Production performance, blood profile and egg quality traits of layer chickens fed pelletized feeds of different particle sizes in two housing types

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Abstract

Production performance, blood profile and egg quality of 240 commercial layers (21-60 weeks old) fed pelletized feeds of different particle sizes in two housing types were studied. The birds were housed in either Battery cage (BC) of 45×40×45 cm dimension with a stocking rate of 3 birds/ cell (0.07 m^2/ bird) or Deep litter (DL) unit with stocking density of 0.39 m^2/bird. The feed particle sizes were fine particle pellets ≤ 1 mm and coarse particle pellets ≤ 2 mm. The experiment was arranged in a 2 x 2 factorial layout. Each treatment consisted of 3 replicates with 20 birds each. At age 21 weeks, daily/ weekly records were taken from the birds to generate data on growth and production performance, blood profile (haematological and serum biochemical parameters) and egg quality traits (external and internal) until 60 weeks old. Results showed main and interactive effects of pellet feed particle sizes and housing types had significant ($p<0.05$) influence on production and growth performance parameters with higher ($p<0.05$) values observed in birds on fine particle pellets housed on DL. Higher ($p<0.05$) packed cell volume, haemoglobin concentration and creatinine were observed in birds fed fine particle-sized pellets. Birds on coarse particle-sized pellets had higher ($p<0.05$) basophil values. In the effects of interaction, birds reared on DL and fine particle-sized pellets showed the lowest ($p<0.05$) basophil and the highest ($p<0.05$) creatinine for those in BC. For external and internal egg quality traits, main effects of feed particle size significantly ($p<0.05$) increased the proportion of the yolk and albumen weight in eggs on coarse-sized particles and fine-sized particles respectively. Interaction effects revealed the highest ($p<0.05$) proportion of yolk in eggs from birds reared in BC on coarse particle pellets and albumen weight in eggs from DL housed birds fed fine particle pellets. The study concluded that layers fed pellets of either fine or coarse-sized particles housed on DL have a better production performance. There were no adverse effects on the health status and egg quality traits of the birds.

Keywords: Particle size, Pellet feeds, Layers, Blood profile, Egg quality traits

Performance de production, profil sanguin et qualité des œufs de poules pondeuses nourries avec des aliments granulés de différentes tailles de particules dans deux types de logements

Résumé

La performance de production, le profil sanguin et la qualité des œufs de 240 pondeuses commerciales (21-60 semaines) nourries avec des aliments granulés de différentes tailles de particules dans deux types de logements ont été étudiés. Les oiseaux étaient logés soit dans des cages de batterie (CB) de dimensions 45×40×45 cm avec un taux de chargement de 3 oiseaux par cellule (0,07 m² par oiseau), soit dans une unité de litière profonde (LP) avec une densité de chargement de 0,39 m² par oiseau. Les tailles de *particules de l'aliment étaient des granulés à particules fines ≤ 1 mm et des granulés à particules grossières ≤ 2 mm. L'expérience était organisée selon un plan factoriel 2 x 2. Chaque traitement consistait en 3 répétitions avec 20 oiseaux chacune. À 21 semaines, des enregistrements quotidiens/hebdomadaires ont été effectués pour générer des données sur la croissance et les performances de production, le profil sanguin (paramètres hématologiques et biochimiques sériques) et les traits de qualité des œufs (externes et internes) jusqu'à 60 semaines. Les résultats ont montré que les effets principaux et d'interaction des tailles de particules d'aliments granulés et des types de logement avaient une influence significative (p<0,05) sur les paramètres de production et de performance de croissance, avec des valeurs plus élevées (p<0,05) observées chez les oiseaux nourris avec des granulés à particules fines logés en LP. Un volume de globules rouges, une concentration d'hémoglobine et une créatinine plus élevées (p<0,05) ont été observés chez les oiseaux nourris avec des granulés à particules fines. Les oiseaux nourris avec des granulés à particules grossières avaient des valeurs de basophiles plus élevées (p<0,05). Dans les effets d'interaction, les oiseaux élevés en LP et nourris avec des granulés à particules fines ont montré les plus bas (p<0,05) niveaux de basophiles et les plus élevés (p<0,05) de créatinine par rapport à ceux en CB. Pour les traits de qualité des œufs externes et internes, les effets principaux de la taille des particules d'aliment ont significativement (p<0,05) augmenté la proportion du poids du jaune et de l'albumen dans les œufs à partir de particules grossières et fines respectivement. Les effets d'interaction ont révélé la plus haute (p<0,05) proportion de jaune dans les œufs provenant d'oiseaux élevés en CB sur des granulés à particules grossières et le poids de l'albumen dans les œufs de poules logées en LP nourries avec des granulés à particules fines. L'étude a conclu que les pondeuses nourries avec des granulés de taille fine ou grossière logées en LP présentent une meilleure performance de production. Il n'y avait pas d'effets néfastes sur l'état de santé et les traits de qualité des œufs des oiseaux.*

Mots-clés : Taille de particule, Aliments granulés, Pondeuses, Profil sanguin, Traits de qualité des œufs

Introduction

Eggs play a critical role in meeting Nigeria's nutritional requirements for her growing population. They are rich in amino-acids, carbohydrates, easily digestible fats, minerals and essential vitamins. It is established that eggs comprise of many essential nutrients which include high-quality protein and for centuries, this has made it part of human diets (Bashir *et al*., 2015). There are several species of eggs and examples include; chicken egg, quail egg, and guinea fowl egg (Ajala *et al*., 2018). In Nigeria and other parts of the world, eggs are consumed mainly as protein foods and currently chicken eggs are most commonly eaten by humans, but eggs from other birds are also used for daily consumption (Onyenweaku *et al*., 2018).

As reported by Englmaierová *et al.* (2014), the housing system is an external factor that influences hen performance and their egg quality characteristics. Any housing system has its advantages and disadvantages with regard to bird performance, health, and welfare (Abo Ghanima *et al*., 2020). Housing types for hens range from small, pasture-based flocks to large, commercial-scale operations that intensively confine tens of thousands of hens indoors (Shield and Duncan, 2014) and globally, battery cages are the major system of housing for laying hens (Okedere *et al*., 2020). However, Gerzilov *et al*. (2012) opined that the public perception of cages being deleterious to poultry welfare resulted in increased investigation of alternative housing systems for egg production and examples include barn, deep litter, and free range management systems (Okedere *et al*., 2020) amongst others. Available studies have reported varying effects of housing types on poultry such as birds in cages performed better than those on deep litter (Yakubu *et al*., 2007; Englmaierová *et al*., 2014), while layers housed in deep litter system significantly consumed more feed and had best feed conversion ratio value compared with birds in battery cages (Dikeir Kogoor *et al*., 2021). Selection for high productivity has been carried out in the modern bird and for this genetic potential to be met without compromising welfare, feeding and housing must be at its best (Bryden *et al*., 2021).

The availability of good feed and an effective feeding programme results in successful livestock production (Akinola and Ekine, 2018) with feed intake, digestive organ development, digestion and absorption of nutrients, intestinal health and productive performance of poultry being determined by the particle size of ground grain or feed and the form of feed (Ege *et al*., 2019). A common form for feeding egg laying chicken is mash (Bozkurt *et al.*, 2019) and Wan *et al*. (2021) also reported pellets as a feed form for improving production and nutrition metabolism in laying hens. The provision of reliable information on animal health status is obtainable from their haematological and serum biochemical profiles (Cetin *et al*., 2009) and this according to Galli *et al*. (2018) positively affects final egg quality in poultry. Study on variations in blood picture and constituents of fowls sets a significant basis for studying their growth and egg production which explains the reaction of developed poultry strains to their environments (El-Garhy *et al.*, 2019).

Extensive research by animal scientists in Nigeria over a period of time have shown that common housing systems for laying hens include battery cage or deep litter but information is limited on the effects of these housing systems in relation to nutrition/feeding. In addition, concern is immense for enhanced poultry performance and the industry is persistent in its search for improved techniques that will aid in achieving this. Assessing the effects of interaction between housing and feed in the context of feed particle size on egg type chickens could probably allow for an established conclusion to be formed. Hence, this study investigated the effect of two pellet feed particle sizes on performance, blood profile and egg quality of layers on two housing types.

Materials and Methods

Experimental site

The study was conducted at the Poultry Unit of the Directorate of University Farms, Federal University of Agriculture, Abeokuta (FUNAAB), Ogun State, Nigeria. Analysis for egg quality traits was carried out at the Department of Animal Production and Health whilst blood profile of birds was determined at the Department of Biochemistry, both of the same institution-FUNAAB. The area is located in a derived savanna zone and lies within latitude 7^05’ to 7^08’N and longitude $3^011.2$’E. It has an annual mean temperature of 30^0C and a relative humidity of 82%. The region is 70m above sea level and is situated in the South-Western part of Nigeria (Federal University of Agriculture, Abeokuta, Meteorological Station, 2023).

Experimental birds and management

Two hundred and forty (240) pullets aged 20 weeks were weighed and randomly distributed into four treatment groups consisting of three replicates with 20 birds each. Water and feed were provided *ad libitum* for birds in all the treatment groups. Birds were fed Layers Mash (Table 1) from the 20^{th} week in pelleted form of either fine or coarse feed particles until 60 weeks of age when the study was terminated. Occasional management practices and routine bio security measures were administered to the birds at regular intervals.

Experimental diet types

All feed ingredients were purchased from a reputable commercial feed mill and prepared in same to give two pelletized feed forms (fine particle size and coarse particle size). The macro feed ingredients were divided equally into two portions and consisted of maize, soybean, wheat offal and palm kernel cake. A grinding mill of size 1mm was used for milling one of the two portions and the particles were considered as fine particle size (≤ 1mm). The other portion was milled into coarse particle size (≤ 2mm) using a 2mm sized grinding mill. The micro feed ingredients (ground bone meal, fish meal, oyster shell, vitamin and mineral premix, salt, lysine and methionine) were divided equally into each of the two macro feed ingredient portions of fine particles (0 ≤ 1mm) and coarse particles (1 ≤ 2mm) and each mixed thoroughly. The feed was pelletized afterwards using a pellet mill at 2 mm width for pellets with the feed being conditioned and thermally treated in the fitted conditioners of the pellet mill.

Experimental diet

Table 1: Composition (%) of experimental diet

Ingredients	Layers Mash (%)
Maize	45.00
Wheat offal	20.00
Palm kernel cake	16.00
Soybean cake	12.00
Fish meal (72% CP)	1.00
Bone meal	1.00
Oyster shell	4.00
Lysine	0.20
Methionine	0.20
Salt (NaCl)	0.30
*Premix	0.30
Total	100
Determined analysis	
Crude Protein (%)	16.10
Metabolizable Energy (KCal/kg)	2783.20

**Premix per 1kg contained: Vit. A, 10,000,000* IU*; Vit. D_3, 200,000* IU*; Vit. E, 12,500* IU*; Vit. K, 1.30 g; Vit B_1, 1.30 g; Vit. B_2, 4.00 g; Dicalcium-pantothenate, 1.30 g; Vit. B_6, 1.30 g; Vit. B_{12}, 0.01 g; Nicotinic acid, 15.00 g; Folic acid, 0.05 g; Biotin, 0.02 g; Co, 0.20 g; Cu, 5.00 g; Fe, 25.00 g; I, 0.06 g; Mn, 48.00 g; Se, 0.10 g; Zn, 45.00 g; Choline chloride, 200.00 g; BHT, 50.00 g.*

Housing types for experimental birds

The birds were arranged into experimental treatments in a 2x2 factorial combination of 2 housing types: Battery cage (BC) and Deep litter (DL) within a conventional poultry house. In the BC, a size of 45×40×45 cm was used with a stocking rate of 3 birds per cell (0.07 m^2/ bird). For DL, the stocking density for birds was 0.39 m^2/bird. There were laying nest boxes of dimensions 35×35×35 cm each at a rate of 3 hens per box for birds in DL. Wood shavings were used as bedding materials.

Data Collection

To determine growth and laying performance, initial weight was determined at the commencement of the trial (birds at 21 weeks old) and at the end of the trial period (birds at 60 weeks old), final weight was determined. Body weight gain was calculated from these data. Feed intake was recorded on a daily basis by subtracting weight of feed left over the following morning from feed weighed and administered to birds a day before. Feed conversion ratio is ratio of feed intake to body weight gain.

Total egg laid was calculated as total of egg number produced per bird. Average egg weight was considered per treatment. It was total weight of eggs laid and then calculation of their average. Measurement was done with a digital weighing balance (sensitivity of 0.01g). Hen-Day Egg Production (HDEP) was calculated as the percentage of total number of eggs produced within a particular period per total number of hens in the same period. Egg Mass was calculated as HDEP x Average egg weight.

Blood Parameters

Sterile syringe and needles were used to collect blood samples from the *vena basilica* of wings from each of three birds randomly selected per replicate at the end of the 40-week experimental period. Blood measuring 2 ml was collected into labelled and sterile sample bottles containing Ethylene Diamine Tetra-Acetate (EDTA), an anti-coagulant for haematology analysis. For serum biochemistry, 2 ml of blood was collected into plain sample bottles without anti-coagulant. The samples were transported immediately to the laboratory for analysis. The following haematological indices were determined: Packed Cell Volume (PCV), Haemoglobin concentration (Hb), Red Blood Cell count (RBC), White Blood Cell count (WBC), Heterophils, Lymhocytes, Eosinophils, Basophils and Monocytes. For biochemistry analysis the following parameters were considered: Total protein, Albumin, Globulin, Creatinine, Aspartate transaminase (AST), Alanine transaminase, (ALT), Uric acid and Blood cholesterol (Mitruka and Rawnsley, 1977; Dacie and Lewis, 1991).

Egg Quality

During the 40-week period of the trial, eggs were picked twice a day (morning and evening) and six eggs were taken per replicate from each treatment for the evaluation of egg quality traits at every interval of 4 weeks. The collected eggs were transported to the laboratory for analysis.

For external egg qualities: Egg and dry shell weights were measured with the use of a sensitive weighing scale; Egg length and width were determined using Vernier callipers; Egg Shape Index (ESI) was measured using this formula:

$$ESI = \frac{Width\ of Egg(mm)}{Length\ of Egg\ (mm)} \times 100;$$

Shell thickness was determined by measuring for thickness to the nearest 0.01mm using micrometre screw gauge.

Albumen height was measured with a tripod micrometre; Albumen and yolk weights were measured using sensitive weighing scale; Yolk colour was determined using a Hoffman-LaRoche yolk colour fan; Percentages for Albumen, Yolk and Shell and Haugh unit. (Sogunle *et al*., 2022). The Haugh unit was calculated using the values obtained for the egg weight and albumen height as expressed by Şekeroğlu and Altuntaş (2009) in the formula shown below:

$$HU: 100 \log (H+7.57 - 1.7W^{0.37})$$

Where, H = Albumen height in mm

W = Egg weight in gram.

Statistical Design

The experimental design was a Two-way Analysis of Variance using the PRO GLM (General Linear Model) of SAS (2010) at 5% level of significance. Significantly (<0.05) different means were separated using Duncan's Multiple Range Test contained in the SAS package.

Model;

$$Y_{ijk} = \mu + Hi + S_j + (HS)_{ij} + \varepsilon_{ijk}$$

Where:

Y_{ijk} = Observed values of dependent variables;

μ = Population mean

H_i = Fixed effect of the i^th^ pellet feed particle sizes (i = Coarse, Fine)

S_j= Effect of the j^th^ housing types (j = Battery cage, Deep litter)

$(HS)_{ij}$ = Effect of the interaction between pellet feed particle size and housing type

ε_{ijk} = Random error associated with each observation.

Results

Effects of pellet feed particle size and housing type on performance of layers

The main effect of pellet feed particle size and housing type on performance of layers is shown in Table 2. Pellet feed particle size significantly ($p<0.05$) influenced average feed intake and cost of feed consumed. Birds on pellet feed with fine particles had higher values for average feed intake and cost of feed consumed (104.89 g/bird/day and ₦10.41) compared with birds on pellet feed with coarse particles (103.03g/bird/day and ₦10.22).

Housing type significantly ($p<0.05$) affected final weight, average weight gain, average feed intake, total egg laid, hen day egg production, egg mass and cost of feed consumed with birds on deep litter showing higher ($p<0.05$) values compared with those in battery cage.

Table 3 presents the interaction effects of pellet feed particle sizes and housing type on growth and laying performance of layers. Significant ($p<0.05$) differences were observed in final weight, average weight gain, average feed intake, egg mass, and cost of feed consumed with birds on deep litter and fed either of the pellet feed particle sizes bearing values that were similar but significantly ($p<0.05$) higher compared with birds in battery cage.

Table 2: Main effect of pellet feed particle size and housing type on performance of layers

Parameter	Feed form				Housing type			
	Fine	Coarse	SEM	P-value	Battery cage	Deep litter	SEM	P-value
Initial weight (g)	1216.70	1173.30	6.30	0.420	1173.30	1216.70	36.30	0.42
Final weight (g)	1713.30	1666.70	26.50	0.250	1625.0^{b}	1755.0^{a}	26.50	0.00
Average weight gain (g/bird/day)	3.23	3.20	0.12	0.900	2.93^{b}	3.50^{a}	0.12	0.00
Average feed intake (g/bird/day)	104.89^{a}	103.03^{b}	0.29	0.002	100.34^{b}	107.55^{a}	0.29	0.00
Total egg laid	921.50	839.50	51.60	0.290	767.70^{b}	993.30^{a}	51.60	0.01
HDEP	59.84	54.51	3.35	0.290	49.85^{b}	64.50^{a}	3.35	0.01
Average egg weight (g)	61.33	60.67	1.34	0.730	60.25	61.75	1.34	0.45
Egg mass	36.49	33.14	1.78	0.220	30.06^{b}	39.57^{a}	1.78	0.00
FCR	1.72	1.70	0.03	0.740	1.67	1.75	0.03	0.15
Cost of feed consumed (₦)/kg	10.41^{a}	10.22^{b}	0.03	0.002	9.96^{b}	10.67^{a}	0.03	0.000

^{ab} Means on the same row having different superscripts are significantly ($p<0.05$) different.

HDEP = Hen Day egg Production

FCR = Feed Conversion ratio

Table 3: Interaction effect of pellet feed particle size and housing type on performance of layers

Feed form	Fine		Coarse			
Housing type	Battery Cage	Deep Litter	Battery Cage	Deep Litter	SEM	P-value
Parameters						
Initial weight	1200.0	1233.30	1146.70	1200.00	51.40	0.85

(g)						
Final weight (g)	1623.30[b]	1803.30[a]	1626.70[b]	1706.70[ab]	37.50	0.21
Average weight gain (g/bird/day)	2.75[b]	3.70[a]	3.12[ab]	3.29[ab]	0.16	0.04
Average feed intake (g/bird/day)	101.57[b]	108.21[a]	99.15[c]	106.00[a]	0.41	0.21
Total egg laid	793.30	1049.70	742.0	937.00	73.00	0.68
HDEP	51.52	68.16	48.18	60.84	4.74	0.68
Average egg weight (g)	62.83	59.83	57.67	63.67	1.89	0.04
Egg mass	32.35[ab]	40.62[a]	27.76[b]	38.53[ab]	2.52	0.63
FCR	1.62	1.81	1.72	1.68	0.05	0.04
Cost of feed consumed (₦)/kg	10.08[b]	10.74[a]	9.84[c]	10.61[a]	0.04	0.210

[ab] Means on the same row having different superscripts are significantly ($p<0.05$) different.

HDEP = Hen Day egg Production

FCR = Feed Conversion ratio

Effects of pellet feed particle size and housing type on blood profile of layers

The main effects of pellet feed particle size and housing type on blood profile of layers are as shown in Table 4. Pellet feed particle size significantly ($p<0.05$) influenced the values for packed cell volume, haemoglobin concentration, basophil and creatinine. Birds fed fine particle pellet feeds had higher ($p<0.05$) packed cell volume (33.75%), haemoglobin concentration (11.05g/dl) and creatinine (1.90mg/dl) compared with birds on coarse particle pellet feeds (28.75% for packed cell volume, 9.48g/dl for haemoglobin concentration and 1.40mg/dl for creatinine). Conversely, birds fed coarse particle pellet feeds had higher ($p<0.05$) values for basophil (2.75%) compared with birds on fine particle pellet feeds (1.00%). However, housing types had no significant ($p>0.05$) influence on all haematology and biochemistry parameters considered.

The interactive effect of pellet feed particle size and housing type on blood profile of layers (Table 5) showed significant ($p<0.05$) influence was obtained for basophils with deep litter housed birds fed fine particle pellet feeds having the lowest ($p<0.05$) value compared with birds on coarse particle pellet feeds of the same housing type. Creatinine was also significantly ($p<0.05$) affected and birds in the battery cage housing type fed fine particle pellet feeds had the highest ($p<0.05$) value of creatinine (2.05mg/dl) across the treatment groups.

Table 4: Main effects of pellet feed particle size and housing type on blood profile of layers

Parameter	Feed form				Housing type			
	Fine	**Coarse**	**SEM**	**P value**	**Battery cage**	**Deep litter**	**SEM**	**P value**
Haematological parameters								
Packed cell volume (%)	33.75^a	28.75^b	0.96	0.02	30.25	32.25	0.96	0.21
Haemoglobin concentration (g/dL)	11.05^a	9.48^b	0.39	0.04	9.88	10.65	0.39	0.23
Red blood cell counts (x10^{12}/L)	2.97	2.52	0.19	0.17	2.75	2.75	0.19	1.00
White blood cell counts (x10^9/L)	11.92	12.30	0.75	0.74	12.25	11.97	0.75	0.81
Heterophil (%)	29.50	30.25	3.70	0.89	28.00	31.75	3.70	0.51
Lymphocytes (%)	64.00	63.00	3.62	0.85	65.00	62.00	3.62	0.59
Eosinophil (%)	2.50	1.75	0.46	0.32	2.25	2.00	0.46	0.72
Basophil (%)	1.00^b	2.75^a	0.30	0.01	2.00	1.75	0.30	0.59
Monocytes (%)	3.00	2.25	0.81	0.54	2.75	2.50	0.81	0.83
Serum biochemical parameters								
Total protein (g/dL)	7.20	5.28	0.96	0.23	6.33	6.15	0.96	0.90
Albumin (g/dL)	3.73	2.98	0.49	0.34	3.40	3.30	0.49	0.89
Globulin (g/dL)	3.48	2.30	0.50	0.17	2.93	2.85	0.50	0.92

Creatinine (mg/dL)	1.90[a]	1.40[b]	0.06	0.00	1.65	1.65	0.06	1.00
AST (U/L)	71.00	63.75	3.71	0.23	68.25	66.50	3.71	0.75
ALT (U/L)	28.00	29.25	1.85	0.65	27.00	30.25	1.85	0.28
Uric acid (mg/dL)	3.10	3.28	0.35	0.73	3.45	2.93	0.35	0.34
Triglycerides (mg/dL)	96.25	88.25	4.83	0.306	90.00	94.50	4.83	0.546
High Density Lipoprotein (mg/dL)	70.52	77.73	2.23	0.085	74.38	73.88	2.23	0.882
Low Density Lipoprotein (mg/dL)	32.47	39.63	4.73	0.345	37.63	34.47	4.73	0.662
Very Low Density Lipoprotein (mg/dL)	19.25	17.65	0.97	0.306	18.00	18.90	0.97	0.546
Total cholesterol (mg/dL)	122.25	135.00	6.17	0.218	130.00	127.25	6.17	0.768

[ab] Means on the same row having different superscripts are significantly ($p<0.05$) different.
AST = Aspartate transaminase
ALT = Alanine transaminase

Table 5: Interaction effect of pellet feed particle size and housing type on blood profile of layers

Feed form	Fine		Coarse			
Housing type	**Battery Cage**	**Deep Litter**	**Battery Cage**	**Deep Litter**	**SEM**	**P-value**
Haematological Parameters						
Packed cell volume (%)	31.50	36.00	29.00	28.50	1.37	0.14
Haemoglobin concentration (g/dL)	10.20	11.90	9.55	9.40	0.53	0.17
Red blood cell ($x10^{12}$/L)	3.00	2.95	2.50	2.55	0.27	0.86
White blood cell ($x10^{9}$/L)	12.40	11.45	12.10	12.50	1.07	0.56
Heterophil (%)	25.50	33.50	30.50	30.00	5.24	0.46
Lymphocytes (%)	67.50	60.50	62.50	63.50	5.12	0.47
Eosinophil (%)	2.50	2.50	2.00	1.50	0.66	0.72
Basophil (%)	1.50[ab]	0.50[b]	2.50[ab]	3.00[a]	0.43	0.15
Monocytes (%)	3.00	3.00	2.50	2.00	1.15	0.83
Serum biochemical parameters						
Total protein (g/dL)	6.95	7.45	5.70	4.85	1.36	0.64

Albumin (g/dL)	3.65	3.80	3.15	2.80	0.69	0.77
Globulin (g/dL)	3.30	3.65	2.55	2.05	0.71	0.83
Creatinine (mg/dL)	2.05[a]	1.75[ab]	1.25[c]	1.55[bc]	0.09	0.02
AST (U/L)	66.00	76.00	70.50	57.00	5.25	0.08
ALT (U/L)	25.00	31.00	29.00	29.50	2.61	0.35
Uric acid (mg/dL)	3.45	2.75	3.45	3.10	0.49	0.73
Triglyceride (mg/dL)	99.00	93.50	81.00	95.50	6.83	0.21
High Density Lipoprotein (mg/dL)	70.65	70.40	78.10	77.35	3.16	0.94
Low Density Lipoprotein (mg/dL)	33.05	31.90	42.20	37.05	6.69	0.78
Very Low Density Lipoprotein (mg/dL)	19.80	18.70	16.20	19.10	1.37	0.21
Total cholesterol (mg/dL)	123.50	121.00	136.50	133.50	8.73	0.97

[ab] Means on the same row having different superscripts are significantly ($p<0.05$) different.

AST = Aspartate transaminase

ALT = Alanine transaminase

Effect of pellet feed particle size and housing type on egg quality of layers

The main effect of pellet feed particle size and housing type on egg quality of layers is presented in Table 6. Pellet feed particle size significantly ($p<0.05$) influenced yolk percentage and albumen weight in eggs. Whilst eggs from birds fed coarse particle pellet feeds recorded a significantly ($p<0.05$) higher value of 24.47% for yolk percentage compared with 21.21% in fine particle pellet feed birds, it was *vice versa* for albumen weight with birds on fine particle pellet feeds showing a higher ($p<0.05$) value of 33.20g compared with 29.13g for birds fed coarse particle pellet feeds.

In Table 7, the interactive effect between pellet feed particle size and housing type on egg quality of layers is presented. Significant ($p<0.05$) differences were observed only in yolk percentage and albumen weight. Eggs from battery cage housed birds fed coarse particle pellet feeds had the highest ($p<0.05$) value of 24.73% for yolk percentage. Conversely, eggs from birds on fine particle pellet feed and housed on deep litter had highest ($p<0.05$) value of 35.23 g for albumen weight when compared with values from eggs in other treatments.

Table 6: Main effects of of pellet feed particle size and housing type on egg quality of layers

Parameters	Feed type				Housing type			
	Fine	Coarse	SEM	P-value	Battery cage	Deep litter	SEM	P-value
Egg weight (g)	53.84	48.13	1.88	0.053	49.65	52.31	1.88	0.336
Egg length (mm)	53.11	49.94	1.22	0.092	50.63	52.41	1.22	0.323

Egg width (mm)	40.34	38.68	1.87	0.542	39.92	39.09	1.87	0.758
Egg Shape Index	75.59	77.39	2.31	0.592	78.74	74.24	2.31	0.194
Yolk colour	1.25	1.25	0.16	1.000	1.375	1.13	0.16	0.295
Yolk weight (g)	11.43	11.79	0.59	0.673	10.89	12.33	0.59	0.112
Yolk %	21.21[b]	24.47[a]	0.83	0.017	22.03	23.64	0.83	0.196
Albumen height (mm)	8.38	6.91	0.56	0.091	8.14	7.15	0.56	0.239
Albumen weight (g)	33.20[a]	29.13[b]	1.23	0.038	31.10	31.23	1.23	0.944
Albumen%	62.25	60.39	2.39	0.592	62.46	60.18	2.39	0.511
Shell weight (g)	5.787	5.250	0.18	0.057	5.53	5.51	0.18	0.962
Shell%	10.91	10.97	0.57	0.923	11.24	10.65	0.57	0.477
Shell thickness (mm)	0.54	0.511	0.02	0.361	0.536	0.52	0.02	0.579
Haugh unit	91.97	85.42	2.95	0.143	91.61	85.78	2.95	0.188

[ab] Means on the same row having different superscripts are significantly ($p<0.05$) different.

Table 7: Interaction effect of of pellet feed particle size and housing type on egg quality of layers

Feed form	**Fine**		**Coarse**			
Housing type	**Battery Cage**	**Deep Litter**	**Battery Cage**	**Deep Litter**	**SEM**	**P-value**
Parameters						
Egg weight (g)	53.13	54.55	46.18	50.08	2.66	0.65
Egg length (mm)	52.81	53.40	48.45	51.43	1.73	0.50
Egg width (mm)	42.33	38.34	37.52	39.84	2.64	0.25
Egg Shape Index	80.15	71.03	77.34	77.44	3.27	0.18
Yolk colour	1.50	1.00	1.250	1.25	0.23	0.29
Yolk weight (g)	10.35	12.50	11.43	12.15	0.84	0.41
Yolk, %	19.34[b]	23.08[ab]	24.73[a]	24.21[ab]	1.18	0.09
Albumen height (mm)	9.48	7.28	6.80	7.03	0.80	0.15
Albumen weight (g)	35.23[a]	31.18[ab]	26.97[b]	31.28[ab]	1.75	0.03
Albumen, %	66.62	57.88	58.31	62.47	3.38	0.08
Shell weight (g)	5.65	5.93	5.40	5.10	0.26	0.28
Shell, %	10.72	11.09	11.76	10.21	0.80	0.25
Shell thickness (mm)	0.55	0.54	0.53	0.50	0.03	0.68
Haugh unit	97.59	86.34	85.63	85.22	4.17	0.21

[ab] Means on the same row having different superscripts are significantly ($p<0.05$) different.

Discussion

The feed (layer's mash) in this study was processed into pellets and previous study states that further processing of mash diet to pellets optimizes feed utilization and improves feed conversion efficiency associated with enhanced intestinal starch and nitrogen absorption (Bozkhurt *et al.,* 2019). In this study, average feed intake was greater in birds on pellet feed with fine particles. Safaa *et al*. (2009) observed that though particle size did not affect the productive performance of young brown hens, feed intake was greater in hens fed coarsely ground cereals than in hens fed medium and fine ground cereals. Performance parameters except for average feed intake and cost of feed consumed in this study were not affected by particle size. This agrees with Chewning *et al*. (2012) who demonstrated that performance in broilers fed pellet diets was not changed because of grain particle size. They added that the weight and feed conversion ratio of both male and female broilers fed pellet diets with different particle sizes of grain in their study were similar. Particle size of dietary grains according to Koçer *et al.* (2016) had no significant effect on egg production rate or the body weight of hens. Amerah *et al*. (2008) reported lack of significant difference in body weight gain of broilers due to fine and coarse particle sizes. Again, feed particle size was reported to have no remarkable effects on growth performance of broilers in crumble-pellet diets and this was attributed to the masking of the effects of different particle sizes by pelleting (Lv *et al.,* 2015). Pelleting according to Svihus *et al*. (2004) explained the differences in particle size distribution.

Housing type influenced several growth and laying performance parameters of layers in this study. Birds on deep litter showed higher values compared with those in cages. This is consistent with previous studies (Tauson *et al.,* 1999) that hens housed on litter had approximately 10% higher feed consumption per day than hens from cages. Sonkamble *et al.* (2020) reports that higher feed intake in birds reared on deep litter housing was probably as a result of higher loco-motor activity in the birds causing them to consume more feed compared with those in cages. Vits *et al.* (2005) reported there was greater egg mass from birds in floor pens than in cages and Singh *et al.* (2009) observed that body weight for hens in the floor system was higher compared with hens in the caged system. The highest number of eggs per hen per day, higher percentage of hen day production and egg mass index was recorded for hens on deep litter (Okedere *et al.,* 2020). Yet varying reports (Rouf *et al.*, 2015) showed no significant differences in body weight of birds in different rearing systems. Furthermore, Sonkamble *et al.* (2020) added that housing hens on litter had no effect on egg production.

The pellet feed particle size and housing type with no interactive effects on laying performance parameters in this study agrees with the average hen day and hen house egg production values that were not affected due to different housing systems (Sonkamble *et al.,* 2020). While there was higher egg production for birds in cage systems compared with barn and free range systems (Dikmen *et al.*, 2016), other reports reveal that egg production for hens reared in different housing systems was found to be similar (Neijat *et al.*, 2011; Ahammed *et al.*, 2014).

Interactive effects for performance parameters (final weight, average weight gain, average feed intake, egg mass, and cost of feed consumed) in birds on deep litter were higher compared with birds in battery cage irrespective of the pellet particle size (fine or coarse). This is similar to broiler growth performance parameters that were significantly affected interactively by feed form, feed particle size and pellet binder when birds fed pellet-coarse particle size-3% pellet binder diet showed enhanced feed consumption and gained more body weight. This confirmed the importance of pellet physical quality (Abadi *et al*., 2019).

Animal health status is derived from valuable information on their haematological and serum biochemical parameters which also reflects their response to internal and external environmental conditions (Egu, 2017). In this study, birds fed fine particle pellet feeds had higher PCV, Hb and creatinine. With higher Hb, in the cytoplasm of red blood cells for birds on fine particle pellet feed, the oxygen carrying capacity of blood for birds in this study can be described as effective (Oguntoye *et al.,* 2018a). Absence of muscle wastage in the birds indicates no incidence of high creatinine as this implies that birds' survival at the expense of their body reserve (Oguntoye *et al.,* 2018b). Creatinine is a measure of adequate quality of protein, protein quantity and degree of utilization (Okorie *et al.,* 2011). Blood parameters were not significantly influenced by housing types in this study. Pavlík *et al*. (2007) reported that total protein and albumin in blood serum of Isa Brown Layers in different housing systems were not significantly affected but within the range of reference values (Meluzzi *et al*., 1992; Bounous and Steadman, 2000) . This is inconsistent with housing system reported to have significant influence on cholesterol and AST (Kraus *et al.,* 2021). The values for blood parameters were however within the range reported for healthy birds. This therefore indicates that neither pellet feed particle size nor housing type considered in this experiment caused infections or allergies in the birds.

The quality of eggs plays a significant role for producers and consumers alike (Hernandez *et al*., 2005). While yolk percentage and albumen weight were influenced by pellet feed particle size and housing types, other parameters depicting egg quality in this study were not significantly affected. This is inconsistent with the significant influence of housing on egg weight, egg surface area (Kraus *et al.,* 2019) egg shell thickness and egg shell strength (Sokolowicz *et al.,* 2018). A previous study (Hafeez *et al*., 2015) indicated that most of the internal and external egg quality parameters of economic importance were not affected by screen size of feed particles after a 21-day feeding period. Koçer *et al*. (2016) reported there were no significant effects on eggshell thickness, eggshell breaking strength, albumin percentage and haugh unit due to the distinct alterations in feed form and particle size. Egg quality is expressed usually by proportion and index however, particle size did not affect the egg quality of young brown hens as reported by Safaa *et al*. (2009). Albumen and yolk quality is a major concern for consumers (Tolimir *et al*., 2017). Egg quality traits like albumen index, yolk index and haugh unit score were higher for eggs laid by birds in cage housing compared with those on deep litter housing (Sonkamble *et al.,* 2020) for instance, higher haugh unit score was observed in caged hens (Hidalgo *et al.,* 2008).

Conclusion

The study concluded that laying chickens showed varying values with no consistent trends based on the interplay of effects of different pellet feed particle sizes and housing types on performance, blood profile and egg quality of layer chickens considered. Layer chickens fed either coarse or fine particle size pellets and housed on deep litter showed better final weight, average weight gain, average feed intake, total egg laid, hen day egg production, egg mass and cost of feed consumed. There were no adverse effects on their health status or egg qualities.

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