# EFFECTS OF PARTIAL REPLACEMENT OF MAIZE WITH CASHEW KERNEL MEAL ON THE GROWTH AND REPRODUCTIVE PERFORMANCE OF LAYER PULLETS AND SEMEN CHARACTERISTICS OF COCKERELS

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**ABSTRACT**
***The effects of partially replacing maize with cashew kernel meal (CKM) on the growth and subsequent laying performance of 13-week-old pullets and semen quality traits of cockerels were investigated. CKM was initially incorporated into a grower diet at 0, 2.5, 7.5, and 12.5 % replacing equal amounts of maize. A total of 240 Lohmann Brown pullets and 32 cockerels were randomly but equally allotted to diets which were in quadruplicate lots in a completely randomised design. Each replicate included 15 pullets and two cockerels; the grower phase lasted till the 20th week after which they were transferred to layer diets containing the same levels of CKM. The layer phase was terminated at week 45. Parameters measured included body weight changes, feed intake, feed conversion ratio, and the economics of production. With respect to the laying phase, the following were also studied: age at first egg, weight of first egg, mean egg weight, hen-day egg production, cost per kg eggs, fertility and hatchability of eggs. Semen quality traits studied included semen volume, sperm concentration, sperm morphology, sperm motility and vitality. In the grower phase, the feeding of CKM had no significant (p>0.05) effect on daily weight gain although the final live weight increased up to the level of 7.5% CKM. During the layer phase, CKM had no significant (p>0.05) effect on feed conversion ratio, while feed intake increased up to 7.5% CKM while cost/kg diet declined influence on any of the parameters measured except the cost per kg feed which declined as CKM levels increased. CKM did not influence (p>0.05) any of the semen quality traits studied. The results showed that CKM could be incorporated up to 7.5% in grower diets and up to 12.5% in layer diets with no adverse effect on growth, egg production and reproductive performance of layers and cockerel semen quality traits.***

**Keywords:** *cashew kernel meal**;** sperm penetration holes; hatchability; fertility; spermatozoa*

## INTRODUCTION

The high cost and frequent shortages of conventional feed ingredients like maize, fishmeal and soybean meal are the major problems facing the sustainability of the poultry industry in Ghana as in many other developing economies. In the past several years, animal nutrition research has therefore focused on the development and exploitation of locally available and cheaper alternative feed resources that could replace the more conventional ingredients and help to bring down costs (Tona, 2018). These so-called unconventional feed resources include agro-industrial by-products such as cashew nut testa, cassava peels and rice bran (Donkoh *et al*., 2012; Ghomsi *et al*., 2017; Fang *et al*., 2018; Pangeran *et al*., 2021).

The large-scale cultivation of cashew as a cash crop in Ghana has resulted in the production of nuts for both local consumption and export (Oddoye *et al*., 2012). According to Ricau (2019), Ghana produced 115,000 MT of raw cashew nuts in 2018. During the processing of cashew nuts for human consumption, about 30% of the kernels are rejected and discarded as wastes because they are either broken or burnt (Oddoye *et al*., 2012). Nonetheless, these rejected cashew kernels are rich in nutrients and thus may be used as an alternative feed resource in non-ruminant diets. Odunsi (2002) reported a high-energy content of cashew kernel meal and, recommended its use as a substitute for maize. Fanimo *et al*. (2004) similarly reported that cashew kernels (CKM) contained 21.5% protein and 45.5% percent ether extract. Sogunle *et al*. (2006) reported higher weight gain for broiler chicks fed on a diet containing cashew kernel meal than those on the control diet. According to Fernandes *et al*. (2016), the kernels contain high energy and protein and may be substituted respectively for maize and soyabean meal in diets for meat quails to reduce cost and increase profitability.

Oluwasola (2006) partially replaced soyabean meal (SBM) protein in broiler diets with equi-protein amounts of discarded cashew nut meal (DCNM) protein and reported that DCNM significantly improved final weight and weight gain and fat retention in muscles compared to birds receiving no DCNM. Yusuf and Aliyu-Paiko (2020) studied the effects of dietary cashew nut meal on the performance and blood biochemical characteristics of broilers and reported that diets containing 2% CNM, significantly improved growth rate compared to broilers on the control diet or on the diet having 4% CNM ($P<0.05$) although blood biochemical parameters were not affected. They also observed a significant increase in the contents of antioxidant enzymes including superoxide dismutase, and catalase. However, there is limited information on the effect of CKM on the growth and reproductive performance of layers. Semen quality is critical to the full realization of the reproductive performance of female chickens. Therefore, the objective of the experiments was to assess the effects of CKM on the growth of pullets and the subsequent reproductive performance of layers as well as the semen quality parameters of cockerels,

## MATERIALS AND METHODS

The experiment was carried out at the Poultry Section of the Department of Animal Science, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana. The experimental procedures employed in this study were carried out according to the approved animal experiment protocol issued by the Animal Research Ethics Committee (AREC), KNUST.

### Processing of cashew kernel meal

The cashew kernels used for the study were purchased from Mim Cashew Processing Industry in the Ahafo Region of Ghana. The kernels were ground in a hammer mill with a sieve mesh size of 3 mm and air-dried for five days to produce CKM.

### Proximate analysis of CKM

CKM was analysed for its proximate fractions following AOAC (1990). Dry matter (DM) was determined using a convection oven at 105$^o$C (AOAC 930.15 and 925.10), gross energy (GE) by bomb calorimetry (Leco Corporation, St Joseph, MI, USA) and nitrogen (N) using the Dumas total combustion method (AOAC 968.06). Crude protein (CP) content was calculated as N x 6.25. The ash content was measured by placing samples in a furnace at 550$^o$C (AOAC 942.05), and ether extract (EE) were determined by the Soxtec extraction method (AOAC 991.36), and crude fibre (CF) determine following AOAC method 985.29.

### Experimental design, birds and management

The trial was divided into grower and layer phases and diets were formulated to meet NRC

(1994) requirements. Cashew kernel meal was added to the grower diet at 0, 2.5, 7.5 and 12.5% and replaced an equal amount of maize (Table 1). Grower birds were fed from week 13 to week 19. Each treatment was replicated four times with each replicate having 15 pullets and two cockerels. At 20 weeks of age, the birds were offered layer diets containing the same level of CKM as in the pullet phase. Tables 1 and 2 show the respective dietary compositions and calculated nutrient contents of the experimental diets. Lohmann Brown pullets and cockerels were obtained from a local hatchery (Akate Farms and Trading Company Limited, Kumasi, Ghana) and were allocated to the treatments in a completely randomized design (CRD). Birds were weighed individually before allocation to ensure that the mean weight for experimental birds was 946.0±2 g for each replicate lot. Birds were housed in open-sided deep litter pens allowing a floor space of 0.20 $m^2$. The floors were covered with wood shavings to a depth of 5 cm at the time of placement. Feed and water were provided *ad libitum* throughout the experimental period.

**Parameters measured**

Parameters measured included feed intake, weekly weight gain (live weight, daily average weight gain, feed conversion efficiency and cost of gain), while reproductive traits included egg

**Table 1: Composition and calculated nutrient content of grower diet on percent dry matter basis**

| Ingredient | Quantity (kg) | | | |
|---|---|---|---|---|
| | 0% CKM | 2.5% CKM | 7.5% CKM | 12.5% CKM |
| Maize | 62.4 | 59.9 | 54.9 | 49.9 |
| Cashew Kernel Meal (CKM) | - | 2.5 | 7.5 | 12.5 |
| Wheatbran | 12.0 | 12.0 | 12.0 | 12.0 |
| Fishmeal | 11.0 | 11.0 | 11.0 | 11.0 |
| Maize bran | 11.0 | 11.0 | 11.0 | 11.0 |
| Oyster shell | 0.95 | 0.95 | 0.95 | 0.95 |
| Dicalcium phosphate | 1.65 | 1.65 | 1.65 | 1.65 |
| Vitamin premix[1] | 0.5 | 0.5 | 0.5 | 0.5 |
| Common salt | 0.5 | 0.5 | 0.5 | 0.5 |
| Total | 100 | 100 | 100 | 100 |
| ***Calculated Nutrient composition*** | | | | |
| Dry matter | 86.34 | 86.40 | 86.5 | 86.66 |
| Crude protein (%) | 15.20 | 15.34 | 15.62 | 15.89 |
| Metabolisable energy ($kcalkg^{-1}$)[2] | 2756 | 2796 | 2874 | 2953 |
| Crude fibre (%) | 3.66 | 3.68 | 3.71 | 3.75 |
| Calcium (%) | 1.18 | 1.26 | 1.33 | 1.40 |
| Available phosphorus (%) | 0.38 | 0.38 | 0.38 | 0.37 |
| Lysine (%) | 0.77 | 0.86 | 1.05 | 1.24 |
| Methionines (%) | 0.34 | 0.37 | 0.43 | 0.49 |
| Cystine (%) | 0.60 | 0.62 | 0.67 | 0.69 |
| Ether extract | 4.22 | 5.10 | 6.86 | 8.61 |

[1] *Vitamin premix contributed per kg diet: Vitamin A (103IU); Vitamin D3 (2.0 IU); Vitamin E (10.0 IU); Vitamin K3 (1.5 mg); Vitamin B2 (10mg); Vitamin B12 (0.5mg); Folic acid (0.6mg); Nicotinic acid (5 mg); Calcium panthotenate (4mg); Choline (0.078mg).*

[2]*ME was calculated using NRC (1994) values for the various ingredients*

production rate (hen-day egg production), fertility and hatchability of eggs, sperm penetration and semen quality traits. Birds were weighed at the beginning of the trial and then at two weeks' intervals. The onset of laying and weight of the first eggs on each dietary treatment was recorded. Weekly egg production, egg weight and feed consumption were recorded on replicate basis. The prevailing market prices of the ingredients at the time of the study were used to calculate the cost of 1 kg of feed and the cost of feed consumed.

Feed intake was measured as the difference between feed supplied to a replicate and feed leftover at the end of each day was recorded as daily feed intake per replicate. These were added up at the end of each week to give weekly consumption values. The weekly consumption value was then divided by the number of birds to obtain the average weekly feed consumption. Birds were weighed using a box on top-pan balance at the start of the experiment and also at weekly intervals. Weight measured at the end of the earlier week was deducted from that of the present week to get the weight picked up for the week. The week after week body weight gain was then divided by the number of birds in a replicate to get mean week body weight gain per bird per replicate. Feed conversion ratio was calculated as the amount of feed intake divided by the amount of gain. Hen-day egg production was calculated as the number of eggs produced in a day divided by the number of birds alive on that day multiplied by 100. Cost of 1kg of feed was calculated as the total cost of ingredient in 100 kg the diet divided by 100. The cost of feed consumed per bird was calculated by multiplying the feed consumed in kg by cost of 1 kg of feed.

**Table 2: Composition and calculated nutrient content of layer diet on percent dry matter basis**

| Ingredient | Quantity (kg) | | | |
|---|---|---|---|---|
| | 0% CKM | 2.5% CKM | 7.5% CKM | 12.5% CKM |
| Maize | 63.5 | 61 | 56 | 51.0 |
| Cashew kernel meal (CKM) | - | 2.5 | 7.5 | 12.5 |
| Wheatbran | 4.0 | 4.0 | 4.0 | 4.0 |
| Fishmeal | 12.5 | 12.5 | 12.5 | 12.5 |
| Soyabean meal | 8.5 | 8.5 | 8.5 | 8.5 |
| oyster shell | 8.0 | 8.0 | 8.0 | 8.0 |
| Dicalcium phosphate | 2.5 | 2.5 | 2.5 | 2.5 |
| Vitamin premix[1] | 0.5 | 0.5 | 0.5 | 0.5 |
| Common salt | 0.5 | 0.5 | 0.5 | 0.5 |
| Total | 100 | 100 | 100 | 100 |
| ***Calculated Nutrient composition*** | | | | |
| Dry matter | 81.14 | 81.2 | 81.29 | 81.39 |
| Crude protein (%) | 18.07 | 18.2 | 18.5 | 18.8 |
| Metabolisable energy (kcalkg$^{-1}$)[2] | 2751 | 2790 | 2869 | 2947 |
| Calcium (%) | 4.17 | 4.20 | 4.37 | 4.35 |
| Available phosphorus (%) | 0.52 | 0.52 | 0.52 | 0.51 |
| Lysine | 1.04 | 1.13 | 1.33 | 1.50 |
| Methionine (%) | 0.40 | 0.43 | 0.49 | 0.55 |
| Cystine (%) | 0.70 | 0.72 | 0.76 | 0.79 |
| Crude fibre (%) | 2.31 | 2.32 | 2.36 | 2.39 |
| Ether extract | 3.75 | 4.63 | 6.384 | 8.14 |

[1]*Vitamin premix contributed per kg diet: Vitamin A (103IU); Vitamin D3 (2.0 IU); Vitamin E (10.0 IU); Vitamin K3 (1.5 mg); Vitamin B2 (10mg); Vitamin B12 (0.5mg); Folic acid (0.6mg); Nicotinic acid (5 mg); Calcium panthotenate (4mg); Choline (0.078mg).*
[2]*ME was calculated using NRC (1994) values for the various ingredients*

**Fertility and hatchability**

The collection of eggs for incubation and hatching began three weeks after the onset of laying (birds were 24 weeks old) and subsequently at three-week intervals. Eggs were collected for seven days each week but only eggs weighing between 50 and 60 g were selected for hatching. In addition, the following eggs were rejected: dirty, misshapen, cracked and thin-shelled. The same number of eggs was selected from each treatment. They were set large-end-up in a Pas Reform incubator (Pas Reform, Zeddam, Netherlands) for 21 days at a temperature and relative humidity of 37.7$^{O}$C and 65%, respectively. Eggs were candled on day 18 of incubation to remove infertile ones (transparent to the naked eye). Fertile eggs were then transferred to the hatcher and chicks were removed on day 21 in the morning (10 hr local time). % fertility was calculated as:

$$\frac{\textit{Total number of fertile eggs}}{\textit{Total number of eggs set}} \text{ x } 100$$

% Hatchability of fertile eggs was calculated as:

$$\frac{\textit{Total chicks hatched}}{\textit{Total number of fertile eggs}} \text{ x } 100$$

**Sperm penetration assay**

Sixteen (16) hatchable eggs were selected randomly from each treatment, weighed, opened and a portion of the perivitelline layer removed as described by Hamidu *et al*. (2010) and used to perform the sperm penetration assay (Bramwell *et al.,* 1995) with some modifications: the yolk was separated from the albumen on an egg separator placed over a beaker (Hamidu *et al*., 2010), rotated gently with tissue paper over the separator until the blastoderm became visible. A white litmus paper was cut to cover a portion of the perivitelline layer over the germinal disc region overlaying the yolk. The perivitelline layer was cut around the litmus paper, lifted gently at about 45$^{o}$ angle, and allowed yolk residue to drain out. The cut perivitelline layer was rinsed in a sodium chloride solution and straightened on a microscope slide. It was fixed with 4% formalin and stained with gentian violet to darken the intact portion of the outer layer. The layer was then rinsed with ordinary water and viewed under a Leitz HM Lux 3 electronic microscope (Leitz, Wetzlar, Germany) and the sperm holes were counted.

**Semen collection and evaluation**

Sixteen cockerels comprising four birds from each treatment were randomly selected, housed in different pens, and used for semen collection and quality assessment. Their abdominal area was shaved and the cocks were allowed seven days to adapt to the abdominal massage method (Burrows and Quinn, 1935) before actual semen collection. A single ejaculation of semen was collected with a graduated test tube from each cockerel two times a week. Semen colour was visually assessed and placed under three colour categories: 1 for creamy white, 2 for milky (between opaque and creamy white) and 3 for opaque (Peters *et al*., 2008). Semen volume was read off the graduated test tube. Drops of semen samples were placed on chromatographic paper and compared with colours on a universal indicator chart to determine their pH.

Sperm motility was assessed by placing a drop of semen on a slide, covered using a coverslip and viewed under an electronic microscope at 100x magnification (Birkhead *et al*., 1999). The hemocytometer method described by Brillard and McDaniel (1985) was used to determine spermatozoa concentration. The technique involved mixing 0.05 ml of semen and sodium bicarbonate solution at a dilution ratio of 1:200 with an eosin solution. The diluted semen was poured into the Neubauer counting chamber, coverslipped, viewed and counted under an electronic microscope. Sperm concentration was calculated using the formula, Sperm concentration = No. of sperm in 0.1 mm$^3$ x 4 x 16 x 200 x 1000 ml. Total sperm count was calculated by multiplying sperm concentration by semen volume. Eosin-nigrosin staining was used to differentiate dead sperm from live ones: 200 spermatozoa were counted to determine the percentage of live spermatozoa.

**Statistical Analysis**

All data collected were subjected to analysis of variance using the generalized linear model procedure of SAS (2013) with fixed effect of dietary treatments. Differences between the treatment LS means were separated by the probability difference method (PDIFF) of SAS (2013) at $p<0.05$.

## RESULTS AND DISCUSSION

**Proximate composition of cashew kernel meal**

Chemical analysis showed that cashew kernel meal contained 14.2% crude protein, 39% crude fat, 2.7% crude fibre, 1.0% ash and 34.1% Nitrogen Free Extract (NFE). The crude fat content is comparable to the values reported by Odunsi (2002), Ojewola *et al.* (2004), Aremu *et al.* (2006) and Akande *et al.* (2015) and reinforces the belief that CKM can be a high-energy ingredient for poultry. This is buttressed by higher calculated gross energy for CKM (5005 kcal/kg) compared with 3430 kcal/kg for maize meal. The CP was rather low compared to value of 38.12% obtained by Ojewola *et al.* (2004) and 25% by Aremu *et al.* (2006); nevertheless, it suggests that CKM can also be at least a moderate source of protein. The low fiber content indicates that non-starch polysaccharides may not be important in determining the nutritive value of CKM for monogastric animals. Variations in processing methods, duration of storage, age at harvest, and the soil type for crop cultivation may lead to differences in the nutrient composition of feedstuffs (Madeni *et al*., 2017).

**Performance of birds during the grower phase**

The performance of pullets on grower diets is summarized in Table 4. The mean initial weights of birds did not differ among treatments and averaged 946.0 g. The final live weight was however significantly increased ($p<0.05$) in birds fed the 7.5 % CKM diet (1. 47 kg as against 1. 40 kg for control birds) while there was no difference between the control and birds on either the 2.5 or 5.0% CKM diets. The superior weight of birds on the 7.5% CKM could be attributed in part to their high feed intake as well as their higher feed conversion efficiency even though this was not significantly different ($p>0.05$) from the other birds. Akande *et al.*

**Table 4: Growth performance of birds during 13-19 weeks**

| Production index | 0% CKM | 2.5% CKM | 7.5% CKM | 12.5% CKM | SEM | *p value* |
|---|---|---|---|---|---|---|
| Initial weight, g | 946.25 | 945.5 | 945.5 | 944.75 | 2.008 | 0.9625 |
| Final weight/b, g | $1403^{b}$ | $1420^{b}$ | $1469^{a}$ | $1409^{b}$ | 0.019 | 0.0415 |
| Total weight gain/b, g | 456.5 | 474.1 | 524.1 | 464.1 | 0.280 | 0.0529 |
| Daily weight gain/b, g | 10.88 | 11.28 | 12.48 | 11.05 | 0.392 | 0.0532 |
| Weekly feed intake/b, g | $460.54^{ab}$ | $476.96^{a}$ | $479.29^{a}$ | $448.9^{b}$ | 5.836 | 0.009 |
| Daily feed intake/bird, g | $65.78^{ab}$ | $68.14^{a}$ | $68.47^{a}$ | $64.13^{b}$ | 0.834 | 0.0095 |
| Feed conversion ratio (FCR) | 6.073 | 6.018 | 5.493 | 5.80 | 0.156 | 0.0834 |
| Cost of 1kg feed, GH¢ | $1.08^{a}$ | $1.07^{b}$ | $1.06^{c}$ | $1.05^{d}$ | 0.000 | 0.0001 |
| Cost of weekly intake/bird, GH¢ | $0.50^{a}$ | $0.51^{a}$ | $0.51^{a}$ | $0.47^{b}$ | 0.005 | 0.0007 |

*Values with superscripts within the same row differed significantly from each other (P<0.05).*
*SEM: standard error of the mean*

(2015) working with layers and Oluwasola (2006) working with broilers observed significantly lower weight in birds on the control diet than those fed CKM-based diets. Odunsi's (2002) work, however, showed only a non-significant decrease in weight with increasing levels of CKM. CKM at either 5.0 or 7.5% of the diet significantly increased feed consumption while the 12.5% CKM decreased feed intake ($p<0.05$). Ojewola *et al*. (2004) and Aroyeun (2009) attributed the higher feed intake to improved feed palatability. The reduced consumption of the 12.5% CKM diet might be due to the higher energy content of the diet due to the relatively higher energy contribution by the highest inclusion rate of CKM. This could have reduced feed intake since chickens eat to satisfy their energy requirements (Leeson *et al*., 1997). The feeding of CKM did not have any effect on the efficiency of feed utilization ($p>0.05$).

The addition of CKM to grower diets resulted in a significant ($p>0.05$) decrease in the cost of a kilogram of feed averaging approximately 2% less than the cost of the control diet. A similar observation was made by Oddoye *et al*. (2012). Odunsi (2002) and Ojewola *et al*. (2004) also recorded an insignificant decrease in feed cost with the incorporation of CKM. The reduced feed per kg cost was due to the relatively lower unit cost of CKM compared to maize which it replaced. On the other hand, the total feed cost was higher for birds receiving the 2.5 and 7.5% CKM diets since they consumed significantly more feed.

**Performance of birds during the layer phase**

During the layer phase, CKM had no significant effect ($p>0.05$), whether adverse or positive, on any of the parameters studied except for cost per kilogram feed which decreased as CKM levels increased. Age at first egg, weight of first egg, mean egg weight and hen-day egg production tended to increase with increasing CKM up to 7.5% while feed per kg eggs decreased. Results differ from those of Akande *et al*. (2015) and Oyedeji *et al*. (2015) who reported a reduction in feed intake with increased CKM.

The onset of laying was slightly delayed in both

**Table 5: Production performance of birds during 20-30 weeks**

| Production index | 0% CKM | 2.5% CKM | 7.5% CKM | 12.5% CKM | SEM | *p value* |
|---|---|---|---|---|---|---|
| Weekly intake/bird, g | 657.13 | 664.98 | 659.86 | 645.99 | 9.669 | 0.576 |
| Daily feed intake/bird, g | 94.03 | 95.00 | 94.23 | 92.28 | 1.372 | 0.571 |
| Age at first egg, days | 150 | 146 | 147 | 150 | 1.497 | 0.144 |
| Weight of first egg, g | 40.23 | 46.05 | 46.20 | 44.81 | 2.903 | 0.456 |
| Mean egg weight, g | 54.24 | 55.40 | 55.90 | 56.34 | 1.986 | 0.888 |
| Weight gain /bird/day, g | 5.50 | 5.55 | 5.23 | 5.88 | 0.181 | 0.144 |
| Kg feed / Kg eggs | 2.78 | 2.65 | 2.63 | 2.67 | 0.097 | 0.680 |
| Hen-day egg production, % | 63.42 | 66.08 | 67.49 | 63.38 | 1.927 | 0.380 |
| Cost/Kg feed, GH¢ | $1.34^{a}$ | $1.33^{b}$ | $1.32^{c}$ | $1.31^{d}$ | 0.000 | 0.000 |
| Cost of weekly intake/ bird, GH¢ | 0.13 | 0.13 | 0.12 | 0.12 | 0.002 | 0.168 |
| Feed/egg, kg | 3.12 | 2.93 | 2.86 | 2.95 | 0.080 | 0.187 |

*Values with superscripts within the same row differed significantly from each other (P<0.05).*
*SEM: standard error of the mean*

the birds fed 0% and 12.5% CKM (150 days) compared to 2.5% and 7.5% CKM which recorded 146 and 147 days, respectively. However, pullets on the control diet attained sexual maturity (Table 6) by 150 days compared favourably with pullets reared on normal feed. The findings also agree with the results of Odunsi (2002), who recorded first egg ages of 149, 153, 154, 150 and 152 (days) for 0, 5, 10, 15 and 20 (% CKM), respectively. The general laying rate of birds fed the cashew kernel meal-based diets did not differ from those on the control diet. The result for hen-day production is slightly higher than Odunsi (2002), who reported values of 64.3, 63.4, 62.6, 62.7 and 61.3% for birds feeding on 0, 5, 10, 15 and 20% cashew kernel meal, respectively from week 21 to 28. The current result differed slightly from the result of Akande *et al.* (2015), who observed a significant difference across the treatments.

**Reproductive performance of birds**

A summary of reproductive data is shown in Table 5. The feeding of CKM had no significant influence on any of the reproductive parameters. Fertility of eggs ranged from approximately 89 to 91% and was only slightly lower than the values obtained in other studies (Fayeye *et al*., 2005; Wondmeneh *et al*., 2011). The lower fertility could be probably due to differences in breed, nutrition, and/or factors relating to the cocks and hens (Babatunde and Fetuga, 1976; Islam *et al*., 2002; Brillard, 2003). Both hatchability of fertile and total eggs set tended to decrease with increasing CKM. Hatchability values in this study were lower than those reported for Ethiopian local chickens (Wondmeneh *et al*., 2011). Fertility and hatchability are affected by both genetic and environmental factors including storage duration and temperature, relative humidity, nutrition, disease, and shell quality (King'Ori, 2011). Average day-old chick weighs ranged from 37.8 g for the control treatment to around 36 g for chicks hatched from eggs from CKM diets and compare well with Islam *et al.* (2002) who recorded values between 38 g and 39 g, for Barred Plymouth Rock, White Leghorn, Rhode Island Red and White Rock. Wondmeneh *et al*. (2011) reported chick weights of 30.2 g and 29.7 g respectively for Horro and Fayoumi strains. Chick weight as a percent of egg weight varied from 61 to 70 which is within acceptable values (Wilson, 2012). Chick weight is determined to a large extent by egg weight (Abiola *et al.,* 2008).

**Table 6: Reproductive performance of birds during 24-30 weeks**

| Production index | 0% CKM | 2.5% CKM | 7.5% CKM | 12.5% CKM | SEM | *p value* |
|---|---|---|---|---|---|---|
| Fertility, % | 88.57 | 90.82 | 88.56 | 90.48 | 1.603 | 0.6467 |
| Hatchability of total eggs, % | 70.57 | 68.7 | 64.94 | 61.79 | 2.660 | 0.1442 |
| Hatchability of fertile eggs, % | 77.75 | 77.72 | 73.38 | 68.40 | 3.351 | 0.2086 |
| Normal chicks, % | 99.32 | 98.67 | 99.37 | 97.85 | 0.787 | 0.5072 |
| Abnormal chicks, % | 0.68 | 1.33 | 0.63 | 2.15 | 0.787 | 0.5072 |
| Number of pips, % | 7.24 | 7.60 | 10.04 | 14.07 | 1.972 | 0.1055 |
| Dead-in-shell, % | 15.41 | 14.67 | 16.15 | 17.53 | 1.836 | 0.7290 |
| Chick weight, g | 37.75 | 35.71 | 36.13 | 36.19 | 2.085 | 0.9041 |
| Cockerels, % | 38.43 | 39.50 | 34.51 | 34.99 | 1.748 | 0.1656 |
| Pullets, % | 61.57 | 63.14 | 65.49 | 66.13 | 1.272 | 0.0884 |
| Mortality, % | 8.15 | 6.66 | 6.43 | 6.35 | 2.282 | 0.8850 |
| Survivability, % | 91.85 | 93.34 | 93.57 | 93.61 | 2.765 | 0.9633 |

*SEM = standard error of mean*

**Table 7: Effects of dietary treatment on semen parameters of cocks and sperm holes**

| Production index | 0% CKM | 2.5% CKM | 7.5% CKM | 12.5% CKM | SEM | *p value* |
|---|---|---|---|---|---|---|
| Cock weight | 2.81 | 2.81 | 2.97 | 2.83 | 0.060 | 0.1857 |
| Semen volume (ml) | 0.42 | 0.55 | 0.55 | 0.63 | 0.068 | 0.2022 |
| Semen pH | 7.18 | 7.28 | 7.26 | 7.35 | 0.071 | 0.4312 |
| Semen appearance | 2.17 | 2.25 | 2.42 | 2.58 | 0.212 | 0.5231 |
| Motile sperm (%) | 70.92 | 73.08 | 72.58 | 76.83 | 2.530 | 0.4135 |
| Sperm conc.($x10^9$) | 2.62 | 2.62 | 2.60 | 2.81 | 2.284 | 0.9058 |
| Total sperm count ($x10^9$) | 1.12 | 1.46 | 1.47 | 1.74 | 2.128 | 0.2405 |
| Live sperm (%) | 88.67 | 88.67 | 82.92 | 82.75 | 1.973 | 0.0546 |
| Dead sperm (%) | 11.33 | 11.33 | 17.08 | 17.25 | 2.604 | 0.4160 |
| Normal sperm (%) | 87.67 | 88.58 | 88.08 | 88.25 | 1.105 | 0.9485 |
| Abnormal sperm (%) | 12.33 | 11.42 | 11.92 | 11.75 | 1.105 | 0.9485 |
| Egg weight (g) | 56.48 | 57.64 | 57.19 | 57.90 | 0.871 | 0.6731 |
| Number of sperm holes | $66^b$ | $86^c$ | $38^a$ | $47^a$ | 6.574 | 0.0137 |

*SEM= standard error of mean*

Birds fed 7.5% and 12.5% CKM registered the lowest (*p< 0.05*) number of sperm holes (Table 7) although there no differences in the dead in shells. According to Hemmings and Birkhead (2015), oligospermic penetration of avian ovum adversely affects early embryo survival and that supernumerary sperm are essential to fertilization and early embryogenesis success. Birds fed CKM diets recorded a higher incidence of pipping. The percentage of saleable chicks and abnormal chicks (Table 5) from layers under the four treatments was not significantly different (*p>0.05*). The production of normal chicks in this study is slightly higher than the findings of Wondmeneh *et al*. (2011). Sex ratio was skewed in favour of females (approximately 63 females to 37 males) suggesting that embryonic mortality was higher in male chicks. This finding contrasts with the report of Li *et al.* (2008) who analysed the sex ratios of early-dead embryos of five breeds during the first week of incubation and reported an overall female-to-male sex ratio of 1.53:1. Chick mortality ranged from 6.4 to 8.2 percent but the differences were not significant (*p> 0.05*).

**Semen Parameters and sperm penetration holes**

Semen quality parameters and sperm penetration holes did not differ significantly (*p>0.05*) among cockerels on the various treatments (Table 6). Values obtained for semen quality traits in this experiment (semen volume, semen pH, semen appearance, sperm count, live: dead sperm, morphologically normal sperm) were within the acceptable range for artificial insemination (Hafez, 1987). This indicates that levels of CKM used in this experiment did not exert any deleterious influence on semen quality characteristics.

## CONCLUSION

From the results, it can be concluded that CKM can be incorporated in pullet diets up to 7.5% and up to 12.5% in laying hens and cockerel diets without any adverse effects on performance and reproductive and semen quality parameters.

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