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Growth Performance, Digestibility and Gut Morphology of Grower Pigs fed Diets Substituted with Watermelon Waste

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ABSTRACT

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This study was carried out to assess the performance of growing pigs fed diets substituted with watermelon (*Citrullus lanatus*) waste (WMW). Thirty-six crossbred (Landrace×Large White) pigs were randomly allotted to four dietary treatments in a completely randomised design. The control (CON) group was fed a ration containing 40% cassava peel meal and 60% concentrate, while the other three groups were fed the same diet but with 20 (WM-20), 40 (WM-40) and 60 (WM-60) parts of the concentrate component substituted with watermelon waste on an equivalence basis. The experiment lasted for 8 weeks. Data were collected on performance indices, nutrient digestibility, and gut morphology. Pigs on CON diet had highest ($P<0.05$) final body weight (31.70 kg) while least body weight of 21.76 kg was observed for pigs on WM-60. Weekly feed intake was highest ($P<0.05$) in pigs fed WM-20 (9.51 kg) but not different from pigs fed CON (9.15 kg) and WM-40 (9.16 kg) while pigs on WM-60 had the least intake of 7.75 kg. Feed conversion ratio increased ($P<0.05$) with increasing levels of WMW with pigs in CON having least FCR (3.51) while it was highest for WM-60 (5.11). Crude protein digestibility was highest ($P<0.05$) in pigs on WM-40 (71.48) and WM-60 (71.48) while fat (40.91) and crude fibre (21.13) digestibility were least in WM-60, compared to other treatments. Morphological measurements of ileum and jejunum were not significantly ($P>0.05$) affected by increasing levels of WMW except for the crypt depth in ileum and jejunum which was higher in CON (349.60 μm) and WM-60 (216.65 μm). In conclusion, it can be said that watermelon waste can be used as a substitute for concentrate at 20% level in diets of growing pigs without any detrimental effect on growth.

Keywords: *Citrullus lanatus,* Economics, Grower pigs, Gut morphology, Performance.

INTRODUCTION

Livestock rearing plays an important role in sustaining the livelihood of livestock farmers all over the world (FAO, 2011) with the swine sub-sector, like other livestock

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sectors, contributing immensely to animal protein availability in many countries of the world. Meanwhile, current recorded success in pig production in most developing countries like Nigeria is based on the importation of an almost complete package of technology, including parent and breeding stock, equipment, drugs and feed (Perez, 1997). Most of the feeds for pigs are composed mainly of cereal grains and oil meals, which in principle, compete directly or indirectly with human food. In order to achieve sustainable livestock development, efficient use of available feed resources and expansion of the feed resource base towards unconventional feedstuffs not competing with human food must be explored (FAO, 2013).

One of such feed resources is fruit wastes. The use of fruit wastes as animal feed is an alternative of high interest because of its environmental and public benefits besides reducing the cost of animal production (Westendorf, 2000). Roughly, one-third of the food produced in the world for human consumption every year, approximately 1.3 billion tonnes, get lost or wasted. Global quantity of food losses and wastes per year is roughly 40-50% for fruits and vegetables (FAO, 2017). Watermelon (*Citrullus lanatus*) waste like other fruit wastes in most cases is being disposed of either by composting or dumping in the landfills or rivers causing environmental pollution. Alternatives to such disposal methods could be its recycling through feed resources for livestock. This approach can reduce the cost of feeding, giving higher profits to farmers and also contribute to sustainable intensification of the livestock industry (Wadhwa and Bakshi, 2013).

Pigs, which are one of the most prolific and fast-growing livestock are efficient in converting food waste to valuable animal products (Osaro, 1995). Recent researches on fruit wastes utilisation in livestock production showed that dried citrus pulp may be included up to 5, 20 and 15 per cent in diets of growing pigs, pregnant and lactating sows, respectively, without affecting reproductive and productive performance (O'Sullivan *et al.,* 2003). It can also be incorporated in diets of rabbit at 20-30 per cent levels (Hon *et al.*, 2009). Adebiyi *et al.* (2017) reported significant variations in weight and feed conversion of pigs fed rice waste-based diet, with maximal growth of weaned pigs observed at 37.5% rice waste inclusion. Fresh tomato pomace can be used at 6 and 35 per cent as a supplementary feed in grower and finisher pigs, respectively, without any adverse effect on their performance with decreased feed cost/kg gain. Dried tomato pomace can also be fed up to 20% to growing rabbits without significantly affecting performance (Sayed and Abdel-Azeem, 2009) while it can be included up to 10-20% in chicken diets without any adverse effect on egg production, body weight (Calislar and Uygur, 2010) and overall egg quality (Salajegheh *et al.,* 2012); however, higher levels may depress hen-day production (Jafari *et al.*, 2006). Dried mango peels up to 10% in the diet of finishing pigs had no deleterious effect on feed conversion ratio or performance and economized feeding cost (Rao *et al.*, 2003). This study, therefore, was carried out to investigate the digestibility and performance of growing pigs fed diets substituted with fresh watermelon waste.

MATERIALS AND METHODS

The experiment was carried out at the Piggery Unit of the Teaching and Research Farm, University of Ibadan, Ibadan, Nigeria. The temperature ranges from 21 to 32°C, humidity 71.53 to 76.00% and an annual rainfall of 1250 to 1500 mm. The watermelon wastes were obtained from Bodija fruit market in Ibadan, Oyo state. The watermelon wastes were obtained daily, chopped and incorporated fresh into daily feed rations.

Experimental animals, feeding and management

A total of 36 crossbred (Landrace×Large White) growing pigs with an average weight of 11.56±0.48 kg were obtained from a reputable commercial farm in Ibadan, Oyo State, Nigeria. The animals were adapted for one week before commencement of the experiment, which lasted for eight weeks. Experimental animals were randomly allotted to four dietary treatments with three replicates each and three animals per replicate. Pigs were housed in properly disinfected pens and all routine management practices were strictly observed. The control (CON) group was fed a ration containing 40% cassava peel meal and 60% concentrate, while the other three groups were fed the same diet but with 20 (WM-20), 40 (WM-40) and 60 (WM-60) parts of the concentrate component substituted with watermelon waste on an equivalence basis (Table 1).

Table 1. Composition of experimental diets

	Dietary groups†			
	CON	WM-20	WM-40	WM-60
Ingredient composition (%)				
Cassava peels	40	40	40	40
Concentrate‡	60	40	20	0
Watermelon waste	0	20	40	60
Nutrient composition (%)				
Moisture	10.15	13.53	15.62	24.43
Crude protein	17.59	16.59	16.17	15.68
Crude fat	4.49	5.59	6.28	5.40
Crude fibre	4.72	4.37	4.81	5.00
NFE	53.27	49.34	50.00	42.49
Ash	9.78	10.58	7.12	7.00
ME (kcal/kg)§	2855	2781	2533	2401

†Basal diet of cassava peels and concentrate (CON) or the same containing 20 (WM-20) 40 (WM-40) and 60 (WM-60) per cent of watermelon waste replacing the concentrate

‡Composed of (kg/per 100 kg): Maize 43.00, soyabean meal 15.00, wheat offal 15.00, groundnut cake 7.00, palm kernel cake 15.00, palm oil 3.00, limestone 1.25, salt 0.50 and premix 0.25.

§Calculated value

Data collection

The feed intake was obtained by subtracting the total leftover feed from the total quantity of feed offered weekly. Body weight gain was determined by subtracting the initial live weight from the final live weight. Feed conversion ratio (FCR) was obtained by dividing the total feed consumed by total weight gain for each pig. Proximate composition of feed samples was determined using AOAC (1990) methods of analyses.

Three animals were randomly allotted from each treatment into metabolic cages for 5 d for a digestion trial. The first 2 d were for cage adaptation and the faecal collection was done during the next 3 d. Daily feed intake was recorded; faeces were collected from individual animals and thereafter weighed to determine the fresh weight. Faecal samples were oven-dried at 65°C until constant weight and pulverised for further analysis. Faecal samples were analysed for crude protein, fibre, ether extract and ash (AOAC, 1990). The market cost of feedstuff during the study was used to calculate the total cost of feed, cost of feed per kg, cost per kg live weight and the economy of feed conversion.

Gut morphological measurements

This was carried out as reported by Adebiyi *et al.* (2012). At the end of the experiment, three pigs from each treatment were slaughtered and eviscerated. Tissue samples for histology were taken from the ileum and jejunum. Briefly, tissue samples were fixed in 10% buffered formalin and stored in bottles with a tightly sealed lid until further processing. The processing consisted of serial dehydration, clearing and impregnation with wax. Tissue sections, 5-μm thick (3 cross-sections from each sample) were cut by a microtome and fixed on slides. A routine staining procedure was carried out using hematoxylin and eosin. The slides were examined on an Olympus AX70 (Olympus Corporation, Tokyo, Japan).

Twenty-four (24) well-oriented villi and crypts from ileum and jejunum were measured along their length, height and depth, respectively, and width. Villus height was measured from the crypt-villus junction to the brush border at the tip while villus width was measured parallel to the adjoining villus. The crypt depth was measured from the base near the lamina propria to the crypt-villus junction and crypt width was measured parallel to the adjoining crypt. Villus height and crypt depth formed total mucosal thickness. All measurements were made to the nearest micrometer. Total intact well-oriented crypt-villus units were selected in triplicate for each intestinal cross-section for each sample. The criterion for villus selection was based on the presence of intact lamina propria.

Statistical analysis

All data were subjected to analysis of variance (ANOVA) using SAS (2012). Significant means were separated using Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Performance

Results on the performance of grower pigs and cost analysis of feeding diets supplemented with varying levels of watermelon waste in Table 2 shows a significant ($P<0.05$) variation among treatments except for their initial weights. Pigs on CON diet had highest ($P<0.05$) final body weight (31.70 kg), followed by pigs fed WM-20 (29.83 kg). Least ($P<0.05$) body weight was observed for pigs on WM-60 (21.76 kg). Weekly feed intake was highest ($P<0.05$) in pigs fed WM-20 (9.51 kg) but not different from pigs fed CON (9.15 kg) and WM-40 (9.16 kg), pigs on WM-60, however, had the least intake of 7.75 kg. Feed conversion ratio increased ($P<0.05$) with increasing level of WMW with pigs in CON having least FCR (3.51) while those on WM-60 had the highest FCR (5.11). Feed cost per kg was highest (₦ 463.41) for CON and reduced with increasing levels of watermelon waste. Similar trends were also observed for feed cost per weight gain of pigs.

Mean average intake of the pigs on the four diets showed that pigs fed only cassava peels- watermelon waste (WM-60) had significantly ($P<0.05$) lower intake than those on the other treatments, which indicates that the higher inclusion of watermelon waste negatively influenced feed consumption in growing pigs. Replacement of up to 60% concentrate feed with watermelon waste in the diets resulted in increased bulk, crude fibre and moisture content of the watermelon based diets (Table 1), hence, lowered energy content is expected. This could still be responsible for the reduction in the feed intake of the pigs fed the WM-60 diet. This agreed with the reports of Adebiyi *et al*. (2017) that higher inclusion of rice waste reduced feed intake

Table 2. Performance of growing pigs fed diets supplemented with watermelon waste

Parameters	Dietary groups†				SEM
	CON	WM-20	WM-40	WM-60	
Growth performance					
Initial BW (kg)	12.68	11.87	12.08	11.10	0.08
Final BW (kg)	31.70^{a}	29.83^{ab}	27.46^{b}	21.76^{c}	0.32
Net BW change (kg)	19.02^{a}	17.96^{ab}	15.38^{b}	10.66^{c}	1.42
ADG (g)	340^{a}	321^{a}	275^{b}	190^{c}	8.11
BW change/week (kg)	2.72^{a}	2.57^{ab}	2.20^{b}	1.52^{c}	0.17
Feed intake/week (kg)	9.15^{a}	9.51^{a}	9.16^{a}	7.75^{b}	0.32
Feed conversion ratio	3.51^{c}	3.73^{c}	4.18^{b}	5.11^{a}	0.03
Economics of feeding					
Feed cost (₦/kg)	463.41	320.76	154.47	125.36	-
Feed cost/weight gain (₦/kg)	170.37	124.81	70.21	82.47	-

†Basal diet of cassava peels and concentrate (CON) or the same containing 20 (WM-20) 40 (WM-40) and 60 (WM-60) per cent of watermelon waste replacing the concentrate.
^{abc}Means along the same row with different superscript are significantly ($P<0.05$) different.

and consequently weight change in weaner pigs. Reports of study by Ogunsipe *et al.* (2017) also showed reduced feed intake and weight gain in grower pigs fed increasing levels of cocoa bean shell meal in replacement of maize. However, the findings of this study negate that of Kwak and Kang (2006) who observed a higher feed intake due to relatively low energy levels in food waste mixture. The result showed significant ($P < 0.05$) difference in the FCR values which increased with higher inclusion of watermelon waste into the diet and was lowest in the CON, which contained no watermelon waste. This means that the CON group had a better utilisation of feed compared to others. The reduced utilisation can also be attributed to the increased dietary fibre content and a lower concentration of energy as the WMW increased (Raj *et al.*, 2006).

It is interesting to consider the prices of feed in the various treatments, even though FCR was higher for pigs fed the waste supplemented diets, the cost of production was reduced. This shows that it is economical to use watermelon waste in pig diets, but at levels that do not have a negative effect on growth performance. This agrees with the work of Ezekwe *et al.* (2011) and Adebiyi *et al.* (2017) who reported reduced cost on the performance of growing/weaner pigs fed palm oil sludge and rice waste, respectively. However, Esteban *et al.* (2007) recorded increased cost (by 20%) with the inclusion of fruit-vegetable and fish waste as alternative feedstuff in pig diets; the cost incurred was due to processing and conservation. Therefore, from the findings of this report, the cost of feed compared economically with weight gain in WM-20 due to their comparable FCR and weight changes but at a lesser cost compared to the control diet (CON).

Nutrient digestibility

Significant ($P < 0.05$) differences were observed in nutrient digestibility (Table 3) among the dietary treatments by the experimental pigs. The WM-40 groups had highest ($P < 0.05$) values for CP (71.48%), EE (79.12%) and ash (41.84%) digestibility but was not significantly different for WM-60 for CP for treatment 4. Similar ($P < 0.05$) digestibility values were however observed in CON (69.12%, 68.83%) and WM-20 (73.27%, 73.13%) for CP and fat, respectively. Treatment WM-40 was observed to have ($P < 0.05$) highest ash (41.84%) digestibility.

Table 3. Nutrient digestibility of grower pigs fed diets supplemented with watermelon waste

Parameters	Dietary groups†				SEM
	CON	WM-20	WM-40	WM-60	
Crude protein, %	69.12^{b}	68.83^{b}	71.48^{a}	71.42^{a}	0.20
Fat, %	73.27^{b}	73.13^{b}	79.12^{a}	40.91^{c}	2.50
Crude fibre, %	41.72^{c}	50.55^{a}	45.10^{b}	21.13^{d}	1.85
Ash, %	40.11^{b}	34.02^{d}	41.84^{a}	38.13^{c}	0.48

†Basal diet of cassava peels and concentrate (CON) or the same containing 20 (WM-20) 40 (WM-40) and 60 (WM-60) per cent of watermelon waste replacing the concentrate.

^{abc}Means along the same row with different superscript are significantly ($P < 0.05$) different.

High digestibility values obtained for most of the nutrients suggests that the diets were highly degraded in the guts of the animals. The crude protein digestibility followed no regular pattern across the treatments and was highest in WM-40 (71.48%) followed by WM-60 (71.42%). This suggests that protein digestibility increased with increasing levels of watermelon waste. This result is in line with the findings of Westendorf *et al.* (2000) who reported a CP digestibility by pigs fed food waste as compared to those fed with corn/soybean meal diets. It also conforms to the work of Adesehinwa (2011) who observed an increase in CP digestibility of growing pigs fed increasing levels of cassava peel meal but negates the findings of Okolo *et al.* (2012). Pigs in WM-60 group with the highest waste inclusion were seen to have had the least fat digestibility.

Also, among the other treatments, WM-40 showed the highest digestibility. It was observed that digestibility coefficients, although presenting significant differences between the types of feed preparation, were high and satisfactory when compared with those obtained by Westendorf *et al.* (2000) in an experiment that involved food waste as feed for swine. Crude fibre digestibility values varied from 21.13 to 50.55%. Pigs in WM-20 (50.55%) were seen to have had higher crude fibre digestibility while WM-60 (21.13%) had the least. This showed poor utilisation of the crude fibre from WMW even as its inclusion level increased in the diets and this could be attributed to reduced fermentation of the fibre in the gut of the pigs. It has been reported that utilisation of crude fibre by non-ruminants has been reported to vary

Table 4. Gut morphology of grower pigs fed diets supplemented with watermelon waste

Parameters	Dietary groups[†]				SEM
	CON	WM-20	WM-40	WM-60	
Ileum					
Villus length, μm	2142.90	2219.10	1820.40	2033.00	25.02
Villus width, μm	235.62	190.30	208.23	190.05	3.09
Villus height, μm	1752.50	784.50	692.30	840.00	3.8
Crypt depth, μm	349.60[a]	173.15[b]	155.35[b]	149.09[b]	17.02
Mucosal cell density ($\times 10^3$)	3.67	6.37	3.97	2.90	0.22
Jejunum					
Villus length, μm	2352.60	2088.40	1905.9	2411.90	34.02
Villus width, μm	142.91	161.86	172.21	217.09	4.54
Villus height, μm	1045.40	943.70	747.80	965.20	18.23
Crypt depth, μm	176.15[ab]	121.32[b]	148.17[b]	216.65[a]	5.88
Mucosal cell density ($\times 10^3$)	5.27	4.56	4.44	4.75	0.16

[†]Basal diet of cassava peels and concentrate (CON) or the same containing 20 (WM-20) 40 (WM-40) and 60 (WM-60) per cent of watermelon waste replacing the concentrate.
[abc]Means along the same row with different superscript are significantly ($P<0.05$) different.

considerably according to the fibre source, degree of lignification, level of inclusion and the extent of processing (Freira *et al.*, 2000; Galassi *et al.*, 2004; Wang *et al.,* 2004). Finally, the apparent digestibility of the crude ash contained in the diets were significantly (P<0.05) affected by the watermelon waste inclusion. The replacement levels brought about slight numerical variations in the crude ash digestibility by the animals, the levels were sufficient and above results in variation to reports of Adsos *et al*. (2015). These variations could be attributed to the differences in the experimental diets.

Gut morphology

Villus length, villus width, villus height and the mucosal cell density of the ileum of experimental pigs fed diets supplemented with watermelon waste (Table 4) showed no significant (P>0.05) difference. However, significant (P<0.05) difference was observed in crypt depth which was highest in CON (349.60 μm) was not different (P>0.05) for WM-20 (173.15 μm), WM-40 (155.35 μm) and WM-60 (149.09 μm). Similar trends were observed for jejunum morphology. However, WM-60 recorded the highest (P<0.05) crypt depth (216.65 μm) value. Higher and wider villus observed in pigs in CON and WM-20 showed pronounced digestion and absorption in these treatments. This finding is in agreement with Gu and Li (2004) who reported a linear increase in crypt depth in the jejunum, but not in the duodenum and ileum, with an increase in dietary CP level. Though there was no regular pattern across the treatments, all the parameters measured except for crypt depth showed no significant (P>0.05) difference across the treatments.

Also, the results for jejunum morphology showed no significant (P>0.05) difference for all parameters measured except for crypt depth. Villus length followed no regular pattern, as WM-60 (2411.90 μm) was longest, villus width increased across treatment, with the inclusion of watermelon waste as WM-60 (217.09 μm) showing wider crypt. In terms of crypt depth, WM-60 had significantly deeper crypt than the other treatments. This also indicates more and better absorption and digestion activities.

CONCLUSION

Watermelon waste which is a good source of nutrients can be fed fresh and supplemented with other diets in growing pigs without affecting their performance, carcass quality, digestibility and gut morphology. It led to effective and efficient utilisation of the waste which could be used to reduce the production cost, thereby, increasing profits and also helping in waste management and reduction in environmental pollution. It can be concluded, therefore, that 20% inclusion of watermelon waste can serve as an excellent supplemental feed resource for growing pigs.

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