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Research Article

Effect of Different Dietary Vitamin–Mineral Premixes, Housing Systems and Duration of Storage on Physical Characteristics and Proximate Compositions of Eggs at the Late Laying Stage

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ABSTRACT: Effect of the different dietary proprietary vitamin–mineral premixes (PVMP) and housing systems (HS) on physical characteristics and proximate compositions of egg in the duration of storage (DOS) at the late laying phase were investigated in this study. Bovan Nera Black pullets (n=240) at week 71 of life were equally allotted to battery cage (BC) and deep litter (DL) HS. Pullets were further allotted in each HS to five dietary treatments. Each treatment was in triplicate of eight birds. The isocaloric and isonitrogenous diet formulated was supplemented with one of the five PVMP. Eggs (n=75) were sampled from each HS and stored at ambient conditions (temperature: 27.1-32.8°C and relative humidity: 41-76%). Egg indices were assessed at days 0, 7, 14, 21 and 28. The trial was a '2 × 5 × 5' factorial arrangement in a completely randomized design. Effect of HS on weight, length, width, Haugh unit, yolk height, shape index and weight loss of eggs was not significant ($p>0.05$). Yolk index of eggs from hens fed diet containing PVMP 1 group (20.41±2.73) and 4 group (20.53±2.42) differed significantly ($p<0.05$) from those on supplemental PVMP 2 group (18.49 ± 2.43), 3 group (19.66 ± 2.64) and 5 group (20.02 ± 2.64). Eggs weight reduced with increased DOS. Ether extract and ash of eggs from hens in DL were significantly higher ($p<0.05$) compared to those from BC while crude protein in egg from BC was significantly higher ($p<0.05$) than those from DL. Interactions of BC, PVMP and DOS on egg weight, shell weight, shell thickness and weight loss differed, significantly ($p<0.05$). Relationships of yolk index and moisture content relative to DOS were negative ($R^2 = 0.908$ and $R^2 = 0.631$, respectively) and highly significant ($p<0.01$). Egg qualities were affected by the different HS, dietary PVMP used in layer diets as well as the eggs DOS.

Keywords: Vitamin-mineral premixes, Egg quality characteristics, Days of storage, Housing systems

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INTRODUCTION

Egg quality is directly influenced by the nutrition of the laying hens (1, 2). Supplementation of vitamin and mineral in layer nutrition is indispensable due to their participation in all the biochemical processes in the body systems of layers (3). When nutritionally compromised, hens will not produce eggs efficiently and eggs produced would be of inferior quality (4). Therefore, the essence of incorporating quality vitamin-mineral premix in layers diet cannot be over-emphasized.

Durations of egg storage has also been reported to affect the egg qualities (5,4,6,7). The deteriorations have been adduced to the degree of egg yolk mottling; as the vitelline membrane degenerates during storage, water enters the yolk causing mottling and after prolonged storage, albumen proteins also enter the yolk increasing the severity of the mottling.

Alternative housing systems have been demonstrated to alter some quality features and nutritional composition of eggs. (8,9,10). Other study reported better yolk and albumen quality in deep litter (DL) over eggs produced in battery cages (BC) (11). (12) and (13) in their reviews did not establish DL as being superior to BC. Although, both authors concluded that both systems have their *pros* and *cons*. This study was therefore aimed at further assessing effect of the different proprietary vitamin-mineral premixes (PVMP), HS and DOS on egg physical characteristics and proximate composition at the late stage of lay.

MATERIALS and METHODS

The study was carried out at the Poultry Unit, Teaching and Research Farm, University of Ibadan, Ibadan, Nigeria. Black Bovan Nera pullets (n=240) at week 71 with a track record of vaccination schedule, medication, and productive performance from one-day old were used for this study. Hens were randomly allotted to five dietary treatments and each treatment was in triplicate of eight birds each. Water and feed were offered to birds *ad libitum.* The gross composition of the experimental diets and the compositions of the test VMP as indicated on their labels have been documented (6,7,14) and are shown in Tables 1 and 2, respectively.

At week 71, a total of 75 eggs were pooled from each HS. The eggs were stored at ambient conditions (temperature: 27.1-32.8°C and relative humidity: 41-76%). Proximate compositions (15) and physical (external and internal) characteristics of eggs were determined at days 0, 7, 14, 21 and 28 days of storage. Eggs weight was measured with Amput High Precision Weighing Balance. Eggs length and width were measured with Vernier calliper. Egg shell was air dried at room temperature for 24 hours after which the shell weight and thickness were measured. The shell weight was measured also with Amput High Precision Weighing Balance while the shell thickness was measured with micrometre screw gauge. Egg diameter and shell thickness were determined in three places (the small end, middle and broad end) and the average was taken (16). Egg weight loss was

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determined as the difference in successive weight of eggs at different weighing days which were 0, 7, 14, 21, 28, respectively (17). Each egg was broken on a flat plate. The albumen height was measured with tripod micrometre. The yolk was separated carefully from the albumen and the yolk height and diameter were measured with the Vernier calliper. Yolk weight was measured with Amput High Precision Weighing Balance. The weight of the petri dish used to hold the yolk was noted and the parameters of the yolk height and weight were calculated from the difference. Albumen weight was determined by the difference between the egg weight, yolk weight and yolk weight. Haugh units were determined from albumen height and egg weight using the equation as described (18) $HU= 100 \log (h+7.6-1.7W^{0.37})$ where HU is Haugh unit, h is albumen height (mm), W= the weight of egg tested (g).

Data were subjected to analysis of variance using general linear model of SAS (19). Means were separated by the LSD option of the same software.

Table 1. Gross composition (%) of experimental diets fed to layers

Ingredients	T1	T2	T3	T4	T5
Maize	59.00	59.00	59.00	59.00	59.00
Soybean meal	24.37	24.37	24.37	24.37	24.37
Wheat bran	3.00	3.00	3.00	3.00	3.00
Palm kernel cake	3.00	3.00	3.00	3.00	3.00
Salt	0.30	0.30	0.30	0.30	0.30
Di-calcium phosphate	0.11	0.11	0.11	0.11	0.11
Limestone	9.30	9.30	9.30	9.30	9.30
Biotronics	0.30	0.30	0.30	0.30	0.30
Mycofix	0.10	0.10	0.10	0.10	0.10
DL-Methionine	0.15	0.15	0.15	0.15	0.15
L-Lysine	0.12	0.12	0.12	0.12	0.12
Premix 1	0.25	-	-	-	-
Premix 2	-	0.25	-	-	-
Premix 3	-	-	0.25	-	-
Premix 4	-	-	-	0.25	-
Premix 5	-	-	-	-	0.25
Total	100.00	100.00	100.00	100.00	100.00
Calculated nutrients					
ME (Kcal/kg)	2.687.56	2.687.56	2.687.56	2.687.56	2.687.56
Crude protein (%)	17.00	17.00	17.00	17.00	17.00
Crude fibre (%)	3.80	3.80	3.80	3.80	3.80
Fat	3.59	3.59	3.59	3.59	3.59
Lysine (%)	0.97	0.97	0.97	0.97	0.97
Meth + Cyst (%)	0.71	0.71	0.71	0.71	0.71
Calcium (%)	3.68	3.68	3.68	3.68	3.68
Available Phosphorus (%)	0.40	0.40	0.40	0.40	0.40

Meth+cyst: methionine+cysteine; T1, T2, T3, T4, T5- Treatment 1,2,3,4, and 5 respectively; ME- Metabolizable Energy

Table 2. Composition per 2.5 kg of test samples of Layer vitamin-mineral premixes as shown on the labels

Vitamins and Minerals	Premix 1	Premix 2	Premix 3	Premix 4	Premix 5
Vit. A (IU)	10.000.000	10.000.000	10.000.000	12.000.000	10.000.000
Vit. D3 (IU)	2.000.000	2.000.000	2.000.000	2.400.000	2.000.000
Vit. E (IU)	12.000	12.000	12.000	12.000	23.000
Vit. K3 (mg)	2.000	2.000	2.000	2.000	2.000
Vit. B1 (mg)	1.500	1.500	1.500	1.500	3.000
Vit. B2 (mg)	5.000	4.000	5.000	4.000	6.000
Vit. B6 (mg)	1.500	1.500	1.500	1.800	5.000
Vit. B12 (mcg)	10	10	10	10	25
Niacin (mg)	15.000	15.000	15.000	25.000	50.000
Cal. Pantothenate (mg)	5.000	5.000	5.000	5.000	10.000
Folic acid (mg)	600	500	600	500	1.000
Biotin (mcg)	20	20	20	25	50
Choline chloride (mg)	150.000	100.000	150.000	240	400.000
Manganese (mg)	80.000	75.000	75.000	80.000	120.000
Zinc (mg)	60.000	50.000	50.000	50.000	80.000
Iron (mg)	40.000	20.000	25.000	20.000	100.000
Copper (mg)	8.000	5.000	5.000	5.000	8.500
Iodine (mg)	1.000	1.000	1.000	1.200	1.500
Selenium (mg)	150	200	100	200	120
Cobalt (mg)	250	500	400	200	300
Antioxidant (mg)	100.000	125.000	125.000	125.000	120.000

Vit.: Vitamin, Cal.: Calcium

Table 3. Effect of duration of storage on albumen and yolk characteristics

Parameters	0	7	14	21	28
Albumen Height (mm)	8.17±0.32^{a}	4.68±0.19^{b}	3.58±0.15^{c}	4.60±0.09^{b}	3.54±0.05^{c}
Albumen Weight(g)	40.86±0.91^{a}	36.90±0.63^{b}	34.51±0.62^{c}	32.29±0.56^{d}	32.80±0.77^{cd}
Haugh Unit	85.46±1.83^{d}	102.53±0.79^{c}	107.90±0.81^{ab}	105.45±1.21^{cb}	110.39±1.03^{a}
Yolk weight(g)	17.05±0.38^{b}	17.71±0.41^{b}	18.94±0.32^{a}	18.04±0.39^{ab}	17.90±0.32^{ab}
Yolk Height	1.48±0.03^{a}	1.09±0.02^{b}	0.65±0.03^{c}	0.43±0.03^{d}	0.39±0.02^{d}
Yolk width	3.70±0.04^{e}	4.36±0.06^{d}	4.95±0.06^{c}	5.44±0.08^{b}	5.78±0.07^{a}
Yolk Colour	1.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00
Yolk Index (%)	40.11±0.69^{a}	25.16±0.57^{b}	13.32±0.86^{c}	7.92±0.55^{d}	6.78±0.44^{d}

a,b,c means with different superscripts on the same row differ significantly (p<0.05); 0, 7, 14, 21 and 28- days of storage

Table 4. Effect of housing systems and duration of storage on external characteristics of chicken eggs

Storage time	Rearing System	Egg weight (g)	Egg weight loss (%)	Shell weight (g)	Shell thickness (mm)
0	Battery Cage	65.26±1.84	-	6.11±0.24^{b}	0.15±0.01
	Deep Litter	62.13±1.45	-	6.08±0.19^{b}	0.13±0.01
7	Battery cage	59.75±1.02^{ab}	2.24±0.41	5.79±0.12	0.14±0.01
	Deep Litter	60.96±1.14^{a}	2.07±0.07	5.62±0.15	0.13±0.01
14	Battery cage	57.94±1.04^{abc}	4.82±0.49^{e}	5.30±0.18^{ab}	0.93±0.01^{ab}
	Deep litter	59.90±0.91^{a}	4.64±0.15^{de}	5.74±0.13^{b}	0.94±0.01^{bc}
21	Battery cage	56.27±0.97	6.70±0.40^{cd}	5.87±0.09^{ab}	0.89±0.06^{ab}
	Deep litter	56.00±1.27	6.75±0.31^{c}	5.38±0.15^{b}	0.96±0.01^{bc}
28	Battery cage	57.96±1.49^{ab}	7.99±0.49	5.98±0.17^{ab}	0.84±0.03^{ab}
	Deep litter	55.80±1.20^{c}	8.36±0.38	5.72±0.18^{a}	0.82±0.02^{a}

a,b,c,d means with different superscripts on the same column differ significantly (p<0.05)

RESULTS and DISCUSSION

Effect of duration of storage on albumen and yolk characteristics is shown in Table 3. The albumen weight, albumen height, yolk height, and yolk index of eggs reduced significantly (p<0.05) as the DOS increased (20) also observed a reduction in the albumen height during storage which was adduced to gaseous diffusion of CO_2 and O_2 from the thick albumen during storage (21) postulated that the variations observed in the albumen quality during storage might be due to changes occurring in the ovomucin particularly, the thick albumen.

Relationship of yolk index to eggs DOS is shown in Figure 1. The regression equation was;

$$y = -0.000x^4+0.011x^3-0.152x^2-1.549x+40.10 \quad (R^2 = 0.908)$$

which indicated a strong negative regression and highly significant relationships (p<0.01) (22) stated that the flattening of the yolk is primarily due to increased water content caused by osmotic migration from the albumen through the vitelline membrane.

Table 4 shows the interaction of HS and DOS on external characteristics of eggs. The interactive effect of HS and DOS on egg weight, egg weight loss, shell weight and shell thickness differed significantly (p<0.05).

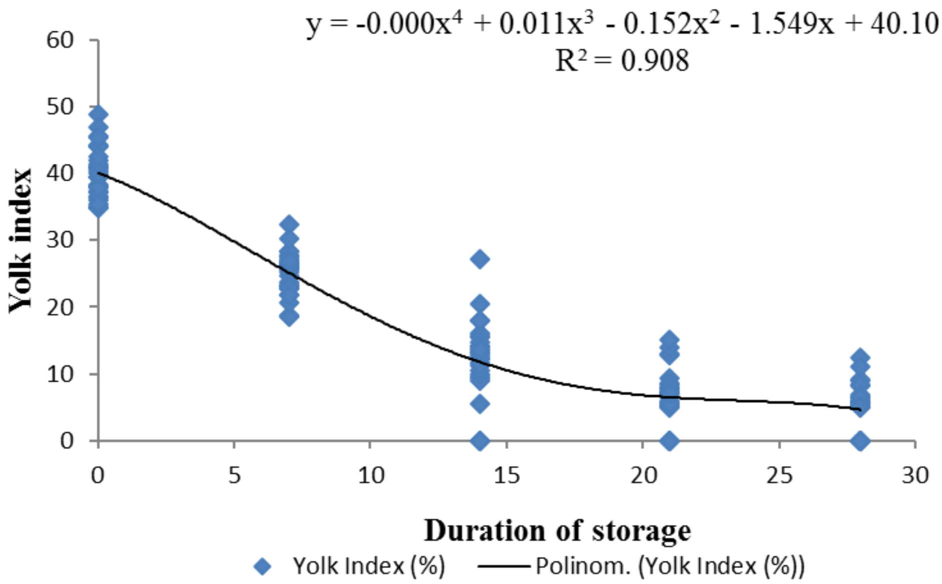

Figure 1. Relationship of yolk index and duration of eggs storage

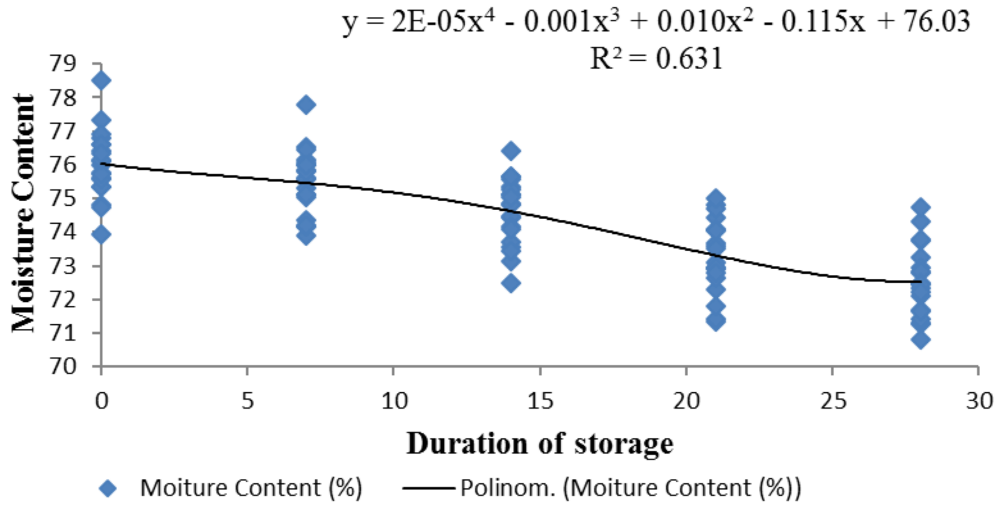

Figure 2. Relationships of moisture and the duration of eggs storage

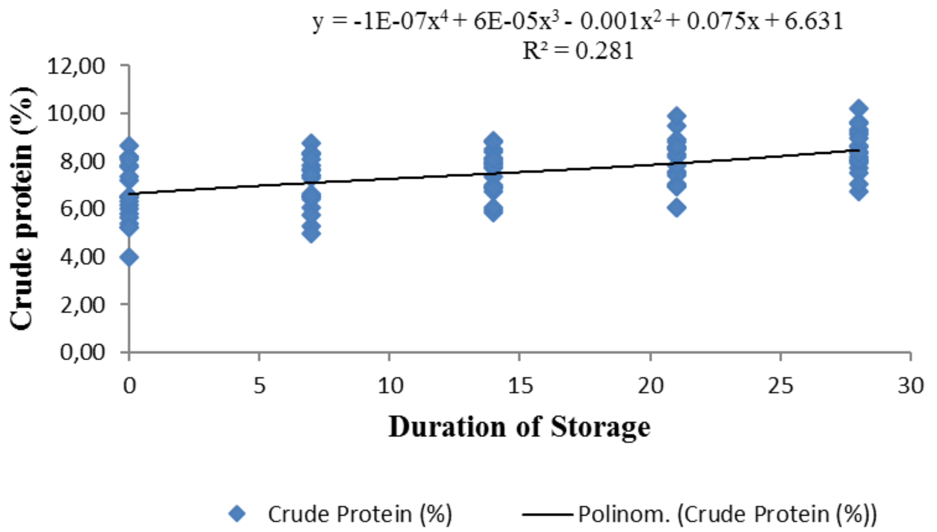

Figure 3. Relationships between eggs crude protein and the duration of egg storage

Table 5. Effect of housing systems and duration of storage on albumen characteristics of chicken eggs

Storage time	Rearing System	Haugh unit	Albumen height (mm)	Albumen weight (g)
0	Battery Cage	82.37±2.17	8.79±0.34	42.15±1.45
	Deep Litter	102.31±1.41	7.56±0.51	39.56±1.03
7	Battery cage	101.91±1.27	4.78±0.31^{bc}	36.26±0.85
	Deep Litter	88.54±2.79	4.58±0.25^{c}	37.55±0.94
14	Battery cage	109.33±1.27^{ab}	3.44±0.17^{d}	34.08±0.86
	Deep litter	103.15±0.97^{a}	3.69±0.23^{cd}	34.85±0.90
21	Battery cage	107.60±1.98	4.59±0.08^{cd}	32.59±0.79
	Deep litter	106.47±0.91	4.60±0.16^{b}	32.04±0.82
28	Battery cage	110.34±1.57^{ab}	3.60±0.08	32.85±0.98
	Deep litter	103.29±1.23^{b}	3.47±0.07	32.75±1.24

^{a,b,c,d} means with different superscripts on the same column differ significantly (p<0.05)

Table 6. Effect of housing systems and duration of storage on yolk characteristics of chicken eggs

Storage time	Rearing System	Yolk Height (cm)	Yolk weight (g)	Yolk index (%)	Yolk width (cm)
0	Battery Cage	1.46±0.04	17.66±0.58	38.86±0.86	3.77±0.06
	Deep Litter	1.50±0.04	16.44±0.45	41.35±1.01	3.63±0.05
7	Battery cage	1.08±0.04	17.63±0.47^{ab}	24.90±0.92	4.34±0.07
	Deep Litter	1.11±0.03	17.79±0.68^{ab}	25.43±0.69	4.37±0.09
14	Battery cage	0.60±0.06	18.49±0.47^{bc}	12.27±1.41^{cd}	4.98±0.09
	Deep litter	0.69±0.04	19.31±0.43^{a}	14.15±1.04^{c}	4.93±0.07
21	Battery cage	0.36±0.02	17.94±0.58^{bc}	6.74±0.37^{cd}	5.37±0.14
	Deep litter	0.49±0.04	18.13±0.54^{ab}	8.93±0.90^{d}	5.51±0.09
28	Battery cage	0.38±0.03	18.11±0.46^{bc}	6.31±0.63^{cd}	5.90±0.08
	Deep litter	0.41±0.03	17.68±0.46^{c}	7.24±0.62^{c}	5.65±0.11

^{a,b,c,d} means with different superscripts on the same column differ significantly (p<0.05)

Table 7. Effect of battery cage, vitamin-mineral premix and duration of storage on external characteristics of chicken eggs

Factors		Egg weight (g)	Shell weight (g)	Shell Thickness (mm)	Shape Index (%)	Weight loss (%)
VMP	ST					
T1	0	64.12±2.05^{ab}	4.73±0.35^{b}	0.12±0.03^{b}	71.75±1.59	-
	7	60.25±3.55 $^{a-h}$	6.20±0.35^{b}	0.15±0.01^{b}	72.32±0.89	3.85±2.07^{j-o}
	14	57.36±2.72^{b-g}	4.74±0.73^{ab}	0.89±0.04^{ab}	70.18±1.62	6.16±2.27^{k-o}
	21	57.45±3.72^{b-g}	6.05±0.12^{ab}	0.65±0.31^{ab}	71.82±1.82	5.79±0.41^{g-o}
	28	58.58±4.11^{b-g}	5.63±0.42^{ab}	0.87±0.09^{ab}	74.24±2.30	8.03±1.17^{f-k}
T2	0	63.90±7.62^{c-g}	6.24±0.46	0.17±0.02	73.28±0.81	-
	7	61.11±1.91^{a-e}	5.66±0.12	0.14±0.03	72.35±4.07	1.75±0.10^{o}
	14	60.72±1.78^{a-e}	5.61±0.32	0.86±0.02	71.46±1.23	3.97±0.18^{i-o}
	21	57.87±2.52^{c-g}	5.83±0.16	0.96±0.01	72.72±2.53	6.09±0.39^{f-k}
	28	59.74±3.81^{a-d}	6.36±0.41	0.89±0.07	70.78±1.16	7.89±0.72^{f-j}
T3	0	65.05±3.41^{a-d}	6.34±0.22^{b}	0.14±0.01^{b}	72.03±2.35	-
	7	59.57±3.27^{a-g}	5.67±0.33^{b}	0.14±0.01^{b}	64.16±11.49	1.80±0.05^{no}
	14	60.61±1.31^{a-e}	5.77±0.19^{ab}	0.98±0.03^{ab}	72.10±1.97	4.38±0.56^{h-o}
	21	54.35±1.24^{c-g}	5.82±0.26^{ab}	0.95±0.02^{ab}	72.63±0.86	8.33±1.73^{f-k}
	28	61.81±2.31^{a-d}	5.99±0.30^{ab}	0.88±0.06^{ab}	73.81±0.64	8.70±1.21^{f}
T4	0	64.58±5.21^{a-g}	6.38±0.50^{b}	0.16±0.06^{b}	72.73±3.60	-
	7	57.99±0.99^{b-g}	5.71±0.22^{b}	0.15±0.01^{b}	72.47±1.57	1.88±0.18^{mno}
	14	56.15±3.32^{a-g}	5.42±0.10^{ab}	0.94±0.01^{ab}	72.63±1.99	4.13±0.22^{f-n}
	21	55.50±0.84^{d-g}	5.80±0.14^{ab}	0.96±0.01^{ab}	72.14±0.32	6.47±0.33^{f-j}
	28	52.87±2.16^{fg}	5.95±0.30^{ab}	0.78±0.06^{ab}	73.42±2.30	7.44±2.11^{f-k}
T5	0	68.64±3.24^{a}	6.87±0.27	0.16±0.02	76.29±0.32	-
	7	59.80±2.48^{a-f}	5.72±0.28	0.14±0.01	67.89±4.87	2.24±0.41^{mno}
	14	54.85±0.75^{d-g}	4.95±0.29	0.95±0.01	73.34±0.93	4.82±0.49^{g-o}
	21	56.19±2.55^{b-g}	5.85±0.40	0.94±0.01	75.28±4.41	6.70±0.40^{f-k}
	28	56.82±3.61^{a-g}	5.96±0.55	0.79±0.04	74.98±1.03	7.99±0.49^{f-k}

VMP: Vitamin-mineral premix, ST: Storage time, $^{a-o}$ means with different superscripts on the same column differ significantly (p<0.05)

On day 0, there was no significant difference (p>0.05) in the weight of eggs (65.26 ± 1.84, 62.13±1.45), shell weight (6.11 ±0.24, 6.08±0.19), and thickness (0.15±0.01, 0.13±0.01) in BC and DL systems. No significant difference was observed in the weight of egg on day 21(56.27±0.97, 56.00±1.27) in BC and DL. Also, there was no significant difference (p>0.05) in egg weight loss between the HS at days 7 (2.24 ±0.41, 2.07±0.07) and 28 (7.99±0.49, 8.36 ±0.38).

Table 5 shows the effect of HS and DOS on albumen characteristics of chicken eggs. The Haugh unit on days 0, 7 and 21 were statistically similar (p>0.05) in both HS although those in BC (101.91±1.27, 107.60±1.98) were numerically higher compared with those on DL (88.54±2.79, 106.47±0.91) at days 7 and 21, respectively. There was no significant difference (p>0.05) in the albumen heights on days 0 (8.79±0.34, 7.56±0.51) and 28 (3.60±0.08, 3.47±0.07) although albumen height were higher in BC than in DL.

Interactions of HS and DOS on yolk characteristics of eggs are shown in Table 6. There was no significant difference (p>0.05) in yolk weight and yolk index on days 0 and 7 in both HS. Yolk index of eggs from DL (41.35±1.01, 25.43±0.69, 14.15±1.04, 8.93±0.90, 7.24±0.62) was higher (p<0.05) than those in BC (38.86±0.86, 24.90±0.92, 12.27±1.41, 6.74±0.37, 6.31±0.63) throughout the egg DOS. Interactions of BC, VMP and DOS on the external qualities of eggs are shown in Table 7. Weight of eggs from hens on VMP 4 significantly (p<0.05) decreased (64.58± 5.21, 57.99±0.99, 56.15±3.32, 55.50±0.84, 52.87±2.16) as DOS increased. Interactive effects of DL HS, VMP, and DOS on external egg characteristics are shown in Table 8. The shape index was not significantly (p>0.05) affected by the interactions of DL, VMP and DOS. The shell thickness of eggs on VMP 1 (0.17±0.02, 0.16±0.01, 0.91 ±0.03, 0.97 ±0.01, 0.78 ± 0.06), 4 (0.11 ± 0.03, 0.07 ± 0.03, 0.95 ± 0.02, 0.95± 0.01, 0.86± 0.03) and 5 (0.15± 0.01, 0.14± 0.01, 0.96 ± 0.01, 0.95 ± 0.01, 0.83± 0.04) was statistically similar to corresponding eggs of the DL in the DOS.

Effect of HS on proximate composition of chicken eggs is shown in Table 9. Ether extracts (10.61± 0.12 >

10.38±0.11), ash (1.10± 0.03 > 1.02± 0.03) and NFE of eggs from DL were significantly ($p<0.05$) higher than in the BC. The higher ether extracts of eggs from DL could be due to accessibility of the laying hens to fly larvae which is rich in fat. Also, laying hens housed in DL pecks the litter which is high in ash and this could be the reason for the observed higher ash in the DL eggs.

Table 10 shows the effect of DOS on proximate composition of eggs. Moisture content of eggs was observed to reduce ($p<0.05$) as the DOS increased (76.03 ±0.16 to 72.53 ±0.16). During storage, water is lost from eggs through shell to the environment; however, this depends on temperature and relative humidity of the environment in which the egg was stored.

Moisture content of eggs was related to eggs DOS and the regression equation as shown in Figure 2 was $y = 2E\text{-}05x^4 - 0.001x^3 + 0.010x^2 - 0.115x+76.03$ ($R^2 = 0.631$) which indicated a strong negative and highly significant relationships ($p<0.01$).

As DOS increased, crude protein (6.64 ± 0.19 to 8.48± 0.14) of eggs significantly increased ($p<0.05$). The crude protein content of eggs was relative to the DOS is shown in Figure 3. The regression equation was;

$$y=-1E\text{-}07x^4+6E\text{-}05x^3-0.001x^2+0.075x+6.631 (R^2=0.281)$$

which indicated a positive relationship but showed the increased crude protein was solely not mainly due to DOS.

Table 8. Effect of deep litter, vitamin-mineral premix and duration of storage on external characteristics of chicken eggs

Factors		Egg weight (g)	Shell weight (g)	Shell Thickness (mm)	Shape Index (%)	Weight loss (%)
VMP	ST					
T1	0	60.49±3.80^{a-g}	6.56±0.42^{b}	0.17±0.02	74.16±1.77	-
	7	63.18±2.29^{abc}	6.27±0.28^{b}	0.16±0.01	74.37±0.86	2.14±0.27^{l-o}
	14	60.62±3.85 $^{a-e}$	5.47±0.16^{b}	0.91±0.03	73.01±2.15	4.70±0.03^{g-o}
	21	62.67±0.79^{a-d}	5.96±0.14^{b}	0.97±0.01	68.54±1.52	7.30±0.77^{fgh}
	28	55.57±0.71^{d-g}	5.61±0.11^{ab}	0.78±0.06	69.56±2.40	8.04±1.11^{f-k}
T2	0	61.41±2.88^{a-g}	6.09±0.42^{b}	0.13±0.02^{b}	67.47±6.60	-
	7	60.67±2.29^{a-e}	5.67±0.14^{b}	0.14±0.01^{b}	70.66±0.82	1.85±0.16^{mno}
	14	59.66±1.10^{a-g}	5.32±0.11^{b}	0.93±0.02^{b}	72.22±2.74	5.05±0.27^{f-l}
	21	53.67±3.27^{e-g}	5.53±0.40^{b}	0.96±0.01^{b}	73.29±0.97	6.33±0.76^{f-k}
	28	54.24±4.50^{fgh}	5.63±0.47^{a}	0.85±0.03^{a}	77.94±2.25	7.85±0.93^{h-o}
T3	0	64.79±2.22^{a-g}	6.03±0.45^{b}	0.09±0.02^{b}	74.67±3.72	-
	7	61.03±2.26^{a-e}	5.67±0.26^{b}	0.13±0.01^{b}	69.05±1.82	2.06±0.06^{l-o}
	14	61.48±2.32^{a-d}	5.89±0.35^{b}	0.96±0.01^{b}	73.62±1.17	4.90±0.39^{g-m}
	21	52.66±1.08^{fg}	5.29±0.13^{b}	0.97±0.01^{b}	73.13±1.18	7.01±0.22^{f-i}
	28	51.87±3.01^{g}	5.07±0.42^{ab}	0.79±0.05^{ab}	69.00±1.27	9.86±0.41^{f-i}
T4	0	63.12±5.82^{ab}	6.05±0.41	0.11±0.03	70.19±2.98	-
	7	61.72±3.29^{a-d}	5.18±0.21	0.07±0.03	69.61±2.96	2.20±0.11^{l-o}
	14	59.60±1.29^{a-g}	6.07±0.32	0.95±0.02	72.67±3.55	3.89±0.20^{j-o}
	21	56.22±2.00^{c-g}	5.37±0.38	0.95±0.01	71.08±1.76	6.48±1.00^{f-k}
	28	59.01±1.50^{a-g}	6.06±0.34	0.86±0.03	71.69±2.19	7.62±0.79^{fg}
T5	0	60.86±2.47^{a-g}	5.68±0.56^{b}	0.15±0.01	74.22±3.68	-
	7	58.20±3.56^{b-g}	5.32±0.45^{b}	0.14±0.01	67.96±3.12	2.12±0.05^{l-o}
	14	58.14±1.62^{b-g}	5.95±0.38^{b}	0.96±0.01	74.88±0.37	4.65±0.40^{g-o}
	21	54.80±2.94^{b-g}	4.74±0.12^{ab}	0.95±0.01	68.38±3.06	6.64±0.87^{i-o}
	28	58.29±1.01^{b-g}	6.23±0.40^{b}	0.83±0.04	68.88±1.93	8.45±0.73^{fg}

VMP: Vitamin-mineral premix, ST: Storage time, $^{a-o}$ means with different superscripts on the same column differ significantly ($p<0.05$)

Table 9. Effect of housing systems on proximate composition of chicken eggs

Rearing Systems	Moisture content	Ether extract	Crude protein	Ash	NFE
Battery Cage	74.44±0.18	10.38±0.11^{b}	7.97±0.11^{a}	1.02±0.03^{b}	6.20±0.16^{b}
Deep Litter	74.35±0.15	10.61±0.12^{a}	7.09±0.11^{b}	1.10±0.03^{a}	6.85±0.16^{a}

^{a,b} means with different superscripts on the same column differ significantly ($p<0.05$)

Table 10. Effect of duration of storage on proximate composition of chicken eggs

Storage time	Moisture content	Ether extract	Crude protein	Ash	NFE
0	76.03±0.16^{a}	10.14±0.14^{c}	6.64±0.19^{e}	0.93±0.05^{c}	6.25±0.23^{b}
7	75.47±0.15^{b}	10.30±0.14^{bc}	7.10±0.17^{d}	1.02±0.04^{c}	6.11±0.24^{b}
14	74.63±0.15^{c}	10.21±0.19^{c}	7.49±0.14^{c}	0.98±0.04^{c}	6.68±0.22^{ab}
21	73.31±0.17^{d}	10.59±0.16^{b}	7.92±0.16^{b}	1.13±0.03^{b}	7.05±0.27^{a}
28	72.53±0.16^{e}	11.22±0.20^{a}	8.48±0.14^{a}	1.24±0.03^{a}	6.52±0.30^{ab}

$^{a-e}$ means with different superscripts on the same column differ significantly ($p<0.05$)

CONCLUSION

Eggs physical characteristics reduced during storage. Eggs proximate composition increased as a result of interactions of duration of storage and supplemental vitamin-mineral premixes. Eggs from hens in battery cage had higher crude protein while those on deep litter had increased ash content. Egg weight reduction during storage was dependent on type of supplemental VMP. Therefore, supplemental VMP type must be of consideration when formulating layers feed.

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