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Original Research Article

Effect of varying dietary levels of *Aspilia africana* on performance, egg quality and microbial load of pullet chickens

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Abstract

The use of *Aspilia africana* as a nonconventional feedstuff to reduce the cost of feed has not been fully explored in poultry production. Therefore, an experiment was conducted on one hundred and ninety-two (192) twelve weeks old birds to determine the effect of *Aspilia africana* leaf meal (ALM) diet on the performance, egg quality and faecal microbial load. The birds were divided into four groups, each consisting of forty-eight birds. After a two-week acclimatisation, experimental diets that consisted of 0% (Diet 1), 10% (Diet 2), 20% (Diet 3) and 30% (Diet 4) ALM substitution of soybean were fed to the birds. Data on growth performance were collected in the first phase, whereas egg quality, laying performance and faecal count was examined in phase two of the experiment. The data collected were subjected to one-way analysis of variance and significant means were separated via Duncan Multiple Range Test (DMRT). The obtained results identified best ($p < 0.05$) outcome for growth performance and faecal bacterial load at 30% ALM inclusion in the diet. ALM offered at 20% was optimal for overall egg quality, though egg weight at first lay was superior in pullets fed 10% ALM diet. When consumer attraction to yolk colour is the criterion for purchase, preference for eggs from birds supplied 30% dietary ALM is expected.

Keywords: Nonconventional feedstuff; soybean; eggs; shell; albumen; yolk; *Staphylococcus aureus*

INTRODUCTION

Poultry consistently play a significant role in the improvement of protein consumption globally and Africa benefit significantly from poultry and its products. The poultry industry is a growing sector with potential to offset the dietary reference protein intake set at 0.8 gram/kg of body weight (Institute of Medicine, 2005). The Nigerian poultry sector comprises approximately 180 million birds, next to South Africa (Sahel, 2015) – with FAOSTAT (2017) yield report of 650,000 tonnes of eggs in 2013. Poultry – termed nutritious and cheapest protein among animal-based protein sources have chicken eggs as the increasingly common poultry supply bridge among consumers attributed to its quality known to be indiscriminately available to both the affluent and economically-challenged citizens without any religious bias.

The consistently increasing population drive up the demand of livestock products that present a challenge to meet the daily protein requirement. To sustain production and uninterrupted supply of animal protein, it is expedient to find suitable alternative feed sources to substitute (whole or part-replacement) the scarce and expensive (70% of the total cost of production) conventional feedstuffs such as maize, soybeans and fish meal (Sugiharto, 2019). The incessant rise in feed cost and the consequent depletion in animal protein supply have encouraged exploration of locally available yet cheap animal feed resources to forestall threat to the future of poultry production as well as promote growth (Runjaic-Antic et al., 2010; Obuzor and Ntui, 2011).

Leaf meals of some tropical plants are reportedly cheap sources of proteins, vitamins and minerals. *Amaranthus cruentus*, papaya and dried sweet potato vines are examples of such leaf meals (Fasuyi and Akindahunsi, 2009; Onyimonyi and Ernest, 2009; Tsega and Tamir, 2009), with crude protein content that ranges from 11.85% to 13.52% (Agbede et al., 2012). Beneficial effects of other leaf meals such as *Amaranthus, Tephrosia, Tithonia*, and *Centrosema* reportedly influence microbial growth and yolk coloring effects in eggs of laying birds (Oko et al., 2011).

Aspilia africana is a plant popularly found in the rain forest zone of West Africa reportedly known to compete vigorously with cultivated crops for nutrients. Oko and Agiang (2011) identified *A. africana* as a rich protein source. Adedeji et al. (2015) detailed the proximate composition of crude protein (20.65%), crude fibre (14%), ether extract (8%) and minerals (15%) present in the leaf meal. The nutritional profile of *A. africana* shows its potential use as a substitute of soymeal in the diet of laying hens with cost reduction as benefit.

Also, the medicinal value of *A. africana* is relevant in the treatment of various diseases in humans, rabbits and rats (Oko et al., 2011). Okoli et al. (2007) also showed that the extract from fractions of *A. africana* yielded varying impact on growth inhibition in clinical isolates of *Pseudomonas fluorescens* and *Staphylococcus aureus* as well as typed strains of *Pseudomonas aeruginosa* (ATCC 10145) and *Staphylococcus aureus* (ATCC 12600). Some of these clinical isolates were found in the faeces of pullets. The effect of *A. africana* as soybean substitute on growth-layer performance of egg-type chickens at the pullet – layer phase can give insight into the potential economic alleviation of feedstuff cost with the egg quality improved.

We hypothesised that the replacement of soyabean with *A. africana* will improve the laying performance, egg quality and reduce bacteria load of egg type chicken. Therefore, this study is designed to fill the knowledge gap on the influence of *A. africana* leaf meal on growth-laying performance, subsequent egg quality and microbial load of egg-type chickens.

MATERIALS AND METHODS

Experimental site

The experiment was carried out at the Institute of Food Security, Environmental Resources and Agricultural Research (IFSERAR), Federal University of Agriculture, Abeokuta (FUNAAB). The site lies within latitude 7°10”N, longitude 3°2”E and altitude 76 mm (Google Earth, 2018) with humid climate and mean annual rainfall of 1037 mm and temperature of about 34.7 °C from the Agrometeorological station (AGROMET) in FUNAAB.

Wild marigold (*Aspilia africana*) leaf meal preparation

Fresh wild marigold (*Aspilia africana*) plant leaves were harvested, spread on cemented floor and air-dried for three (3) days until it was crispy to touch. The dried leaves were milled and incorporated into compounded feed at designed levels of inclusion.

Chemical composition of the leaves

Dry matter, crude protein, acid detergent fibre, neutral detergent fibre, carbohydrate, fat, ash and total minerals were determined using the AOAC (1990, 2006) standard methods; see Table 1.

Table 1. The determined proximate analysis of *Aspilia africana*

Parameters	Leaf meal
Moisture (%)	18.27
Dry Matter (%)	81.73
Crude Fat (%)	1.16
Total Ash (%)	2.67
Crude Fibre (%)	9.78
Crude Protein (%)	10.67
Nitrogen-Free Extract (%)	57.25
Gross Energy (kcal/kg)	2783.6

Experimental birds and management

The study protocol was approved by Animal Welfare Committee guideline of the Federal University of Agriculture, Abeokuta, Nigeria (FUNAAB, 2013) FUNAAB (2013): Policy on Research of the Federal University of Agriculture, Abeokuta, Nigeria. http://www.unaab.edu.ng (05/06/2017).

One hundred and ninety-two, twelve-week-old, Isa Brown pullets were sourced from a reputable farm in Ibadan, Oyo State, Nigeria. The birds were housed in a battery cage system and given commercial feed for two weeks for post-purchase acclimatisation prior to the commencement of the experiment. Subsequently, at

Table 2. Composition (%) of the experimental diets for the post-acclimatisation grower phase

	Dietary levels of *Aspilia africana* Leaf Meal			
Feed Ingredient	**(Control)**	**(10%ALM)**	**(20%ALM)**	**(30%ALM)**
Maize	42.00	42.00	42.00	42.00
Wheat bran	23.00	23.00	23.00	23.00
Soybean Meal	15.10	13.59	12.08	10.57
Aspilia africana	0.00	1.51	3.02	4.53
Bone meal	2.00	2.00	2.00	2.00
Limestone	2.00	2.00	2.00	2.00
Lysine	0.20	0.20	0.20	0.20
Methionine	0.20	0.20	0.20	0.20
***Grower Premix**	0.25	0.25	0.25	0.25
Palm kernel cake	15.00	15.00	15.00	15.00
Salt	0.32	0.32	0.32	0.32
Total	100.00	100.00	100.00	100.00
Determined analysis				
ME (MJ/kg)	10.11	10.11	10.11	10.11
Crude Protein (%)	14.87	14.40	13.92	13.40
Calcium (%)	1.34	1.36	1.38	1.39
Crude fibre (%)	5.89	5.88	5.87	5.86
Methionine (%)	0.45	0.45	0.45	0.45
Lysine (%)	0.90	0.88	0.85	0.82
Available Phosphorus (%)	0.43	0.43	0.44	0.44

*Grower premix per kg: Vitamin A 8,000,000 IU; Vitamin D 32,000,000 IU; Vitamin E 14,000 IU; Vitamin K1,600 mg; Thiamine 600 mg; Riboflavin 2,000 mg; Niacin 7,200 mg; Pantothenic acid 2,800 mg; Vitamin B 6,800 mg; Vitamin B 12,5 mg; Folic Acid 600 mg; Biotin 2.8 mg; Choline Chloride 100,000 mg; Cobalt 200 mg; Copper 2,400 mg; Iodine 440 mg; Iron 8,000 mg; Manganese 32,000 mg; Selenium 80 mg; Zinc 20,000 mg; Antioxidant 50,000 mg.

fourteenth week of age, experimental diets (grower and layer, Tables 2 and 3) were compounded with dried leaf meal incorporated at both phases. The grower and layer phases each lasted for four weeks post-acclimatisation. Each of the four treatment groups was allotted to forty-eight pullets in four replicates of twelve (12) pullets each. At the 15th and 16th week, pullets were vaccinated against Newcastle and Infectious bronchitis disease.

Experimental diets

Four feed types that consist of soybean substituted with *A. africana* leaf meal were compounded for the experiment at both grower and layer phases. Feed type 1 (ALM 0%) which is the control diet, has no dried *A. Africana* leaf meal. Feed type 2 (ALM 10%), feed type 3 (ALM 20%) and type 4 (ALM 30%) had 10%, 20% and 30%, respectively, of soybean meal substituted with *A. africana.*

Growth performance

Feed intake and weight gain records were taken weekly using the method described by Adedeji et al. (2014), whereas feed conversion ratio (FCR) was obtained by calculation. The number of eggs laid daily was recorded, and feed consumption and average feed intake were monitored weekly throughout the period of the experiment.

The Hen/day production was calculated at the end of the experiment using the formula below:

$$\text{Hen/day production} = \frac{\text{No. of eggs}}{\text{No. of birds}} \times 100$$

Measurement of egg weight was done using a top loading electronic balance (Mettler Toledo PB 3002) to the nearest 0.01 g while egg length and egg width to the nearest 0.01 cm was measured with Vernier callipers. Shell thickness was measured using micrometre screw-gauge in millimetre (mm) while the shell weight was measured to the nearest 0.01 g using a sensitive scale.

The albumen height was measured to the nearest 0.01 mm at a midway point between the inner and outer edges of the thick albumen using tripod micrometre (Doyon et al., 1986)

The yolk was separated using an egg separator and each yolk was weighed with an electronic balance to the nearest 0.01 g. Yolk weight was recorded and expressed as a percentage of individual eggs. The

Table 3. Composition (%) of the experimental diets for pullets at the layer phase

	Dietary levels of *Aspilia africana* Leaf Meal			
Feed Ingredient	**(Control)**	**(10% ALM)**	**(20% ALM)**	**(30% ALM)**
Maize	50.00	50.00	50.00	50.00
Wheat bran	15.00	15.00	15.00	15.00
Soybean Meal	17.00	15.30	13.60	11.90
Aspilia africana	0.00	1.70	3.40	5.10
Bonemeal	2.50	2.50	2.50	2.50
Oyster shell	7.25	7.25	7.25	7.25
Lysine	0.20	0.20	0.20	0.20
Methionine	0.36	0.36	0.36	0.36
Grower Premix	0.25	0.25	0.25	0.25
Palm kernel cake	7.19	7.19	7.19	7.19
Salt	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00
Determined analysis				
ME (MJ/kg)	10.33	10.33	10.34	10.34
Crude Protein (%)	15.93	15.53	15.12	14.69
Calcium (%)	4.61	4.96	4.24	4.89
Crude fibre (%)	5.92	6.78	6.08	6.52
Methionine (%)	0.45	0.45	0.45	0.45
Lysine (%)	0.90	0.88	0.85	0.82
Available phosphorus (%)	0.43	0.43	0.44	0.44

*Layer premix per kg: Vitamin A 4,000,000 IU; Vitamin D 3,800,000 IU; Vitamin E 4,800 mg; Vitamin K 3,800 mg; Vitamin B 1600 mg; Vitamin B 22000 mg; Vitamin B 6,600 mg; Vitamin B 12,4 mg; Niacin 6400 mg; Folic Acid 240 mg; Biotin 8 mg; Antioxidant 40,000 mg; Choline Chloride 60,000 mg; Manganese 32,000 mg; Iron 16,000 mg; Zinc 24,000 mg; Copper 3200 mg; Iodine 400 mg; Cobalt 100 mg; Selenium 60 mg

albumen weight for each egg was calculated by subtracting the yolk and air-dried shell weights from the whole egg weight and expressed as a percentage of the whole egg. Yolk colour was scored for each egg yolk when compared with colours of the chips of the DSM yolk colour fan with colour intensity ranging from pale yellow (scored 1) to deep orange (scored 15). The weights of albumen, yolk and shell were divided by the whole weight of egg and subsequently multiplied by 100 to calculate the weight percentages (Romanoff and Romanoff, 1949). The Haugh Unit for each egg was calculated using the equation below:

$$H.U = 100\log(H - 1.7(W)^{0.37} + 7.6)$$

where:
H.U.....Haugh unit,
H ....height of the thick albumen (mm)
W ....weight of the individual egg in grams.

The egg shape index was determined via measurement described by Reddy et al. (1979) and Anderson et al. (2004).

Faecal microbial count

Ten (10) grams of faecal sample was collected aseptically from each replicate. The bulk of the droppings was collected by replicates using flat plastic plates spread under the cage. Wet portion needed was measured out using a sensitive scale to determine microbial count.

Statistical Analysis

Statistical analysis was performed using the analysis of variance (ANOVA). Birds were allotted into groups in a completely randomised design, whereas data obtained were subjected to a one-way analysis of variance. Significant ($p < 0.05$) means were separated by the Duncan's Multiple Range Test using SAS (2012) software package.

Statistical Model

$$Y_{ij} = \mu + T_i + e_{ij}$$

where:
Y_{ij} ....is the observed variable of interest
μ ....is the population mean
T_i ....is the effect of ith *A. Africana* in the diet
e_{ij} ....is the random residual errors

RESULTS

Growth performance of pullets offered grower mash containing *A. africana* leaf meal (ALM) is shown in

Table 4. Growth performance of pullets fed *Aspilia africana* Leaf Meal diet at the grower phase (weeks 14–18)

Dietary levels of *Aspilia africana* Leaf Meal					
Variables	**0%ALM**	**10%ALM**	**20%ALM**	**30%ALM**	**S.E.M.**
Initial weight (kg/b)	1.15	1.18	1.15	1.12	0.01
Final weight (kg/b)	1.44^{b}	1.50^{a}	1.45^{b}	1.47^{b}	0.01
Average weight gain (kg/b)	0.29^{b}	0.32^{ab}	0.30^{ab}	0.35^{a}	0.01
Average feed intake (kg/b)	2.39^{ab}	2.40^{ab}	2.47^{a}	2.36^{b}	0.02
FCR (feed/gain)	8.19^{ab}	7.58^{ab}	8.35^{b}	6.92^{a}	0.23

^{a,b}Means in the same row with different superscripts differ significantly (p <0.05).S.E.M. Standard error of the mean; FCR– Feed conversion ratio

Table 4. All indicators measured were significant excluding the initial weight of the pullets. Chickens supplied grower diet containing 10% ALM inclusion had the highest ($p < 0.05$) final live weight at week 18 when compared with least ($p < 0.05$) weight of other groups. Average weight gain and feed intake of pullets on 30% ALM diet was highest and lowest, respectively, at the end of week 18. On the other hand, average weight gain was least among groups given 0% ALM while highest weight gain, though similar ($p < 0.05$) to the two other groups on ALM (10% and 20% ALM) was recorded among chickens supplied 30% ALM diet. Feed conversion ratio was significantly ($p < 0.05$) best, although not statistically different from 0% and 10% ALM groups, for pullets fed 30% ALM diet at the expiration of week 18 of the pullets.

The laying performance and egg quality indicators of egg-type chickens on ALM diet are presented in Table 5. Hen-day was not influenced in laying pullets offered ALM diet. The weight of birds at 1st lay; average weight and width of eggs; egg albumen, yolk and shell weight of eggs as well as yolk colour were influenced ($p < 0.05$) by leaf meal inclusion in the diet of the chickens. On the contrary, age of birds and weight of eggs at 1st lay, average length and height of eggs, egg albumen, yolk and shell weight (%), egg shape index, shell thickness, and Haugh unit values were not significantly ($p < 0.05$) affected by ALM inclusion in the diet of pullet chickens.

The weight of birds at 1st lay for chickens fed ALM at 0 and 20% dietary inclusion levels had least ($p < 0.05$) weight at first lay as opposed to group offered 10% ALM diet that had the highest ($p < 0.05$) weight though comparable with 30% ALM inclusion. Minimum

Table 5. Laying performance and egg quality of birds fed *Aspilia africana* Leaf Meal diet (weeks 19–22)

Dietary levels of *Aspilia africana* Leaf Meal					
Variables	**0%ALM**	**10%ALM**	**20%ALM**	**30%ALM**	**S.E.M.**
Age at first lay (day)	131.938	135.188	133.063	136.50	1.23
Weight at 1st lay (kg/b)	1.44^{b}	1.50^{a}	1.43^{b}	1.45^{ab}	0.01
Weight of 1st egg (g)	42.83	45.29	42.00	42.64	0.86
Hen-day from wk 18–22 (%)	43.16	40.77	33.40	33.33	2.09
Average weight of egg (g)	44.58^{b}	44.72^{b}	51.05^{a}	46.79^{b}	0.77
Average length (mm)	50.60	46.41	51.88	49.63	0.94
Average Width (mm)	39.69^{ab}	37.71^{b}	41.86^{a}	39.74^{ab}	0.65
Egg Shape Index (%)	78.46	77.78	80.67	80.21	1.18
Shell weight (g)	4.70^{b}	4.80^{b}	5.52^{a}	4.68^{b}	0.13
Shell weight (%)	10.54	10.73	10.83	10.00	0.19
Shell thickness (mm)	0.61	0.55	0.54	0.53	0.01
Yolk weight (g)	9.38^{c}	9.94^{b}	11.06^{a}	10.13^{b}	0.17
Yolk weight (%)	21.06	22.25	21.67	21.66	0.20
Yolk colour	3.72^{b}	4.59^{ab}	2.21^{b}	6.45^{a}	0.54
Albumen height (mm)	8.73	9.53	9.13	9.96	0.27
Albumen weight (g)	30.51^{b}	29.98^{b}	34.48^{a}	31.98^{b}	0.55
Albumen weight (%)	68.42	67.03	67.51	68.35	0.29
Haugh unit	97.20	100.65	97.38	101.87	1.13

^{a,b,c}Means on the same row having different superscripts were significantly different ($p < 0.05$); Key: mm – millimetres, (%) – percentage; S.E.M. – Standard error of the mean

Table 6. Faecal bacterial load of egg-type chickens fed on *Aspilia africana* Leaf Meal diet

Dietary levels of *Aspilia africana* Leaf Meal					
Variables	**0%ALM**	**10%ALM**	**20%ALM**	**30%ALM**	**S.E.M.**
Total bacterial count (cfu/g)	1.10	1.40	1.80	1.45	0.12
***Escherichia coli* (cfu/g)**	0.20	0.30	0.53	0.45	0.37
***Streptococcus faecalis* (cfu/g)**	0.40	0.43	0.38	0.25	0.09
***Staphylococcus aureus* (cfu/g)**	0.30^{b}	0.52^{ab}	0.90^{a}	0.20^{b}	0.10
***Pseudomonas aeruginosa* (cfu/g)**	0.03	0.05	0.00	0.10	0.02
***Salmonella typhi* (cfu/g)**	0.18	0.10	0.00	0.18	0.04

^{a,b} Means on the same row having different superscripts were significantly ($p < 0.05$) different. ALM – *Aspilia africana* leaf meal; S.E.M. – Standard error of the mean;

and maximum egg average width was obtained from chickens supplied 10% and 20 % ALM diet, respectively. A similar trend was documented for albumen weight of eggs. Birds of other groups had least ($p < 0.05$) weight excluding chickens offered 20% ALM diet.

Egg yolk weight of egg-type chickens fed the control diet was significantly ($p < 0.05$) lowest, lower than yolk weight values from birds fed 10% and 30% ALM diet. On the contrary, highest ($p < 0.05$) yolk weight was recorded from birds supplied 20% leaf meal inclusion. The egg yolk colour for birds fed 30 % ALM diet was best ($p < 0.05$), but at 0 and 20% inclusion, it was least ($p < 0.05$) though similar (p < 0.05) in value as groups given ALM diet at 10% soybean meal substitution. Also, egg shell weight was heaviest among chickens fed 20% ALM diet inclusion with egg shell weight obtained from the other groups significantly ($p < 0.05$) lighter.

Faecal bacteria count of pullets fed diet containing ALM is documented in Table 6. Bacterial population of species (*Escherichia coli, Streptococcus faecalis, Staphylococcus aureus, Pseudomonas aeruginosa and Salmonella typhi*) analysed were not significant ($p > 0.05$) excluding *Staphylococcus aureus*. At 0 and 30 % ALM inclusion in the diet, *Staphylococcus aureus* population was least ($p < 0.05$), though, statistically similar to 10% ALM group. Highest ($p < 0.05$) *Staphylococcus aureus* population was recorded for the group fed 20% dietary *A. africana* leaf meal. This population, however, is statistically similar to that of 10% ALM group.'

DISCUSSION

The inclusion of ALM in the diet of egg-type chickens as replacement for soya bean meal at 30% in the diet of egg-type chickens effected best feed conversion ratio and least feed intake at first lay. Experiment conducted by Adedeji et al. (2014) revealed *A. africana* to have a high content of tannins and as reported by Castellini et al. (2002), tannins bind feed protein to the salivary gland and epithelium of the mouth, which makes the feed unpalatable with subsequent depressed voluntary intake. Yet, a study by Eweka and Eweka (2008) on the effect of *A. africana* leaf extract on Wistar rats showed a possible curative effect of the leaf on duodenal ulcers as it heals Brunner's glands and epithelial cells of the small intestine of adult Wistar rats. This possibly explains the depressed intake but best FCR among egg-type groups fed 30% *A. africana* leaf meal.

Bird weight at first lay was highest ($p < 0.05$) among pullets offered 10% *A. africana* leaf meal. Possible unpalatability of feed at higher levels of *A. africana* inclusion suppressed voluntary intake as revealed in Table 4. Expectedly, the attainment of optimum weight for first egg to be laid corresponds to intake and digestibility values that define the time of oviposition. The result contradicts the output of Oko et al. (2011) whose experiment on quail showed compromised weight values at 10% inclusion of *A. africana* into the diet but agrees with Agiang et al. (2011) findings that increased intake of *A. africana* leaf extract suppressed weight gain in quails. Average weight of eggs at first lay was highest at 20% *A. africana* leaf meal supply in the diet. At 20% inclusion level, egg-type birds fed *A. africana* had the highest intake and best FCR in Table 4 as well as highest egg weight at first lay in Table 5. This possibly shows the activity of ALM at 20% inclusion optimum for pullet laying performance. Lean weight in laying birds contributes to egg size. Hence, such observed relationship can be deduced as well as attributed to leaf meal inclusion at an optimum level for egg-weight at first lay. This further explains how significant internal and external properties (egg average width, albumen weight, shell weight and yolk weight) of the egg were optimum for groups offered 20% ALM diet. The research by Oko et al. (2018) on quails further supports the findings from this study that albumen weight, yolk weight and shell thickness were significantly improved following dietary ethanolic extract supplementation of *A. africana*. This affirms that the leaf possesses strong growth promoting and stimulatory properties that influence laying performance and egg quality of the egg-type chickens. Also, albumen weight best at 20% inclusion level could be attributed to *A. africana* stimulation of increased ovomucin production according to Wang et al. (2018) to maintain the albumen viscoelasticity.

The result reveals that *A. africana* leaf meal inclusion at 30% showed the highest yolk colour intensity. The yolk colour showed a progressive yellowish colour intensity with increasing leaf meal inclusion which corresponds with the increased presence of xanthophyll, beta-carotene and tocopherols – requirements for yellow egg yolk coloration. This agrees with the research documented by Oko et al. (2018) who reported improved yolk coloration in the diet of quails as supplemented *A. africana* supply increased.

The impact of *A. africana* leaf meal inclusion impact on *Staphylococcus aureus* count can be attributed to the competitive retention of certain bacteria possibly facilitated by altered pH through acid fermentation in the caecum of egg-type chickens influenced *Staphylococcus aureus* population (Ravangard et al., 2017). At 0% and 30% ALM inclusion, the faecal pH favoured suppressed *Staphylococcus aureus* population.

CONCLUSION

Findings from this study reveal that growth performance and faecal bacterial load was best at 30% ALM inclusion in the diet without deleterious effects on the birds at the pullet layer phases, respectively. Also, upon expiration of the layer phase, significant indices for external and internal properties of eggs indicate ALM inclusion at 20% was optimal for overall egg quality, though the egg weight at first lay was superior among groups offered 10% ALM diet. Also, when consumer attraction to yolk colour is the criterion for purchase, preference for eggs from birds supplied 30% dietary ALM is expected.

CONFLICT OF INTEREST

The authors declared no conflicts of interest with respect to research, authorship and publication of this article.

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