Nigerian J. Anim. Sci. 2021, 23 (2): 114-125

Effect of different feed forms with or without Oyster mushroom inclusion (*Pleurotus ostreatus*) on egg production and egg quality of egg-type chicken

[1]Odekunle, T. E., *[2]Safiyu, K. K., [1]Odutayo, O. J., [1]Sogunle, O. M., [1]Adeyemi. O. A. and [3]Jegede, A. V.

[1]Department of Animal Production and Health, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria; [2]Department of Animal Production and Livestock Management, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria; [3]Department of Animal Nutrition, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

***Corresponding Author:** safiyu.kamorudeen@mouau.edu.ng, temitopeesther80@gmail.com, **Phone Number:** +2348032074315*

***Target Audience:** Feed millers, Poultry Farmers and Animal Scientists*

Abstract

This study investigated the effect of different feed forms with or without oyster mushroom inclusion (Pleurotus ostreatus) on egg production and egg quality of egg-type chicken. One hundred and sixty 16-week old pullets were purchased and acclimatized for 2 weeks. Afterwards, the birds were distributed on the basis of feed forms (mash and pellet) and oyster mushroom inclusion (with or without) into 4 treatments consisting of 40 birds per treatment. Each treatment was sub-divided into 5 replicates of 8 birds per replicate. External and internal egg qualities were investigated in three phases; early-lay (20-27 weeks of age), mid-lay (28-35 weeks of age) and late-lay (36-43 weeks of age). Data obtained were arranged in a 2 × 2 factorial arrangement in a Completely Randomized Design. Result showed Total Egg Production (TEP) and Hen Day Egg Production (HDEP) were significantly ($p<0.05$) higher in birds fed pellet feed and lowest in birds fed mash feed during early and mid-lay phases. However, birds fed diets with oyster mushroom inclusion recorded significantly ($p<0.05$) lower TEP and HDEP (161.30 eggs and 36.00%, respectively) during the early-lay phase. Yolk colour score at mid-lay was significantly ($p<0.05$) higher (5.80) in birds fed pellet feed than 4.30 in birds fed mash feed. Shell thickness was significantly ($p<0.05$) higher (0.84 mm) in birds fed pellet feed than 0.66 mm in birds fed mash feed. Therefore, optimal egg production with darker yolk colour can be achieved at the mid-lay phase via feeding laying birds with pellet feed with oyster mushroom.

***Keywords:** Feed forms, Oyster mushroom, internal and external egg qualities, egg type chicken.*

Description of Problem

The economic successes of laying flocks depend greatly on the number of quality eggs produced and sold. But for optimum egg production and egg quality to be achieved, the hens' daily nutrient requirement for energy, amino acids, vitamins, and critical minerals such as Ca, P, and Mn must be met (1). In the same vein, feed form plays a critical role in determining nutrient digestion, intestinal health and productive performance of poultry (2, 3, 4). The two commonly used forms of feeds in commercial egg production are mash and pellet. Mash is a form of poultry feed that is finely ground and mixed thoroughly so that ingredients cannot be separated easily (5) while pellets are produced from mash via a feed processing technique in which the ingredients are agglomerated by mechanical action, in combination with moisture, temperature and pressure (6). Mash diets have been reported to enhance starch digestibility as well as improve feed conversion ratio and intestinal glucose uptake in broilers (7). But the replacement of mash feed with pellet reduced ingredient segregation and formulation cost as well as improved ease of handling and feed flow in the equipment (6). The physical form of feed has been reported by (8) to improve meat yield of broilers, therefore many commercial feed mills have ventured into the production of different forms of feed for different groups of birds. Manipulations in macro and microstructure of feed have been reported to improve digestive efficacy, productive performance and intestinal health in broiler chickens (9, 10). However, feed form remains an obscure and undervalued area in the nutrition of laying birds, as mash feed is generally fed in practice (11, 12).

Interest in the effects of different feed forms, particle size and energy density has increased in recent years (3, 13) as nutritionists, researchers and other stakeholders in the egg industry seek out ways to optimize the utilization of feed and production efficiency. Recent studies (14, 15) revealed the laying performance of layers had no significant respond to manipulations in particle size and feed form (mash vs. pellets). However, this result was probably influenced by nutrient composition of ingredients and feed, pellet hardness, genotype, and production performance potential of laying birds (16). Also, literature is limited on the quality of eggs from poultry birds fed different feed forms. Egg quality is measured using the shell, albumen and yolk as indices for the production of eggs with excellent internal and external qualities (17). Eggs are considered a perishable foodstuff, due to the low efficiency of their natural protection barriers, therefore, the sustainable production of high quality eggs is of great importance to consumers and many egg product manufacturers because it allows for better separation of egg components without crossover contamination (18).

Furthermore, the extensive use of antibiotic growth promoters for poultry production has resulted in the rapid emergence of antibiotic-resistant forms of microorganisms. Consequently, the use of phytogenic feed additives or herbal plants have recently received much greater attention as alternatives to conventional antibiotics (19). These herbal plants are considered as natural products, and thus many consumers are willingly accepting them to be included in poultry feeds. Investigations of phytogenic plants have indicated their growth promoting, antioxidant, anti-inflammatory and antimicrobial functions (20, 21). In addition, herbal plants possess beneficial effects on the digestive system by increasing the production of digestive enzymes and enhancing liver functions for efficient feed utilization (22, 23). However, knowledge about their applications in poultry nutrition is still limited. One of such herbal plants; Oyster mushrooms (*Pleurotus ostreatus*) are known to possess antioxidant and immunomodulatory properties (24) and have been reported to improve growth, intestinal health and immunity in poultry (25, 26, 27, 28) as well as prevent the damage of food nutrient (29, 30).

Based on this background, this study aimed to determine the effect of different feed forms with or without Oyster mushroom inclusion (*Pleurotus ostreatus*) on external and internal egg qualities of egg-type chickens.

Materials and Method

Location of study

The study was carried out at the Poultry Unit of the Teaching and Research Farms, Federal University of Agriculture, Abeokuta, Ogun State while egg quality analyses were carried out in the Animal Products and Processing Laboratory of the Department of Animal Production and Health, Federal University of Agriculture, Abeokuta, Ogun State.

Preparation of Oyster mushroom

Fresh *P. ostreatus* mushrooms were purchased from an open market in Ibadan, Oyo State. The mushroom was cleaned and oven dried at 60 °C in an electric oven for one hour. Afterwards, the dried mushrooms were finely grinded and mixed with the formulated diet as an additive at the rate of 1 g per kg of feed.

Experimental birds and management

One hundred and sixty pullets aged 16 weeks were purchased and acclimatised for 2 weeks in deep litter houses. Afterwards, the birds were distributed after weight equalisation into 4 treatments consisting of 40 birds per treatment on the basis of feed forms (mash and pellet) and oyster mushroom inclusion (with or without). Each treatment was divided into 5 replicates of 8 birds per replicate. The description of treatments are; Mash feed with oyster mushroom inclusion, mash feed without oyster mushroom inclusion, pellet feed with oyster mushroom and without oyster mushroom inclusion. Uniformity in management practices was maintained across treatments. Commercial layers mash (containing Metabolisable Energy of 10.65 MJ/kg and Crude protein of 16.80%) and water were provided for the birds throughout the experimental period.

Data collection

Egg production parameters

The following parameters were measured in three phases; early-lay (20-27 weeks of age), mid-lay (28-35 weeks of age) and late-lay (36-43 weeks of age).

Total Egg Production: This is the number of eggs produced per bird from each replicate.

Hen day Egg Production (HDEP): This can be calculated using the formula;

$$\text{HDEP} = \frac{\text{Total number of eggs produced during the period}}{\text{Total number of hen-days in the same period}} \times 100$$

Egg quality parameters

Four (4) eggs were collected from each replicate for quality assessment in three phases; early-lay (20-27 weeks of age), mid-lay (28-35 weeks of age) and late-lay (36-43 weeks of age).

External egg quality evaluation

The egg weight and egg shell weight, (in grams) were taken on individual eggs from the replicates of each treatment using Mettler top loading electronic weighing balance having sensitivity of 0.01g. Egg length was taken as the longitudinal distance between the narrow and the broad ends and egg width was measured as the diameter of the widest cross-sectioned region of the egg using a vernier calliper with accuracy of 0.1 mm. Egg shell Thickness of individual air-dried shells was measured nearest to 0.01mm using micrometer screw gauge.

Egg Shape Index (ESI) was calculated as the percentage of the egg width to the length (Gunlu *et al*., 2003). The formula is as follows:

$$\text{Egg Shape Index} = \frac{\text{width of egg (mm)}}{\text{Length of egg (mm)}} \times 100$$

The Shell Surface Area was determined according to formula reported by Carter (1975): Shell surface area (SSA) = $(4.67 \times SW^{0.667})$

Where SW = Shell weight

Table 1: Main effect of feed forms and Oyster mushroom inclusion on egg production and egg qualities of egg-type chickens during early-lay (20-27 weeks of age)

	Feed form				Oyster mushroom inclusion			
Parameters	**Mash**	**Pellet**	**SEM**	**P Value**	**With**	**Without**	**SEM**	**P value**
Total Egg Production (eggs)	157.80[b]	175.20[a]	3.41	0.002	161.30[b]	171.70[a]	3.41	0.05
Hen Day Egg Production (%)	35.22[b]	39.11[a]	0.76	0.002	36.00[b]	38.33[a]	0.761	0.05
External qualities								
Egg weight (g)	50.60	48.92	3.36	0.74	47.95	51.57	3.36	0.49
Egg Length (mm)	52.90	52.53	1.01	0.81	52.5	53.24	1.01	0.51
Egg Width (mm)	41.35	40.78	0.98	0.7	40.51	41.62	0.98	0.47
Shell Weight (g)	4.68	4.430	0.30	0.59	4.68	4.43	0.30	0.59
Shell Thickness (mm)	0.56	0.52	0.03	0.39	0.58	0.50	0.02	0.14
Egg Shape Index (ESI)	78.19	77.60	0.62	0.25	77.64	78.15	0.62	0.59
Shell Surface Area (cm^2)	13.06	12.56	0.59	0.58	13.06	12.56	0.59	0.58
Internal Qualities								
Albumen height (mm)	10.20	9.65	0.59	0.55	9.21	10.64	0.59	0.16
Albumen weight (mm)	32.92	30.67	2.46	0.55	30.65	32.95	2.46	0.55
% Albumen	65.07	62.52	1.03	0.15	63.90	63.69	1.03	0.89
Yolk weight (g)	11.30	11.92	0.53	0.45	11.15	12.08	0.53	0.28
% Yolk	22.33	24.66	1.39	0.30	23.26	23.72	1.39	0.83
Yolk Colour	4.75	4.25	0.43	0.46	4.25	4.75	0.43	0.46
Haugh Unit	101.49	99.91	2.26	0.65	98.15	103.25	2.26	0.19

[a,b] Means in the same row with different superscripts differ significantly (P<0.05)

Internal egg quality evaluation

The following internal quality parameters were measured in selected eggs**;** for the Albumen Height (mm), the eggs were broken out on a flat surface and the maximum albumen height was measured using spherometer. The albumen and yolks were separated, weighed using Mettle top loading machine and each calculated as a percentage of the egg weight. Yolk colour was determined by comparing the colour with colour chips of a Hoffman-La Roche yolk colour fan on a scale of 1-15. Haugh unit was calculated using the values obtained for the egg weight and albumen height as expressed by Haugh (1937) and enunciated by Asuquo *et al.* (1992) in the formula:

$$HU = 100\log_{10} (H + 7.57 - 1.7EW^{0.37})$$

Where H = albumen height in mm, EW = egg weight in gram.

Statistical Analysis

Data obtained was arranged in a 2 × 2 factorial experimental layout and subjected to Analysis of Variance using General Linear Model Procedure as contained in Minitab® statistical package. Means with significant (P<0.05) differences were separated using Tukey Test of the same package.

Table 2: Interaction effect of Feed forms and Oyster mushroom inclusion on egg production and egg qualities of egg-type chickens at early-lay (20-27 week of age)

Feed form	Mash		Pellet			
Oyster Mushroom inclusion	With	Without	With	Without	SEM	P value
Parameters						
Total Egg Production (eggs)	156.60^{b}	159.00^{b}	166.00^{ab}	184.40^{a}	4.82	0.12
Hen Day Egg production (%)	34.96^{b}	35.49^{b}	37.05^{ab}	41.16^{a}	1.08	0.12
External Qualities						
Egg Weight (g)	48.50	52.70	47.40	50.45	4.75	0.91
Egg Length (mm)	51.81	53.99	52.58	52.48	1.43	0.47
Egg Width (mm)	40.88	41.82	10.15	41.41	1.39	0.92
Shell Weight (g)	4.65	4.70	4.70	4.15	0.43	0.52
Shell Thickness (mm)	0.58	0.55	0.59	0.45	0.45	0.31
Egg Shape Index(ESI)	78.91	77.46	76.37	78.84	0.88	0.09
Shell Surface area (cm^2)	13.02	13.11	13.11	12.01	0.83	0.51
Internal Qualities						
Albumen Height (mm)	9.16	11.23	9.26	10.04	0.83	0.48
Albumen weight (mm)	31.55	34.30	29.75	31.60	3.49	0.90
% albumen	65.06	65.08	62.74	62.29	1.45	0.88
Yolk weight (g)	10.95	11.65	11.35	12.50	0.75	0.78
% Yolk	22.55	22.10	23.97	25.34	1.97	0.67
Yolk Colour	4.50	5.00	4.00	4.50	0.61	1.00
Haugh Unit	97.82	105.16	98.49	101.35	3.20	0.52

^{a,b} Means in the same row with different superscripts differ significantly (P<0.05)

Table 3: Main effect of feed forms and Oyster mushroom inclusion on egg production and egg qualities of egg-type chickens at mid-lay (28-35 Weeks of age)

	Feed form				Oyster mushroom inclusion			
Parameters	Mash	Pellet	SEM	P Value	With	Without	SEM	P value
Total Egg Production (eggs)	212.60^{b}	259.90^{a}	8.63	0.00	234.8	237.7	8.63	0.82
Hen day Egg Production (%)	47.46^{b}	58.01^{a}	1.93	0.00	52.41	53.06	1.93	0.82
External Qualities								
Egg Weight (g)	58.10	57.80	1.48	0.89	57.40	58.50	1.48	0.61
Egg Length (mm)	56.76	56.54	0.63	0.81	56.46	56.83	0.63	0.68
Egg Width (mm)	42.93	43.64	0.61	0.43	43.00	43.57	0.61	0.52
Shell Weight (g)	4.90	5.00	0.12	0.57	5.10	4.80	0.12	0.10
Shell Thickness (mm)	0.44	0.46	0.02	0.56	0.46	0.44	0.02	0.53
Egg Shape Index (ESI)	75.70	77.22	1.02	0.31	76.23	76.69	1.02	0.76
Shell Surface Area (cm^2)	13.47	13.47	0.27	0.39	13.84	13.44	0.27	0.31
Internal Qualities								
Albumen Height (mm)	6.81	6.75	0.44	0.92	6.67	6.89	0.44	0.73
Albumen weight (g)	36.70	34.40	1.95	0.42	34.80	36.30	1.95	0.59
% Albumen	63.27	59.43	2.89	0.36	60.51	62.20	2.89	0.68
Yolk weight	14.00	14.20	0.72	0.44	13.70	13.70	0.72	1.00
% Yolk	24.31	23.02	1.09	0.42	23.89	23.44	1.09	0.78
Yolk Colour	4.30^{b}	5.80^{a}	0.32	0.01	5.30	4.80	0.33	0.30
Haugh Unit	81.87	81.02	2.95	0.84	80.88	82.01	2.95	0.79

^{a,b} Means in the same row with different superscripts differ significantly (P<0.05)

Table 4: Interaction effect of feed forms and Oyster mushroom inclusion on egg production and egg qualities of egg-type chickens at mid-lay (28-35 weeks)

Feed form	Mash		Pellet			
Oyster Mushroom inclusion Parameters	With	Without	With	Without	SEM	P value
Total Egg Production (eggs)	205.4^{b}	219.8^{ab}	264.2^{a}	255.6^{a}	12.2	0.36
Hen day Egg Production (%)	45.85^{b}	49.06^{ab}	58.97^{a}	57.05^{a}	2.73	0.36
External Qualities						
Egg Weight (g)	56.20	60.00	58.60	57.00	2.09	0.22
Egg Length (mm)	55.58	57.93	57.34	55.74	0.89	0.04
Egg Width (mm)	42.48	43.38	43.52	43.75	0.86	0.71
Shell Weight (g)	5.00	4.80	5.20	4.80	0.17	0.57
Shell Thickness (mm)	0.44	0.45	0.49	0.44	0.03	0.42
Egg Shape Index(ESI)	76.49	74.91	75.97	78.46	1.45	0.18
Shell Surface Area (cm^2)	13.66	13.29	14.02	13.60	0.38	0.96
Internal Qualities						
Albumen Height (mm)	6.96	6.66	6.38	7.12	0.62	0.42
Albumen Weight (mm)	36.60	36.8	33	35.8	2.75	0.64
% albumen weight	65.10	61.44	55.92	62.95	4.09	0.21
Yolk weight (g)	14.00	14.20	13.40	13.20	1.02	0.85
% yolk weight	24.97	23.64	22.80	23.24	1.54	0.57
Yolk Colour	4.80^{ab}	3.80^{b}	5.80^{a}	5.80^{a}	0.46	0.30
Haugh unit	83.61	80.13	78.14	83.89	4.17	0.29

^{a,b} Means in the same row with different superscripts differ significantly (P<0.05)

Results and Discussion

The main effects of feed forms and oyster mushroom inclusion on egg production and egg qualities of egg-type chickens during early-lay are presented in Table 1. Feed form significantly (p<0.05) influenced egg production parameters measured with significantly (p<0.05) higher Total Egg Production and Hen Day Egg Production (175.20 eggs and 39.11%, respectively) recorded in birds fed pellet feed and lower values (157.80 eggs and 35.22%, respectively) recorded in birds fed mash. It has been previously reported (31) that pelleting of feeds improved the laying rate in chickens. This may imply that nutrients required for egg formation were adequately utilized and absorbed in laying birds with the consumption of pellets during early stage of laying. Results were consistent with recent report (32) where the egg laying rate of both Hy-Line grey and Hy-line brown hens fed with the pellet diet were higher than those fed the mash diet. Conversely, performance at the beginning of peak production in white layer strain did not show significant response to alterations in feed form (mash *vs.* pellet) (14). This varying trend in responses to feed forms reported are probably confounded by a number of factors such as ingredient composition and nutrient balance of the feed, pellet hardness, genotype, and production performance potential of birds used in the experiments. Though limited information is available on the effects of mushrooms on layers' performance and egg characteristics, it was observed in this study that birds fed diets with oyster mushroom inclusion recorded significantly (p<0.05) lower (161.30 eggs and 36.00%) Total Egg Production and Hen Day Egg Production respectively during the early-lay phase when compared with their counterparts fed diets without oyster mushroom (171.70 eggs and

38.33%). Similarly, the interaction between feed form and oyster mushroom inclusion at early-lay revealed Total Egg Production and Hen Day Egg Production were significantly (p<0.05) highest in birds fed pellet feed without Oyster mushroom (Table 2). This reduction in egg production contradicted previous observations (33) that fermented spent mushroom substrates could be used as a resource in laying hen feed at 5% to 15% without adversely affecting egg-related performance and egg quality. This contradiction therefore suggests the need to increase the inclusion level of oyster mushroom in layers diets before beneficial impact on egg production and egg quality can be achieved.

Table 5: Main effect of feed forms and Oyster mushroom inclusion on egg qualities and egg production of egg-type chickens at late-lay (38-43 weeks of age)

	Feed form				Oyster mushroom inclusion			
Parameters	**Mash**	**Pellet**	**SEM**	**P value**	**With**	**Without**	**SEM**	**P value**
Total Egg Production (eggs)	305.70	310.10	4.10	0.46	304.00	311.80	4.10	0.20
Hen day Egg Production (%)	68.24	69.22	0.92	0.46	67.86	69.60	0.92	0.20
External qualities								
Egg Weight (g)	55.60	54.40	1.60	0.60	55.70	54.30	1.60	0.55
Egg Length (mm)	40.06	40.61	0.87	0.66	39.89	40.78	0.87	0.48
Egg Width (mm)	25.33	24.57	0.38	0.18	25.22	24.68	0.38	0.33
Shell Weight (g)	4.90	5.20	0.22	0.36	5.20	4.90	0.22	0.36
Shell Thickness (mm)	0.66^{b}	0.84^{a}	0.05	0.03	0.72	0.77	0.05	0.55
Egg Shape Index (ESI)	63.49	60.66	1.46	0.19	63.47	60.68	1.46	0.20
Shell Surface area(cm^2)	13.45	14.00	0.41	0.35	14.00	13.45	0.41	0.35
Internal Qualities								
Albumen height	7.68	6.40	0.46	0.07	6.73	7.35	0.46	0.36
Albumen weight	33.80	32.40	1.24	0.44	33.3	32.90	1.24	0.82
% Albumen	60.66	59.47	0.86	0.35	59.67	60.46	0.86	0.53
Yolk weight	14.95	15.40	0.46	0.50	14.95	15.40	0.46	0.50
% Yolk	26.95	28.42	0.73	0.17	27.00	28.38	0.731	0.20
Yolk colour	1.90	2.00	0.21	0.74	1.90	2.00	0.21	0.74
Haugh Unit	87.92	79.35	3.42	0.10	81.83	85.43	3.42	0.47

^{a,b} Means in the same row with different superscripts differ significantly (P<0.05)

In Table 3, the main effects of feed forms and Oyster mushroom inclusion on egg production and egg qualities of egg-type chickens during mid-lay were depicted. Similar to what was observed in the early-phase, Total Egg Production and Hen Day Egg Production were also significantly (p<0.05) higher (259.90 eggs and 58.01%, respectively) in birds fed pellet feed and lowest (212.60 eggs and 47.46%, respectively) in birds fed mash feed. In addition, yolk colour score, a practical measurement that determines intensity of pigmentation of egg yolk was significantly (p<0.05) higher (5.80) in birds fed pellet feed than 4.30 in birds fed mash feed. Yolk colour plays a major role in consumer preference and a darker yolk colour is highly desirable (34). The colour of yolk in eggs is mostly determined by the main cereal of the diet which is yellow maize or the amount of xanthophyll added to feed. In this study, feed was mainly based on maize and no synthetic yolk colour pigment was added to the feed. Therefore, higher yolk colour score for pellet regimen might indicate the utilization of xanthophyll in pellet-fed hens was more than that of the mash-fed hens. More so, the inclusion of oyster mushroom had no effect ($p>0.05$) on all parameters measured. This contradicted earlier reports (35) that egg production significantly increased by the shiitake mushroom supplementation when compared with the control group, but other laying parameters were not affected. The authors also indicated that Haugh unit significantly increased in shiitake groups, but a thinner egg shell was observed in the shiitake 0.25% group and thicker egg albumen in the shiitake 0.5% group compared to the control group. In addition, the interaction effect between feed form and Oyster mushroom inclusion on egg production and egg qualities of egg-type chickens during mid-lay revealed significantly ($p<0.05$) highest Total Egg Production and Hen Day Egg Production were recorded in birds fed pellet with oyster mushroom and birds fed pellet without oyster mushroom while lowest was recorded in birds fed mash with Oyster mushroom (Table 4). Yolk colour was also significantly ($p<0.05$) highest (5.80) in birds fed pellet feed with oyster mushroom and birds fed pellet feed without oyster mushroom, respectively and lowest (3.80) in birds fed mash feed without Oyster mushroom.

Table 6: Interaction effect of feed forms and Oyster mushroom inclusion on egg production and egg qualities of egg-type chickens at late-lay (38-43 weeks of age)

Feed form	Mash		Pellet			
Oyster mushroom inclusion	With	Without	With	Without	SEM	P value
Parameters						
Total egg production (eggs)	299.80	311.60	308.20	312.00	5.80	0.50
Hen day egg production (%)	66.92	69.55	68.79	69.64	1.30	0.50
External qualities						
Egg weight (g)	55.40	55.80	56.00	52 .80	2.27	0.44
Egg length (mm)	39.32	40.80	40.46	40.76	1.23	0.64
Egg width (mm)	25.28	25.38	25.16	23.98	0.54	0.25
Shell weight (g)	5.00	4.80	5.40	5.00	0.36	0.76
Shell thickness (mm)	0.67	0.65	0.78	0.89	0.08	0.41
Egg shape index (ESI)	64.70	62.29	62.24	59.07	2.07	0.86
Shell surface area (cm^2)	13.64	13.26	14.37	13.64	0.58	0.76
Internal qualities						
Albumen height	7.06	8.30	6.40	6.40	0.65	0.36
Albumen weight	32.40	35.20	34.20	30.60	1.76	0.09
% Albumen	58.34^{ab}	62.98^{a}	61.00^{ab}	57.94^{b}	1.22	0.01
Yolk weight	14.70	15.20	15.20	15.60	0.65	0.94
% Yolk	26.72	27.18	27.27	29.58	1.03	0.39
Yolk colour	1.80	2.00	2.00	2.00	0.29	0.74
Haugh unit	84.55	91.28	79.10	79.59	4.83	0.53

^{a,b} Means in the same row with different superscripts differ significantly ($P<0.05$)

Furthermore, the main effects of feed forms and Oyster mushroom inclusion on egg qualities and egg production of egg-type chickens at late-lay are shown in Table 5. Similar to observations during the mid-lay phase, the effect of oyster mushroom inclusion had no effect ($p>0.05$) on all parameters measured. Feed form also had negligible effect ($p>0.05$) on egg production parameters measured. This was in accordance with the suggestions made by previous researchers (36) and (37) that there was little difference between pellets and mash diets on chicken performance, especially during the late phase of production. However, result also revealed shell thickness was significantly ($p<0.05$) higher (0.84 mm) in birds fed pellet feed than 0.66 mm in birds fed mash feed. This may imply pellet feed will provide laying hens with adequate mineral required for egg shell formation. Pelleting does not only permit the use of low density and bulky feeds, it enhances the availability of phosphorus in feed (38). Moreover, the interaction effect of feed forms and Oyster mushroom inclusion at late-lay presented in Table 6 revealed significantly ($p<0.05$) highest percent albumen (62.98%) in birds fed mash feed without oyster mushroom while lowest (57.94%) was recorded in birds fed pellet feed without oyster mushroom. Since limited evidence exists on the impact of mushrooms on egg production and egg quality, increasing inclusion levels may enable oyster mushrooms exert their beneficial activities for improved egg production and egg quality.

Conclusion and Application

1. Feeding egg-type chickens with pellet feed without oyster mushroom at early-lay phase will improve egg production.
2. Optimal egg production with darker yolk colour can be achieved at the mid-lay phase via feeding laying birds with pellet feed with oyster mushroom.
3. During late-lay phase, pellet feeding improves shell thickness while mash feeding without oyster mushroom will increase albumen content of eggs.

References

1. Sainsbury, D. (2000). *Poultry Health and Management: Chickens, Ducks, Turkeys, Geese and Quail (4th edition). Blackwell Science Inc., Malden, MA.*
2. Abdollahi, M.R., Ravindran, V. and Svihus, B. (2014). Influence of feed form on growth performance, ileal nutrient digestibility, and energy utilisation in broiler starters fed a sorghum-based diet. *Livestock Science*, 65: 80–86.
3. Guzman, P., Saldana, B., Mandalawi, H.A., Perez-Bonilla, A., Lazaro, R. and Mateos, G.G. (2015). Productive performance of brown-egg laying pullets from hatching to 5 weeks of age as affected by fiber inclusion, feed form, and energy concentration of the diet. *Poultry Science*, 94: 249–261.
4. Abadi, M.H.M.G., Moravej, H., Shivazad, M., Torshizi, M.A.K. and Kim, W.K. (2019). Effects of feed form and particle size, and pellet binder on performance, digestive tract parameters, intestinal morphology, and cecal microflora populations in broilers. *Poultry Science* 98: 1432–1440.
5. Amerah, A.M., Ravindran, V., Lentle, R.G. and Thomas, D.G. (2007). Feed particle size: Implications on the digestion and performance of poultry. *Worlds Poultry Science Journal*, 63: 439–455.
6. Massuquetto, A., Panisson, J.C., Schramm, V.G., Surek, D., Krabbe, E.L. and Maiorka, A. (2020). Effects of feed form and energy levels on growth performance, carcass yield and nutrient digestibility in broilers. *Animal*, 14: 1139–1146.
7. Corzo, A., Mejia, L. and Loar, R.E. (2011). Effect of pellet quality on various broiler production parameters. *Journal of Applied Poultry Research*, 20: 68–74.
8. Jahan, M.S., Asaduzzaman, M. and Sarkar, A.K. (2006). Performance of broiler fed on mash, pellet and crumble. *International Journal of Poultry*

Science, 5(3):265–270.
9. Abdollahi, M.R., Ravindran, V., Wester, T.J., Ravindran, G. and Thomas, D.V. (2012). Effect of improved pellet quality from the addition of a pellet binder and/or moisture to a wheat based diet conditioned at two different temperatures on performance, apparent metabolisable energy and ileal digestibility of starch and nitrogen in broilers. *Animal Feed Science and Technology*, 175: 150–157.
10. Xu, Y., Stark, C.R., Ferket, P.R., Williams, C.M., Auttawong, S. and Brake, J. (2015). Effects of dietary coarsely ground corn and litter type on broiler live performance, litter characteristics, gastrointestinal tract development, apparent ileal digestibility of energy and nitrogen, and intestinal morphology. *Poultry Science*, 94: 353–361.
11. Svihus, B. (2006). The role of feed processing on gastrointestinal function and health in poultry. Pages in 183–194 in Avian Gut Function in Health and Disease. G. C. Perry (Ed.). CAB International, Wallingford, UK.
12. Röhe, I., Ruhnke, I., Knorr, F., Mader, A., Boroojeni, F.G., Lowe, R. and Zentek, J. (2014). Effects of grinding method, particle size, and physical form of the diet on gastrointestinal morphology and jejunal glucose transport in laying hens. *Poultry Science*, 93:2060–2068.
13. Saldana, B., Guzman, P., Camara, L., Garc´ıa, J. and Mateos, G.G. (2015). Feed form and energy concentration of the diet affect growth performance and digestive tract traits of brown-egg laying pullets from hatching to 17 weeks of age. *Poultry Science*, 94: 1879–1893.
14. Ruhnke, I., Rohe, I., Kramer, C., Goodarzi Boroojeni, F., Knorr, F., Mader, A., Schulze, E., Hafeez, A., Neumann, K., Lowe, R. and Zentek, J. (2015). The effects of particle size, milling method, and thermal treatment of feed on performance, apparent ileal digestibility, and pH of the digesta in laying hens. *Poultry Science* 94: 692–699.
15. Herrera, J., Saldana, B., Guzman, P., Camara, L. and Mateos, G.G. (2017). Influence of particle size of the main cereal of the diet on egg production, gastrointestinal tract traits, and body measurements of brown laying hens. *Poultry Science* 96: 440–448.
16. Ege, G., Bozkurt, M., Kocer, B., Tuzun, A.E., Uygun, M. and Alkan, G. (2019). Influence of feed particle size and feed form on productive performance, egg quality, gastrointestinal tract traits, digestive enzymes, intestinal morphology, and nutrient digestibility of laying hens reared in enriched cages. *Poultry Science* 98: 3787–3801.
17. Kul, S. and Seker, I. (2004). Phenotypic correlations between some external and internal egg quality traits in the Japanese quail (*Cortunix cortunix japonica*). *International Journal of Poultry Science*, 3(6): 400-405
18. Jones, P.L., Chavez, J.R. and Mitchell, B.D. (2002). Production of Australian freshwater crayfish in earthen-based systems using pelleted diets and forage crops as food. *Aquaculture International*, 10 (2): 157-175
19. Khan, S. H., Mukhtar, N. and Iqbal, J (2018). Role of Mushroom as Dietary Supplement on Performance of Poultry. *Journal of Dietary Supplements*, 1-14. DOI: 10.1080/19390211.2018.1472707
20. Windisch, W., Schedle, K., Plitzner, C. and Kroismayr, A. (2008). Use of phytogenic products as feed additives for swine and poultry. *Journal of Animal Science* 86:140-148.
21. Gheisar, M.M. and Kim, I.H. (2017). Phytobiotics in poultry and swine nutrition: a review. *Italian Journal of*

Animal Science, 17: 92-99.
22. Prakash, U.N. and Srinivasan, K. (2010). Beneficial influence of dietary spices on the ultrastructure and fluidity of the intestinal brush border in rats. *British Journal of Nutrition,* 104: 31-39.
23. Abou-Elkhair, R., Ahmed, H.A. and Selim, S. (2014). Effects of black pepper (Piper nigrum), turmeric powder (Curcuma longa) and coriander seeds (Coriandrum sativum) and their combinations as feed additives on growth performance, carcass traits, some blood parameters and humoral immune response of broiler chickens. *Asian-Australasian Journal of Animal Science*, 27(6): 847-854.
24. Elmastas, M., Isildak, O., Turkekul, I. and Temur, N. (2007). Determination of antioxidant activity and antioxidant compounds in wild edible mushrooms. *Journal of Food Composition and Analysis* 20: 337–345.
25. Guo, F.C., Savelkoul, H.F.J., Kwakkel, R.P., Williams, B.A. and Verstegen, M.W.A. (2003). Immunoactive, medicinal properties of mushroom and herb polysaccharides and their potential use in chicken diets. *World's Poultry Science Journal* 59: 427–440.
26. Giannenas, I., Pappas, I.S., Mavridis, S., Kontopidis, G., Skoufos, J. and Kyriazakis, I. (2010). Performance and antioxidant status of broiler chickens supplemented with dried mushrooms (*Agaricus bisporus*) in their diet. *Poultry Science,* 89: 303–311.
27. Daneshmand, A., Sadeghi, G.H. and Karimi, A. (2012). The effects of a combination of garlic, oyster mushroom and propolis extract in comparison to antibiotic on growth performance, some blood parameters and nutrients digestibility of male broilers. *Brazilian Journal of Poultry Science* 14(2): 141–147.
28. Sogunle, O. M., Labinjo, O. S., Olanite, J. A., and Adebowale, A. A. (2019). Growth performance and blood profile of cockerel chickens on administration of oyster mushroom (*Pleurotus ostreatus*) in water and feed. *Archivos de Zootecnia,* 68 (261): 24-30.
29. Park, P.J., Je, J.Y. and Kim, S.K. (2004). Free Radical Scavenging Activities of Differently Deacetylated Chitosans Using an ESR Spectrometer. *Carbohydrate Polymers*, 55: 17-22.
30. Je, J.Y. and Kim, S.K. (2006). Antioxidant Activity of Novel Chitin Derivatives. *Bioorganic and Medical Chemistry Letters,* 16: 1884-1887.
31. Abdollahi, M.R., Ravindran, V. and Svihus, B. (2013). Pelleting of broiler diets: An overview with emphasis on pellet quality and nutritional value. *Animal Feed Science and Technology* 179: 1–23.
32. Wan, Y., Ma, R., Khalid, A., Chai, L., Qi, R., Liu, W., Li, J., Li, Y. and Zhan, K. (2021). Effect of the Pellet and Mash Feed Forms on the Productive Performance, Egg Quality, Nutrient Metabolism, and Intestinal Morphology of Two Laying Hen Breeds. *Animals*, 11, 701. https://doi.org/10.3390/ani 11030701
33. Cho, Y.J., Choi, E.J., Shin, P.G., Yoo, Y.B., Cho, Y.U., Kim, H.C., Gal, S.W., Moon, Y.H. and Cho, S.J. (2010). Effect of spent mushroom (*Pleurotus eryngii*) substrates addition on egg quality in laying hens. Proceedings of the 6th Meeting of East Asia for Mushroom Science. p. 139.
34. Roberts, J.R. (2004). Factors affecting egg internal quality and egg shell quality in laying hens. *Japanese Poultry Science*, 41: 161–177.
35. Hwang, J.A., Hossain, M.E., Yun, D.H., Moon, S.T., Kim, G.M. and Yang, C.J. (2012). Effect of shiitake [*Lentinula edodes* (Berk.) Pegler] mushroom on laying performance, egg quality, fatty

acid composition and cholesterol concentration of eggs in layer chickens. *Journal of Medicinal Plants Research*, 6(1): 146–153.

36. Lemme, A., Wijtten, P.J.A., VanWichen, J., Petri, A. and Langhout, D.J. (2006). Responses of male growing broilers to increasing levels of balanced protein offered as coarse mash or pellets of varying quality. *Poultry Science*, 85: 721–730.
37. Dozier, W.A., Behnke, K.C., Gehring, C.K. and Branton, S.L. (2010). Effects of feed form on growth performance and processing yields of broiler chickens during a 42-day production period. *Journal Applied Poultry Research*, 19: 219–226.
38. Food and Agriculture Organization. (1980). Aquaculture development and coordination programme. Lectures presented at the FAO/UNDP Training course in Fish feed technology, Seattle, Washington, 9 October – 15 December 1978. FAO/ADCP/REP/80/11.FAO: 400 pp.