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Egg production, economic indices, and external and internal egg quality parameters of laying Japanese quails (*Coturnix japonica*) fed palm (*Elaeis guineensis*) kernel cake

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SUMMARY

The feeding trial aimed to evaluate the economic benefits of using palm kernel cake, a by-product of palm oil production, in the diets of laying Japanese quails, and its effect on egg production and quality parameters. Two hundred (200) nine-week-old laying Japanese quails were randomized into 5 groups of 10 birds each, replicated 4 times, in a six-week trial. Palm kernel cake (PKC) was included at 0%, 10%, 20%, 30% and 40% in the feed for the quails. Analysis of the chemical composition of the PKC revealed that it had 91,50% dry matter; 15,78% crude protein; 18,01% crude fibre; 12,27% ether extract; 1,49% ash; 43,95% nitrogen-free extract and 12,66 MJ kg^{-1} metabolizable energy. All egg production parameters were significantly affected (P ≤ 0,05) by PKC inclusion. The results of the study showed a significance influence on feed cost/kg, feed cost per crate, profit per crate, and egg-to-feed-price ratio (P ≤ 0,05), as well as shell percentage, yolk + albumen weight, albumen weight, yolk height, yolk colour, and yolk index. In conclusion, dietary PKC can be included at up to 40% of the diet of laying Japanese quails with no negative effect on laying performance, which improves the cost-benefit ratio, shell percentage, albumen weight and percentage, and yolk index; however, the yolk colour becomes lighter with increased PKC inclusion.

KEY WORDS: egg, Japanese quail, palm kernel, egg qualities, economic indices

INTRODUCTION

Japanese quails (*Coturnix japonica*) are most often reared for their eggs. These eggs are rich in quality protein and have high biological value, and thus can be used to improve consumption of animal protein (Ojediran et al., 2018), especially in developing countries. Moreover, they reach sexual maturity quickly (NRC, 1991), laying the first egg at 35 days of age (Hemid et al., 2010).

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However, as with all livestock, the performance of quails depends on the feed provided. Formulating feeds to meet National Research Council (NRC) recommendations is the norm, but in the face of rising prices of conventional feedstuffs, livestock farmers are focusing on increasing income, profit maximization, and economic alternatives (Ojediran et al., 2018). Teguia and Beynen (2004) emphasize that in the search for alternatives allowing farmers to remain competitive by decreasing production costs, it is still important to provide consumers with quality products.

Several factors influence the laying potential of birds, including breed, weather conditions, and housing, but nutrition plays a crucial role (Ekine and Oruwari, 2012). That study also confirmed the earlier findings of Summers (2000) that the source of oil in feed influences hen-day production and egg weight. Isika et al. (1999), demonstrated that the addition of palm oil to the diet of pullets increases egg production.

Palm kernel cake (PKC), a co-product from deoiling of the *Elaeis guineensis* nut, is copious in the tropics. The nutritional composition of PKC varies, and the residual oil content is dependent on the oil extraction method (Adesehinwa, 2009; Sharmila et al, 2014, Ojediran et al., 2020). PKC has been classified as a feedstuff with moderate levels of energy, protein and fibre (Adesehinwa, 2007; 2009; Kim et al., 2016; Sathitkowitchai et al., 2018). PKC is used in livestock feeds for cattle (Alimon, 2004), cockerels (Bello et al., 2011), broilers (Alshelmani et al., 2021), and swine (Adesehinwa, 2009; Ojediran et al., 2020), but knowledge of the use of PKC in quail diets, especially in the laying phase, is scarce. Therefore, this study examined the cost benefits of the use of palm kernel cake in the diet of quails and its effects on egg production and external and internal egg quality parameters.

MATERIAL AND METHODS

Ethics approval

The feeding protocol met the guidelines of the Animal Science code and was approved by the Animal and Research Ethics Committee of the Department of Animal Nutrition and Biotechnology, Ladoke Akintola University of Technology, approval number ANB/20/20/4309-21P.

Experimental site

The dietary trial was performed at the Poultry Unit of the Ladoke Akintola University of Technology Research Farm, Ogbomoso, Nigeria (4°16' E, 8°10' N. The height above sea level ranges from 300 and 600 m, with an average annual temperature of about 27°C and 1247 mm of rainfall in the derived savanna zone (Ojedapo, 2013).

Management of the experimental quails

Two hundred (200) laying Japanese quails at the age of nine weeks were chosen based on their uniformity and acclimated to a conventional layer quail diet before being grouped into five sets of 10 layers each, replicated four times. The feeding trial spanned six weeks. Palm kernel meal was incorporated in the diet at 0%, 10%, 20%, 30% and 40%. The ingredients were ground in an attrition mill before mixing. The diets were designated Diet 1 (PKC0), Diet 2 (PKC10), Diet 3 (PKC20), Diet 4 (PKC30), and Diet 5 (PKC40) (Table 1).

Table 1

Gross formulation of experimental diets

Ingredients (%)	Diet				
	1 (PKC0)	2 (PKC10)	3 (PKC20)	4 (PKC30)	5 (PKC40)
Maize	50,00	42,00	38,00	33,25	27,00
Soybean meal	12,00	11,00	11,00	12,00	15,00
Groundnut cake	26,00	25,00	20,00	15,75	10,00
Maize bran	4,25	4,25	3,25	1,25	0,25
Palm kernel cake	-	10,00	20,00	30,00	40,00
Bone meal	2,00	2,00	2,00	2,00	2,00
Limestone	4,85	4,85	4,85	4,85	4,85
Lysine	0,15	0,15	0,15	0,15	0,15
Methionine	0,25	0,25	0,25	0,25	0,25
Premix	0,25	0,25	0,25	0,25	0,25
Salt	0,25	0,25	0,25	0,25	0,25
Total	100,00	100,00	100,00	100,00	100,00
Calculated composition					
ME (MJ kg^{-1})	11,69	11,45	11,39	11,31	11,18
Crude protein	21,65	21,95	21,18	21,02	21,05
Ether extract	4,04	4,23	4,34	4,47	4,54
Crude fibre	3,28	4,82	6,20	7,57	9,01
Calcium	2,30	2,32	2,33	2,34	2,30
Available phosphorus	0,40	0,40	0,40	0,40	0,41
Lysine	0,999	0,99	0,96	0,96	1,00
Methionine	0,54	0,55	0,56	0,57	0,59
Cost kg^{-1} (₦)	122,52	106,38	98,83	96,59	91,79

ME - Metabolizable energy, ₦ - Naira

Parameters determined

Egg production parameters, economic indices, and external and internal egg quality parameters were determined. Egg production parameters (feed intake, number of eggs produced, egg weight, hen-day production, daily feed consumption per crate of eggs produced, and feed cost per crate of eggs produced) were recorded daily. Ten eggs were collected for external and internal parameters on two consecutive days from each replicate, weighed using a sensitive digital scale, and evaluated as described by Ojediran et al. (2018). Egg length and width were measured using a digital vernier calliper. Each egg was broken carefully and emptied onto a flat surface. The albumen and yolk height were measured using a tripod micrometer. Yolk length was measured using a digital vernier calliper.

The eggshell was dried using tissue paper and weighed. Eggshell thickness was measured together with the shell membranes using a micrometer screw gauge. The weights of the egg, yolk, albumen and shell were measured using an electronic digital scale. The Roche colour fan was used to score the yolk. The economic indices were calculated as described by Ojediran et al. (2018).

Analysis

The proximate analysis was determined using AOAC (2012) procedures, and the metabolizable energy was estimated using the equation proposed by Pauzenga (1985). The data were statistically analysed by one-way ANOVA using SPSS for Windows (SPSS v16). Significant differences between means were determined by Duncan's multiple comparison test using the same software at a ≤ 5% probability level.

RESULTS AND DISCUSSION

The chemical composition of palm kernel cake (PKC) is shown in Table 2.

Table 2

Chemical composition of palm kernel cake (PKC)

Parameter	Percentage (%)
Dry matter	91,50
Crude protein	15,78
Crude fibre	18,01
Ether extract	12,27
Ash	1,49
Nitrogen free extract	43,95
Metabolizable Energy [$MJkg^{-1}$]	12,66

Palm kernel cake is comparable to other defatted oil seeds such as copra cake, with moderate crude protein content, but has the advantage of being readily available and cheap (Sundu et al., 2006). The nutritional composition of the PKC was similar to that described by Ojediran et al. (2020), possibly because they were from the same source. The efficiency of the sheller used to separate the shell and the kernel contributes to the level of fibre in PKC (Adesehinwa, 2007). Boateng et al. (2008) attributed the ether extract fraction to the oil extraction method employed. The metabolizable energy is comparable to that reported by Adesehinwa (2007), which suggests that the oil extraction methods were similar.

Table 3 presents the egg production of layer quails offered different levels of palm kernel cake. All the parameters were significantly influenced ($P \leq 0,05$) by the diets except average egg weight, TFI:TEP, and feed consumed per crate. Average daily feed intake increased linearly. Birds fed diets 1-3 were not different ($P > 0,05$), but differed from those fed other diets ($P \leq 0,05$). The total eggs produced and hen-day production had a similar linear increase ($P \leq 0,05$), with the highest value recorded for quails fed diet 5 ($P \leq 0,05$). The ratio of total feed intake to total eggs produced was reduced in quails offered PKC feeds compared with those fed the control. The feed consumed per crate of eggs in birds given PKC diets was comparable to the value for those fed diet 1. The egg weights of birds fed diets 1-4 were not significantly different (P > 0,05). However, they were significantly different (P ≤ 0,05) from quails receiving diet 5, which laid heavier eggs.

Table 3

Egg production of layer quails fed varying levels of PKC

Parameters	1	2	3	4	5	SEM	P-value
ADFI (g/b/d)	25,41^{c}	25,30^{c}	25,76^{c}	28,43^{b}	31,41^{a}	0,65	0,01
TEP	186,00^{b}	176,00^{b}	191,00^{b}	204,00^{b}	306,50^{a}	14,97	0,05
HDP (%)	51,81^{b}	41,90^{b}	45,48^{b}	50,62^{b}	72,98^{a}	3,38	0,05
AEW (g)	9,60	10,06	10,26	9,35	10,70	0,26	0,53
TFI:TEP	61,98	65,01	56,85	60,32	43,06	3,21	0,23
FCON30 (kg)	2,07	2,17	1,89	2,01	1,44	0,11	0,22
AEMASS	4,97^{b}	4,41^{b}	4,66^{b}	4,79^{b}	7,81^{a}	0,43	0,03

a, *b* – means with different superscripts in the same row are significantly different.
SEM – Standard error of mean, ADFI –Average daily feed intake, TEP – Total eggs produced, HDP – Hen-day production, AEW – Average egg weight, TFI:TEP – Total feed intake: total eggs produced, FCON30 – daily feed consumption per crate produced, AEMASS – Average egg weight; Diet 1 = PKC0, Diet 2 = PKC10, Diet 3 = PKC20, Diet 4 = PKC30, Diet 5 = PKC40.

Chong et al. (2008) observed increased feed intake in layers as PKC inclusion increased. Sundu et al. (2006) attributed such an increase to the energy level of the PKC used. The increase in dietary crude fibre was similar to that reported by Duarte et al. (2013), who included soybean hulls in diets for laying quails, raising the crude fibre level from 2,788% to 8,683%. In contrast to the feed intake in this study, they observed non-significant feed intake. However, the authors claimed that laying Japanese quails could tolerate higher fibre owing to their larger caecum than that of chickens, as well their morphologically more developed mucosa. Dias et al. (2020) stated that soluble fibre types such as β-glucans, arabinoxylans and pectins, found in barley and oats, wheat and rye, and fruits and sugar beet pulp, respectively, increase intestinal viscosity and reduce the rate of feed passage, thereby reducing the feed intake and absorption rate (Jiménez-Moreno and Mateos, 2013).

In contrast, the insoluble fibre types predominant in oat and sunflower hulls exert different effects on the gastrointestinal tract (Jha et al., 2015; González-Alvarado et al., 2010). They have been found to affect upper tract chyme retention, enhance gizzard functions, stimulate endogenous enzyme production, and improve the digestibility of starch, lipids, and other dietary components (Mateos et al., 2012). Consequently, PKC has lower soluble fractions. Ubaoji et al. (2020) showed that the contents of insoluble fractions of lignin, hemicelluloses and cellulose in PKC were 15,09%; 4,79%;

14,60% and 63,83%, respectively. This may explain why Mateos et al. (2012) stated that the fibre level needed for optimum response in quails is unknown and contingent on the fibre source, age of the bird, and characteristics of the fibre components. Therefore the elevated feed intake observed as the PKC levels increased in the diets was favoured by the age of the laying quails and particle size. Also, the insoluble fibre fractions in PKC played a role in digesta viscosity and gut motility, resulting in increased feed intake.

The increase in total eggs produced and hen-day production as the PKC level increased supports the earlier report by Isika et al. (1999) that 5% Elaeis guineensis oil included in the diet of pullets increases egg production. Ekine and Oruwari (2012) confirmed the earlier findings of Summers (2000) that the source of oil in feed influences hen-day production and egg weight. This suggests that the ether extract remaining in the PKC after oil extraction influenced egg generation, hen-day production and egg weight. March et al. (1990) had demonstrated earlier that linoleic acid, which is abundant in palm kernel cake, mediates egg production and size. This advantage was also confirmed in our study in the ratio of feed intake to eggs produced, feed consumed per crate of eggs, and egg weight. However, crude protein content may have played a role in the production parameters, as Manju et al. (2015) observed reduced egg turnout with 16% CP, while Ojediran et al. (2018) reported heavier eggs at 19% CP with 0,99% lysine compared to lower CP diets, despite higher lysine supplementation. The profitability of a layer flock is dependent on its output of eggs and their quality (Monira et al., 2003). According to Hrncar et al. (2014), egg weight is the most important quality parameter for the consumer, while Ojediran et al. (2018) showed that all egg production parameters are important to the farmer.

Table 4 shows the economic indices of layer quails fed varying levels of palm kernel cake. The results of the study showed that feed cost per kg (FC/kg), feed cost per crate (FC/30), profit per crate, and egg feed price ratio (EFPR) differ significantly ($P \leq 0,05$). The feed cost decreased from diets 1 to 5 as PKC inclusion increased, ranging from 122,52 in diet 1 to 91,79 in diet 5. The feed cost per crate was reduced in quails fed PKC diets compared to those offered the control diet ($P \leq 0,05$), which translated to increased profit per crate. Birds fed diets 2-5 were significantly more profitable than those given diet 1 ($P \leq 0,05$). The EFPR increased with PKC inclusion: 1,76; 2,06; 2,39; 2,36 and 3,37 for diets 1-5, respectively.

Table 4

Economic indices of layer quails fed varying levels of PKC

Parameter	1	2	3	4	5	SEM	P-value
Feed cost/kg (₦)	122,52^{a}	106,38^{b}	98,83^{bc}	96,59^{bc}	91,79^{c}	3,13	0,00
Feed cost/ 30 (₦)	253,14^{a}	229,69^{a}	187,04^{ab}	192,91^{ab}	131,73^{b}	13,77	0,02
Profit/ 30 (₦)	246,86^{b}	270,31^{b}	312,96^{ab}	307,09^{ab}	368,27^{a}	13,77	0,02
Egg feed price ratio	1,76^{b}	2,06^{b}	2,39^{b}	2,36^{b}	3,37^{a}	0,16	0,00

a, b – means with different superscripts in the same row are significantly different.
SEM – Standard error of mean, / 30 – per crate of eggs produced, ₦ – Naira, Diet 1 = PKC0, Diet 2 = PKC10, Diet 3 = PKC20, Diet 4 = PKC30, Diet 5 = PKC40.

The reduction in feed cost can be attributed to the lower price of PKC. Thus, increasing the level of PKC translated to a decrease in the cost of feed (Ojediran et al., 2020). According to Adesehinwa (2009), feed should not be chosen only for its lower price; the cost reduction must be accompanied by optimum production performance. The aim of using an alternative feed resource in this study was achieved, because FC/30 decreased with the use of PKC. This was in contrast to the report of Ojediran et al. (2018), where the use of low-crude-protein diets fortified with lysine did not influence FC/30 eggs produced. An increased profit per crate of eggs is therefore not unexpected, since the FC/kg and FC/30 of eggs produced was reduced. An egg feed price ratio of 1.4 and above has been considered good (Sujatha et al., 2014).

Table 5 shows the external egg quality parameters of layer quails fed varying levels of PKC. The eggshell percentage differed significantly ($P \leq 0{,}05$), unlike other parameters. The eggshell percentage of birds fed diets 2 and 4 differed ($P \leq 0{,}05$), while the values for those fed other diets were intermediate between them. According to Ojediran et al. (2018), eggshell strength and thickness are important quality traits because they enhance protection of the internal contents. Santos et al. (2011) attributed changes in external egg parameters to age, maturity, nutrition, genetic composition, and environmental differences. Egg quality affects the price (Monira et al., 2003) because it determines consumer acceptability (Dudusola, 2010).

Table 5

External egg quality parameters of layer quails fed varying levels of PKC

Parameters	1	2	3	4	5	SEM	P-value
Egg length (cm)	3,19	3,19	3,15	3,17	3,19	0,01	0,78
Egg width (cm)	1,69	1,69	1,68	1,66	1,67	0,01	0,52
Shell weight (g)	2,07	1,64	1,67	2,00	1,83	0,14	0,14
Shell thickness (mm)	0,70	0,69	0,69	0,69	0,69	0,51	0,51
Shell percentage (%)	$17{,}93^{ab}$	$14{,}67^{b}$	$15{,}48^{ab}$	$18{,}58^{a}$	$16{,}01^{ab}$	0,56	0,02
Egg shape index	52,81	53,02	53,27	52,48	52,42	0,19	0,66

a, b – means with different superscripts in the same row are significantly different.
SEM – Standard error of mean, Diet 1 = PKC0, Diet 2 = PKC10, Diet 3 = PKC20, Diet 4 = PKC30, Diet 5 = PKC40

Internal egg parameters of layer quails fed varying levels of PKC are shown in Table 6. Mean yolk and albumen weight (internal contents), albumen weight, yolk height, yolk colour, albumen percentage, and yolk index differ significantly ($P > 0{,}05$). The average yolk + albumen weight and albumen weight had a similar pattern. Birds offered diets 2 and 5 did not differ significantly, but differed significantly from those given diets 3 and 4, while the values for those fed diet 1 were intermediate. The yolk height was lowest ($P > 0{,}05$) in quails offered diets 3 and 4 and highest in those given diet 2 ($P \leq 0{,}05$), while the values for quails offered diets 1 and 5 were intermediate. The yolk colour decreased linearly with increasing PKC ($P \leq 0{,}05$). The albumen percentage values were 54,34; 58,71; 57,19; 53,82 and 55,73 for birds fed diets 1-5, respectively. The yolk index of quails receiving diets 1, 3 and 4 was lower ($P \leq 0{,}05$) in comparison with those supplied diet 2 ($P \leq 0{,}05$).

Egg weight is important to both the producer and the consumer in economic terms. Quail eggs are much lower in weight than a standard chicken egg, which weighs around 60 g (Genchev, 2012). The egg weight recorded in our study is comparable to that obtained by Gonzalez (1995). The average albumen weight of quail eggs ranges between 4,9 and 5,0 g; i.e. about 53,5-59,5% of the total egg weight, while the egg yolk weighs about 4,3-4,5 g (Salawu et al., 2007) and largely determines the nutritive value of the egg as a whole. The relative proportion of yolk is 31-37% of the egg's weight (Panda and Singh, 1990). The albumen weight and thus the albumen percentage were greater than in reports by Wan et al. (2013) and Okon et al. (2020). This can be attributed to the protein content in the diets. Lower albumen height suggests low viscosity, which can be due to poor storage condition or the age of birds (Genchev, 2012). The non-significant values for albumen height in this study can be attributed to the short waiting time before analysis. The yolk height observed was lower than that observed by Udoh et al., (2020). The yolk index and Haugh unit recorded in the study were higher than that reported by Gonzalez (1995) for Japanese quails, which according to Imai et al. (1986) and Genchev (2012) is indicative of good quality. Yolk colour in quail eggs is not affected by genotype (Hrncar et al., 2014) but by diet composition (Ojediran et al., 2018). PKC in the amount of up to 40%, as demonstrated in this trial, does not adversely affect the yolk index or Haugh unit, which are important positive internal quality parameters of eggs, according to Adeogun and Amole (2004).

Table 6

Internal egg parameters of layer quails fed varying levels of PKC

Parameters	1	2	3	4	5	SEM	P-value
Egg weight (g)	10,54	11,17	10,78	10,77	11,40	0,13	0,14
Yolk + albumen weight (g)	$9,47^{ab}$	$9,53^{a}$	$9,11^{ab}$	$8,80^{b}$	$9,58^{a}$	0,11	0,01
Albumen weight (g)	$6,27^{ab}$	$6,56^{a}$	$6,17^{ab}$	$5,81^{b}$	$6,36^{a}$	0,09	0,05
Albumen percentage (%)	$54,34^{c}$	$58,71^{a}$	$57,19^{ab}$	$53,82^{c}$	$55,73^{bc}$	0,56	0,01
Yolk weight (g)	3,20	2,97	2,94	3,00	3,22	0,07	0,62
Yolk percentage (%)	27,74	26,62	27,32	27,86	28,28	0,56	0,93
Albumen height (cm)	4,97	5,02	4,84	4,78	5,08	0,05	0,19
Yolk height (cm)	$0,71^{ab}$	$0,76^{a}$	$0,70^{b}$	$0,70^{b}$	$0,74^{ab}$	0,01	0,05
Yolk length (cm)	2,26	2,22	2,19	2,22	2,24	0,01	0,57
Yolk colour	$5,07^{a}$	$4,72^{ab}$	$4,72^{ab}$	$4,36^{b}$	$4,00^{c}$	0,10	0,00
Yolk index	$0,32^{b}$	$0,34^{a}$	$0,32^{b}$	$0,32^{b}$	$0,33^{ab}$	0,00	0,05
Yolk:albumen	0,51	0,45	0,48	0,52	0,51	0,01	0,55
Av Haugh unit	92,17	92,78	92,06	91,79	92,78	0,18	0,30

a, b – means with different superscripts in the same row are significantly different.

SEM – Standard error of mean, Diet 1 = PKC0, Diet 2 = PKC10, Diet 3 = PKC20, Diet 4 = PKC30, Diet 5 = PKC40

CONCLUSIONS

This study demonstrated that up to 40% PKC in the diets of laying Japanese quails had no harmful effect on laying performance, enhanced the cost-benefit ratio, and improved shell percentage, albumen weight, and yolk index, but the yolk colour became lighter with increased PKC inclusion.

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