OPEN ACCESS
Journal of Animal Health and Production

Research Article

Effect of Replacing Maize with Boiled Sweet Potato on Performance Characteristics and Expression of Insulin-Like Growth Factor-1 Gene in Pigs

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Abstract | This study was conducted to determine the effects of boiled red sweet potato meal on performance and gene expression of Insulin-like growth factor 1 (IGF-1) in growing pigs. Total of 45 growing pigs weighing 4.90 - 9.25kg were randomly allotted into five treatments of nine pigs each. Treatment one (T1) had 100% maize based diet as control, treatment two (T2) had 100% boiled red sweet potato meal, treatment three (T3) had 50% boiled red sweet potato meal + 50% maize, treatment four (T4) had 25% boiled red sweet potato meal + 75% maize, while treatment five (T5) had75% boiled red sweet potato meal + 25% maize. Chemical analysis showed higher nitrogen-free extract (NFE) and lower crude protein content in boiled red sweet potato meal than in the maize. Nutrient digestibility was significantly different (P<0.05) among treatments. The average total weight gain ranged from 13.22kg in T2 to 17.18kg in T1 followed closely by 16.44kg in T3. There were significant differences (P<0.05) among the treatments for all the performance characteristics studied, except average daily weight gain and feed conversion rate. Average daily weight gain was 0.24kg in T1 and 0.17kg in T2, while T3 had the highest gross margin. IGF-1 expression patterns were significantly different (P<0.05) between treatments, increased inclusion of sweet potato meal increased expression of IGF-1 gene. This study therefore suggests that inclusion of 75% boiled red sweet potato meal in diet of growing pigs might be used, but supplementation of 50% maize with 50% boiled red sweet potato meal is recommended for optimal performance.

Keywords | Insulin, Sweet Potato, Gene Expression, Nutrient Digestibility, Growth Performance

Received | November 12, 2021; **Accepted** | March 25, 2022; **Published** | June 15, 2022
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Citation | Moemeka AM, Sorhue UG, Omeje SI, Bratte L, Onainor R, Oghenesuvwe O (2022). Effect of replacing maize with boiled sweet potato on performance characteristics and expression of insulin-like growth factor-1 gene in pigs. J. Anim. Health Prod. 10(3): 293-302.
DOI | http://dx.doi.org/10.17582/journal.jahp/2022/10.3.293.302
ISSN | 2308-2801

INTRODUCTION

The pork industry in Nigeria is facing serious challenge due to high cost of pig feed which accounts for 60-80% of total cost of production (Obinne, 2009). The most important problem is sub-standard nutrition which needs urgent attention, since the production potential of pigs depends mainly on the type of feed given (Amaefule et al., 2006). Reduced cost of livestock feed is undoubtedly the most important focus of researchers in developing countries today, and the keen competition between man and the livestock industry for grains has been implicated in the rising cost of livestock production (Oruwari et al., 2003; Nworgu, 2006). Unfortunately, the survival of the piggery industry is dependent on the availability of feedstuffs, which are mainly components of human food. Therefore, the animal nutritionist needs to urgently seekradical alternatives to the inadequate and expensive conventional feedstuff, to forestall an impending food crisis (Okah and Onwujiariri., 2010). Consequently, alternative sources

of livestock feed such as sweet potatoes (Ipoema batatas) are receiving closer attention in order to augment for grain usage. Considering the fact that sweet potato is traditionally grown as a staple crop in Nigeria, this makes it locally available and relatively cheap. Presently in Nigeria, sweet potato is cheap and has less alternative uses compared with maize (Afolayan et al., 2013). Its potential for high yield and adaptation to tropical climate makes it well recognized.Sweet potato is a plant grown for its root tubers, and part of the production is also used for animal feeding. Its main nutritional importance has been its starch content. More so, sweet potato can be a source of other nutritionally important dietary factors such as Vitamins A, Ascorbic acid, Thiamine, Riboflavin, Niacin, as well as vital minerals like magnesium (Dominquez., 1990; Schulze et al., 2007). Arising from reports (Iyayi et al., 2005; Akpodiete et al., 1999; Moemeka et al., 2015), paying greater attention to the production of pigs at low cost could increase the supply of animal protein to humans, especially for low income and non-wage earners. Regrettably, increased pig production is hampered by high cost of conventional feedstuff (Amaefule *et al*., 2006). In order to advance pig production, there is need to source for cheaper alternative feedstuff for which there is less competition with humans. In addition to potentially bridging the energy gap and reducing competition for maize, the sweet potatoes have also been reported to possess characteristic features**,** with the capacity to regulate insulin production (Schulze et al., 2007). Insulin-like growth factor1 gene has structural correspondence with insulin, and has been reported to bind to insulin receptors in stimulating glucose transport, maintaining glucose homeostasis, and at the same time sensor insulin secretion (Clemmons, 2004; Frystyk, 2004). It is evident that physiological processes in farm animals depend on the expression of many genes acting together, and their regulation in terms of nutrient intake, management, and genetic factors such as breed types (Wang et al., 2014, Malek et al., 2008). Hence, results from feeding sweet potato based diet to pigs and monitoring the expression of Insulin-like growth factor 1 (IGF-1) gene may further strengthen information of existing literature**s** on the role of sweet potato in the regulation of blood sugar level. As the demand for livestock product is not likely to decline in the future, pork producers need to control livestock performance more accurately by improving quantification, requirements and evaluating animal responses to varying nutritional inputs according to their genetic potential (Malek et al., 2008). One way to achieving these results is by conducting studies using available feed ingredients in different forms in other to ascertain the best feedstuff that will provide the most performance at the lowest possible cost. Such feed ingredient should be able to compete with maize, and have lesser usage by man compared to other conventional feedstuff. This study was therefore, designed to evaluate cost effectiveness, nutrient utilization, and to predict the insulin-like growth factor1 gene responses of growing pigs subjected to whole and partial replacement of boiled sweet potato meal to maize.

MATERIALS AND METHODS

Statement for Ethical Approval of Study

This study was approved by the Boards of Department of Animal Science and Faculty of Agriculture, Delta State University Abraka, Nigeria.

Experimental Animals and their Management

This research was conducted at the piggery unit of the teaching and research farm, Delta State University, Asaba campus. A total of forty-five weaned pigs weighing between 4.90 and 9.25kg were used for this study. The experimental animals were fed test diets for 12weeks, and water and the test diets were supplied *ad-libitum* during the experimental period. Good sanitary condition of the pen was maintained. The pens were washed and disinfected before the arrival of the animals. There was routine sweeping and washing of the pen. Each experimental animal was weighed on weekly basis and weight gain computed.

Experimental Design

The experimental design consist of 5 treatments with replacement rates as follows: 100% maize (T1), 100% boiled red sweet potato meal (T2), 50% maize + 50% boiled red sweet potato meal (T3), 25% boiled red sweet potato meal + 75% maize (T4), and 75% boiled red sweet potato meal + 25% maize (T5). The 45 weaned pigs were allocated randomly into the five treatment groups at nine animals per treatment. Each dietary treatment was fed to the treatment groups for twelve (12) weeks.

Experimental Diets

The potato tubers used for this study were sourced from local markets. The potato tubers were sliced, boiled and sun-dried for several days to achieve effective drying of up to 13% moisture content. The test ingredient was milled and mixed with other ingredients at the required proportion in the growing pig ration to give crude protein between 19 and 22% in the diets of weaned pigs. The composition of experimental diets is presented in Table 1.

Data Collection

The quantity of the daily feed provided and the residue of the previous day's feed was weighed to determine the daily feed intake. Samples of the experimental diets and faeces were collected during the experiment for dry matter (DM), digestibility determination, and chemical analysis. The samples were weighed, dried, and then stored for chemical analysis. To monitor the growth pattern of the animals in response to the experimental treatments, the

animals' weights were taken once a week before the morning feeding.

Live Weight Gain, Feed Intake and Feed Efficiency

The pigs were weighed at the beginning of the experiment and subsequently on weekly basis. Weight gain was calculated as the final live weight minus initial live weight. Average daily live weight gain (ADG) was obtained by adding together the weight of pigs and subtracting it from the previous week's value, and dividing the result by the number of days in a week. Feed intake was determined by subtracting the quantity left over from the quantity offered. Average daily feed intake (ADFI) was then computed thus: Daily feed intake divided by number of pigs in the treatment. Feed conversion Ratio (FCR) was calculated as feed intake divided by weight gain.

Feed Cost/Gain

The market cost of the feed ingredients at the time of the experiment was used to compute the total cost of 100kg of each of the five experimental diets. The cost per kg of each diet was calculated by multiplying the percentage composition of the feedstuff with the price per kg and summing all. The total feed intake multiplied by cost per kg feed gave the feed cost. Feed cost per kg weight gain was calculated as FCR multiplied by cost per kg of diet.

Sample Harvest

Three animals from each of the respective treatment group were slaughtered through avascularisation at the end of the feeding trial (84 days) to examine the mRNA expression patterns of Insulin Growth Factor (IGF-1). The liver was collected from the experimental animals and stored at –80°C for RNA extraction.

RNA Extraction and Reverse Transcription

RNA extracted from a 25mg tissue was used for RNA extraction with the aid of β-mertacaptoethanol and 400ul RB buffer mixture. Geneaid RNA extraction protocol was followed. The concentration and purity of the isolated RNA were assessed by a spectrophotometer (Nanodrop) to check for 230/260 ratio. A 20 µL reverse transcription reaction was performed according to Sorhue et al (2021).

Real-Time Polymerase Chain Reaction

The mRNA expression level of IGF was measured using a 7500 Real-Time PCR System with a 20 µL reaction system as reported by Sorhue et al (2021). GAPDH of Sus scrofa was used as the house-keeping gene. The primers for GAPDH gene was designed using the appropriate method. The details of primers used were presented in Table 2. The relative expression was calculated using the Delta-Delta CT method.

Statistical Analysis

All data collected were subjected to a one-way analysis of variance (ANOVA) in a completely randomized design (CRD) using the General Linear Model (SAS package 2002). Significant differences between treatment means were separated using Least Significant Differences (LSD).

Linear Model

$$X_{ij} = \mu + A_i + e_{ij}$$

Where X_{ij}= the observed value of the response (growth rate, FCR, nutrient digestibility)

µ = the overall population.

A_i= observed effect of the i^{th} dietary treatment on the response variable.

e_{ij} = random residual error due to the experimentation

RESULTS

Evaluation of the Nutritional Value of Maize and Boiled Sweet Potato Meal

The proximate chemical composition of the test ingredients is presented in Table 3. There were variations in their chemical compositions. The result showed that there is a wide range between the protein content of maize (9.56%) and that of boiled sweet potato meal (4.22%). The ether extract content of maize is 3.06, while boiled sweet potato meal had 1.84%. Crude fibre and ash content of maize were 2.27% and 2.22%, while boiled sweet potato meal had 2.35% and 1.32%, respectively. In the same vein, the percentage nitrogen free extract of maize sample was 71.01 while boiled sweet potato meal was 79.38%.

Proximate Composition of Growing Pig's Diets

The proximate composition of the experimental diets is presented in Table 4. The crude protein content of the five experimental diets ranged from 22.69% to 19.41%, with treatment1 (control diet) having the highest value. The ether extract ranged from 5.80% to 3.98%, with treatment 4 (25% Boiled Sweet Potato Meal) having the highest value. The percentage crude fibre, ash and nitrogen-free extract ranged from 3.96% to 3.03%, 3.63% to 3.10%, and 61.57% to 57.08%, respectively. Result of the gross energy shows there were slight differences in the gross energy of the different diets. The values ranged from 4369.50 kcal/kg in treatment 4 to 4190.30 kcal/kg in treatment 5.

Nutrient Digestibility by Pigs Fed Experimental Diet

The results of the nutrient digestibility by pigs fed experimental diets are presented in Table 5. The dry matter digestibility as well as the crude fibre, and ash digestibility were appreciably high for all the experimental animals. The crude protein digestibility values ranged from 19.48g/day in treatment 3 to 5.28g/day in treatment 5. Crude protein

Table 1: Percentage composition of experimental diets for weaned pigs

	Treatments				
Ingredients	**1**	**2**	**3**	**4**	**5**
Maize	34.17	-	15.10	27.90	9.30
BSPM	-	34.17	17.10	9.30	27.90
Spent grain	16.33	16.33	15.80	10.80	10.80
PKC	18.67	18.67	21.17	21.17	21.17
Soya bean	24.83	24.83	24.83	24.83	24.83
Fish meal	2.00	2.00	2.00	2.00	2.00
Bone meal	3.00	3.00	3.00	3.00	3.00
Salt	0.50	0.50	0.50	0.50	0.50
Methionine	0.25	0.25	0.25	0.25	0.25
Vit/Min. premix	0.25	0.25	0.25	0.25	0.25
Total	100	100	100	100	100
Calculated Composition					
Crude Protein%	19.39	19.01	20.54	22.02	22.02
Crude fibre	4.85	5.72	5.54	6.94	6.94
ME(Kcal/kg)	3478.57	3200.57	3339.31	3339.31	3339.31

BSPM- Boiled Sweet Potato Meal; PKC-Palm Kernel Cake; Vit/min. premix: vitamin A-7,000000i.u,vitamin D3-1,400000i.u,Vitamin E-5,000i.u,vitamin K-1,000mg, vitamin B2-3,000mg,VitaminC-20g, Niacin-10,000mg, Panthothenic Acid-3,000mg, Vitamin B6-3,000mg, vitamin B12-10,000mg, Folic Acid-500mg, Biotin-400mg,Choline Chloride-130,000mg, Cobalt-100mg, Copper-1,000mg, Iodin-10,000mg, Iron-15,000mg, Manganese-70,000mg, Selenium-100mg, Zinc-20,000mg, Antioxidant-1,250.

Table 2: Used primers

Genes		**Primer Sequence**	**PL**	**GBAN**	**GC%**
IGF1	F	GATGCGGGAGCTGGAGGATGGC	152	NM213883.2	68.18
	R	GCTCTCCACGAAGCGGCGAC			66.09
GAPDH	F	CGGGACATCAAGGAGAAGC	273	DQ845173	50.00
	R	ACAGCACCGTGTTGGCGTAGAG			65.00

IGF1-Insulin-like Growth Factor1; GAPDH- Housekeeping Gene; F-Forward; R-Reverse; PL-Product length; GBAN-Gene bank accession number; GC%- Guanine-Cytosine content.

Table 3: Proximate Composition of Test Ingredients

Components	**Maize**	**BSPM**
Dry matter	88.12	89.11
Crude protein	9.56	4.22
Eher extract	3.06	1.84
Crude fibre	2.27	2.35
Ash	2.22	1.32
NFE	71.01	79.38
MOSTURE	11.88	10.89
Gross Energy	18.90	17.10

BSPM: Boiled Sweet Potato Meal; NFE: Nitrogen Free Extract

digestibility, as well as nitrogen-free extract digestibility of the experimental diet was relatively low. Pigs in treatment 2 with digestibility value of 34.68g/day, recorded the highest intake for nitrogen-free extract. Result of analysis of variance revealed that there were significant differences (P0.05) in the nutrient digestibility among the treatments.

Table 4: Proximate Compositions of Weaner pig's Diets (% DM)

	Treatments				
Nutrients	**T1**	**T2**	**T3**	**T4**	**T5**
Crude Protein	22.69	19.65	19.41	21.98	21.83
Ether Extract	4.11	4.85	3.98	5.80	4.68
Crude Fibre	3.03	3.06	3.32	3.28	3.96
Ash	3.63	3.10	3.21	3.34	3.54
NFE	58.77	61.57	61.19	57.67	57.08
Gross energy	4281.60	4292.67	4190.30	4369.50	4263.32

NFE: Nitrogen Free Extract

Table 5: Nutrient Digestibility by Pigs Fed Experimental Diet

	Treatments				
Nutrients	**T1**	**T2**	**T3**	**T4**	**T5**
Dry matter	92.23±0.00^{a}	92.23±0.00^{a}	91.11±0.00^{b}	92.07±0.00^{a}	91.08±0.00^{b}
Crude Protein	13.59±0.01^{c}	17.68±0.00^{b}	19.49±0.01^{a}	11.48±0.01^{d}	5.29±0.01^{e}
Ether Extract	31.39±0.01^{c}	18.98±0.01^{e}	25.14±0.01^{d}	32.27±0.02^{b}	52.78±0.01^{a}
Crude Fibre	75.65±0.01^{a}	75.75±0.01^{a}	73.32±0.01^{b}	75.96±0.01^{a}	70.49±0.01^{c}
Ash	58.01±0.01^{e}	67.58±0.00^{a}	63.34±0.01^{d}	66.77±0.01^{b}	64.44±0.01^{c}
NFE	32.16±0.01^{c}	34.69±0.01^{a}	30.15±0.01^{e}	34.51±0.03^{b}	30.36±0.01^{d}

a,b,c,d,e: Means within row with different superscript are significantly different (p< 0.05). NFE: Nitrogen Free Extract

Table 6: Performance characteristics of Weaner pigs fed experimental diets

	Treatments				
Parameters	**T1**	**T2**	**T3**	**T4**	**T5**
AIWT (kg)	8.88±0.44^{a}	9.01±1.24^{a}	4.90±0.53^{b}	6.27±0.25^{b}	9.25±0.55^{a}
AFWT (kg)	26.06±0.77^{a}	22.22±2.58^{ab}	21.33±1.06^{ab}	20.67±0.69^{b}	24.50±1.30^{ab}
ATWG(kg	17.18±0.33^{a}	13.22±1.36^{bc}	16.44±0.55^{a}	14.40±0.45^{ab}	15.25±1.26^{ab}
ADFI (kg)	0.80±0.00^{a}	0.80±0.00^{a}	0.53±0.72^{b}	0.76±0.38^{a}	0.80±0.00^{a}
ADG(kg)	0.24±2.41	0.17±1.24	0.22±2.03	0.20±1.55	0.21±2.00
(FCR)	3.33±0.19	4.71±0.18	2.41±0.18	3.80±0.20	3.81±0.20

AIWT-Average Initial Weight; AFWT- Average Final Weight; ATWG- Average Total Weight Gain; ADFI- Average Daily Feed Intake; ADG- Average Daily Gain; FCR- Feed Conversion Ratio.

a,b,c: Means within row with different superscript are significantly different (p< 0.05)

Table 7: Cost-benefit of replacing maize with boiled red sweet potato in diet of growing pigs

	Treatments				
Parameters	**T1**	**T2**	**T3**	**T4**	**T5**
Cost/kg Feed (₦)	125.8±0.58^{a}	118.9±0.01^{b}	121.1±0.01^{c}	126.4±0.01^{a}	122.7±0.01^{c}
Total of feed consumed (kg)	67.2±0.01^{a}	67.2±0.01^{a}	44.5±0.00^{c}	63.8±0.00^{b}	67.2±0.01^{a}
Cost of feed consumed (₦)	8453.5±0.32^{a}	7991.9±0.40^{bd}	5388.9±0.37^{e}	8064.3±0.32^{cd}	8245.4±0.23^{ac}
Cost/kg gain(₦)	418.80.01^{d}	560.20.06^{a}	291.80.01^{e}	480.30.01^{b}	467.50.01^{c}
Cost diff./kg wt gain (₦)	----------	-141.3±0.03^{a}	127.00.01^{b}	-61.50.01^{c}	-48.70.01^{d}
Gross Margin (₦600/kg pork)	181.2±0.04^{b}	39.8±0.06^{e}	308.2±0.01^{a}	119.7±0.01^{d}	132.5±0.01^{c}

Cost/kg feed-cost per kg of experimental diet; Total feed consumed-Total feed consumed per pig; Cost of feed consumed-cost/kg feed x total feed consumed pig; Cost of feed/kg weight gain-cost/kg feed x feed conversion ratio; Cost differential/kg weight-cost/weight gain in treatment 1 – cost/kg weight/treatments; Gross margin-price/kg pork – total cost of producing 1 kg pork; ₦ = Naira (1₦ =$365). Cost/kg feed ingredients (₦): Maize-110, BSPM-90, PKC-40, BDG-35, FM-1200, BM-400, SALT-100, Methionine-2000, and Premix-520.

a,b,c,d,e: Means within row with different superscript are significantly different (p< 0.05)

Performance characteristics of growing pigs fed experimental diets

The results for performance characteristics are shown in Table 6. The mean value for initial weight ranges from 8.88kg in treatment 1 to 9.25kg in treatment 5. Result of analysis of variance revealed significant differences ($P<0.05$) among the treatments for all the parameters studied except ADG and FCR. The mean values for final weight ranged from 26.06kg for treatment 1 to 20.67kg for treatment 4. The mean weight gain ranges from 17.18kg in treatment 1, to 13.2kg in treatment 2. Treatments 1, 2 and 5 have similar mean value of 0.80kg daily feed intake, followed closely by treatment 4 with mean value of 0.76kg; treatment 2 had the least mean value of 0.53kg.Treatment 1 had the highest average daily weight gain of 0.24 kg, followed by treatment 3 with mean value of 0.22kg. Treatment 2 had the least mean value of 0.17kg for average daily weight gain. The mean values for feed conversion ratio ranged from 2.41 in treatment 3 to 4.71kg in treatment 2. There was no significant difference ($P>0.05$) in FCR among the treatments.

Cost-benefit of replacing maize with boiled red sweet potato in diet of growing pigs

The cost-benefit of feeding the experimental animals on the test diets for twelve weeks is presented in Table 7. From the result, there were significant differences ($P<0.05$) between treatments in all the parameters measured. Treatment 4 recorded the highest cost/kg feed of 126.40 while treatment 2 had the least value of 118.9. Total feed consumed (kg) were consistent with treatments 1, 2 and 5, while treatment 3 had the least feed consumption value of 44.5kg. In similar manner, treatment 3 recorded the least cost of feed consumed at the value of 5388.9, while treatment 1 had the highest cost of feed consumed at 8453.5. However, treatment 3 recorded the least cost per kg gain, with a value of 291.8 and highest gross margin value of 308.2.

IGF-1 gene expression in the Liver of growing pigs fed sweet potato and maize based diet

The expression pattern of IGF-1 gene in the liver of growing pigs fed sweet potato and maize based diet is shown in Figure 1. The expression patterns were significantly different ($P<0.05$) between treatments. Treatment 2 had the highest abundance of IGF-1 in the liver of growing pigs. IGF-1 was expressed in 7.46folds in treatment 2 (100% Boiled Sweet Potato Meal) compared to treatment 1(100% maize), followed by treatment 5 (75% Boiled Sweet Potato Meal) with fold change of 1.44 compared to treatment 1 (100% maize). However, Treatment 1 was expressed in 1.37 folds, and 2.38 folds for treatment 3 (50% Boiled Sweet Potato Meal) and treatment 4 (25% Boiled Sweet Potato Meal) respectively. This report suggests that IGF-1 expression increased with increased inclusion of boiled sweet potato meal.

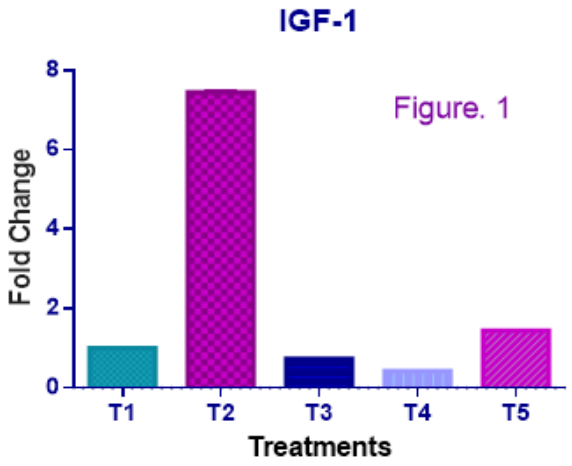

Figure 1: Shows the mRNA expression pattern of Insulin-like growth factor-1 (IGF-1) gene in liver of growing pigs fed boiled sweet potato meal (BSPM) as replacement for maize.

DISCUSSION

Nutrient composition of the Test Ingredient (Boiled Sweet Potato Meal)

The proximate composition of boiled sweet potato meal (BSPM) recorded crude protein content of 4.22%, which is less than 5.36% recorded by Afolayan (2010), 6.40% recorded by Dominguez (1990), but similar to 4.40% recorded by Noblet et al (1990) and 4.31% recorded by Chakrabartie et al. (2017), and 4.8% (Tiwari and Jha, 2016). Crude protein range of 1.27% –10.05% with the mean of 4.50% reported by Li (1982), 4.38% – 8.98% with the mean value of 6.29% reported by Dickey et al. (1984) were also similar to the values reported in this study. The 1.84% reported for ether extract in this study is lower than 2.7% and 2.8% value (Monday and Mueller,1977; Tiwari and Jha, 2016), but higher than 0.71% recorded by (Afolayan, 2010). The low crude fiber value of 2.35% recorded in this study is below 5.7% and 9.22% reported by Afolayan (2010), and Tiwari and Jha (2016). Similarly, the low ash content of 1.32% in this study is less than 2.0% and 2.93% total ash recorded by Afolayan (2010), and Tiwari and Jha, (2016). The nitrogen free extract (NFE) value of 79.38% is comparable with 81.78% recorded by Afolayan (2010), but dissimilar to the 89.00% recorded by Oyenuga and Fetuga (1975). With exception of low percentage crude protein, as well as ether extract and ash, which can be augmented with soya bean meal, the test ingredient can be replaced up to 60% in diets for pigs (Naskar et al., 2008), seeing that the nitrogen-free-extract in this tuber is high irrespective of its low to moderate glycemic index (McClellan et al., 2007).

Nutrient Digestibility by Pigs Fed Experimental Diet

The dry matter digestibility in this study is higher than the range of 80.33 – 83.33 reported by Mutetika et al. (2017). The digestibility values for dry matter, ether extract, crude fibre, ash and nitrogen-free-extract in this study were fairly high except for crude protein. This is in agreement with the study conducted by Dominquez et al. (1992) which confirmed that nitrogen digestibility is low due to the poor digestibility of sweet potato protein, even when boiled. The poor nitrogen digestibility could be attributable to antitryptic factors, which though low, are not eliminated completely by cooking (Lin et al, 1988).

Performance Characteristics of Grower Pigs Fed Experimental Diets

The performance characteristics of grower pigs fed boiled sweet potato meal are presented in Table 6. The results from performance evaluation showed that there were significant differences ($P<0.05$) in initial weight and final weight between the grower pigs on the control diet, and those on the remaining four treatment diets. There was, however, no significant difference ($P>0.05$) among the mean values for average total weight gain, average daily weight gain and feed conversion ratio (FCR). These findings are in consonance with Gonzalez et al. (2002) who reported similar results among pigs fed diets containing sweet potato meal as supplement to maize and sorghum. In the present study, animals in treatment 2 (100% BSPM) receiving the diet with no maize had the poorest performance of 13.22kg as compared with those from the control diet in treatment 1 (100% maize) with value of 17.18kg, whereas those fed graded levels of BSPM showed intermediate responses of 16.44kg, 14.40kg and 15.25kg for treatment 3 (50% BSPM / 50% maize), treatment 4 (25% BSPM / 75% maize) and treatment 5 (75% BSPM / 25% maize) respectively. Treatment 3 had the highest average total weight gain, connotes that grower pigs can perform well and tolerate up to 50% BSPM inclusion in their diet. Average daily weight gain of treatments 3 and 5 compares favorably with that of pigs on the control diet as there was no significant ($P>0.05$) difference among the treatment. Although, the average daily feed intake by animals in treatment 3 was lower than other dietary treatment, they seem to have performed better, probably because at the level of 50% BSPM and 50% maize, there seems to be a balance of supply of digestible energy and protein. Despite the low feed conversion ratio and average daily feed intake of animals in diet 3 (50% BSPM / 50% maize), it seems not to have any negative impact on the average total weight gain of the animals. However, the fact that the average daily weight gains of pigs in the control diet were better than the other dietary treatments, the varying inclusion levels as replacement for maize in the experimental diets did not have any negative effect on the overall performance of the animals. This study has revealed that boiled sweet potato meal could be added in growing pigs diets without any problem. The percentage inclusion level as shown by this study indicates that growing pigs could tolerate boiled sweet potato (BSPM) inclusion levels up to 75% replacement but for optimal performance 50% replacement for maize is recommended.

Cost Analysis of the Effect of the Experimental Diets on Grower Pigs

The different experimental diets were compounded based on the level of inclusion of the test ingredient (boiled red sweet potato meal). The result presented indicates that there were significant differences ($P<0.05$) among the parameters measured. The trend for cost /kg feed follows thus in an increasing order: diet 2 (100% BSPM) cost 118.9, diet 3 (50% BSPM/50% maize) cost 121.1, diet 5 (75% BSPM / 25% maize) cost 122.7, while diet 1 (100% maize) and diet 4 (25% BSPM / 75% maize) cost 125.8 and 126.4, respectively. Treatment 3 recorded the highest cost/kg gain as well as gross margin. This reduction in the cost of production as a result of the inclusion of boiled sweet potato meal in the grower pig's diet suggests that sustainable and profitable grower pig production is attainable with BSPM inclusion up to 50% as replacement for maize. This finding is in line with earlier report by Moemeka et al. (2015) stating that there is need for the use of boiled sweet potato meal as energy source to replace maize in order to reduce cost of production. Nguyen et al. (2000) and Chakeabarti et al. (2017) also made a similar recommendation. Dietary inclusion of BSPM in formulating grower pig's ration at 50% supplementation in treatment 3 reveals the financial benefits (gross margin) over the other treatments. This is an encouragement for pig production, because the study showed that feeding growing pigs with diets containing 50% BSPM in replacement for maize will greatly reduce the cost of production and increase the farmers' income.

Expression Pattern of IGF-1 Gene in the Liver of Grower Pigs Fed Sweet Potato and Maize Based Diets

The expression patterns of IGF-1 were significantly different ($P<0.05$) between treatments. Treatment 2 had the highest abundance of IGF-1 in the liver of growing pigs, and was expressed in 7.46folds compared to treatment 1(100% maize), followed by treatment 5 (75% BSPM) with fold change of 1.44 compared to treatment 1 (100% maize). However, Treatment 1 was expressed 1.37 folds, and 2.38 folds compared to treatment 3 (50% BSPM) and treatment 4 (25% BSPM), respectively. This report suggests that IGF-1 expression increased with increased inclusion of BSPM. Pietrangelo (2018) reported that IGF-1 gene helps to control growth hormone secretion in the pituitary gland and works with growth hormones to promote

growth and development of bone and tissue; this implies that insertion of the IGF-1 gene in pigs may result in improved weight gain and other economically important traits. The present study contradicts the reports of Pietrangelo (2018) as treatments with high expression of IGF-1 had the poorest average weight gain and feed conversion ratio. In another report, Wang et al. (2014) posited that IGF-1 gene has complex biological functions and plays an important role in animal growth, which is in line with the findings of this study, as boiled sweet potato meal affected average daily gain and feed conversion ratio; nevertheless, treatment with higher inclusion of the test ingredient had lesser growth output. This study also runs counter to reports that increased IGF-1 expression favours body weight gain and feed conversion ratio as reported by (Schmoelzl et al., 1996; Biziene et al., 2011; Sorhue et al., 2019), since treatment reporting higher expression of the target gene had the poorest ADG and FCR. Reports also indicated that zinc supplementation increased IGF-1 gene expression, while insulin therapy restored IGF-1 to normal concentrations in diabetic animals; hence insulin, glucorticoids, Zinc and amino acids are likely nutritional mediators that can perhaps interfere with liver IGF-1 levels (Xilong et al., 2006; Simmen et al., 1998). Consequently, the increased IGF-1 in treatments 2 and 5 in this study could be traceable to reports that sweet potatoes have a relatively low glycemic index (McClellan et al., 2007); this connotes that they release sugar into the bloodstream slowly, contrary to most starchy foods. The increased IGF-1 could also be ascribable to the high fiber content of sweet potato with over 77% of its fiber being insoluble, which is essential in promoting insulin sensitivity (Weickert and Pfeiffer, 2008), the reason being that the fiber content of feed is positively correlated to calories deposition, and insulin regulation. Low levels of IGF-1 reported in treatments 3 and 4 could be attributable to negative energy balance (Simmen et al., 1998). This study therefore suggests that sweet potato can be used instead of other starchy foods to boost insulin production.

CONCLUSION

The study established that boiled red sweet potato meal (BSPM) is a suitable replacement for maize as energy source in growing pigs. It was established that 50% inclusion level of BSPM in feeding growing pigs is cost effective; thus, farmers can adopt this level. In addition, this study has revealed that sweet potato increased expression of insulin-like growth factor 1 gene, and contributes to existing literature on the role of sweet potato in insulin production and regulation of blood sugar levels.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

ACKNOWLEDGEMENT

The authors extend their appreciation to the Management of Delta State University, Asaba Campus, Management and staff of Songhai-Delta Sapele, and staff of African Biosciences limited Ibadan Nigeria, for providing us with lab space and reagents.

NOVELTY STATEMENT

This is one of the very few studies that have unravel the performance of growing pigs fed boiled sweet potato meal based diet. This study has set a baseline for the inclusion of boiled sweet potato meal in growing pig's diet. This paper have also contributed to existing literature on the potentials of sweet potato in insulin regulation, which can be used as a model for human medicine in the control of blood sugar level, especially for diabetic patients; considering that 100% based diet of sweet potato recorded the highest expression of IGF-1 gene in the liver of experimental animals.

AUTHORS CONTRIBUTION

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