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REGULAR ARTICLES

Response of broiler chickens to pineapple and orange-based diets under a single-phase feeding

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Abstract

This study evaluated the effect of partial replacement of maize meal with peels from pineapples and oranges on growth indices, apparent nutrient digestibility, carcass characteristics and sensory attributes of broiler chickens. Day old unsexed Ross 308 broiler chickens ($n=480$) were allocated randomly into four diets in a completely randomized design. Each diet had six (6) replicates of twenty birds. The four dietary treatments were: control (0 g kg^{-1} peels); 50 g kg^{-1} pineapple peels (PP); 50 g kg^{-1} orange peels (OP); and 25 g kg^{-1} each of pineapple and orange peels (POP). Feed and fresh water were offered *ad libitum.* The experiment lasted for 56 days. Results showed that the dietary treatments influenced all the growth parameters measured with birds on the control diet doing better ($P<0.05$) than the treated diets. The apparent nutrient digestibility results showed that birds fed the pineapple/orange mixed peels diet were similar to the control group in crude protein (71.53 vs. 76.22%) and ash digestibility (64.01 vs. 59.12%). The birds fed the mixed peels diet had higher DM (83.55 vs. 83.03%) and NFE (95.89 vs. 93.26%) digestibility values than those fed the control diet. The carcass results indicated that the control diets did better than the other treatments only in the live weight (1410.25 g) of the birds. In the dressing percentage (73.73 vs. 69.00%) and drumstick weight (10.01 vs. 8.99%), birds on the pineapple/orange mixed peels did better than those on the control, while there were no differences between them and those on the control diet in most of the other carcass parameters measured. Meat from birds fed the pineapple/orange mixed peels had better aroma and tenderness than that of the control group. It was concluded that 50 g kg^{-1} of maize could be replaced with an equal mixture of pineapple and orange peels in the diet of broiler chickens.

Keywords Broilers · Pineapple peels · Orange peels · Dietary maize

Introduction

Due to their nutritional quality and availability, the intake of chicken meat and eggs is steadily increasing in developing countries. Chicken meat's availability is attributed to fast growth, high feed efficiency, and adaptability to various environments. However, as demand for poultry products rises, the cost of feed, which constitutes about 75% of production costs, also increases (Louw et al. 2011). The FAO projects that the world's population may increase to 9.1 billion by 2050. This will exacerbate feed competition between humans, animals, and industries. The present shift towards renewable fuel (biofuel) in which feedstuffs, especially maize is a promising resource, will further increase the feed competition and worsen the food security problems. This situation creates a need for appropriate and inexpensive alternative feed sources. Therefore, there is a need for alternative, cost-effective feed ingredients with nutritional and

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palatability values. We propose that pineapple and orange peels, readily available as waste products, can replace a portion of maize in broiler diets, achieving optimal meat quality and reducing production costs.

The high cost of conventional feedstuffs like soybeans and maize has led to the exploration of non-conventional feed ingredients. Although various non-conventional feedstuffs have been successfully used (Moury et al. 2018; Morais et al. 2020; Makinde et al. 2021, 2024), studies on fruit peels, particularly orange and pineapple peels, are limited as alternatives to maize in poultry diets.

In the developing countries such as Nigeria, there are orange and pineapples varieties which are consumed on a high scale. The peels, are seen littering the roadsides and streets thereby constituting environmental hazards. Available literature showed that sweet orange peel contains similar proximate contents as maize. Aduku (2004) reported that maize contained 8.9%, 2.7%, 4.0%, and 72% crude protein (CP), crude fibre (CF), ether extract (EE), and nitrogen free extract (NFE), respectively. Orayaga et al. (2010) reported that orange peel meal on dry matter basis contained CP (9.30- 10.96%), EE (2.35–2.90%), NFE (65.30–67.95%), and ash (5.07%). In the same vein, Pereira (2009) opined that pineapple waste is poor in minerals but contain appreciable amounts of CP (4–8%), NDF (60–72%), soluble sugars (40–75%) and pectin. This is an indication that they can be used as a replacement for maize. Furthermore, studies have shown various inclusion levels of orange peels in feed formulations for goats (Yashim et al. 2016), pullets (Oyewole et al. 2013) and pineapple peels for rabbits (Aboh et al. 2013) and poultry (Sugiharto 2023).

However, the combinatorial effects of proportional mixture of these peels are scarce in literature. This study evaluated the response of broiler chickens to orange and pineapple-based proportionally mixed diets in a single-phase feeding.

Table 1 Gross composition of experimental diets

Ingredient, g kg^{-1} DM	Diets			
	Control	PP	OP	POP
Maize	510	460	460	460
Maize offal	90	90	90	90
Ground nut cake	170	170	170	170
Full fat soya	140	140	140	140
Fishmeal (imported)	30	30	30	30
Orange peel	0.00	0.00	50	25
Pineapple peel	0.00	50	0.00	25
Limestone	20	20	20	20
Bone meal	20	20	20	20
Palm oil	10	10	10	10
Salt	2.5	2.5	2.5	2.5
*Vit/min Premix	2.5	2.5	2.5	2.5
Dl-Methionine	2.5	2.5	2.5	2.5
L-Lysine	2.5	2.5	2.5	2.5
Total	**1000**	**1000**	**1000**	**1000**
Calculated analysis, g kg^{-1}				
Crude protein	205.2	200.7	200.7	200.7
Crude fibre	40.5	39.4	39.4	39.4
Ether extract	70.0	68.1	68.1	68.1
Phosphorus	45	45	45	45
Calcium	14.5	1.45	14.5	14.5
Meth + Cys	61	59	59	59
Lysine	11.2	11.2	11.2	11.2
ME/Kcal/kg	3089.37	2964.02	2967.02	2966.02
Determined analysis, g kg^{-1}				
Dry matter	908.0	892.0	900.0	926.0
Crude protein	238.0	234.5	245.0	224.0
Crude fibre	40	50	45	45
Ether extract	170	165	175	145
Ash content	100	85	90	100
NFE	360	367.5	340	412

Vitamin – Mineral Premix. Vitamin A 1500 IU, Vitamin D 300 IU, Vitamin E 3.00, Vitamin K 0.25 g, Thiamine 0.2 mg, Pantothenic acid 1.00 mg, Riboflavin 0.6 mg, Niacin 4.00 mg, Pyridoxine 0.4999 mg, Folic acid 0.10 mg, Vitamin B12 0.002 mg, Choline chloride 0.05 g, Biotin 0.008 mg, Manganese 0.0096 g, Antioxidant 0.012 g, Copper 0.0006 g, Iodine 0.006 g, Zinc 0.0060 g, Cobalt 0.004 mg, Selenium 0.024. ME: Metabolizable energy PP = Pineapple peels, OP = Orange peels and POP = Pineapple and orange peels, meth = methionine, cys = cysteine

Materials and methods

Experimental site

The study was conducted at the Teaching and Research Farm of the Animal Production Department, Federal University of Technology, Minna is located in the Southern Guinea Savanna zone at an altitude of 75 m above sea level, with a temperature range of 38–40 °C and an annual rainfall of 1,200-1,300 mm. The region experiences wet (April-October) and dry (November-March) seasons (Climatemp 2020).

Feed preparation

Pineapple and orange peels were sorted to remove dirt and impurities, then washed with clean water, and sun-dried on a clean concrete floor for five days, turning constantly until a 10% moisture content was achieved. The dried peels were ground to mash and passed through a 2 mm sieve, then mixed with other ingredients as shown in Table 1.

The experimental diets and design

Day-old unsexed Ross 308 broiler chickens ($n = 480$) were randomly allocated to four dietary treatments: control (0 g kg^{-1} peels), 50 g kg^{-1} pineapple peels (PP), 50 g kg^{-1}

orange peels (OP), and 25 g kg^{-1} each of pineapple and orange peels (POP). Each diet had six replicates of twenty birds, housed in floor pens (1.5 m² per pen) in a completely randomized design. Isocaloric and isonitrogenous experimental diets were formulated (Table 1). Feed and water were provided *ad libitum* for 56 days.

Managements of the experimental birds

Prior to the feeding trial, the research pens were thoroughly cleaned and disinfected (Vinkokill;150 ml per 25 L of water) and allowed to dry. Birds were weighed on arrival, and feeders and drinkers were washed daily. The birds were raised on a deep litter system and brooded using charcoal for heat and solar lamps for illumination. Vaccination followed local guidelines: Gumboro vaccine in the first and third weeks, and Newcastle vaccine in the second and fourth weeks through drinking water (0.005 ml/bird). Anti-stress (Vitalyte 1 g/2 L water) was administered before and after vaccination to reduce vaccination-induced stress in the birds.

Data collection

The following parameters were measured and recorded: initial body weight of the birds at the commencement of the experiment and thereafter weekly feed intake and body weight were recorded using digital weighing scale (RADWAG, Radom, Poland) throughout the 56-d study. These parameters were used to determine weight gain, feed conversion ratio, apparent nutrient digestibility and carcass evaluation was also determined following the procedure of McDonald et al. (1995). The sensory attributes were also evaluated. Feed was weighed for the birds in each replicate, the amount of daily feed intake was obtained using the formula below:

$$Average daily feed intake\,(g) = \frac{\mathrm{Weight\,of\,feed\,given\,(g) - Weight\,of\,the\,refused\,feed\,(g)}}{\mathrm{Number\,of\,birds\,in\,the\,replicate}}$$

(McDonald et al. 1995).

The weekly mean body weight gain (g) was obtained by difference between the body weight for the proceeding week (g) and current week (g). Feed conversion ratio was calculated as the ratio of feed intake to weight gain = $\frac{\text{Average weekly feed intake (g)}}{\text{Avearage weekly weight gain(g)}}$

Nutrient digestibility

Immediately the feeding trial was terminated, four birds per replicate were randomly selected and transferred into the metabolic cage for a nutrient digestibility trial. A total collection method was used with a specially designed metabolism cage having separate watering and feeding troughs. The birds were allowed three (3) days adjustment which was followed by total faecal collection for five (5) days. Dietary feed was weighed and water was served *ad-libitum* daily. Total droppings were collected daily on plastic sheets placed under the metabolic cages. The faeces were removed, weighed and stored in a refrigerator (4 °C). At the 5th d, the samples were pooled based on the treatment, oven dried at 80 °C for 24 h using hot air oven (Gallenkamp Uk OVL 570 010 J vacuum), weighed and stored in airtight plastic container until used for chemical analysis. The apparent nutrient digestibility was calculated using the equation recently reported by Mohammed et al. (2020).

$$Apparent Nutrient Digestibility\,(\%) = \frac{\mathrm{Nutrients\,in\,feed\,consumed - Nutrients\,voided\,in\,dropping}}{\mathrm{Nutrients\,in\,feed\,consumed}}$$

Carcass evaluation

Carcass evaluation was done at the 56th day of the study. Eight birds per treatment were randomly selected, and fasted for 12 h as earlier cited by Aduku and Olukosi (2000). The final weights of all the birds were taken with the use of a sensitive electronic weighing scale (RADWAG, Radom, Poland). They were then slaughtered by severing the jugular vein, dressed and re-weighed. The weights of the carcass cuts (drumstick, breast, thigh, and wing meat) were taken as the percentage (%) of the dressed weight while the visceral organs (gizzard, heart, liver, lung and spleen) were taken as the percentage of the live weight.

Sensory evaluation of birds

The method earlier reported by Ruiz-Capillas et al. (2021) was used for the sensory evaluation. Samples of the breast muscle (*Pectoralis superficialis*) were taken, and cooked for twenty (20) minutes in an aluminium pot containing 500 mls of water. A pinch of common salt was added without any spices. The cooked meats were then served to volunteered semi-trained panelists (40 males and 20 females aged between 25 and 60 years) of the Federal University of Technology, Minna, Nigeria. The volunteers confirmed they had no sensory impairments and were not allergic to food of animal origin. A 9-point hedonic rating scale from 1 to 9 (1=disliked extremely; 2=dislike very much; 3=dislike moderately; 4=dislike slightly; 5=neither like nor dislike; 6=like slightly; 7=like moderately; 8=like very much; 9=like extremely) was used to evaluate the sensory attributes of the chicken meat.

Table 2 Proximate composition of orange (OP), pineapple (PP) and the mixture of pineapple and orange peels (POP)

Parameters, %	PP	OP	POP
Dry matter	92.80	90.80	91.50
Crude Protein	5.60	7.00	6.90
Ash Content	6.10	6.01	6.00
Crude Fibre	3.50	2.10	1.50
Ether Extract	3.00	5.00	5.00
Nitrogen free extract	74.60	70.69	72.10

PP = Pineapple peels, OP = Orange peels and POP = Orange and pineapple peels

Chemical analysis

The chemical composition of the experimental diets and faecal droppings were carried out at the laboratory of the Animal Production Department following the procedures of AOAC (2000). The results were used to calculate apparent nutrient digestibility.

Data analysis

Data generated were analysed using a one-way analysis of variance (ANOVA) and when significant differences were detected, means were separated through the Duncan Multiple Range Test as contained in the SAS package version 15.0. (SAS, 2002)

Results

The proximate composition of orange and pineapple peels is presented in Table 2. As shown in Table 3, growth parameters were significantly affected ($P<0.05$) by the dietary treatments.

The daily weight gain of birds fed the control diet was the highest ($P<0.05$), followed by pineapple peels (PP), pineapple and orange (POP) and orange peels (OP) diets, respectively. Birds fed the control and POP diets had the highest daily feed intake ($P<0.05$), with the lowest feed intake observed in birds fed the OP diet. Feed conversion ratio (FCR) was better ($P<0.05$) among birds fed the control diet, followed by PP, POP, and OP diets, respectively.

Apparent nutrient digestibility of broiler chickens fed pineapple and orange peels-based diets (Table 4) was significantly influenced by dietary treatments, except for crude fibre. Crude protein, dry matter, and ash digestibilities were higher ($P<0.05$) among birds fed the POP diet compared to the control and other treatments. Birds fed the control, PP, and OP diets had similar ether extract (EE) digestibility values ($P>0.05$), while the EE digestibility of birds on the control diet was higher ($P<0.05$) than those on the POP diet. Nitrogen free extract (NFE) digestibility values for the control and PP diets were similar ($P>0.05$) but lower

Table 3 Growth performance of broiler chicken fed Sun-dried orange and pineapple Peels-Based diets

Parameters	Diets				SEM	*P*-Value
	Control	PP	OP	POP		
Initial weight, g	37.66	38.30	38.03	37.95	0.06	0.059
Final weight, g	1410.25^{a}	1399.58^{b}	1200.22^{d}	1320.49^{c}	22.79	0.001
Daily weight, g	24.5^{a}	23.24^{b}	20.75^{d}	22.90 ^{c}	0.41	0.001
Daily Feed Intake, g	55.05^{a}	54.21^{b}	52.41^{c}	55.04^{a}	0.32	0.001
FCR	2.24^{a}	2.33^{b}	2.52^{d}	2.40^{c}	0.03	0.001

PP = Pineapple peels, OP = Orange peels and POP = Orange and pineapple peels

^{abcd} Means on the same row having different superscripts are not significantly equal ($P<0.05$)

FCR: feed conversion ratio

SEM: Standard Error of Mean

Table 4 Apparent nutrient digestibility of broiler chickens fed Sun-dried orange and pineapple peels based diets

Parameters (%)	Diets				SEM	*P*-Value
	Control	PP	OP	POP		
Dry Matter	83.03^{b}	78.96^{c}	78.78^{c}	83.55^{a}	0.839	0.005
Crude Protein	76.22^{a}	69.39^{b}	74.10^{ab}	71.53^{ab}	1.087	0.047
Ash	59.12^{a}	44.52^{b}	47.91^{b}	64.01^{a}	3.119	0.009
Crude Fibre	63.30	54.86	62.12	56.28	1.623	0.137
Ether Extract	89.51^{a}	87.57^{ab}	89.04^{ab}	88.78^{b}	0.312	0.003
NFE	93.26^{b}	92.83^{b}	88.26^{c}	95.89^{a}	1.063	0.004

PP = Pineapple peels, OP = Orange peels and POP = Orange and pineapple peels

^{abcd} Means on the same row having different superscripts are not significantly equal ($P<0.05$)

SEM: Standard Error of Mean

NFE = Nitrogen free extract

Table 5 Carcass characteristics of broiler chicken fed sun-dried orange and pineapple peels based diets

Parameters	Diets				SEM	*P*-Value
	Control	PP	OP	POP		
Live weight (g)	1410.25^{a}	1399.58^{b}	1200.22 ^{d}	1320.49 ^{c}	22.79	0.001
Slaughter weight (g)	1360^{a}	1250^{ab}	1120^{b}	1270^{ab}	34.098	0.046
Carcass weight (g)	972.50	935.00	855.00	975.00	24.186	0.274
Dressing %	69.00^{b}	69.85^{b}	71.52^{ab}	73.73^{a}	0.612	0.013
Percentage of carcass weight						
Breast	15.48	15.47	15.43	17.26	0.341	0.148
Thigh	12.43	12.58	12.53	12.43	0.173	0.990
Drumstick	8.99^{b}	9.48^{ab}	9.31^{b}	10.01^{a}	0.135	0.035
Wings	8.97	9.23	9.74	9.78	0.175	0.308
Back	12.67^{ab}	12.16^{b}	13.61^{a}	12.69^{ab}	0.231	0.047
Percentage of live weight						
Gizzard	2.16	1.97	2.08	2.01	0.696	0.814
Heart	0.60	0.58	0.53	0.51	0.190	0.263
Liver	2.94^{a}	2.84^{a}	2.90^{a}	2.07^{b}	0.133	0.038
Lungs	0.54^{b}	0.73^{a}	0.61^{ab}	0.61^{ab}	0.302	0.016
Spleen	0.23	0.17	0.19	0.12	0.202	0.448

PP = Pineapple peels, OP = Orange peels and POP = Orange and pineapple peels

^{abcd} Means on the same row having different superscripts are not significantly equal ($P<0.05$)

SEM: Standard Error of Mean

Table 6 Sensory evaluation of broiler chicken fed sun-dried orange and pineapple peels based diets

Parameters	Diets				SEM	*P*-Value
	Control	PP	OP	POP		
Colour	6.80	6.20	5.87	6.87	0.174	0.260
Juiciness	6.60	6.67	6.47	7.13	0.206	0.696
Appearance	7.00	647	6.33	7.00	0.179	0.424
Flavour	7.07	7.27	6.47	7.46	0.196	0.307
Aroma	7.33^{b}	6.80^{ab}	6.20^{b}	7.20^{a}	0.176	0.047
Tenderness	7.73^{b}	6.53^{ab}	6.33^{a}	6.93^{ab}	0.226	0.038
Over all Acceptability	7.60	7.60	7.13	7.89	0.169	0.495

PP = Pineapple peels, OP = Orange peels and POP = Orange and pineapple peels

^{abcd} Means on the same row having different superscripts are not significantly equal ($P<0.05$)

SEM: Standard Error of Mean

($P<0.05$) than those of birds fed the POP diet and higher than those fed the OP diet.

Carcass characteristics (Table 5) were influenced by dietary treatments ($P<0.05$). Birds fed the control, PP, and POP diets had similar slaughter weights ($P>0.05$). The dressing percentage and drumstick weight of birds on the POP diet were higher ($P<0.05$) than those on the control and PP diets, while the back weight of birds on the control, OP, and POP diets were similar ($P>0.05$). Higher back weights were observed among birds fed the OP diet compared to those on the PP diet.

Internal organ weights showed significant differences ($P<0.05$) for liver and lung weights. Birds on the control, PP, and OP diets had similar liver weights ($P>0.05$), which were higher ($P<0.05$) than those on the POP diet. Lung weights were higher ($P<0.05$) in birds fed the PP diet compared to the control diet, with no variations ($P>0.05$) among birds on the control, OP, and POP diets.

As shown in Table 6, the sensory evaluation indicated significant differences ($P<0.05$) in aroma and tenderness. Meat from birds fed PP and POP diets had similar aroma ($P>0.05$), but the POP diet resulted in better aroma ($P<0.05$) compared to the control diet. Meat tenderness was similar among birds fed PP, OP, and POP diets ($P>0.05$), with birds on the OP diet having better tenderness ($P<0.05$) compared to the control diet.

Discussion

The peels of pineapple (PP), orange (OP) and pineapple and orange (POP) mixture contained dry matter (DM) values of 91.80, 90.80 and 91.50%, respectively. These DM values are quite high and showed tendency to be stored for considerable period without spoilage or microbial growth. The higher the DM, the more stable the product (Kung et al. 2018). The proximate values for orange and pineapple peels were similar to those previously reported by Orayaga et al. (2010) and Nurhayati (2013) with the proximate compositions of the orange and pineapple peels as 1.96% EE, 12.32% CF, 7.22% CP, 61.49% NFE, 3.67% ash and DM 88.95%, ash 3.83%, crude fibre 27.09%, crude protein 8.78%, and fat 1.15% respectively. The similarity in the proximate value in the previous reported values of peels collected in different locations suggests that weather and/or environmental changes may not adversely affect the composition of these peels and therefore eliminate the issue of variation in feed formulation due to differences in geographical origin of the peels. Interestingly, the proximate analysis of orange and pineapple peels (POP) was also similar to the orange or pineapple peels, indicating good percentage composition of the dietary formulations.

Regarding the growth indices, birds on the control and POP diets recorded similar daily feed intake but higher than those of birds on PP and OP diets, though the birds fed PP diet had higher daily feed intake than those fed OP diet. This suggests a better nutritional advantage of POP diet than PP and OP. Additionally, since the feed efficiency of birds fed the POP diet was significantly better than those fed the OP diet the combination of orange and pineapple peels may be advised. The feed utilization was better in the birds fed control diet than those on the orange, pineapple and their mixture, suggesting that nutrients in the control diet were better converted to body tissue as compared to the orange and pineapple mixture treatment. The higher crude fibre content of orange and pineapple peels than maize (Oluremi et al. 2007) may be responsible for poor feed utilization (Ibrahim et al. 2020) because high fibre diets are hard to digest by poultry and thus, decrease the utilisation of nutrients. Additionally, the result of the present study is consistent with previous report of Ahaotu and Ekenyem (2009) which showed that higher dietary fibre depresses weight gain in broiler chickens. The presence of some phytonutrients in the peels could also have been the cause of reduced performance of the broiler chicks on the peel meal-based diets in this study (Oluremi et al. 2007).

The nutrient digestibility of broiler chickens fed orange-pineapple peels mixture indicated an improvement in dry matter intake. This might be unconnected with the proximate results; as the results indicate a numerically higher dry matter content in the dietary orange-pineapple mixture. The broiler chickens fed the control and orange-pineapple mixed diets exhibited superior nutrient digestibility than the diets containing orange and pineapple peels. It might imply that the orange-pineapple mixed based diets are more adequate than using orange and pineapple peels separately. This might mean that the blend of orange and pineapple peels meet up the deficiencies of both the orange and pineapple peels.

The high digestibility observed in the birds on mixed pineapple and orange peels-based diets did not translate to productivity as observed in the performance results. This might be due to a number of reasons. Weurding et al. (2001) established that there are differences that exist in the site, rate and extent of starch digestibility and utilisation and this may result in metabolic consequences, thus, affecting feed utilization in broiler chickens. Another reason could be inhibitors, which result in underutilisation. Cowieson et al. (2006) reported that phosphorylated *myo*inositol has potent to chelate many mineral ions which form insoluble salts at intestinal pH, reducing the availability of these minerals for absorption.

For the carcass parameters, the low live weight observed in birds fed peels-based diets compared to the control could be as a result of fibre content of the peel-based diets. This is in agreement with Adeyemo and Longe (2007), who observed significant variations in live weights, plucked weights and dressed weights of broiler chickens fed graded levels of pineapple waste-based diets. The live weight values (1.20–1.41 kg) in this study were lower than 1.60–1.95 kg reported by Adeyemo and Longe (2007). This might be as a result of differences in breeds and environmental conditions. The similar slaughter weights observed in the control and those fed pineapple and pineapple-orange mixed diets might mean that the mixed peels diet measured d adequately with the control diet. The higher dressing percentage in the birds on pineapple/orange peels mixed diet could mean that they had less of visceral contents compared to those fed the control diet. The values of dressing percentage (69.00–73.73%) were similar with 65.63–73.33% (Adeyemo and Longe 2007) and 67.6–82.07% (Zanu et al. 2017) for birds fed graded levels of pineapple waste-based diets. A similarity in growth performance of finisher broilers fed up to 200 g kg^{-1} sweet orange peels meal (SOPM) in place of maize was reported by Agu et al. (2010), suggesting it was safe to feed broilers with SOPM. The differences observed in the drumstick and back weights confirmed the earlier assertion of Jiménez-Moreno et al. (2009) that dietary fibre could increase the relative weight of the various sections of the gastro-intestinal tracts in birds. Fafiolu et al. (2015) however observed similar weights of the cut-up parts, organs and length of the gastro-intestinal tracts among broiler chickens fed high fibre palm kernel extraction residue (PKER) and palm kernel sludge (PKS) diets. The high liver weight in the control could be part of what reduced the carcass weight when compared to those from birds fed pineapple/orange peels-based diet. The observed differences in the liver and lung weights disagree with the report of Noman et al. (2015), who observed no differences between groups in weights of heart, liver, gizzard, pancreas or spleen. Agu et al. (2010) also found that the dietary SOPM had no effect on the internal organs of broiler chickens.

Of the sensory attributes evaluated, only aroma and tenderness were significantly affected in this study. Koohmaraie et al. (2002) highlighted three components that influence meat tenderness: these are contraction degree of the sarcomere; proteolysis and the contents of connective tissues. One of the factors that affect these components is diet. Thus, it might imply from this study orange peels played a significant role in meat tenderness when compared with the control diet. The significant results observed in the meat aroma and tenderness are similar to those of Omojola and Adesehinwa (2007) who further stated that tenderness and aroma are the two important parameters consumers consider when buying meat. Ventanas et al. (2010) observed that fat stimulates the senses during eating, acts as a carrier and reservoir of aroma compounds, as well as a precursor for flavour.

Conclusions

Results from this study showed that the dietary treatment influenced all the growth parameters measured with birds fed the control diet performing better than the treated diets. The apparent nutrient digestibility results, indicated that birds fed the pineapple/orange mixed peels diet and the control were similar in crude protein (71.53 vs. 76.22%) and ash (64.01 vs. 59.12%). The birds on the mixed peels diet had higher dry matter (83.55 vs. 83.03%) and nitrogen free extract (95.89 vs. 93.26%) digestibility values than those fed the control diet. The carcass results indicated that the control diets did better than the other treatments only in the live weight (1410.25 g) of the birds. In the dressing percentage (73.73 vs. 69.00%) and drumstick weight (10.01 vs. 8.99%), birds on the pineapple/orange mixed peels diet did better than the control, while there were no differences between them and those on the control diet in most of the other carcass parameters measured. The meat from birds fed containing pineapple/orange mixed peels had better aroma and were more tender than the meat from birds on the control diet. It was concluded that 50 g kg^{-1} of maize could be replaced with mixture of pineapple and orange peels in the diet of broiler chickens, without the loss of any productivity gain or quality parameters in poultry production, while reducing the cost of production, purchase price and increase availability.

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Data availability Data will be made available upon reasonable request.

Declarations

Ethical approval This study was performed following the ethical guidelines of Department of Animal Production, Federal University of Technology, Minna.

Conflict of interest The authors declare no conflict of interest.

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