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Growth performance and carcass characteristics of cross-bred rabbits fed diets containing palm kernel oil residue

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This study was conducted to explore the potential of palm kernel oil residue (PKOR), as substitute for wheat bran (WB) on growth performance and carcass characteristics of cross-bred rabbits in Ghana. Forty-eight seven-week old rabbits (1113± 318.20 g) were randomly allotted to 4 dietary treatments in a completely randomized design. The rabbits were given diets in which WB was replaced with PKOR at 0, 25, 50 and 100% during 49 days feeding trial. At the end of the trial, the animals were slaughtered for carcass and meat evaluations. There were no significant ($p > 0.05$) differences in feed intake, growth rates, feed conversion ratio, carcass yield, internal organ weights and most of the primal cuts assessed. The moisture contents reduced whereas the crude protein content increased ($p < 0.001$) and chilling, cooking ($p < 0.001$) losses reduced in meat of animals fed the PKOR-based diets. The use of PKOR to 100% reduced the feed cost to about 14%. PKOR could be used to substitute up to 100% of wheat bran in rabbit rations, without adverse effects on growth performance and carcass characteristics of the meat.

Key words: Rabbit *Oryctolagus cuniculus*, palm kernel oil residue, growth performance, carcass parameters.

INTRODUCTION

Ghana's main sources of animal protein are fish, domesticated livestock and game meat (Obimpeh, 1978). However, according to the Ministry of Food and Agriculture Statistics Research and Information Directorate (SRID) (2017), Ghana produced 173,956 tons of meat in 2016, representing about 86.98% of the estimated national annual requirements of 200,000 tons. The inability of Ghanaians to produce to meet their meat demand, can be blamed on high input costs emanating from feed and medication, competition over some feed ingredients due to inadequate supplies, as well as inadequate land space for agricultural activities due to rapid urbanization. This situation has resulted in some Ghanaians reverting to the rearing of livestock species which have minimum requirements for feed and space. One of such species, is rabbit.

The rabbit (*Oryctolagus cuniculus*), is an important source of good quality meat which is accepted by many consumers in Ghana, and in other countries across the world (FAOSTAT, 2005). Currently, rabbit meat

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consumption is increasing because of its high protein, low fat and cholesterol contents (Moreno, 1991). The meat is also highly palatable and is easily used to substitute for chicken in Ghana and in some West African countries such as Nigeria (Moreki, 2007). Rabbit meat is reported to produce less uric acid during metabolism; therefore, its consumption is being encouraged for good health, especially for diabetics, hypertensive patients and the aged (Iyeghe-Erakpotobor, 2007). Reproductive wise, rabbits have relatively higher litter size with short gestation period (30 days), so multiply within a short period of time (Akinmutimi et al., 2006). According to Owen (1976), a female rabbit is able to reproduce to supply a minimum of 120 kg of high-quality meat within 12 months of production. Consequently, commercial rabbit production is gradually becoming a specialized operation that is gaining popularity in many tropical countries, especially in West Africa (Akaeze et al., 2014). Feeding of rabbits with forage as a sole diet in the tropics, has been reported to result in inconsistensies in growth rates, due to seasonal fluctuations in quality and quantity of forage (Bamikole and Ezenwa, 1999; Cheeke et al., 1983; Hue and Preston, 2006). In order to ensure constant and uniform patterns of growth and reproduction in rabbits, there is need to supplement forage fed, with formulated feed. The challenge with this suggestion however, is the high cost of providing these supplements, making rabbit meat quite expensive to consumers (Iyeghe-Erakpotobor, 2007).

Feed costs account for over 50% of the total cost of rearing rabbits intensively (Madubuike and Ekenyem, 2001); this has resulted in a change in approach by most livestock producers (Yilmaz et al., 2005). Animal nutritionists have therefore, stepped up efforts at screening non-conventional, but less expensive agro-industrial by-products (AIBP) for compounding affordable but nutritious diets for livestock (Ray, 1995). One of such by-products with high potential for use in rabbit production is Palm Kernel Oil Residue (PKOR); the solid waste left after manual extraction of oil from the kernel of palm fruits by cottage industries in Ghana and in other West African countries (Odoi et al., 2007). PKOR and its close variants have been successfully utilized as feed ingredients for poultry, pigs, sheep and goats (Odoi et al., 2007; Stein et al., 2015; Teye et al., 2015; Yangtul, 2013), but inadequate information on its effects on growth rates of rabbits. PKOR is currently dumped at the production sites, and this has been reported to cause nuisance to humans, due to the emission of

offensive odor when the oil in the product becomes rancid. In addition, the oil seeps into the soil, thus minimizes aeration and water percolation, and consequently, makes the soil unsuitable for crop production (Odoi et al., 2007).

Wheat bran is an ingredient which is commonly used in the rations of most livestock species, thus there is competition over same. This usually results in artificial shortages and price hikes due to high demand for it (Flake and Ashitey, 2008). PKOR is comparable to wheat bran in terms of ingredient density and major nutrient contents, and could likely be used as a substitute for wheat bran in livestock rations.

Meanwhile, according to Teye et al. (2006), the type of feed given to animals has significant effects on the carcass parameters of the animals involved. This study was therefore aimed at replacing wheat bran (a relatively more expensive ingredient in high demand) with PKOR (a waste product causing nuisance in the environment) in rabbit rations, to determine its effects on some growth, carcass and meat characteristics of the rabbits. It was hypothesized that, the use of PKOR as substitute for wheat bran in rabbit rations, would have adverse effects on growth, carcass and meat characteristics of animals fed such diets.

MATERIALS AND METHODS

Experimental site

The study was conducted at the Animal Experimental and Meat Processing Units of the Teaching and Research Farm of the School of Agriculture, University of Cape Coast, Ghana. The experimental site lies in the coastal belt, characterized by hot and humid conditions. The annual average temperatures range between 24.0°C in the coolest parts of the year, to 34.5°C in the hottest parts of the year. The annual rainfall is about 1500 mm and a relative humidity of 65 to 80% (Hagan and Apori, 2013).

Animals and experimental design

Forty-eight cross-bred (New Zealand White × Indigenous Breed) rabbits (24 males and 24 females) at 7 weeks old, with an average initial body weight of 1113 ± 318.20 g were selected, and randomly allotted to 4 dietary treatments (12 rabbits per treatment: 6 males and 6 females) in a completely randomized design. The rabbits were housed individually in wooden cages (20 cm×22 cm × 31 cm), and were made to acclimatize to the experimental feed for seven days, after which their initial weights were recorded.

PKOR was collected from processing sites in Cape Coast, Ghana. It was sun-dried for 48 h, at an average temperature of 30°C. During the period of drying, the residue was spread out on concrete platforms and stirred every 30 min, while lumps were broken up and foreign materials present were removed. The proximate composition of dried PKOR were deternimed (Table 1). All other ingredients used in formulating the experimental diets were purchased from the open market in Cape Coast, Ghana.

Four experimental diets were formulated using the Windows User-Friendly Feed Formulation Excel file (Thomson et al., 2009); where PKOR was used to replace wheat bran at 0% (control, T1), 25% (T2), 50% (T3), and 100% (T4) (Table 2). The feeding trial lasted for 49 days, feed and water were available *ad-libitum*. All diets were formulated to meet all requirements for essential nutrients, as recommended for growing rabbits (National Researcch Council, 1994).

Growth performance traits

At the start of the study, initial body weights of the rabbits were

Table 1. Proximate composition of palm kernel oil residue.

Parameter	PK0R	SD
Dry matter (%)	88.20	0.07
Ash (% DM)	2.78	0.17
Crude protein (% DM)	18.46	0.15
Ether extract (% DM)	2.81	0.04
Crude fiber (% DM)	13.25	0.27
* Nitrogen free extract (% DM)	50.89	0.40
*Metabolizable energy(Kcal/kg)	2666.44	7.92

SD= Standard Deviation.

Table 2. Composition of the experimental diets.

Ingredient (%)	Treatments			
	T1	T2	T3	T4
Maize	45.00	45.00	45.00	45.00
Wheat bran	35.00	26.00	17.50	-
PKOR	-	9.00	17.50	35.00
Soyabean meal	15.00	15.00	15.00	15.00
Fish meal	3.00	3.00	3.00	3.00
Oyster shells	1.45	1.45	1.45	1.45
Common salt	0.30	0.30	0.30	0.30
Vitamin/mineral premix	0.25	0.25	0.25	0.25
Total	100	100	100	100

Premix (0.25%) ovides the following: Vit A 10.000 IU; Vit D3 2,000 IU; Vit E 15 mg; Vit K3 stab 1.5 mg; Vit B1 0.5 mg; Vit B2 2.5 mg; Vit B6 1.0 mg; Vit B12 6µg; Niacin 5 mg; Calpan 4 mg; Folic Acid 100 µg; manganese 60 mg; iron 40 mg; zinc 50 mg; copper 2.5 mg; iodine 1mg; Selenium 0.2 mg; choline 100 mg; antioxidant 125 mg.

taken, using an electronic scale (RADWAG 2012, RADWAG®). Subsequently, weekly body weights of the animals were taken. The live weight gained was calculated as the difference between previous weight and weight recorded in the following week. The feed intake per rabbit per day was calculated as the difference between feed offered and spilled/leftover feed (after 24 h of feeding). The feed conversion ratio (FRC) was calculated as the ratio of feed taken, to weight gained after a week of feeding, using the formula:

Feed Conversion Ratio = (feed taken)⁄(weight gained)

Feed cost

Prevailing prices per kilogram weight of ingredients were multiplied by the quantities of the respective ingredients used in formulating each of the experimental diets. The cost of 1 kg compounded feed was multiplied by the feed conversion ratio of rabbits fed the corresponding diet (EL-Maaty et al., 2014), and was calculated as:

Feed cost per kg weight gained = feed to gain ratio (FCR) × cost per kg of feed

Slaughtering of experimental rabbits

Ethical clearance was sought from the *Institutional Review Board* (IRB) of the University of Cape Coast, Ghana, to conduct this study. At the end of the feeding trial, eight rabbits from each treatment (4 males and 4 females), were randomly selected and weighed with an electronic scale (Sartorius, CP 245S). Prior to their slaughter, the rabbits were stunned with a captive bolt pistol, Matador SS3000 (Termet, France) to prevent the animals from feeling the pain of slaughter, followed by a ventral neck incision with a sharp knife (GIESSER, Germany). Carcasses were bled for about 60 s. The carcasses were then scalded in warm water, at a temperature of about 80°C for about a minute, and the furs were scraped off with sharp knives. The de-furred carcasses were washed and eviscerated, after which they were again washed with pipe-borne water. The dressed carcasses were weighed and stored in a refrigerator at 4°C, and re-weighed after 24 h of chilling, to determine the chilling loss. The heart, kidney, lungs and liver were all separated and weighed, and weights expressed as percentages of liveweight. Primal cuttings (loin, shoulder, breast, rack and thigh muscles) were made from the chilled carcasses, based on procedures described by Malcom (2012); each was weighed and expressed as a percentage of the carcass weight. The *Quadriceps femoris, Semi-tendinosus, Semi-membranosus* and *Biceps femoris* muscles were minced and homogenized for evaluation of protein and fat contents of the carcasses.

Cooking loss determination

The *Longissimus thoracis* and *Lumborum* muscles of each carcass was weighed and grilled until a core temperature of about 72°C was attained, using a digital thermometer (Hangzhou Realwayto Ind. Co. Ltd, RWT 2251) in a microwave oven (IFB 23SC3). The products were then cooled and the surfaces wiped with filter paper, and were reweighed, using an analytical balance (Nikmaram et al., 2011). Cooking losses were calculated as differences between the fresh and cooked we ights, calculated as follows:

$$\text{Cooking loss} = \frac{wt.of\ sample\ \ bef\,ore\ cooking - wt.of\ sample\ \ after\ \ cooking}{wt.of\ sample\ \ before\ \ cooking} \times 100$$

Proximate composition of PKOR, diets and leg meat of rabbits

Samples of dried PKOR, experimental diets and leg meat of the experimental rabbits were analyzed for proximate composition. The crude protein (CP) contents were determined using the Kjeldahl method, ether extract using the Soxhlet method, moisture and ash contents according to the methods described by the AOAC (2000). The leg meat was deboned and minced with a domestic blender (model MX-X61-W, National, Japan) to homogenize the muscles, before the proximate analyses was conducted. All analyses were conducted in triplicate.

Statistical analysis

Data collected were analyzed for differences due to diet treatment, using the One-Way Analyses of Variance component of Genstat (2012). Where significant differences existed, means were separated using the Tukey pairwise comparison, at 5% level of significance.

RESULTS AND DISCUSSION

Proximate composition of the experimental diets

The proximate composition of the experimental diets, is presented in Table 3. The experimental diets had CP contents ranging between 19.02 and 20.05%. The crude protein level in the PKOR-based diets was not significantly ($p > 0.05$) different from the control diet. The ether extract (fat) contents of the T3 and T4 diets were significantly ($p < 0.001$) higher than those in the T1 and T2 diets. The crude fiber contents increased significantly ($p < 0.001$) with the increasing of PKOR inclusion. Fats in livestock rations serve as secondary sources of energy to the animals, and therefore, animals take less of feed which have higher fat contents (Pond et al., 1995). The higher fat contents of the diets with higher PKOR inclusions (T3 and T4) could result in lower intake of such diets, compared with conventional rabbit feed. The proximate composition of the experimental diets were within the recommended levels prescribed by the NRC (1994) for growing rabbits, thus, their use is not expected to have adverse effects on the growth rate of rabbits fed such diets.

Growth performance of rabbits

Table 4 shows the growth parameters assessed in the study. The body weights of the animals at the commencement of the feeding trial were similar ($p > 0.05$) among treatments. Similarly, there were no significant differences ($p > 0.05$) in the final weight gained, growth rates, total feed intake and feed conversion ratio (FCR) of the experimental animals. This observation might be due to the similar crude protein and metabolizable energy contents of the experimental diets, as these nutrients play significant roles in growth and reproduction in animals.

The growth rates of the animals in this study ranged between 20.14 and 23.43 g per rabbit per day. These values were quite higher than those from the findings of Ayoola (2014); Iyeghe-Erakpotobor and Adeyegun (2012), who reported growth rates ranging between 14.83 to 16.70 g, and 10.37 to 10.73 g respectively in growing rabbits. The relatively higher growth rates observed in the current study might be due to superior breeds of animals or higher quality feed used in the current study, compared with the previous studies.

Cost-benefit analyses of using PKOR in place of wheat bran in rabbit feed

The costs of acquiring 100 kg each of the experimental feed, are shown in Table 5. Feed cost per 100 kg diet formulated reduced by up to 13.87%, as PKOR inclusions increased in the formulations. However, savings on the cost of feed, and feed cost per kg weight gained increased with increasing levels of PKOR in the diets. Wheat bran substitution with PKOR, reduced the cost of rearing the animals, by up to GH¢ 19.00 ($ 3.50) per 100 kg feed formulated. In addition, the use of PKOR in place of wheat bran would reduce competition over wheat bran, which is usually scarce or expensive when available, as well as help minimize nuisance associated with dumping PKOR at production sites. The findings from this study, are similar to that of Yangtul et al. (2013), who reported decreasing feed costs and higher net revenue from broiler and layer chicken production respectively, when PKOR was used to substitute for wheat bran in their diets. This implies that if rabbit farmers use PKOR in the rations of their animals, they would make some savings on feed, and in addition, minimize competition over wheat bran, which is quite expensive due to inadequate supply of the commodity.

Carcass yield, internal organs and primal cuts evaluation

The carcass characteristics, organ weights and primal

Table 3. Proximate composition of the experimental diets.

Parameter	Treatments				SEM	Sig. Level
	T1	T2	T3	T4		
Dry matter (%)	87.63[ab]	87.32[b]	87.47[ab]	87.84[a]	0.11	*
Ash (%DM)	6.93[a]	5.35[ab]	4.98[b]	5.22[b]	0.37	*
Crude protein (%DM)	19.47	19.02	19.51	20.05	0.81	NS
Ether extract (%DM)	0.21[b]	0.17[b]	0.74[a]	1.04[a]	0.02	***
Crude fiber (%DM)	8.23[c]	8.65[bc]	9.10[b]	11.15[a]	0.12	***
# NFE (%DM)	52.80[ab]	54.13[a]	53.14[ab]	50.38[b]	0.75	*
# ME (Kcal/kg)	2546.88[b]	2574.94[ab]	2605.50[a]	2553.24[b]	7.52	**

Means in a row with similar superscripts are not significantly different (p > 0.05). # - Calculated; NFE – Nitrogen Free Extract; ME – Metablisable Energy; *= p < 0.05; **= p < 0.01; ***= p < 0.001; NS: Not Significant (p > 0.05); SEM: Standard Error of Means. DM: Dry matter.

Table 4. Growth performance of the experimental rabbits.

Parameter	Treatments				SEM	Sig.
	T1	T2	T3	T4		
Initial weight (g/rabbit)	1123	1123	1074	1132	177.40	NS
Final weight (g/rabbit)	2156	2203	2222	2119	449.50	NS
Total weight gained (g/rabbit)	1033	1080	1148	987	342.30	NS
Growth rate (g/day/rabbit)	21.08	22.04	23.43	20.14	2.25	NS
Total feed consumed (g/rabbit)	4167.45	4088.56	4253.69	3786.23	22.1	NS
Daily feed intake (g/day)	85.05	83.44	86.81	77.27	3.15	NS
FCR/rabbit	4.03	3.79	3.71	3.84	0.52	NS

Table 5. Cost-benefit analyses of using PKOR in place of Wheat bran in rabbit feed.

Parameter	Treatments			
	T1	T2	T3	T4
Cost per 100 kg feed (GH¢)	137.00	132.00	127.00	118.00
Savings on feed (GH¢)	0.00	5.00	10.00	19.00
Feed cost/kg weight gained (GH¢)	5.52	5.00	4.71	4.53
Savings on feed cost/kg weight gained (GH¢)	0.00	0.52	0.81	0.99
5.5 Ghana Cedis = $1.00 USD				

cuts of the experimental rabbits are presented in Table 6. There were no significant (*p* > 0.05) differences in almost all the parameters assessed, except the thigh weight, which was significantly (*p* < 0.05) higher in the rabbits fed with the T2 and T3 diets. The thigh is a valuable primal cut, and therefore, any feed that ensures higher thigh weights, would be cherished by rabbit farmers and consumers of rabbit meat.

The dressing percentage of carcasses from this study, ranged between 55.35% and 57.35%. These values fall within the dressing percentage range of 55%-61%, reported by Ouhayoun (1998); but were quite higher than the findings of Akinmutimi and Akufo (2006); Sobayo et al. (2008), who reported dressing percentages of 43.24 - 53.83% and 52.05 - 53.36% respectively in rabbits. The variations in the dressing percentages between animals in this study and those used in previous studies, may be ascribed to differences in parts of carcasses which are considered edible, the nutrition plane, age, breed, pre-slaughter handling and general health conditions of the animals (Adejinmi et al., 2013).

The weights of the visceral organs were not significantly (p > 0.05) different among the treatments, an indication that the use of PKOR in place of wheat bran, had no adverse effects on the health of the animals. Occurrence of disease in animals, according to Teye et al. (2015), is evident in change in size/shape, weight and/or colour of visceral organs of animals.

Table 6. Carcass characteristics, organ weights and primal cuts of the rabbits.

Parameter	Treatments				SEM	Sig.
	T1	T2	T3	T4		
Carcass characteristics						
Live weight prior to slaughter (g)	2138	2183	2168	2066	135.1	NS
Warm carcass weight (g)	1186	1246	1225	1163	108.6	NS
Dressing percentage (%)	55.37	57.35	56.35	55.35	2.3	NS
Chilled carcass weight (g)	1152	1234	1214	1146	104.7	NS
Weight of internal organs (% of live weight)						
Heart	0.22	0.22	0.23	0.22	0.02	NS
Liver	2.82	2.48	2.76	2.37	0.14	NS
Kidney	0.52	0.32	0.5	0.45	0.05	NS
Lungs	0.93	0.87	0.79	0.65	0.27	NS
Filled Intestine	18.04	19.12	19.95	22.57	1.97	NS
Primal cuts (% of carcass weight)						
Thigh	25.20^{b}	27.88^{a}	27.96^{a}	27.55^{ab}	0.89	*
Shoulder	14.43	15.19	16.61	17.2	0.78	NS
Rack	14.7	14.15	15.04	13.48	0.58	NS
Loin	26.97	27.8	24.69	26.76	0.78	NS
Breast	7.45	6.52	6.24	5.73	0.56	NS

Means in a row with similar superscripts are not significantly different ($p > 0.05$). *= $p < 0.05$, NS- Not Significant.

Table 7. Proximate composition, chilling and cooking losses in meat of the experimental rabbits.

Parameter	Treatments				SEM	Sig. Level
	T1	T2	T3	T4		
Moisture	72.68^{a}	71.72^{a}	69.62^{b}	68.77^{b}	0.36	***
Crude protein	20.55^{c}	21.51^{b}	21.60^{b}	22.74^{a}	0.67	***
Fat	1.82	2.33	2.36	2.38	0.61	NS
Chilling Loss (%)	2.71^{a}	1.00^{b}	0.97^{b}	1.30^{b}	0.3	**
Cooking Loss (%)	26.75^{a}	20.25^{b}	23.25^{a}	20.00^{b}	0.65	***

Results are means of triplicate determinations; **= $p < 0.01$; ***= $p < 0.001$. Means in a row with different superscripts are significantly different ($p < 0.01$; $p < 0.001$).

Proximate composition, chilling and cooking losses of the carcasses

The proximate composition, chilling and cooking losses of the carcasses are presented in Table 7. The moisture contents of the meat decreased ($p < 0.001$), whilst the protein contents increased ($p < 0.001$) with increases in PKOR inclusions. The fat content however, were not significantly ($p > 0.05$) different across the treatments. It was anticipated that the fat content of the meat would increase as PKOR inclusions increased, due to the higher fat contents of the PKOR used in formulating the feed, but that was not the case. This is good news to consumers who are avoiding excess dietary fats due to perceived adverse effects on human health.

Meat is consumed mainly for its protein content. According to Warriss (2010), meat is nutritionally graded, based on the quality and quantity of protein it contains. Proteins are required in higher levels in growing children and also for productive functions such as nurturing pregnancy and lactation, due to increased output of proteins in the products of conception and in milk (Pond et al., 1995). Therefore, with a higher crude protein level in meat, just a small quantity of it will be required by consumers to meet their nutrient requirements. This will reduce expenditure on meat and meat products, as well as satisfy consumer health concerns over excessive meat intake.

The chilling losses reduced significantly ($p < 0.01$) in carcasses of animals fed the PKOR rations. The chilling losses in general, were quite low, indicating that the water holding capacity of the muscles was high. Moisture loss from carcasses, is of economic concern to meat processors and consumers, because it adversely affects weight of products along the distribution chain and during cooking (Okubanjo et al., 2003). Carcasses with lower chilling losses, are much desired by meat processors and consumers in general, as weight losses of such meats in storage would be lower.

Conclusion

The use of PKOR as substitute for wheat bran in rabbit rations, has no adverse effects on growth and carcass characteristics of the animals. However, the protein content of the meat, increased with increasing PKOR inclusions. The cost of formulating 100 kg of feed for rabbits, reduced by up to GH¢ 19.00 (about $ 3.50), as a result of substituting up to 100% of wheat bran with PKOR in rabbit rations. It is recommended that where available, PKOR could be used successfully to replace wheat bran in rabbit rations. This would reduce costs of feeding, as well as minimize the environmental nuisance associated with PKOR disposal at the production sites. Further studies will be need to assess the impact of feeding diets containing PKOR to rabbits, on sensory characteristics and fatty acid profile of the meat.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Ethical approval

All authors hereby declare that all experiments performed in this study involving animals have been examined and approved by the University of Cape Coast Institutional Review Board. This complied with the ARRIVE guidelines and was carried out in accordance with the U.K. Animals (Scientific Procedures) Act, 1986 and associated guidelines, EU Directive 2010/63/EU for animal experiments.

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