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Nutritive value of palm oil sludge and its influence on fat composition and deposition in grower pigs

Adebiyi O.A.[1], Oboli U.T.[1], Adejumo, I. O.,[2]* Osinowo O.A.,[3] and Martha Olumide[4] and Adeshola[1] A. T.

[1]*Department of Animal Science, University of Ibadan, Ibadan, Nigeria*
[2]*Animal Nutrition, Food Security and Food Safety Laboratory, Department of Animal Science, Federal University Gashua, Yobe State, Nigeria*
[3]*Department of Agricultural Education, Federal College of Education, Osiele, Abeokuta, Nigeria*
[4]*Department of Agriculture and Industrial Technology, School of Science and Technology, Babcock University, Ilishan Remo, Ogun State, Nigeria*

***Corresponding Author: e-mail:** *smogisaac@gmail.com;* **Telephone Number:** *+234(0)8066446246*

Abstract

Globally, pig is the main species for meat consumption. Meat animals are manipulated for reduced lipid deposition in order to enhance their production efficiency while improving meat quality. Grower pigs (n = 40) were randomly allotted to four compounded dietary treatments having 0%, 10%, 20% and 30% processed palm oil sludge (POS) replacing maize respectively. Growth response and lipid profile of the animals were determined using standard protocols. POS-based diets compared with the control group for growth response. The POS lowered low-density lipoproteins, the reduction was more pronounced for 20% and 30% POS inclusion level having 18.15 mg/dl and 19.60 mg/dl respectively. 30% POS inclusion increased high-density lipoprotein concentration (38.00 mg/dl), while 10% and 20% POS inclusion compared well with the control group. POS could be said to enhance the quality of pork meat for human consumption. This study may further be developed towards controlling some cardiovascular diseases in human.

Key words: *cholesterol; food safety; food security; palm oil sludge; swine*

Description of problem

Meat animals have been described as important experimental models for adipocyte studies as well as lipid metabolism because of their direct economic value for animal production (1). Meat animals include ruminants such as cattle and non-ruminant animals such as poultry and pigs. Globally, pig is the main species for meat consumption, accounting for over 40% of the total world produced meat (2, 3). Meat animals are manipulated for reduced lipid deposition in order to enhance their production efficiency while improving meat quality. Some of the methods adopted for reduction in lipid deposition in animals include nutritional manipulation, hormonal supplementation, breeding selection and housing management (4).

It has been observed that research with meat animals may chant the course to understanding regulation of physiology of adipocyte as well as metabolism of lipid, and coupled with understanding ectopic lipid storage observed in humans may help in the overall understanding of lipid storage. The advantages of the methods used to manipulate lipid deposition include enhancing meat quality as well as enhancing human health through metabolic regulation in humans, particularly in individuals with obesity and other related disorders (5). It has been reported that lipid metabolism in pigs, rats and humans are regulated by similar hormones (6, 7), although the liver in pigs is known to have lesser role than in rodents, especially when fed with high-energy diet.

Some of the factors affecting fat deposition include nutrition, sex, age, live weight, ambient temperature and genetic background (8). The advantages and limitations of feeding saturated, unsaturated and polyunsaturated fatty acids on cardiovascular diseases have been documented (9, 10, 11). Considering the aforementioned advantages, coupled with the need to reduce cost of pig production in developing countries, where food security is currently a challenge, it is logical to concentrate studies on enhancing wastes and agro-by-products which are not directly consumed by man into the production of safe meat for human consumption. Conversion of agricultural wastes or by-products into animal feed have been documented (12, 13).

Palm oil sludge (POS) is a waste of crude palm oil industry and relatively cheap to come by in Nigeria. Hence, it is reasonable to take the advantage of the ability of animals to turn this unconventional animal feed ingredient into useful animal products for human consumption and assess its potential in reducing lipid deposition in pigs. Earlier research involving its use for feeding pigs has been documented (14). This study therefore aimed to assess the influence of POS, a high energy ingredient, on the growth performance and lipid profile of grower pigs, to investigate if it would result in safe meat for human consumption.

Materials and method

Procurement and management of experimental animals

This study was conducted at the Piggery Unit of the Teaching and Research Farm, University of Ibadan, Nigeria, having the protocol and experimental design approved by the Ethics and Animal Care Regulatory Committee of the Department of Animal Science, University of Ibadan, Nigeria. Forty same sex grower pigs (Large White × Landrace) with an average body weight of 11.45 kg from a reputable source, with good farm records were used for the study. The animals were kept and monitored for two weeks for acclimatization before the experiment commenced. The pigs were randomly allotted to four groups, exposed to four dietary groups which contained 0, 10, 20 and 30% processed POS replacing maize. The diets were prepared daily to prevent rancidity. The composition is presented in Table 1. Clean, cool, drinking water was provided for the pigs *ad libitum*. The live body weight of the animals was measured weekly and daily feed intake were measured, using a weighing scale. The values obtained were used for the determination of body weight gain and feed conversion ratio. Nutrient composition of the diet was determined according to the method by the Association of Official Analytical Chemists (15). The study lasted eight weeks.

Collection of data

Venous blood was collected from the animals into EDTA-containing tubes. Plasma total cholesterol and triglycerides were determined by cell Boilab's HDL and LDL/VLDL cholesterol Assay kit according to the procedure described by Hsieh *et al.* (16). The low-density lipoprotein (LDL) concentration was calculated according to the equation of Friedewald *et al.* (17). Plasma cholesterol (total cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL) and triglyceride levels were measured at day one and termination of the study. Back-fat thickness was measured and recorded using ultrasonic probe taken on each side of the spinal column. Pigs were restrained in a modified holding crate, and the hair was clipped over the site to be measured on the right side. A layer of ultrasonic gel was used to maintain acoustic contact between probe and skin. Recordings were made of the sound reflections from the connective tissue partitions over the 12th thoracic vertebra, 65 mm from the midline.

Table 1.
Gross composition of the experimental diets

Parameters (%)	0% POS	10% POS	20% POS	30% POS
Maize	45.00	35.00	25.00	15.00
Oil palm sludge	0.00	10.00	20.00	30.00
Soya Bean Meal	24.50	24.50	24.50	24.50
Wheat Offal	28.00	28.00	28.00	28.00
Dicalcium Phosphate	1.50	1.50	1.50	1.50
Salt	0.25	0.25	0.25	0.25
Grower premix**	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25
Lysine	0.25	0.25	0.25	0.25
Total	100	100	100	100
ME (Kcal)*	2730.00	2811.50	2892.60	2973.70
Crude protein*	19.00	19.16	19.22	19.28
Proximate				
Crude Protein	20.60	20.81	20.88	21.20
Crude Fibre	5.07	6.59	7.20	8.19
Ether Extract	3.09	3.12	3.19	3.48
Dry Matter	91.20	91.00	90.45	90.15

POS = palm oil sludge; *calculated values; ME = metabolizable energy
**2.5kg of premix contains: Vitamin A = 8000000i.u., vitamin D3 = 1500000i.u. vitamin E = 7000mg, vitamin K3 = 1500mg, vitamin B1 = 2000mg; vitamin B2 = 2500mg, niacin = 15000mg, pantothenic acid = 5500mg, vitamin B6 = 2000mg, vitamin B12 = 10mg, folic acid = 500mg, biotin = 250mg, choline chloride = 175000mg, cobalt = 200mg, copper = 3000mg, iodine = 1000mg, iron = 21000mg, manganese == 40000mg, selenium = 200mg, zinc = 31000mg, antioxidant = 1250mg

Table 2.
Composition of palm oil sludge (% dry matter)

Components	Percentage
Dry matter	90.45
Crude protein	8.96
Ash	10.09
Ether extract	18.79
Crude fibre	10.45

Experimental design and statistical analyses

The data were analyzed in accordance with the procedure of one-way analysis of variance. Significant treatment means were separated using Duncan's Multiple Range Test. Regression equation (Y = a + b*X*) was used to predict the lipid profile from back-fat.

Results and discussion

Table 2 shows the composition of palm oil sludge, containing 8.89% crude protein content. Table 3 shows the growth performance of the experimental pigs. The values obtained for all the parameters measured for the POS inclusion groups compared (P<0.05) with the control group. Table 4 shows the lipid profile of the grower pigs fed the control and POS included-diets. Triglyceride, the values obtained for treatment diets were significantly (P<0.05) higher when compared with the control diet for the initial phase, but no significant difference was observed at the final stage. Total cholesterol ranged between 37.50 mg/dl and 45.33 mg/dl at the initial phase. The values obtained were however not significantly different across the treatments. At the final phase, animals on group 20% POS and 30% POS had lower and higher values respectively when compared with other groups.

The POS lowered low-density lipoproteins in the experimental animals. The reduction was more pronounced at 20% and 30% POS inclusion level having 18.15 mg/dl and 19.60 mg/dl respectively. The initial value in 10% POS (10.00 mg/dl) inclusion was lower than the control group (15.00 mg/dl), while 20% (13.00 mg/dl) and 30% POS (14.87 mg/dl) inclusion compared with the control group at the initial phase. High-density lipoprotein was not different among the groups at the initial stage, but 30% POS inclusion lowered its value at the final stage, while 10% and 20% POS inclusion compared with the control group. The back-fat of the experimental animals is shown in Plate 1and re-presented in Table 5 for clarity. The values obtained for the animals on POS compared well with those on the control group. It ranged from 8 mm (control group) to 11.33 mm (10% POS). The functional relationship between the back-fat and the lipid profile of the experimental animals is presented in Table 6. Using the simple linear function (Y = a + bx), the value of coefficient of determination (R^2) ranged from 1.06% to 21.28%, which implies that total cholesterol, high-density lipoprotein cholesterol, and low-density lipoprotein cholesterol depended on back-fat. It therefore can be predicted that a unit (1 mm) increase in the back-fat of pigs resulted in a corresponding increase in the total cholesterol by 36.21 mg/dl with R^2 = 21.28%.

Table 3.
Performance of grower pigs fed high energy diets

Parameters	0% POS	10% POS	20% POS	30% POS	SEM	P-value
Initial weight (kg)	11.33	11.59	11.41	11.48	0.78	0.99
Final weight (kg)	29.30	30.49	29.68	29.83	1.20	0.87
Average weight gain (kg)/week	2.24	2.36	2.28	2.29	0.82	0.72
Average Feed intake (kg)/week	7.80	8.49	8.20	8.31	1.33	0.52
FCR	3.48	3.67	3.60	3.62	0.09	0.91

FCR = feed conversion ratio; POS = palm oil sludge

Table 4.
Lipid profile of grower pigs control diet and POS included-diets

Parameters (mg/dl)		0% POS	10% POS	20% POS	30% POS	P-value	SEM
TAG	Initial	48.33^{b}	63.67^{a}	58.33^{a}	62.33^{a}	0.0267	1.16
	Final	58.67	62.50	63.00	65.33	0.5310	1.19
TC	Initial	44.00^{ab}	37.50^{b}	44.33^{ab}	45.33^{a}	0.1348	0.73
	Final	61.00^{b}	59.50^{b}	46.00^{c}	70.50^{a}	0.0001	0.49
LDL	Initial	15.00^{a}	10.00^{b}	13.00^{ab}	14.87^{a}	0.1342	0.49
	Final	23.93^{a}	20.20^{b}	18.15^{b}	19.60^{b}	0.0034	0.23
HDL	Initial	19.33	18.50	19.67	18.00	0.740	0.44
	Final	25.33^{b}	27.00^{ab}	16.67^{b}	38.00^{a}	0.0219	1.14

^{abc} Mean along the row with the same superscript are not significantly (P<0.05) different from each other, TAG: Triglyceride, TC: Total cholesterol, LDL: Low density lipoprotein, HDL: High density lipoprotein, SEM: Standard Error of Mean; POS = palm oil sludge

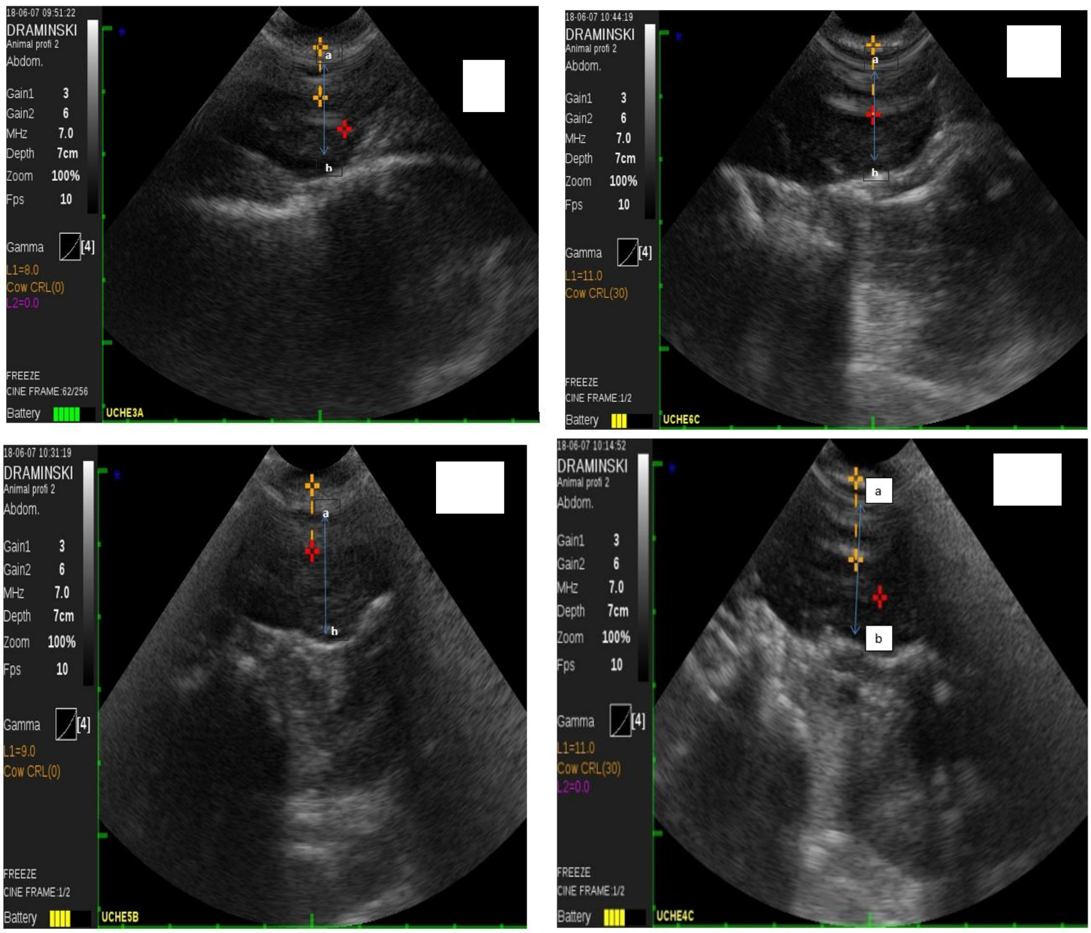

Plate 1. Back-fat scan of pigs fed 0% POS (i), 10% POS (ii), 20% POS (iii) and 30% POS (iv)
The arrow shows the area of back-fat deposition; POS = processed palm oil sludge

Table 5.
Back-fat depth of grower pigs fed the control and POS-included diets

Parameter (mm)	0% POS	10% POS	20% POS	30% POS	P-value	SEM
Back-fat depth	8.00	11.33	9.00	11.00	0.2964	0.33

POS = palm oil sludge; SEM = Standard Error of Mean

Table 6.
Regression equation to predict the lipid profile from back-fat depth

Parameters (mg/dl)	R^2 (%)	Equation	P-value
Triglyceride	13.10	73.94 - 1.17*X*	0.38
Cholesterol	21.28	33.72 + 2.49*X*	0.25
HDL-C	20.74	3.83 + 2.18*X*	0.26
LDL-C	1.06	19.22 + 0.153*X*	0.81

X denotes back-fat depth, R^2 = coefficient of determination, LDL-C = low-density lipoprotein cholesterol, HDL-C = high-density lipoprotein cholesterol

The results of the present study could be used to improve acceptance of pork considering the implication of the result on food safety, especially human consumption of pork. The result of the present study showed that pigs can tolerate POS -included diets without any deleterious effects in their growth response. In line with this finding, Ezekwe *et al.* (14) already reported a similar finding that POS-included diets resulted in increased weight gain and improved feed intake. It is expected that increased feed intake should result in increased body weight gain. Hutagalung *et al.* (18) also reported an increased body weight for POS-based diets. In the present study, feed intake did not differ across the treatments, hence the non-increase in body weight of grower pigs in the present study is considered to be normal.

In the present study, POS-based diets had higher numerical feed intake when compared with the control group, with corresponding weight gain. The increased consumption rate as reported in previous findings could be attributed to the relative increase in the amount of palm oil in the feed which seemed to improve palatability thus making the animals more disposed to ingesting the feed. Addition of POS also reduced the dustiness of feed, which may increase feed intake.

The results for lipid profile obtained is in line with the previous reports (19, 20, 21) but differs from the report of (22). The variation in the results of the present study and that of Bautista *et al*. may be attributed to the variation in the composition of the palm oil used. Interestingly, the results adapted from the American Medical Association, (23) shows that values obtained in the present study for triglyceride, total cholesterol, HDL-C and LDL-C are normal, desirable, low and optimal respectively.

Assessment of fat depot development has been suggested to have the opportunity to provide insight into the relationships between individual fat layers and carcass quality (24). Many factors could influence fat deposition in animals, which may include sex, age, nutrition, live weight, ambient temperature and genetic background. Yang *et al.* (25) earlier noted that an increase in dietary energy content improved fat accumulation in Lantang growing pigs, which may be due to the direct deposition of fat in the adipocyte. The presence of a growing innermost back-fat layer may be indicative of a developmental and energy state in which a pig deposits intramuscular fat. At about 28 kg the first and second back-fat layers are approximately the same thickness and the adipocytes are of a similar size (8). As the animal grows to about 53 kg and beyond, the thickness of the second layer becomes larger than the outer layer. In general, young pigs of less than 60 kg are not likely to consume enough to maximize fat deposition like older pigs, particularly gilts and barrows, can consume energy in excess of that required to maximize fat deposition.

The slight variations observed in the present study and that of the earlier researchers may be due to differences in breed of the animals used, environmental difference (nutrition, management, ambient temperature etc.) where the studies were conducted, as well as the sources and the processing technique of POS.

Total Cholesterol had the highest prediction value (R^2=21.28%), which implies that a unit (1 mm) increase in the back-fat of pigs will result in a corresponding increase in the total cholesterol by 36.21 mg/dl. The total back-fat has been suggested as an indicator of the body lipid content of pigs (26). However, it has been noted that adipose tissue may be involved in the metabolism of cholesterol since significant correlations could be described between plasma cholesterol and various indices of obesity (27). Other researchers however link plasma cholesterol with body weight (28). Research findings reporting on the protective capacities of fish oils and plant oils against the development of metabolic and cardiovascular diseases have been documented (29, 30, 31).

Conclusions and applications

1. From this study, it is evident that grower pigs can tolerate up to 30% dietary inclusion of POS without any deleterious effects on growth performances and lipid profile.
2. The 30% inclusion reduced low-density lipoprotein and increased high-density lipoprotein.
3. The use of POS could enhance the quality of pork meat for human consumption.
4. This study may further be developed towards controlling cardiovascular diseases in human.

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