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Research Paper

Effect of extruded eggshell, limestone and oyster shell on egg production performance of laying hens

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Abstract. The present study was carried out to assess the effect of extruded eggshell, limestone and oyster shells with different levels (L_1= 4% Ca sources, L_2= 8% Ca sources) on egg production performance and profitability at different ages of laying hens. A total of 120, Isa-brown ready-to pullets of 18 weeks old were distributed into three dietary treatment groups; D_1 (diet with limestone), D_2 (diet with oyster shell) and D_3 (diet with extruded eggshell) with 4% and 8% levels having 20 birds each. The birds were reared in individual cage management systems providing diets containing 18% crude protein, 2750 Kcal ME/Kg, 3.0% Ca, 0.5% phosphorus, 0.5% lysine, 0.3% methionine, and 0.2% tryptophan for one year of laying period. Body weight, feed intake, egg production, hen-day, hen-housed, egg mass production, feed conversion ratio (FCR), survivability, production cost and net profit differed significantly among the dietary groups. The highest feed intake was observed in D_1, moderate in D_3 and the lowest in D_2. The diet D_3 showed the highest number of eggs, hen-day, hen-housed and egg mass production, followed by D_1 and D_2, respectively. The D_3 showed the highest survivability and net profit, and the lowest FCR and production cost, followed by D_2 and D_1, respectively. The L_2 performed better than L_1 in terms of egg production performance and net profit. However, the diet with 8% extruded eggshell was superior to the diet with 8% limestone or Oyster shell in terms of egg production and net profit. The egg production and net profit increased with the increased age of the bird. Therefore, the diet with 8% extruded eggshell may be beneficial to use in the diet of laying hens.

Keywords: Bird age, calcium source, egg production, laying hen, calcium source level, net profit.

INTRODUCTION

The poultry industry is one of the most important and profitable businesses in the agriculture sector that provides nutritious meat and egg essential for human consumption, which is produced within the shortest possible time. Quality meat and egg production depend on quality feed. A quality feed with a reasonable price is a key factor for successful poultry farming (Basak *et al.,* 2002). Feed cost accounts for about 65-70% of the total poultry production cost. The fast growth rate in poultry production with increasing demand affect the price of inputs like feed and feed ingredients (Ahmed *et al.,* 2012). In the rearing of layer-type poultry, calcium source feed ingredients are the vital feed item that affects feed cost as well as production cost.

There is constant competition between humans and poultry for conventional feed ingredients. It is essential to find out the feasibility of using an alternative that will be non-competitive feed ingredients in the diet of poultry. Calcium is an important mineral for laying birds because of the formation of bones and the quality of eggshells. An egg contains almost 2 g calcium (Ca), this is why laying birds required 4 g Ca per day. About 50 - 60% of dietary calcium is used for eggshell formation (Harikrishnan and Mohan, 2018). Farmers use DCP, limestone, or oyster shell feed ingredients as a Ca source in the diet of laying hens. Oyster shell is not available in the market. In addition, this is expensive and contains lead (Pb) vestige toxic substances such as Al, Hg, Cd, Pb, Zn, etc. (Badri and Astom, 1983).

The extruded eggshell is one of the cheapest and most abundant unconventional Ca source feed ingredients. Extruded eggshells are available in the hatcheries, fast food-producing industries, egg product factories, kitchens, and restaurants that are considered as waste. This wastage is unconsciously thrown into the dust bean, fallow land, or road side that affects our surrounding environment by disseminating pollutants (Than *et al.,* 2012; King'Ori, 2011). Vandepopuliere *et al*. (1975) reported that the calcium level in an eggshell is comparable to that of limestone with the benefit of a small amount of protein. The formation of eggshells in the uterus is required to maintain adequate blood Ca+2 levels (Sultana *et.al.* 2007).The eggshell contains approximately 98.2% calcium carbonate, 0.9% magnesium and 0.9% phosphorus (phosphate) (Romanoff *and* Romanoff, 1949. Additionally, the eggshell membrane consists of collagen as a component of protein and fibrous that supports the other body tissues, such as skin, bone, tendons, muscles and cartilage. This collagen is very low in autoimmune and allergic reactions but high in bio-safety which is similar to another mammalian collagen (King'Ori, 2011). The solubility of oyster shells is higher than limestone of similar particle size reported by (Guinotte and Nys, 1991; Saunders-Blades *et al.,* 2009). They also reported that solubility of the Ca source affects the hen's ability to utilize in the formation of bone and eggshell. Several scientists suggested using eggshells with the membrane as a Ca source in the diet of laying hen that has no adverse effects on productive performance (Froning and Bergquist, 1990; Gongruttananun, 2011). Scheideler (1998) reported that Ca is available in eggshell which also influences on hatchability of eggs and profitability. Besides these, a quality eggshell with high breaking strength is essential to prevent damage egg as well as to prevent pathogenic bacteria such as *Salmonella* sp. into the eggs (Washburn, 1982; Roland, 1988. Khalil and Anwar (2009) observed the similar retention of Ca or P in the substitution of an oyster shell with limestone in the egg of a laying hen. Lichovnikova (2007) showed that supplementation of eggshell as a Ca source increased Ca and P retention at 56 and 57 weeks age of the laying hens. A study reported the Ca: P ratio in the eggshell was 1.67:1, but low calcium levels increased phosphorus excretion and low phosphorus levels increased calcium excretion (Abdulrahman *et al.,* 2014). The Ca source and its particle size may play an important role in maintaining eggshell quality and bone mineralization (Blister *et al*., 1981; Guinotte and Nys, 1991; Keshavarz *et al.,* 1993). Mroz *et al*., (2007) found a relationship between the mammillae size and hatchability of chicken eggs. They reported higher hatchability in the good mammillae size eggshell than the poor mammillae size eggshell because the defective eggshell inhibits embryo growth and the water loss mechanism that adversely affects the hatchability.

Egg production of laying hen in diets with extruded eggshells was comparable to the diet with limestone or oyster shell (Arvat and Hinners, 1973; Vandepopuliere *et al*., 1978). Vandepopuliere *et al*. (1973; 1975) reported the heavier egg (65.7 g) production of laying hens fed a diet with extruded eggshell compared to the diet with limestone (64.8 g). Extruded eggshell is probably the best and most available unconventional natural source of calcium. In addition, birds highly prefer eggshells even 10-20 times more than limestone or oyster shell (Fig. 1). On the other hand, digestion, as well as utilization of extruded eggshell in the body of birds, is much better than limestone or oyster shell (Bee, 2011). Using extruded eggshells in the diet of poultry will also help to save the environment. Considering the above points, the objective of the present study is to assess the effect of extruded eggshell, limestone, or oyster shell on egg production performance and profitability of laying hens for producing a safe and cost-effective egg.

MATERIALS AND METHODS

The study was approved by the Institutional Committee on Animal Care and Use in Research (ICACUR) of Bangabandhu Sheikh Mujibur Rahman Agricultural University (No. BSMRAU/DEAN/FVMAS/25/ICACUR/19). The experiment was carried out at Bangabandhu Sheikh Mujibur Rahman Agricultural University Poultry Farm, Gazipur-1706, Bangladesh.

Collection and process of eggshell

Extruded eggshell was collected from commercial hatchery, restaurants and student hall. The collected eggshell was boiled in hot water for 2-3 minutes and dried in the sun to grind using a grinding machine and then stored. It was used in the diet of the laying hens during the investigation.

Feeding trial

A total of 120 Isa-brown ready-to pullets, 18 weeks old were collected from CP Bangladesh Ltd. and randomly

Table 1. Composition of diet used in the present experiment

Ingredients	Amount (Kg)					
	Diet (D)					
	D_1		D_2		D_3	
	Level (L)					
	L_1	L_2	L_1	L_2	L_1	L_2
Maize	62.0	61.0	64.0	64.0	64.5	64.5
Soybean meal	19.5	21.5	20.0	23.0	18.5	17.0
Rice polish	4.0	4.5	2.0	1.0	1.5	2.5
Protein Concentrate	6.0	4.5	5.5	3.5	6.0	6.5
Limestone	4.0	8.0	-	-	-	-
Oyster shell	-	-	4.0	8.0	-	-
Extruded eggshell	-	-	-	-	4.0	8.0
Di-calcium Phosphate (DCP)	4.0	-	4.0	-	5.0	1.0
Salt	0.5	0.5	0.5	0.5	0.5	0.5
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated composition						
ME (kcal/kg)	2787.98	2773.16	2789.6	2769.92	2771.04	2782.38
Crude protein (%)	18.01	17.86	17.83	17.72	17.85	18.02
Calcium (Ca) (%)	2.89	3.07	2.87	3.01	2.71	2.92
Phosphorus (P) (%)	1.24	0.51	1.21	0.42	1.96	1.83
Lysine (%)	0.89	0.92	0.89	0.92	0.86	0.84
Methionine (%)	0.36	0.35	0.35	0.34	0.35	0.35
Tryptophan (%)	0.23	0.23	0.23	0.23	0.22	0.22

distributed into 3 dietary treatment groups with 2 levels of Ca sources having 20 birds each (Table 1). The birds were reared in an individual cage management system to investigate egg production performances for one year of laying period. The birds were offered feed as per the standard given by the breeder. Standard management as per the standard given by the breeder was provided to the birds during the investigation.

D_1= Diet with limestone; D_1= Diet with limestone; D_2= Diet with oyster shell; D_3= Diet with extruded eggshell; L_1= 4% Ca sources, L_2 = 8% Ca sources.

Data Recording

Considering the five age groups, the following data were recorded during the investigation.

Body weight and feed intake- the individual bird every month

Egg production- recorded monthly

Egg weight- recorded randomly every month

Dead birds- when occurred

The following parameters were calculated using the formula according to Onunkwo and Okoro (2015).

Egg mass (g/bird) = No. of eggs × egg weight (g)

FCR (Feed intake/dozen egg) = $\frac{\text{Kg of feed consumed}}{\text{Total egg produced}} \times 12$

FCR (Feed intake/kg egg) = $\frac{\text{Kg of feed consumed}}{\text{Kg of egg produced}}$

Hen-day (HDEP) and hen-housed (HHEP) egg production were calculated using the following formula:

HDEP (%) = $\frac{\text{Total number of eggs produced during the period}}{\text{Total number of hens at the end of period x duration of laying period}} \times 100$

HHEP (%)= $\frac{\text{Total number of eggs laid during the period}}{\text{Total number of hens at the beginning of laying period} \times \text{duration of laying period}} \times 100$

Production cost (Taka/dozen eggs or Taka/kg egg) was calculated considering the feed cost, labor cost, utility cost and medicine cost, etc.

Net profit was calculated using the following formula:

Net profit (Taka/dozen eggs) = Price per dozen eggs – production cost per dozen egg

Statistical analysis

The collected data were analyzed in 3 diets x 2 levels Ca sources x 5 age groups factorial design by using the Statistix10 computer package program.

Statistical model

The following statistical model was used for data analysis

$Y_{ijkl} = \mu + Di + L_j + A_k + (DxL)_{ij} + ((L\ xA)_{jk} + (D\times A)_{ik} + (D\ x\ L\ x\ A)_{ijk} + e_{ijkl}$

Where Y_{ijkl} is the observation of the lth replication of the ith dietary group, the jth level of Ca source and the kth age group.

μ is the overall mean.

D_i is the fixed effect of the ith dietary groups (i= 1………. 3)

L_j is the fixed effect of the jth level of Ca sources (j= 1, 2)

A_k is the effect of the kth age groups (k= 1…………5)

$(D\times L)_{ij}$ is the interaction effect of the ith dietary group and

the jth level of Ca source
$(L \times A)_{jk}$ is the interaction effect of the jth level Ca source and the kth age group
$(D \times A)_{ik}$ is the interaction effect of the ith dietary group and the kth age group
e_{ijkl} is a random error.

RESULTS

The dietary groups; D_1 (diet with limestone), D_2 (diet with oyster shell) and D_3 (diet with extruded eggshell) were significantly different in body weight (p<0.01), feed intake (p<0.001), livability (p<0.05), egg production, feed conversion ratio (FCR) (feed intake/dozen egg), FCR (feed intake/kg of egg), egg mass, hen-day, hen-housed egg production, production cost and net profit (p<0.001). The lowest body weight of the bird was observed in D_3, moderate in D_1 and the highest in D_2 (Table 2). However, the lowest feed intake was observed in D_2, moderate in D_3 and the highest in D_1. The diet D_3 showed the highest number of the eggs, hen-day, hen- housed and egg mass production, followed by D_1 and D_2, respectively. The feed conversion ratio (FCR) (Feed intake/dozen egg or feed intake/kg egg) at 72 weeks age of the bird was the lowest in D_3, followed by D_2 and D_1, respectively. The highest percentage of survivability was observed in D_3, followed by D_2 and D_1, respectively. The lowest egg production cost but the highest net profit was observed in D_3, followed by D_2 and D_1, respectively. The number of egg production, survivability, and lowering FCR reduced production costs that affected increasing net profit.

Level 1 (L1= 4% Ca sources) showed a higher feed intake and production cost and a lower net profit than level 2 (L2= 8% Ca sources). Of all the diets with an 8% Ca source, the diet with 8% extruded eggshells showed the highest net profit.

As an effect of age, body weight, feed intake, egg production, hen-day, hen-housed, egg mass production, FCR, production cost and net profit differed significantly, except for the survivability among the age groups (p<0.001*)*. Body weight, feed intake, egg production, hen-day, hen-housed, egg mass production and net profit were increased but decreased FCR and production cost with the increase of the age of the bird. The survivability was statistically similar among the age groups (p>0.05). The level of Ca sources was not different for the traits, except for feed intake, production cost and net profit (p<0.001).[

Diet interacted with level of Ca sources for feed intake (p<0.05), egg production (p<0.001), hen-day, hen-housed egg production (p<0.001), egg mass production, FCR (Feed/dozen eggs) (p<0.05), survivability (p<0.001) and net profit (p<0.01), except for body weight, FCR (Feed/Kg egg) and production cost (p>0.05). No interaction was observed between the level of Ca sources and the age group of the bird for egg production performance traits (p>0.05). The diet with the age of the bird interacted for feed intake (p<0.01), hen-day egg production (<0.05), hen-housed egg production, FCR (feed/kg egg) and production cost (p<0.001), but did not interact for body weight, egg production, egg mass, FCR (feed /dozen eggs), survivability and net profit *(p>0.05).* No interaction of diet, level of Ca sources and age group was observed for egg production performance traits (p>0.05), except for hen-housed egg production (p<0.01).

DISCUSSION

The diet D_3 (diet with extruded eggshell) performed the best among dietary groups in terms of body weight, hen-day, hen-housed, egg mass production, FCR, survivability, production cost and net profit. The calcium sources of level 2 (8% Ca) performed better than level 1 (4% Ca sources) because of a lower feed intake, FCR, production cost, and higher egg production and net profit. Of all the calcium sources, level 2 (8% Ca sources), especially the diet with 8% extruded eggshells, performed the best for egg production performance and net profit. Therefore, the diet with 8% extruded eggshell (D_3) showed the highest egg production and net profit, consistent with the previous findings (Muir *et al*., 1976; Ahammad *et al.,* 2005; Cufadar, 2014). Muir *et al.* (1976) found the lowest body weight of the bird in diet included 10% eggshell. Ahammad *et al.* (2005) reported a higher egg production (305/bird/year) in a diet with 6.5% eggshell meal compared to a diet with 5% eggshell meal. Cufadar (2014) reported the highest egg production in the diet included 15% eggshell meal. Sim *et al.* (1983) found the highest percentage of hen-day, hen-housed egg production in diet with 7% eggshell meal compared to other dietary groups that supported the present findings. In the present study, the diets of 8% calcium sources in the level 2, especially the 8% extruded eggshell, performed the best for FCR, survivability, production cost and net profit, corroborating the previous findings.(Vandepopuliere *et al.,* 1973; Ahmed *et al.,* 2013). They reported the lowest FCR in the diet included 12% dry eggshell compared to the control diet. In the cost-benefit analysis in the present study, the highest profitability was observed in the diet D_3 with 8% extruded eggshell. Therefore, the diet with 8% extruded eggshell showed better performance than the diets with 8% limestone or oyster shell in terms of egg production and profitability of laying hens.

Age affected egg production and profitability, except for the survivability, which was almost similar among age groups. Egg production performances and the net profit were increased but decreased FCR and production cost with the increasing age of the bird, which is consistent with the findings of Gongruttananun (2011). He observed

Table 2. Egg production performance and profitability at different ages of laying hens fed diet included extruded eggshell, limestone and oyster shell for one year of laying period.

Trait	Diet (D)	Level (L)	Age (A)						LSD value & level of Significance+						
			A_1	A_2	A_3	A_4	A_5	Mean	D	L	A	DxL	LxA	DxA	DxLXA
Body weight (g/bird)	D_1	L_1	1664.10	1712.60	1747.00	1860.00	2027.70	180.2.40	33.205***	27.532^{NS}	42.830***	45.969^{NS}	60.145^{NS}	73.633^{NS}	102.790^{NS}
		L_2	1664.50	1773.80	1864.20	1859.40	2039.90	1836.30							
		Mean	1654.30	1743.20	1805.60	1859.80	2033.80	1819.30							
	D_2	L_1	1617.00	1750.00	1790.30	1909.60	2009.70	1819.10							
		L_2	1636.70	1813.60	1817.30	1897.90	2035.70	1847.00							
		Mean	1653.30	1781.80	1803.80	1903.70	2022.70	1833.10							
	D_3	L_1	1636.90	1691.50	1696.10	1847.90	2003.30	1775.00							
		L_2	1547.30	1688.50	1725.30	1869.30	1977.20	1761.50							
		Mean	1592.10	1690.00	1710.70	1858.60	1990.20	1768.30							
Feed intake (g/bird)	D_1	L_1	8537	19089	29440	36196	43238	27300	91.542***	75.903***	118.080***	126.730*	165.810^{NS}	203.000**	283.380^{NS}
		L_2	8424	18854	28882	35668	42685	26903							
		Mean	8481	18971	29161	35932	42962	27101							
	D_2	L_1	8654	19128	29101	35855	42884	27124							
		L_2	8507	18900	28578	35570	42895	26903							
		Mean	8580	19014	28839	35712	42689	26967							
	D_3	L_1	8652	19173	29321	36237	43145	27306							
		L_2	8340	19117	29177	36050	43067	27150							
		Mean	8496	19145	29249	36143	43106	27228							
Egg production (No./bird)	D_1	L_1	50.43	123.53	197.81	247.09	291.70	182.11	3.331***	2.762^{NS}	4.297***	4.612***	6.035^{NS}	7.388^{NS}	10.313^{NS}
		L_2	50.55	128.55	205.75	259.55	307.45	190.37							
		Mean	50.49	126.04	201.78	253.32	299.57	186.24							
	D_2	L_1	57.75	133.32	204.95	256.53	300.22	190.56							
		L_2	55.69	129.20	199.23	251.04	295.56	186.15							
		Mean	56.72	131.26	202.09	253.79	297.89	188.35							
	D_3	L_1	59.53	135.17	207.17	258.59	303.27	192.74							
		L_2	53.50	125.35	206.95	263.20	312.90	192.38							
		Mean	56.52	130.26	207.06	260.89	308.09	192.56							
Hen-day egg production (%)	D_1	L_1	66.44	74.71	77.69	78.66	80.17	75.53	1.627***	1.349^{NS}	2.099***	2.253**	2.948^{NS}	3.609*	5.039^{NS}
		L_2	67.40	77.91	80.68	82.40	84.23	78.52							
		Mean	66.92	76.31	79.19	80.53	82.20	77.03							

Table 2. Contd.

	D_2	L_1	77.00	80.69	80.47	81.61	82.46	80.45							
		L_2	73.46	78.14	78.27	80.06	81.40	78.27							
		Mean	66.91	76.31	79.37	80.84	81.93	79.36							
	D_3	L_1	78.58	81.81	81.34	82.26	83.30	81.46							
		L_2	71.33	75.97	81.16	83.56	85.73	78.55							
		Mean	74.96	78.89	81.25	82.91	84.51	80.50							
Hen-housed egg production (%)	D_1	L_1	63.12	67.30	69.99	70.86	68.25	67.91	1.562^{***}	1.295^{NS}	2.014^{***}	2.162^{***}	2.829^{NS}	3.464^{***}	4.835^{**}
		L_2	67.40	77.91	80.69	82.40	84.23	78.52							
		Mean	65.26	72.61	75.34	76.63	76.24	73.22							
	D_2	L_1	77.00	76.66	76.44	77.00	78.34	77.20							
		L_2	69.78	70.39	66.64	64.22	65.28	67.26							
		Mean	73.39	73.53	71.54	70.87	71.81	72.23							
	D_3	L_1	74.65	77.72	77.27	78.15	79.13	77.38							
		L_2	71.33	75.97	81.15	83.56	85.73	79.55							
		Mean	72.99	76.85	79.21	80.85	82.43	78.47							
Egg mass (g/bird)	D_1	L_1	2231	6814	11327	14213	17437	10405	233.69^{***}	193.76^{NS}	301.43^{***}	323.51^{*}	423.28^{NS}	518.21^{NS}	723.40^{NS}
		L_2	2159	6959	11545	14842	18149	10731							
		Mean	2195	6887	11436	14527	17793	10568							
	D_2	L_1	2770	7237	11655	15102	17883	10929							
		L_2	2588	6980	11361	14684	17335	10590							
		Mean	2679	7109	11508	14893	17609	10759							
	D_3	L_1	2898	7355	11777	15006	17777	10962							
		L_2	2519	6846	11721	15688	18885	11132							
		Mean	2708	7100	11749	15347	18331	11047							
FCR (Feed/dozen eggs)	D_1	L_1	2138.30	1888.00	1798.3	1766.00	1783.6	1774.90	53.563^{**}	44.412^{NS}	69.090^{***}	74.153^{*}	97.020^{NS}	118.780^{NS}	165.810^{NS}
		L_2	2090.00	1782.00	1695.80	1658.50	1675.30	1780.30							
		Mean	2114.10	1835.10	1747.00	1712.30	1729.50	1727.60							
	D_2	L_1	1813.10	1735.90	1710.40	1682.80	1723.90	1733.20							
		L_2	1904.70	1772.00	1724.70	1700.20	1727.50	1765.80							
		Mean	1858.90	1753.90	1717.60	1691.50	1725.70	1749.50							
	D_3	L_1	1814.80	1718.80	1700.10	1683.20	1710.90	1725.50							
		L_2	2051.00	1864.50	1704.10	1651.10	1658.10	1785.80							
		Mean	1932.90	1791.70	1702.10	1667.10	1684.50	1755.70							

Table 2. Contd.

FCR (Feed/kg egg)	D1	L1	4.26	2.85	2.61	2.57	2.49	2.96	0.125***	0.104^{NS}	01.61***	0.173^{NS}	0.227^{NS}	0.277***	0.387^{NS}
		L2	4.33	2.78	2.52	2.42	2.37	2.88							
		Mean	4.29	2.81	2.57	2.49	2.43	2.92							
	D2	L1	3.19	2.67	2.50	2.37	2.41	2.63							
		L2	3.62	2.73	2.52	2.42	2.45	2.75							
		Mean	3.40	2.70	2.51	2.39	2.43	2.69							
	D3	L1	3.20	2.64	2.49	2.42	2.43	2.64							
		L2	3.65	2.86	2.51	2.32	2.29	2.72							
		Mean	3.43	2.75	2.50	2.37	2.36	2.68							
Survivability (%)	D1	L1	99.74	99.44	99.44	99.44	99.12	99.44	0.368*	0.304^{NS}	0.475NS	0.510***	0.667^{NS}	0.817^{NS}	1.141^{NS}
		L2	100.00	100.00	100.00	100.00	100.00	100.00							
		Mean	99.87	99.72	99.72	99.72	99.56	99.72							
	D2	L1	100.00	99.74	99.74	99.74	99.74	9979							
		L2	99.74	99.44	99.12	98.75	98.75	99.16							
		Mean	99.87	99.59	99.43	99.24	99.24	99.48							
	D3	L1	99.74	99.74	99.74	99.74	99.74	99.74							
		L2	100.00	100.00	100.00	100.00	100.00	100.00							
		Mean	99.87	99.87	99.87	99.87	99.87	99.87							
Production cost (Tk/dozen eggs)	D1	L1	89.38	81.80	79.07	78.09	78.62	81.39	1.523***	1.263**	1.965***	2.108^{NS}	2.759^{NS}	3.378***	4.715^{NS}
		L2	83.29	74.62	72.20	71.15	71.62	74.58							
		Mean	86.34	78.21	75.64	74.62	75.12	77.98							
	D2	L1	78.40	76.12	75.36	74.55	75.77	76.04							
		L2	78.25	74.50	73.17	72.48	73.25	74.33							
		Mean	78.33	75.31	74.27	73.51	74.51	75.18							
	D3	L1	79.07	76.18	75.62	75.11	75.95	76.39							
		L2	80.72	75.60	71.20	69.75	69.94	73.44							
		Mean	79.90	75.89	73.41	72.43	72.95	74.92							
Net profit (Tk/dozen eggs)	D1	L1	12.62	20.20	22.93	23.91	23.38	20.60	1.523***	1.263***	1.964***	2.108**	2.759^{NS}	3.377^{NS}	4.715^{NS}
		L2	21.28	27.38	29.80	30.85	30.38	27.42							
		Mean	15.66	23.79	26.36	27.38	26.87	24.01							
	D2	L1	23.60	25.88	26.63	27.45	26.23	25.96							
		L2	23.75	27.50	28.83	29.52	28.75	27.67							
		Mean	23.67	26.69	27.73	28.49	27.49	26.81							

Table 2. Contd.

D_3	L_1	22.93	25.81	26.38	26.88	26.23	25.61
	L_2	21.28	26.40	30.79	32.25	32.06	28.56
	Mean	22.10	26.10	28.57	29.57	29.05	27.08

+NS, P>0.05; *, P<0.05; **, P<0.1; ***, P<0.001; D_1= Diet with limestone; D_1= Diet with limestone; D_2= Diet with oyster shell; D_3= Diet with extruded eggshell; L_1= 4% Ca source, L_2 = 8% Ca source; Tk = Taka; A_1= 32 weeks; A_2= 44 weeks; A_3= 56 weeks;A_4= 64 weeks; A_5= 72 weeks age of the bird

the significant effect of the age of the birds on egg production performances for the use of 15% eggshell meal (EM) in the diet of laying hen.

The interaction of diet and level of Ca sources was observed for feed intake, egg production, hen-day, hen-housed, egg mass production, FCR (feed/dozen eggs), survivability and net profit, but not for body weight, FCR (feed/kg egg) and production cost. No interaction between calcium source level and age group for egg production performance was observed. However, diet interacted with the age group for feed intake, hen-day, hen-housed, FCR (feed/kg eggs) and production cost but not interacted for body weight, egg mass production, survivability and net profit. There was no interaction between the effect of diet, level of Ca sources and age group for egg production performances, except for the hen housed egg production. No previous work related to the present study that interacted between or among three factors was found.

CONCLUSIONS AND RECOMMENDATIONS

The present study reveals that the diet with extruded eggshell (D_3), and the level of 8% calcium sources performed better than the diet with limestone (D_1) or oyster shell (D_2) and levels of 4% calcium sources in terms of egg production performance and net profit. Of all the calcium sources, level 2 (8% calcium sources), especially the 8% extruded eggshell showed better performance than the level of 8% limestone or oyster shell in terms of egg production, survivability and net profit. Therefore, the diet with 8% extruded eggshell may be beneficial to use in the diet of laying hens for producing safe and profitable eggs. However, more studies are needed to confirm the present findings and consider more levels (10-12%) of extruded eggshell in the diet of laying hens before suggesting use in the poultry industry.

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