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Research Article

Fatty Acid Profile, Carcass and Meat Quality Attributes of Rabbit Breeds in Ghana Fed Diets with Graded Levels of Palm (*Elaeis guineensis*) Kernel Oil Residue

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Abstract | This study was conducted to test the fatty acid profile and some meat quality attributes of local breed of rabbits which were given diets formulated with palm kernel oil residue (PKOR), a by-product from manual extraction of palm kernel oil by cottage industries. The feed was compounded with or without PKOR replacing wheat bran at 0% (T1, control), 25% (T2), 50% (T3) and 100% (T4) in rabbit rations. At the end of the feeding trial, 48 (equal number of males and females) out of 144 rabbits fed, were selected and slaughtered. Data obtained were analysed using the Analysis of Variance (ANOVA). Rabbits fed with diets containing PKOR (T2 and T3) had higher liveweights, dressing percentages, warm and chilled carcass weights, than those fed conventional rabbit diets. Moreover, rabbits fed PKOR-based diets (T2 and T3) had higher fat contents and higher muscle weights than those fed on the conventional diets. Sensory evaluation indicated that meat of rabbits on the PKOR-based diets were juicier, more tender, and had better acceptability. The n – 6/n – 3 fatty acid ratios were higher, but saturation (S/P) and Atherogenic Index (AI) significantly decreased ($p < 0.05$) in meat of animals on T2 and T3 diets. In addition, the polyunsaturated fatty acid (PUFA) contents were significantly higher ($p < 0.05$) in the PKOR-fed, than rabbits fed with diets without PKOR. It can be concluded that PKOR could be used to replace up to 50% of wheat bran in rabbit diets to improve carcass and meat quality characteristics.

Keywords | Fatty acid profile, Palm kernel oil, Wheat bran, Sensory evaluation, Rabbit meat, Local rabbit

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INTRODUCTION

Rabbit (*Oryctolagus cuniculus*), provides good quality meat which is patronised by many consumers in Ghana and in countries such as China, Italy, Malaysia, Indonesia and Spain (FAOSTAT, 2005). Rabbit meat consumption is increasing for the following reasons; it is classified as white meat (which is preferred by many consumers), it has high protein content but low in fat (Moreki, 2007). The meat has similar characteristics as chicken, hence, is used to substitute for chicken in Ghana and in some African countries like Nigeria (Moreki, 2007). Rabbit meat consumption is being encouraged for good health among diabetics and hypertensive patients due to its less uric acid content (Iyeghe-Erakpotobor, 2007). Rabbit meat contains 20–21% proteins, and is quite high in some essential fatty acids (oleic and linoleic) and minerals such as potassium, phosphorus, and magnesium (Dalle-Zotte, 2002). In addition, rabbits have short gestation period, so multiply quickly (Akinmutimi et al., 2006).

In Ghana, most of the breeds of rabbits available for commercial production are indeterminate due to multiple crosses between unspecified breeds available locally. Meanwhile, these rabbits are noted to survive and reproduce very well even under unfavourable environmental and husbandry conditions; thus, are very suitable for the Tropical climatic conditions. There is however, little

published literature on the meat, carcass characteristics, and fatty acid profile of these rabbit breeds in Ghana.

Dry season feeding of rabbits has been a major challenge to most commercial rabbit farmers in Ghana, as farmers complain about high costs of feed ingredients to formulate conventional rabbit rations. In response to this, scientists have been investigating the potential of cheaper and readily available alternative ingredients, to reduce the cost of feeding and also possibly increase the unsaturated fatty acid content of the meat. Modifying the type and amount of fatty acids (FA) in animal products is particularly important as a means of enhancing the nutritional properties of animal-based foods or decrease the potential negative effects of some saturated FA on human health (Martínez Marín et al., 2011). One of such ingredients with potential for use in livestock rations, is palm kernel oil residue (Odoi et al., 2007).

Palm kernel oil residue (PKOR) is the solid waste obtained from palm kernel (*Elaeis guineensis*) oil extraction by cottage industries. PKOR is usually dumped in the locality where the oil is extracted, causing nuisance to residents as a result of the oil getting rancid and emitting offensive odour. It also pollutes the soil and nearby water bodies when the oil seeps into the soil. Meanwhile, previous publications indicated that PKOR is a promising feed ingredient which promotes growth and reduces cost of feeding some livestock species (Odoi et al., 2007; Stein et al., 2015). Previous studies by Nuamah et al. (2019) used PKOR to replace wheat bran at 25%, 50% and 100% inclusions, and reported significantly higher ($p < 0.05$) growth rates and reduced cost of feeding crossbred (New Zealand white X local) rabbits. The authors consequently recommended the feed to livestock farmers, who are currently using it for rabbit production with proven results. However, the previous studies did not take into consideration the fatty acid composition of the resulting meat. Analysis of the fatty acid profile of meat is necessary because previous reports indicated that it varies in meat when oil-containing seeds, or their by-products are fed to livestock (Ayerza and Coates, 2000; Peiretti and Meineri, 2008).

This study was aimed at assessing the fatty acid profile, meat and carcass characteristics of indeterminate breed of rabbits in Ghana, fed diets containing graded levels of PKOR as substitute for wheat bran at 0%, 25%, 50% and 100% in rabbit rations.

MATERIALS AND METHODS

Study area

The study was undertaken in the Laboratories of the School of Agriculture, University of Cape Coast, Ghana. The mean annual temperature is about 23°C and relative humidity of about 90% mostly at night, but decreases gradually to about 70% during the day (Teye et al., 2020).

Animals used

Management of all animals in this study complied with the ARRIVE guidelines, and was in accordance with the U.K. Animals (Scientific Procedures) Act, 1986, and the EU Directive 2010/63/EU for animal experiments (Legislation, 1986). A total of 48 local breed of rabbits (similar number of males and females weighing about 1100±0.59 g) were selected from 144 rabbits which were grouped into four, and offered diets with or without PKOR as substitute for 0, 25, 50 and 100% of wheat bran in rabbit rations. The feeding trial lasted for 8 weeks. The feeding trial was started when the animals were 6 weeks old, and it lasted for 8 weeks, thus, were slaughtered at 14 weeks old.

Experimental feed

The composition of the experimental feed was adopted from the studies of Nuamah et al. (2019). This study however used local breeds of rabbits, but the earlier one used crossbred rabbits (New Zealand white × Local breeds).

Slaughtering of animals and primary processing

The 48 rabbits selected from each of the treatments were weighed using an electronic scale (Sartorius, CP 245S, Spain) after 12 hours of withdrawing feed, but not water. Prior to their slaughter, the rabbits were rendered unconscious using a captive bolt pistol, Matador SS3000 (Termet, France) to induce brain dysfunction, followed by a ventral neck incision with a sharp knife (GIESSER, Germany) to cut the major blood vessels in order to cause blood loss and death. Carcasses were bled for a duration of 90 seconds. The bled carcasses were then scalded for about 60 seconds, and furs were scraped with sharp knives. The carcasses were then washed and eviscerated. The internal organs were separated and each part was weighed using the electronic scale.

The dressing percentage and chilling loss of the carcasses were determined according to methods described by Nuamah et al. (2019).

Carcass pH and sensory evaluation of the meat were conducted following methods described by Teye et al. (2015).

Laboratory analyses of meat

Leg muscles of the rabbits *Semitendinosus*, *Semimembranosus*, and *Biceps femoris* were mixed and blended with a domestic blender (Binatone, BLG-621, China), to determine the proximate and mineral compositions. The crude protein, ether extract, moisture and ash contents were all determined according to the methods described by the AOAC (2000).

Bone to muscle ratio of the carcasses

Chilled carcasses were weighed with an electronic scale (Sartorius, CP 245S, Spain), and were deboned. The muscles and bones were weighed separately.

Fatty acid profile analyses

Oil extraction and the GC–MS analyses of extracted fats were performed at the central laboratory of the Chemistry Department of the University of Cape Coast, Ghana. The *Longissimus thoracis et lumborum* muscles were comminuted and extracted with petroleum ether (40-60) in a Soxhlet apparatus for 8 hours. The extract was evaporated to afford a pale-yellow oil. The methods described by Opoku-Boahen and Barku (2007) were then adopted to determine the fatty acid composition of the meat.

Table 1: Proximate composition of the experimental feed.

Parameter (%)	Treatments					
	T1	T2	T3	T4	SED	P-value
Dry matter	86.36±0.06^{a}	86.04±0.02^{ab}	85.28±0.01^{b}	83.23±0.46^{c}	0.58	0.018
Protein	18.56±0.22^{b}	18.92±0.41^{b}	20.15±0.49^{a}	20.88±0.35^{a}	0.43	0.000
Ash	8.42±0.22^{a}	7.98±0.22^{ab}	6.17±0.15^{b}	5.48±0.19^{bc}	0.71	0.006
Ether extract	6.31±0.43^{c}	7.36±0.28^{c}	9.11±0.81^{b}	12.44±0.43^{a}	0.22	0.000
Fibre	8.49±0.68^{b}	8.98±0.06^{b}	9.03±0.44^{b}	11.86±0.15^{a}	0.33	0.004
CHO	53.55±1.54^{a}	52.73±0.96^{a}	49.80±1.88^{b}	47.02±1.43^{c}	0.71	0.001

Means in the same row with similar superscripts are not significantly different ($p<0.05$); SED: Standard Error of Difference; CHO: Carbohydrate.

The fatty acid compositions of palm kernel oil and wheat bran are shown in Table 2.

Table 2: Some important fatty acids in palm kernel oil and wheat bran.

Fatty acid	Palm kernel oil (Mancini et al., 2015)	Wheat bran (Jung et al., 2010)
Caproic acid (C6:0)	0.2	-
Caprylic acid (C8:0)	3.3	-
Capric acid (C10:0)	3.5	-
Lauric acid (C12:0)	47.8	-
Myristic acid (C14:0)	16.3	-
Palmitic acid (C16:0)	8.5	17.0 – 18.2
Stearic acid (C18:0)	2.4	-
Oleic acid (C18:1)	15.4	14.2 – 15.9
Linoleic acid (C18:2)	2.4	54.2 – 60.0
Arachidic acid (C20:0)	0.1	-

The saturation (S/P) and atherogenic index (AI) were computed using the formula of Ulbricht and Southgate (1991), as follows:

$$Saturation\ (S/P)=(C14:0+C16:0+C18:0)/\Sigma MUFA+\Sigma PUFA$$

$$AI=[C12:0+4(C14:0)+C16:0)]/[\Sigma MUFA+\Sigma(n-6)+\Sigma(n-3)]$$

Where; PUFA and MUFA are polyunsaturated and monounsaturated fatty acids, respectively.

Statistical analysis

Data obtained from the study were analysed using the Analysis of Variance (ANOVA) component of the Minitab Statistical Package (Minitab® Inc. version 17). Where significant differences were found, the means were separated using the Tukey pair-wise comparison, at 5% level of significance.

RESULTS AND DISCUSSION

Carcass and organ weights of the experimental rabbits, are presented in Table 3.

The weight of rabbits on diets in which wheat bran was replaced with up to 50% PKOR increased significantly. However, with higher PKOR inclusions (T4, 100% wheatbran replacement), there was a significant reduction in weight of animals. The higher growth rates observed in T2 and T3 animals might be due to the higher ($p < 0.05$) crude protein and crude fat contents of the PKOR-based diets (Table 1). The lower final weight of rabbits on the T4 diet, even though it had highest levels of crude protein and crude fats, might be due to the higher fibre contents of such diet, which might have reduced digestibility of the feed, hence less nutrient available to the animals for growth. Fats are reported to serve as good source of energy, and diets with higher energy and protein levels provide better growth (Pond et al., 1995).

Similarly, the dressing percentage of rabbits on the T2 and T3 diets were significantly ($p < 0.001$) higher than those on the T1 and T4 diets. The dressing percentages from this study were similar to the 58 – 59% reported by Bianospino et al. (2004), but were higher than the 45.3 – 50.2% recorded by Njidda and Isidahomen (2011) when

Table 3: Carcass and organ weights (g) of the experimental rabbits.

	Treatments					
Parameter	**T1**	**T2**	**T3**	**T4**	**SED**	**P-value**
Weight at slaughter	1926.20±84.21^{b}	1931.04±28.34^{b}	1977.10±94.66^{a}	1648.03±76.00^{c}	20.45	0.002
Warm carcass weight	1193.90±90.54^{c}	1204.60±40.00^{b}	1346.70±60.48^{a}	1032.44±20.56^{d}	15.68	0.008
Chilled carcass weight	1168.50±50.96^{b}	1186.58±38.00^{b}	1300.00±59.54^{a}	983.79±22.40^{c}	15.93	0.000
Head weight	138.77±10.48^{b}	144.90±12.67	158.33±11.34^{a}	155.00±6.23	4.70	0.005
Lungs weight	13.39±3.75	14.56±2.88^{b}	14.78±2.48	13.93±4.60^{a}	1.75	0.308
Heart weight	4.15±0.84	4.36±1.43	4.55±0.66	4.67±0.42	0.97	0.339
Kidney weight	11.15±0.89	10.67±1.90	10.44±1.92	10.11±2.40	1.37	0.399
Liver weight	57.77±1.28	56.98±2.24	56.22±2.45	55.34±3.56	3.53	0.778
Dressing %	61.98±2.03^{b}	69.74±1.73^{a}	68.11±2.41^{a}	62.64±1.48^{b}	2.06	0.000
Chilling loss %	2.13±0.21	1.50±0.03	3.47±0.63	4.71±0.33	0.34	0.440
Muscle weight	652.46±12.55^{c}	799.55±8.54^{b}	825.67±13.62^{a}	669.59±9.35^{c}	2.46	0.00
Bone weight	209.34±6.48	387.03±7.46	214.18±9.23	314.20±6.44	1.96	0.12
pH_{45}	6.65±0.62	6.63±0.12	6.52±0.45	6.59±0.05	0.41	0.108
pH_{u}	5.64±0.36	5.48±0.14	5.56±0.43	5.83±0.22	0.44	0.349

Means within the same row with different superscripts are significantly different ($p<0.05$); SED: Standard Error of Difference; pH_{45}: pH of carcass taken at 45 minutes after slaughter; pH_{u}: Ultimate pH taken after 24 hours of chilling carcasses.

Table 4: Proximate and Mineral compositions of the experimental carcasses.

	Treatments					
Parameters	**T1**	**T2**	**T3**	**T4**	**SED**	**P-value**
Proximate composition (%)						
Moisture	72.32±1.61	72.48±1.22	71.96±2.04	70.44±1.86	0.97	0.43
Ash	4.30±0.41	4.44±0.39	4.28±0.68	4.51±0.25	0.48	0.13
Crude protein	25.34±2.02	24.46±2.33	27.52±3.16	27.94±2.74	1.70	0.13
Ether extract	7.76±0.66^{b}	8.90±0.74^{b}	10.24±1.21^{a}	11.46±1.24^{a}	0.64	0.00
Fibre	0.62±0.24	0.58±0.11	0.54±0.41	0.51±0.20	0.14	0.30
NFE	27.36±2.15	27.10±1.96	25.83±2.08	25.46±1.63	1.38	0.10
Mineral content of the meat (mg/100g)						
Iron	6.20±0.55	5.91±0.33	5.16±0.63	5.68±0.38	0.069	0.179
Zinc	3.99±0.03	4.18±0.45	4.26±0.41	4.35±0.38	0.156	0.617
Potassium	346.73±10.43	349±10.11	353.06±12.27	363.66±13.46	0.224	0.142
Copper	2.26±0.34	2.38±0.19	2.57±0.46	3.04±0.42	0.069	0.202
Sodium	58.30±3.12	57.00±3.43	54.65±4.28	53.43±5.35	0.201	0.073
Phosphorus	79.33±7.28^{b}	80.60±4.41^{b}	88.28±9.64^{a}	89.27±3.54^{a}	0.269	0.019
Calcium	5.07±0.24	4.98±0.73	5.09±0.41	5.13±0.33	0.21	0.948
Magnesium	21.05±1.32	21.48±0.64	22.00±2.37	22.42±2.89	0.08	0.017

Means in the same row with different superscripts are significantly different ($p<0.05$); SED: Standard Error of Difference; NFE: Nitrogen Free Extract.

rabbits were fed with diets containing sesame seed meal. Fielding (1991) reported dressing percentages of rabbits between 50–60 %. Differences in dressing percentages might result from differences in parts which are considered edible. In the present study, the head formed part of the carcass, because the head of rabbits is a delicacy in Ghana (personal communication). Other studies may not include the head to the carcass, and that might result in lower dressing percentages. That notwithstanding, higher dressing percentage is advantageous to meat processors and consumers, because it implies higher proportion of meat to non-meat parts. The slaughter weights in this study were expected to be lower than those reported by Njidda and Isidahomen (2011), because feed used in the latter had

higher crude protein and fat contents than in the former study. In addition, the rabbits in the previous study, were slaughtered at older ages (15–19 weeks old), compared to the 14 weeks in the current studies. The higher slaughter weights of rabbits in the current study could imply that the local breeds of rabbits in Ghana have the ability to perform well, if managed properly.

Organ weights in this study, were not different ($p > 0.05$) among animals on the various treatments. According to Teye et al. (2015), disease condition in animals is manifested in changes in size/shape, weight and/or colour of visceral organs of animals. The similarity in weights of organs of rabbits in the current study could imply that PKOR did not have any adverse effects on the health of the rabbits, similar to earlier findings using similar feed ingredients (Nuamah et al., 2019).

Muscle weights of the T2 and T3 animals were higher ($p < 0.05$) than the T1 and T4 animals. This is welcoming to consumers, because for every kilogram of meat purchased, it is expected that the proportion of muscles to bones would be higher (Warriss, 2010).

The pH of the carcasses was not affected ($p > 0.05$) by the experimental feed. The pre-rigor pH (pH_{45}) of all the carcasses were however, higher than 6.0, whiles the pH_u were lower than 6.0. Muscle glycogen reserves are converted to lactic acid post-mortem, and this reduces the pH of carcasses to values below 6.0 (Lawrie and Ledward, 2006). The lower pH of such muscles contributes to better storability, due to unfavourable conditions created for bacterial activities by the acidic medium (Warris, 2010).

The proximate and mineral compositions of meat of the experimental rabbits are presented in Table 4.

The moisture, ash and crude protein contents of the meat were similar ($p > 0.05$) among animals on the various treatments. Ether extract contents were however, higher ($p < 0.05$) in the meat of animals on the PKOR-based diets. This could be ascribed to the higher fat content of the PKOR-based diets (Table 1), which provided additional source of energy, hence the excess energy provided was stored in the body as fats (Warris, 2010). Fat in meat plays important roles in improving juiciness, tenderness and flavour (Teye et al., 2011).

The mineral contents of the meat were similar ($p > 0.05$) across treatments. Phosphorus content was however, higher ($p < 0.05$) in meat of animals fed with the PKOR-based diets. Potassium was the most abundant of the minerals detected in this study (Table 4). The Potassium levels were however, quite higher than the 347±0.26 mg/100g levels detected in earlier studies by Moreiras et al. (2004). Sodium levels recorded in this study, were similar to those reported by Niinivaara and Antila (1973); Combes (2004) and Hermida et al. (2006), who reported levels of 60, 47 and 49 mg/100g in rabbit meat, respectively.

The fatty acid composition of the *Longissimus thoracis et lumborum* muscles of the experimental rabbits, is presented in Table 5.

Contrary to expectations, the levels of C16:0 was significantly higher in the fats of animals fed the conventional diets, than those on the PKOR-based diets. Though palm kernel oil (PKO) has some palmitic acid (Mancini et al., 2015), the level in PKO are lower than in wheat bran (Table 2). This might have contributed to the higher levels of C16:0 in the fats of animals on the T1 diets. The saturated fatty acids C6:0, C8:0 and C10:0 were detected in fats of animals fed the PKOR based diets, but not in those on the control diets. Similarly, Myristic acid (C14:0) was higher in the fat of the PKOR-fed animals, than in the fats of rabbits on the conventional feed. Such saturated fatty acids were detected in palm kernel oil (Mancini et al., 2015), but not in wheat bran, and hence could have been deposited in the fats of animals on the PKOR diet. It was realised that the mono-unsaturated fatty acid C18:1 was high in the fats of animals on the T1 diets. However, this fatty acid was in the trans state, whiles that of rabbits on the PKOR diet exhibited the cis configuration. The reasons behind such observation could however, not be established in the present study. That notwithstanding, the total saturated fatty acid content of fats of the PKOR-fed animals was lower than that of animals fed the conventional diet (contrary to expectation). This observation could partly be due to the higher levels of C16:0 in wheat bran, compared with PKO (Chow, 2007). Though there was higher number of saturated fatty acids in the fats of animals fed the PKOR diets, the levels of these were lower than that of C16:0 present in the fats of animals on the T1 diet. Such long-chain fatty acids (C16:0) are reported to have greater likelihood of being deposited in the adipose tissues of non-ruminant species (Chow, 2007; Gondret et al., 1998), and that could have accounted for their presence in the fats (Musa, 2009). That notwithstanding, the inclusion of PKOR in the diets, significantly ($p < 0.05$) reduced the saturated fatty acid C16:0, and consequently reduced ($p < 0.05$) the total saturated fatty acid (SFA) content of the meat.

Meat of rabbits fed with the PKOR-based diets had significantly higher ($p < 0.05$) polyunsaturated fatty acids (PUFA), and n – 6/n – 3 fatty acid ratios. However, the saturation (S/P) and Atherogenic Index (AI) were lower in fats of the PKOR-fed animals. These observations were similar to findings of Peiretti and Meineri (2008), who observed significantly lower ($p < 0.05$) SFA levels, S/P

Table 5: Fatty acid composition of *Longissimus thoracis et Lumborum* muscles of the experimental rabbits.

	Treatments				
Fatty acid	T1	T2	T3	T4	P-value
C6:0	-	0.13±0.00	0.11±0.02	0.11±0.04	0.435
C8:0	-	0.24±0.02	0.23±0.01	0.24±0.00	0.089
C10:0	-	2.03±0.03	2.01±0.06	2.00±0.05	0.095
C12:0	7.13 ± 0.01	16.98±0.15	17.26 ± 0.02	17.18±0.34	0.056
C14:0	0.53 ± 0.03^{b}	1.54±0.05^{a}	1.56 ± 0.09^{a}	1.57±0.06^{a}	0.002
C16:0	34.21 ± 0.14	1.26±0.06	1.33 ± 0.02	1.31±0.03	0.061
C17:0	1.41 ± 0.02^{b}	4.29±0.04^{a}	4.31 ± 0.01^{a}	4.09±0.05^{a}	0.000
C17:1	0.36 ± 0.01	3.39±0.06	3.41 ± 0.03	3.51±0.00	0.076
C18:0	-	9.59±0.15	9.88 ± 0.13	9.77±0.23	0.780
C18:1	16.84 ± 0.06^{a} (E)	0.06±0.00^{b} (Z)	0.08 ± 0.06^{b} (Z)	0.08±0.02^{b} (Z)	0.000
C18:2 (n - 6)	0.79 ± 0.00^{b}	5.05±0.18^{a}	5.07 ± 0.02^{a}	5.05±0.03^{a}	0.001
C18:3 (n-3)	0.16±0.02	-	-	-	
C20:3 (n-3)	-	0.41±0.03	0.38±0.01	0.40±0.02	0.880
C20:4 (n – 3)	1.25 ± 0.12	2.16±0.22	2.02±0.10	2.09±0.24	0.077
C22:4 (n-6)	0.36±0.08	0.83±0.03	0.77±0.16	0.81±0.02	0.081
ΣSFA	43.48±0.28^{a}	36.06±0.57^{b}	36.69±0.33^{b}	36.27±0.66^{b}	0.000
ΣMUFA	17.20 ± 0.08^{a}	3.45±0.26^{b}	3.49 ± 0.12^{b}	3.59±0.19^{b}	0.002
ΣPUFA	2.56 ± 0.06^{b}	8.45±0.37^{a}	8.24 ± 0.16^{a}	8.35±0.09^{a}	0.000
ΣPUFA (n - 3)	1.41 ± 0.04^{b}	2.57±0.09^{a}	2.40 ± 0.08^{a}	2.49±0.02^{a}	0.004
ΣPUFA (n - 6)	1.15 ± 0.02^{b}	5.88±0.05^{a}	5.84 ± 0.08^{a}	5.86±0.04^{a}	0.000
n – 6/n – 3	0.82 ± 0.01^{b}	2.29±0.03^{a}	2.43 ± 0.06^{a}	2.53±0.02^{a}	0.001
Saturation (S/P)	1.76 ± 0.01^{a}	1.04±0.02^{b}	1.09 ± 0.00^{b}	1.06±0.01^{b}	0.004
Atherogenic index	2.12 ± 0.02^{a}	1.37^{c}	1.72 ± 0.01^{b}	2.07^{ab}	0.000

Means in the same row with different superscripts are significantly different; SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; PUFA (n – 6): polyunsaturated fatty acid series n – 6; PUFA (n - 3): polyunsaturated fatty acid series n – 3; S/P: saturated fatty acid/unsaturated fatty acid.

Table 6: Sensory characteristics of meat from the experimental rabbits.

	Treatments					
Parameter	T1	T2	T3	T4	SED	P-value
Colour	2.64 ±0.60^{b}	2.88±0.30^{b}	3.96 ±0.20^{a}	4.05±0.10^{a}	0.13	0.034
Off-odour	1.80 ± 0.70	1.80±0.40	1.91 ±0.30	1.86±0.70	0.12	0.061
Tenderness	2.35 ± 0.90^{b}	2.89±0.40^{ab}	3.94±0.10^{a}	4.16±0.30	0.63	0.028
Juiciness	3.04±0.30^{d}	3.60±0.90^{c}	4.16±0.60^{b}	4.43±0.10^{a}	0.46	0.033
Rabbit flavour intensity	4.32±0.40	4.41±0.50	4.51±0.10	4.53±0.10	0.69	0.160
Overall acceptability	3.69±0.60^{b}	3.71±0.80^{b}	4.38±0.50^{a}	4.19±0.20^{a}	0.12	0. 010

Means with different superscripts are significantly different; SED: Standard Error of Difference.

and Atherogenic index in meat of rabbits supplemented with *Salvia hispanica* seed meal. According to Cobos et al. (1993), inclusion of oils derived from soybean, sunflower and rapeseed to rabbit rations, increased the proportion of unsaturated fatty acids, resulting in higher degree of unsaturation in the meat.

Findings from this study agree with those of Ayerza et al. (2002); Peiretti et al. (2007); Peiretti and Meineri (2008), who fed oil seeds or their by-products to rabbits, and observed reduced saturated fatty acid levels in the meat. According to Oliver et al. (1997), the use of vegetable fats in rabbit feed, increases the unsaturation of depot lipids and reduce the n – 6/n – 3 ratios (Dal Bosco and Castellinni, 1998).

In the present study, the n – 6/n – 3 fatty acid ratios increased from 0.82 in fats of animals fed the conventional diets, to 2.43 in the fats of those fed the PKOR-based diet. These ratios are usually used to describe the dietary value

of fats, and the lower the ratio, the better the value (Peiretti and Meineri, 2008). These findings imply that, though the PKOR inclusion increased the levels of unsaturated fatty acids in the meat, the value or quality of the fats reduced. It was realised that the S/P ratios of fat in the meat of animals in all treatments, were beyond the 0.45 recommended for balanced diets by the Department of Health and Social Security (1994).

The Atherogenic Index was lower in rabbits fed with the T2 and T3 diets, than those on the control and T4 diets. Such findings are similar to those of Peiretti et al. (2007); Peiretti and Meineri (2008). Several research findings reported that meat containing higher levels of unsaturated fatty acids is beneficial in prevention of atherosclerosis and coronary heart diseases (Wolfram, 2003; Russo, 2009). Long-term diets containing monounsaturated fatty acids have also been reported to reduce platelet aggregation and decrease plasma LDL-cholesterol levels (Smith et al., 2003). Unsaturated fatty acids have been reported to play essential roles in the body, hence higher levels are advantageous to consumers (Tabas, 2002).

The sensory characteristics of meat from the experimental rabbits are presented in Table 6.

The off-odour and rabbit flavour intensity of the meats were not significantly ($p > 0.05$) different among the treatments. Colour was however, significantly ($p < 0.05$) different, with meat of animals on the control diets appearing darker than those on the PKOR-based diets. This observation might be due to the relatively higher fat contents of meat of animals on the PKOR-based diets. Fatty meat appears relatively pale than lean mean from the same species (Lawrie and Ledward, 2006). The tenderness and juiciness of meat from animals on the PKOR-based diets were rated higher ($p < 0.05$). These could be attributed to the higher fat contents of the meat of rabbits on the PKOR-based diets, as several studies reported increased juiciness and tenderness in meat which have higher fat contents (Berry and Wergin, 1993; Troy et al., 1999). Fat in meat plays a major role in improving water holding capacity and binding properties, forming rheological and structural properties that trap moisture in the products to improve juiciness (Hughes et al., 1997; Pietrasik and Duda, 2000; Teye et al., 2012). The improved juiciness and tenderness of the meat of rabbits fed with the PKOR-based diets, probably resulted in the significantly ($p < 0.05$) higher overall liking of such meat.

CONCLUSIONS

Rabbits fed with diets in which PKOR was used to replace up to 50% of wheat bran in their feed, had higher live weights at slaughter, higher warm and chilled carcass weights, and also higher dressing percentages than those fed with conventional diets ($p < 0.05$). In addition, the meat of rabbits fed PKOR-based diets had higher fat content and higher muscle weights. Moreover, the use of PKOR in the feed of rabbits resulted in significantly higher ($p < 0.05$) polyunsaturated fatty acids (PUFA), and higher degree of unsaturation (S/P). The n – 6/n – 3 fatty acid ratios and Atherogenic Index (AI) were however lower in the fats of animals fed diets in which PKOR replaced up to 50% of wheat bran. Again, meat of the PKOR-fed animals was more tender, juicier and had higher overall liking. PKOR can therefore be used to substitute up to 50% of wheat bran in rabbit rations for improved carcass yield, and higher levels of unsaturation of the fatty acids in the meat.

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AUTHORS CONTRIBUTION

Moses Teye, V.Y.A. Barku and Julius K. Hagan designed the study. Moses Teye was in charge of feeding the animals and meat analysis, as well as drafting and finetuning of manuscript. VYA Barku was in charge of the proximate and fatty acid profile analysis of the study. Julius Hagan was in charge of data analyses and proofreading of the manuscript.

CONFLICT OF INTEREST

The authors declare that they have no competing interest, so far as this study is concerned.

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