, especially vitamin C (Manthey, 2004). The utilization of *Citrus sinensis* peel has been reported to improve growth, increase antioxidant status, reduce cholesterol, enhance immunity in broiler chickens; serve as an anti-stress and improve poultry performance (Abbasi *et al.*, 2015; Faiz *et al.*, 2017). Agu (2006) reported that *Citrus sinensis* peel could replace maize up to 20 % in broiler chickens and up to 40 % in layers without affecting their optimum performance while still in lay (Oyewole, 2018). In rabbits, no adverse effect on growth performance was recorded when used up to 40 % replacement level (Oluremi *et al.*, 2005). Since numerous studies have been carried out on the replacement of maize with *Citrus sinensis* peel in broiler diet, then the replacement of wheat offal with *Citrus sinensis* peel should be feasible without having any deleterious effects on the growth and muscle development of broiler chickens. Therefore, this research focused on the implication of the substitution of wheat offal with *Citrus sinensis* peel at lower inclusion rates on the growth, organ, and carcass characteristics of broiler chickens.

MATERIALS AND METHODS

Sampling and proximate analysis of *Citrus sinensis* peel

Fresh *Citrus sinensis* peel selected from physically ripened fruits was gathered from local markets in Akure, Southwestern Nigeria, and sundried to between

Table 1. Gross composition (g/100 g) of the broiler starter experimental diets (0–4 weeks of age)

Ingredients (%)	Composite	Sweet Orange Peel	(CSOP)	levels (%)
	0.00	2.50	5.00	7.50
Maize	46.00	46.00	46.00	46.00
DCSP	0.00	2.50	5.00	7.50
Wheat Offal	7.50	5.00	2.50	0.00
Groundnut Cake	14.00	14.00	14.00	14.00
Soybean Meal	25.15	25.15	25.15	25.15
Fishmeal	2.00	2.00	2.00	2.00
Premix	0.25	0.25	0.25	0.25
Limestone	1.30	1.30	1.30	1.30
Bone meal	1.50	1.50	1.50	1.50
Methionine	0.10	0.10	0.10	0.10
Lysine	0.10	0.10	0.10	0.10
Salt	0.10	0.10	0.10	0.10
Vegetable oil	2.00	2.00	2.00	2.00
Total	100.00	100.00	100.00	100.00
Calculated Nutrient:				
Crude Protein (%)	22.55	22.21	22.02	21.82
Metabolizable Energy (kcal/kg)	2916.60	2936.07	2955.54	2975.01
Crude Fibre (%)	3.90	4.00	4.11	4.22
Calcium (%)	1.09	1.09	1.09	1.08
Phosphorus (%)	0.58	0.58	0.57	0.56
Lysine (%)	1.25	1.23	1.20	1.18
Methionine (%)	0.42	0.42	0.41	0.40

10−13 % moisture content and ground with the aid of a hammer mill.

The AOAC standard method (2010) was used in the determination of the moisture, crude protein, total ash, and crude fiber content of the peel. Seven (7) grams of the sample were placed in an oven set at 105 °C for 3 hours to achieve a constant weight. Crude protein was determined by the Kjeldahl method; Ash content was determined by using a muffle furnace maintained at 550 °C for three hours. The crude fiber was obtained by digesting the sample with H_2SO_4 and NaOH, followed by incinerating it in a muffle furnace at 550 °C for 4 hrs. Carbohydrate content was calculated from the difference of 100 − (% moisture + % ash + % protein + % fat + % fiber).

Animal management and experimental design

Four different diets (A, B, C, and D) were formulated for the starter and finisher phases following the NRC (1994) nutritional recommendations as shown in Tables 1 and 2. Dried *Citrus sinensis* peel (DCSP) replaced wheat offal in diets B, C, and D at 2.50 %, 5.0 %, and 7.50 % except for the control with 0 % inclusion (Diet A). One hundred- and ninety-two-day-old Cobb 500 broiler chicks were randomly distributed to the four experimental diets (48 birds/experimental diet) which were replicated six times (8 birds/replicate) using a completely randomized design. The experimental pen temperature was regulated and maintained at 31 °C ± 2 for the 14 days and gradually reduced by 2 °C after each consecutive 7 days until the experimental house temperature was 26 °C ± 2. The lighting duration was 23 hours per day. The birds were fed *ad libitum* and fresh clean water was served regularly. The experiment lasted for 8 weeks.

Growth performance, and carcass trait analysis

On arrival, the chicks were weighed (initial weight), thereafter the body weight and feed intake of the experimental birds were taken and recorded weekly. The feed conversion ratio was calculated as the ratio of feed intake by the birds to their weight gain.

Table 2. Gross composition (g/100 g) of the broiler finesher experimental diets (4−8 weeks of age)

Ingredients (%)	Composite	Sweet Orange Peel	(CSOP)	levels (%)
	0.00	2.50	5.00	7.50
Maize	51.00	51.00	51.00	51.00
DCSP	0.00	2.50	5.00	7.50
Wheat Offal	7.50	5.00	2.50	0.00
Groundnut Cake	14.00	14.00	14.00	14.00
Soyabean meal	21.00	21.00	21.00	21.00
Fishmeal	1.00	1.00	1.00	1.00
Premix	0.25	0.25	0.25	0.25
Limestone	1.30	1.30	1.30	1.30
Di-calcium phosphate	0.50	0.50	0.50	0.50
Bone meal	1.15	1.15	1.15	1.15
Methionine	0.10	0.10	0.10	0.10
Lysine	0.10	0.10	0.10	0.10
Salt	0.10	0.10	0.10	0.10
Vegetable oil	2.00	2.00	2.00	2.00
Total	100.00	100.00	100.00	100.00
Calculated Nutrient:				
Crude Protein (%)	20.49	20.11	19.74	19.36
Metabolizable Energy (kcal/kg)	2953.85	2907.10	2860.35	2813.60
Crude Fibre (%)	3.77	3.55	3.34	3.13
Calcium (%)	1.03	1.03	1.03	1.03
Phosphorus (%)	0.58	0.58	0.57	0.56
Lysine (%)	1.11	1.09	1.07	1.04
Methionine (%)	0.40	0.39	0.38	0.38

To analyze carcass traits, on the last day of the experiment, the broiler chickens were fasted for 8 hours before slaughter. Twelve (12) birds were randomly selected from each treatment group (2 birds/replicate), weighed (final body weight, FBW), and stunned after which they were sacrificed. The birds were dissected and organs such as the spleen, liver, kidney, lungs, pancreas, and proventriculus were carefully removed and weighed using a sensitive digital scale of 500 grams and 5-kilogram capacity. Commercial cuts such as breast, drumsticks with thighs, wings, back, head, and neck were dissected and weighed.

Data analysis

The data were subjected to a one-way analysis of variance using SPSS version 2016. The differences among the experimental treatment means were determined (P < 0.05) by the Duncan multiple range test of the same statistical package. The analyzed data were presented as mean ± standard error mean (SEM).

RESULTS

Proximate analysis of sun-dried *Citrus sinensis* peel

Table 3 shows the proximate composition expressed in dry matter of the sun-dried sweet orange peel. The DCSP contained moisture (12.51 ± 0.45 %), fat (3.50 ± 0.34 %), crude protein (9.25 ± 1.77 %), crude fiber (8.51 ± 0.71 %), ash (6.32 ± 0.86 %), and Carbohydrate (59.91 ± 1.12 %).

Table 3. Proximate analysis of sun-dried composite sweet orange peel

Parameters	Content
Proximate (%)	
Moisture	12.51 ± 0.45
Fat	3.50 ± 0.34
Crude Protein	9.25 ± 1.77
Crude fibre	8.51 ± 0.71
Ash	6.32 ± 0.86
Carbohydrate	59.91 ± 1.12

Performance of broiler chickens fed varied levels of DCSP

Table 4 revealed the effect of sundried *Citrus sinensis* peel diet on the growth performance of broiler chickens at the starter phase, finisher phase, and overall period. At the starter phase of the study, the inclusion of DCSP in the diets of the broiler chickens did not have a significant influence (P > 0.05 %) on the initial body weight (IBWT), body weight gained (BWG), feed intake (FI), and feed conversion ratio (FCR).

Table 4. Effect of varied levels of sundried *Citrus sinensis* peel on the growth characteristics of broiler chickens

Parameters	Diet A (0.00 %)	Diet B (2.50 %)	Diet C (5.00 %)	Diet D (7.50 %)	P-value
Starter Phase:					
IBW (g/bird)	41.93 ± 0.36	42.24 ± 0.34	42.95 ± 0.21	41.90 ± 0.31	0.13
FBW (g/bird)	742.63 ± 80.17	665.68 ± 23.10	647.67 ± 41.15	673.45 ± 43.19	0.60
BWG (g/bird)	699.74 ± 80.20	622.96 ± 23.11	604.72 ± 41.02	631.56 ± 42.94	0.60
FI (g/bird)	1363.82 ± 84.52	1298.58 ± 22.71	1299.82 ± 44.80	1321.90 ± 26.25	0.79
FCR	1.99 ± 0.19	2.09 ± 0.07	2.16 ± 0.08	2.11 ± 0.12	0.79
Finisher Phase:					
FBW (g/bird)	2513.33 ± 124.84^{a}	2303.33 ± 92.21^{ab}	2160.00 ± 39.05^{bc}	1938.33 ± 90.94^{c}	0.01
BWG (g/bird)	1382.27 ± 55.60^{a}	1298.06 ± 115.01^{a}	1223.16 ± 53.41^{ab}	951.01 ± 95.75^{ab}	0.03
FI (g/bird)	3403.95 ± 6.28	3419.22 ± 3.09	3421.87 ± 5.57	3404.37 ± 10.65	0.21
FCR	1.93 ± 0.09^{b}	2.09 ± 0.10^{b}	2.27 ± 0.12^{ab}	2.26 ± 0.11^{a}	0.03
Overall (1 to 56):					
BWG (g/bird)	2470.85 ± 124.93^{a}	2260.81 ± 92.17^{ab}	2117.05 ± 39.22^{bc}	1896.44 ± 90.96^{c}	0.01
FI (g/bird)	4767.76 ± 78.63	4717.81 ± 24.61	4721.68 ± 41.36	4726.27 ± 18.21	0.86
FCR	1.94 ± 0.08^{b}	2.09 ± 0.09^{ab}	2.23 ± 0.06^{bc}	2.50 ± 0.11^{c}	0.01

IBW – Initial body weight, FBW – final body weight, BWG – body weight gain, FI – feed intake, FCR – feed conversion ratio, g – grams.
^{abc}Means within a row with different superscripts are significantly different (P < 0.05).

However, at the finisher phase and overall period, broiler chickens in the control group had the highest FBW (2513.33 g), BWG (1382.27 g), and the best FCR (1.93) when compared to other treatment groups while no significant differences (P > 0.05) were observed in the feed intake of birds across all the treatment groups. Broiler birds assigned to diet B had FBW (2303.33 g) and BWG (1298.06 g) which were in close range to the control group and better FCR (2.09) while the least FBW (1938.33 g), BWG (951.01 g), and poorest FCR was recorded among birds fed with diets containing 7.50 % DCSP as a substitute for wheat offal.

Carcass characteristics and absolute organ weight of broiler chickens fed diets containing DCSP

Table 5 revealed the carcass characteristics of broiler chickens fed varied inclusion levels of dietary DCSP. The slaughter weight, dressed weight, eviscerated weight, visceral weight, thigh, breast, and drumstick were significantly influenced (P < 0.05) by the varied levels of dietary DCSP except for the wing, head, and neck. Broiler chickens in the control group had the highest slaughter weight (2.42 kg), dressed weight (1.89 kg), eviscerated weight (2.08 kg), visceral weight (307.73 g), thigh weight (298.93 g), breast (593.97 g), and drumstick (271.80 g) followed by birds fed with diet B. The lowest slaughter weight (1.91 g, 1.92 g), dressed weight (1.42 g, 1.43 g), eviscerated weight (1.58 g, 1.59 g), visceral weight (270 g, 270 g), and other carcass cut weights observed was recorded among birds fed with diet C and D. Likewise, the absolute weight of the pancreas, liver, and spleen were significantly affected (P < 0.05) by dietary CSOP except for the heart, lung, gizzard, and proventriculus.

DISCUSSION

Proximate analysis of sun-dried *Citrus sinensis* peel

Citrus is one of the most popular fruit crops in the world consumed as either fresh produce or juice with its peels commonly disposed of as waste. Proximate analysis of feed ingredients or alternative feed materials is essential as it provides information on the basic nutrients present in feed samples (Akiode *et al.*, 2018). From the result presented in Table 3,

Table 5. Effect of dietary DCSP on carcass and absolute organ weight of broiler chicken

Parameters	A (0.00 %)	B (2.50 %)	C (5.00 %)	D (7.50 %)	P-Value
Carcass					
Slaughter wt (kg/bird)	2.42 ± 0.12^{a}	2.17 ± 0.08^{ab}	1.91 ± 0.17^{b}	1.92 ± 0.15^{b}	0.09
Dressed wt (kg/bird)	1.89 ± 0.07^{a}	1.65 ± 0.08^{ab}	1.42 ± 0.17^{b}	1.43 ± 0.13^{b}	0.08
Evisc. wt (kg/bird)	2.08 ± 0.09^{a}	1.82 ± 0.08^{ab}	1.58 ± 0.18^{b}	1.59 ± 0.14^{b}	0.08
Visceral wt (g/bird)	287.73 ± 11.70	279.03 ± 5.09	270.00 ± 9.69	270.00 ± 9.69	0.09
Carcass cuts					
Wing (g/bird)	181.67 ± 4.27	179.57 ± 1.79	152.47 ± 15.69	167.00 ± 12.07	0.23
Thigh (g/bird)	298.93 ± 5.37^{a}	260.50 ± 18.39^{ab}	225.97 ± 23.29^{b}	231.13 ± 26.07^{b}	0.01
Breast (g/bird)	593.97 ± 47.08^{a}	507.37 ± 42.28^{ab}	419.07 ± 57.89^{b}	405.33 ± 42.71^{b}	0.08
Drumstick (g/bird)	271.80 ± 9.57^{a}	256.33 ± 12.09^{ab}	212.23 ± 20.55^{b}	210.23 ± 15.01^{b}	0.04
Head (g/bird)	55.93 ± 6.38	56.73 ± 4.16	51.00 ± 4.22	48.50 ± 4.86	0.62
Neck (g/bird)	151.93 ± 28.69	123.77 ± 4.10	111.57 ± 13.26	119.07 ± 5.59	0.37
Internal Organs					
Lung	12.13 ± 2.40	12.77 ± 1.30	12.70 ± 1.64	11.77 ± 0.58	0.97
Heart	12.17 ± 1.14	10.87 ± 0.61	11.00 ± 0.45	11.97 ± 2.49	0.13
Pancreas	6.47 ± 0.72^{a}	5.60 ± 0.87^{ab}	5.17 ± 0.30^{ab}	4.23 ± 0.44^{b}	0.06
Gizzard	51.73 ± 4.39	53.90 ± 0.40	47.10 ± 3.96	49.10 ± 4.27	0.60
Liver	38.83 ± 3.71^{b}	42.27 ± 2.60^{b}	58.33 ± 6.63^{a}	41.60 ± 5.31^{b}	0.08
Proventriculus	10.77 ± 0.81	10.23 ± 0.41	9.87 ± 0.64	9.73 ± 0.49	0.64
Spleen	1.80 ± 0.11^{b}	1.70 ± 0.06^{b}	1.80 ± 0.11^{b}	2.50 ± 0.15^{a}	0.00

Evisc. wt – Eviscerated weight, wt – weight.
^{ab}Means within a row with different superscripts are significantly different (P < 0.05).

the value obtained for the moisture content of the sun-dried peel was not above 12 % as recommended by Standard of Poultry Feeds Industrial Standard (Nigeria) in 2018, but it was slightly higher than the results obtained by Adewole *et al.* (2014), and Uzama *et al.* (2021) who reported 10.00 % and 10.92 % respectively in dried citrus peel samples. The value of the moisture content present in the sun-dried peel indicated that the peel is safe and could be used in the poultry diet without any risk for microbial spoilage as higher moisture content of feedstuffs could result in the activation of enzymes that break medicinally active compounds, thus increasing their susceptibility to microbial spoilage (Oikeh *et al.* 2013, Akintimehin *et al.*, 2022). Although the value of the crude fat and crude protein contents of the citrus peel was lower when compared with the value obtained by Abdelazem *et al.* (2021), and Adewole *et al.* (2014) respectively, the value of crude fat content obtained in this study aligned with the findings of Uzama *et al.* (2021). The differences in the crude fat and protein contents of the peel could be due to the drying techniques adopted since the peels utilized in the study were sundried rather than the shade-dried technique at room temperature used by the other researchers. It could also be due to the differences in the edaphic factors of the soil on which the citrus fruits were planted. The crude fiber of the sun-dried citrus peel was lower in value when compared with the 14.17 % and 14.87 % reported by Gbenga-Fabusiwa *et al.* (2021). The lower crude fiber content in the sun-dried Citrus peel indicated that there are fewer indigestible fractions (cellulose, hemicellulose, lignin, and pectin) in the peel which could be tolerated by poultry for the maintenance of the hindgut health and microbial population. The quantity of ash available in the sun-dried citrus peel (6.32 %) showed that there is a substantial amount of mineral elements present in the peel which fell within the range of values reported by Adewole *et al.* (2014) and Gbenga-Fabusiwa *et al.* (2022). Also, the carbohydrate content of the peel fell within the range reported by Gbenga-Fabusiwa *et al.* (2021) which revealed that a good amount of soluble carbohydrates (starch and sugar) is available in the peel and could be an energy source when utilized in feed formulation.

Performance of broiler chickens fed dried *citrus sinensis* peel-based diet

The findings from this study revealed that the inclusion of citrus peel in the diet of broiler chicken at the starter phase does not affect the feed intake, final body weight, body weight gain, and feed conversion ratio of the birds which contradicts the report of Ebrahimi *et al.* (2013) and Sunmola *et al.* (2018) but agreed with the findings of Akbarian *et al.* (2013). However, the final body weight of birds at the end of the starter phase fell within the range of values reported by Sumola *et al.* (2018) which is an indication that there is a substantial amount of energy content present in the sweet orange peel to promote weight accretion as underlined by Agu *et al.* (2010) and Adekeye *et al.* (2021).

Orange peel is a rich source of dietary fiber, soluble sugars, and insoluble polysaccharides (Chaib Eddour *et al.* 2023). At the finisher phase, Birds fed the control diet had significantly higher body weight gain, the final body weight, and the best FCR when compared with others fed the 7.50 % DCSP diet even though the feed intake of birds across the different diet groups was unaffected. Likewise, as the level of DSCP in the broiler diet increased from 2.50 % to 7.50 %, the body weight gain and final body weight decreased and therefore, culminated in poor FCR. The reduction in body weight observed in broiler chickens fed DCSP beyond 5.00 % in the diets implied that the sun-dried *Citrus sinensis* peel probably possessed anti-nutrients (saponin) that would not be well tolerated beyond 5.00 % of DCSP in the diet and would have prevented the efficient utilization of nutrients contained in the diets by the birds. Ani *et al.* (2015) reported similar findings on broiler chickens fed a fermented orange peel meal diet at a 5 – 15 % inclusion level. Hence, this observation contradicts the findings of Agu *et al.* (2010) who reported the utilization of sun-dried sweet orange peel up to 20 % in broiler chickens.

Carcass characteristics and absolute organ weight of broiler chickens fed diets containing DCSP

The carcass indices revealed that birds on the control diet had the highest slaughter weight, dressed weight, eviscerated weight, thigh, breast, and drumstick weight followed by the birds fed on the diet containing 2.50 % DSCP, and the least carcass indices weight was observed among birds fed diets C and D. This could be due to the inhibitory effect of sweet orange peel on nutrient utilization by the birds. As the DCSP increased in the diet, the growth of the birds was suppressed and concomitantly culminated in reduced muscle deposition and carcass weights. However, the visceral weights of birds across treatment were unaffected. This observation contradicts the findings of Agu *et al.* (2010) but partly agrees with the findings of Oluremi *et al.* (2006) who observed a similar trend in the carcass weight of birds even though they were statistically nonsignificant.

Generally, the weight of organs in broiler chickens reflects how birds respond physiologically to the administered diet, revealing abnormalities in presence of toxin agents. The weight of the heart, gizzard, and proventriculus were unaffected by the dietary treatment while the pancreas weight gradually decreased as the DSCP inclusion in the broiler diet increased. The pancreas is responsible for the production of digestive enzymes and of the hormones insulin and glucagon which are directly related to carbohydrate metabolism. A reduction in the weight of the pancreas could lower the biosynthesis of these hormones which could hamper optimal carbohydrate metabolism. The spleen is an important immune organ and its size is used as an index of immune responses (Smith and Hunt, 2004). The spleen weight of broiler chickens fed Diet A, B, and C were statistically similar while the weight of the spleen observed in the birds fed diet D was higher. This indicated that the inclusion of DCSP between the range of 2.5 % to 5.0 % did not affect the immune system and the utilization of DCSP at 7.50 % could confer immunocompetence on the birds. Numerous studies have reported the presence of vitamins and trace minerals that possess antioxidant and antimicrobial properties in orange peel. Hence, the immune-boosting property of DCSP on broiler chickens observed in this study aligned with the findings of Ahmad *et al.* (2023). Also, the liver weight of broiler chicken across the treatment group was significantly influenced by dietary DCSP. Statistically, the control diet, diet B and D had a similar impact on the liver weights of the broiler chickens except for birds placed on Diet C. This probably shows that DCSP would not hinder the normal functioning of the liver of the broiler chickens.

CONCLUSION

The findings of this study revealed the potential of sun-dried *Citrus sinensis* peel as a possible replacement for wheat offal in a broiler starter's diet. It was also shown that the inclusion of DSCP in broiler diet would support growth performance, and nutrient utilization and improve livability in broiler starters and finishers up to 5.00 % inclusion level in the diets. Dietary inclusion of DCSP beyond this level could depress growth performance feed utilization in broiler chickens. Hence, DCSP as a substitute for wheat offal could be used up to 5.00 % level at both the starter and finisher stages to minimize the cost of broiler bird production.

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AUTHOR'S CONTRIBUTIONS

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All authors have read and agreed to the published version of the manuscript.

INFORMED CONSENT STATEMENT

Not applicable.

DATA AVAILABILITY STATEMENT

The data presented in this study are available on request from the corresponding author.

CONFLICT OF INTEREST

All authors declare no conflict of interest.

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