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Effect of dietary different ratios of coarse and fine limestone particles on egg production and eggshell quality of laying hens at peak production

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Abstract

This study investigated the influence of different particle sizes of limestone in layer diets on egg production and eggshell quality from 18 to 28 weeks of age. Limestone consisting of small (<1.0 mm) and coarse (2.0 - 3.8 mm) particles that is used in poultry diets was obtained from a South African company. The two particle sizes were mixed to produce five treatments viz. 100% fine (F): 0 coarse (C); 75 F: 25 C, 50 F: 50 C, 25 F: 75 C and 0 F: 100 C. Diets were isocaloric and isonitrogenous. A total of 167 point of lay pullets (18 weeks) were obtained from a commercial pullet farm and were individually caged. The pullets were randomly allocated to five treatments (n = 33) to determine egg production and eggshell quality characteristics (shell thickness, egg weight, egg output, egg surface area, shell percentage and SWUSA). Egg production and eggshell quality data were recorded on individual bird basis and summarised at the end of the week. Dietary treatment did not influence (P>.05) egg production and egg shell quality at 24 weeks of age. Feed intake, body weight, egg production and egg weight increased over time. The present results suggest that the influence of dietary limestone particle size distributions at a later stage of the laying period on egg production and egg quality needs further investigation.

Keywords: Calcium Carbonate, Egg Production, Eggshell Quality, Particle Size

Introduction

Calcium is required for bone development and eggshell formation in laying hens. Any deficiency in the supply or problem in calcium metabolism will lead to weaker eggshells. This will have serious consequences on hatching egg quality, as well as, on the production of table eggs. According to Roland (1986), the average calcium requirements for eggshell formation within a population of hens are high at approximately peak production.

Several factors are involved in egg shell formation of which calcium as a major constituent of the eggshell feature prominently. In this regard, not only the source and level of calcium is important but also the particle size of the calcium source. Several researchers (Scott et al., 1971; Miller and Sunde, 1975; Roland, 1986, 1988; Guinotte and Nys, 1990) reported that larger particles are superior to small or medium in improving egg shell strength and weight. In contrast with these researchers, Roland et al. (1972a), Cheng and Coon (1987), Keshavarz and Nakajima (1993) and Keshavarz, (1998) found no influence of large particle size on egg shell thickness and egg weight.

Solubility of calcium carbonate ($CaCO_3$) depends on the particle size and also on the source of origin (Guinotte and Nys, 1990). Therefore, the ultimate aim should be to supply fine and coarse limestone particles in such a ratio in layer diets that calcium is frequently available for egg shell formation. Small particle sources such as pulverised $CaCO_3$ passes quickly through the digestive tract and the bird may not be able to sufficiently extract enough calcium to meet its needs. On the other hand, ground limestone could be absorbed by the hen during the day when it (hen) is eating while during the dark metering of calcium occurs in the digestive tract from the gizzard because of the breakdown of the shell grit or limestone chips (Woolford, 1994). Larger particle sizes of $CaCO_3$ in the form of coarse limestone or oyster shell) will be retained in the gizzard for a longer period of time (Korver, 1999). This situation allows for a gradual release of calcium from the gizzard to the small intestine for absorption resulting in increased time over which the hen receives dietary calcium. According to Farmer et al. (1986), the aim is to offer the bird a constant supply of calcium to improve the shell characteristics and not an excess since it lowers production. Therefore, it is important to find an alternative avenue of combining both calcium particles with a rapid passage that is a readily available calcium source and those that release the calcium slowly in order to have a constant supply of calcium during the entire day for shell formation and egg contents.

The aim of this study was therefore to investigate the effect of particle size distribution from a specific limestone source in a layer diet on egg production and egg quality at peak production.

Materials and Methods

One hundred and sixty seven 17 weeks old pullets were obtained from a commercial pullet operation. All the pullets received the same layer diet except for the particle size distribution of the calcium supplement that was in the diets during lay. Pullets were randomly allocated to five groups (33 pullets per group). Pullets in each group received one of the five different ratios of fine (less than 1.0 mm) and coarse (2.0 - 3.8 mm) limestone particles namely 100, 75, 50, 25 and 0% fine or coarse particles.

The two particle sizes of limestone grit were obtained from a commercial supplier of limestone to the poultry industry. Fine (F) and coarse (C) particles were 1.0 mm and 2.0-3.8 mm, respectively. The two types were mixed in the following ratios 100F: 0C, 75F: 25C, 50F: 50C, 25F: 75C and 0F: 100C giving five dietary treatments with 33 individual hens in single cages serving as replicates for each treatment. Limestone was screened through sieves to obtain samples with appropriate diameters. An amorphous limestone that contained 90% $CaCO_3$ and 36% calcium was used.

Birds were placed in cages that were fitted with feed troughs, water nipples and perches. Water and feed were given *ad libitum*. Feed intake was recorded weekly. At 17 weeks of age the hens were subjected to 16 hours of light. Egg production and individual egg weights were recorded for all the eggs produced by each hen on a daily basis. Egg production was recorded daily and summarised on a weekly basis throughout the experimental period (*i.e.*, 18-28 weeks). Abnormal eggs (i.e., shell-less and those with defective shells) were also recorded for production calculations. Percent lay was calculated on a daily basis using the formula given by North (1984).

Five eggs from each hen were collected at week 24 to determine the shell quality. Following the measurement of egg weight, eggs were broken and shell thickness and shell weight (including membranes) determined. The shells were washed under slightly flowing water to remove adhering albumen (Kuhl and Seker, 2004) and wiped with a paper towel to remove excessive moisture. A meter sensitive to 0.001 mm was used to measure the eggshell thickness. Three measurements were made on the sharp, blunt and equator of an egg and average thickness obtained for individual location according to the procedures described by Ehtesham and Chowdhury (2002).

The surface area (cm^2) of each egg was calculated using the formula of Carter (1975), ($3.9782W^{.7056}$), where W is the egg weight in grams. Shell weight per unit surface area (SWUSA) expressed as mg/cm^2 and egg volume was calculated according to procedure described by Carter (1975). Egg output (egg mass) was calculated by multiplying percent egg production with egg weight (North and Bell, 1990).

Statistical analyses

Data were subjected to ANOVA using the general linear model procedure (SAS Institute, 1999) to determine the effect of particle size distribution and age on response variables relating to egg production. The same procedure was used to determine the effect of particle size distribution on response variables (shell thickness, shell weight, shell percentage, SWUSA, egg surface area, egg volume and egg contents).

Results and Discussion

Feed intake

The weekly feed intake of the hens fed diets with different particle sizes is shown in Table 1. Different particle size distributions of limestone in the diet did not significantly ($P>0.05$) influence the feed intake of hens. Previous study of Watkins et al. (1977) also reported that particle size distribution did not affect feed intake significantly. An average daily feed intake for the experimental period across treatments was 119 g per bird. The lower feed intake recorded at 18 weeks compared to 19 weeks for the hens in the different treatments could probably be attributed to stress and adaptation to the new surroundings. Fluctuations in feed intake during the experimental period could be attributable to variations in temperatures. The lower feed intakes of hens at weeks 26 and 27 in this study could be due to higher ambient temperatures. A highly significant ($P<0.001$) treatment x age interaction for feed intake occurred. Feed intake significantly ($P<0.001$) increased over time. These results are in agreement with Guinotte and Nys (1990) who found significant increases in feed intake of Leghorns from 66 to 77 weeks of age when hens were fed particulate limestone supplemented with coarse particles of limestone.

Table 1: Effect of limestone particle size distribution on weekly feed intake (g) of layers

Week	Particle size ratios (% fine: coarse)					Significance (P)	CV
	100	75	50	25	0		
18	716	739	686	716	769	0.1682	23.6
19	770	780	762	746	803	0.5618	18.0
20	740	732	727	724	749	0.9330	14.0
21	717	722	734	727	734	0.9583	12.5
22	740	751	766	784	751	0.1767	9.7
23	762	752	751	772	755	0.7155	9.4
24	775	768	770	768	749	0.3524	9.7
25	771	758	785	797	773	0.2956	10.1
26	777	789	801	811	802	0.1556	8.9
27	737	722	707	714	729	0.2923	8.0
28	748	731	739	739	734	0.8497	7.8

CV = Coefficient of variation; Fine <1.0 mm, Coarse >2.0-3.8 mm

Table 2: Body weight (g) of laying hens at 18, 20, 24 and 28 weeks of age

Week	Particle size ratios (fine: coarse)					Significance (P)	CV
	100	75	50	25	0		
18	1783	1805	1782	1828	1828	0.8186	10.2
20	1844	1861	1850	1850	1867	0.9934	8.5
24	1873	1883	1895	1871	1860	0.8513	7.1
28	1929	1933	1938	1915	1900	0.8104	7.2

CV = Coefficient of variation

Table 3: The influence of limestone particle size on egg characteristics at peak production (24 weeks)

Parameter	Particle size ratios (fine: coarse)					Significance (P)	CV %
	100%	75%	50%	25%	0%		
Egg production (%)	79.82	80.09	77.40	81.30	79.68	0.3041	9.0
Egg weight (g)	49.54	48.87	48.13	48.80	47.77	0.4558	8.4
Egg output (g)	39.0	38.0	38.0	37.5	39.5	0.5066	15.6
Egg volume (ml)	41.53	39.73	39.95	40.56	38.92	0.1310	10.2
Egg contents (g)	44.38[a]	44.02[a]	42.89[b]	43.42[b]	42.98[b]	0.0001	14.4
Egg surface area (cm^2)	62.5	61.87	61.21	61.81	60.88	0.1393	9.2
Shell weight (g)	5.16[a]	4.85[b]	5.24[a]	5.38[a]	4.79[b]	0.0017	13.4
Shell percentage (%)	10.44[ab]	9.95[a]	10.98[ab]	11.06[b]	10.12[ab]	0.0001	19.1
SWUSA (mg/cm^2)	82.65	78.39	85.61	87.04	78.68	0.0142	14.3
Shell thickness (mm):							
Sharp end	0.432	0.422	0.432	0.432	0.422	0.1429	4.6
Equator	0.442	0.432	0.432	0.432	0.452	0.3314	11.7
Blunt end	0.432	0.422	0.432	0.432	0.432	0.2468	4.2

[a,b]Means within rows with different superscripts differ at P<0.05, SWUSA = Shell weight per unit surface area, CV = Coefficient of variation

Body weight

The changes in body weight of layers are given in Table 2. In accordance with feed intake, no significant (P>0.05) influence of particle size distribution on the body weight of birds could be detected. A statistically significant (P<0.001) increase in body weight of layers occurred from 18 to 28 weeks of age. The average body weight of hens fed diets containing 100, 75, 50 25 and 0 fine limestone particles were 1.78 kg, 1.77 kg, 1.75 kg, 1.78 kg and 1.83 kg respectively. During the study period the hens that received diets with 100, 75, 50 25 and 0 fine limestone particles showed a weight gain of 146 g,128, g, 156 g, 87 g and 72 g, respectively.

Egg production

It seems from Table 3 that different ratios of limestone particle sizes did not influence (P = 0.3041) egg production. Similarly, Watkins et al. (1977) observed no influence of particle size distribution on egg production. The current results are also in agreement with that of Hurwitz et al. (1969) and Guinotte and Nys (1990) who found that egg production in ISA Brown hens is not affected by particle size.

There was a significant ($P<0.05$) increase in egg production from 18 to 21 weeks of age and thereafter egg production remained constantly high. Leeson and Summers (1982) and McDaniel (1983) reported a non-significant ($P>0.05$) increase in egg production for hens fed oyster shell from 21 to 30 weeks of age.

A significant ($P<0.001$) increase in egg production occurred over the study period. An average production percentage of 80 % was observed up to 28 weeks of age. Sreenivas (1997) found a constant egg production occurred at peak production.

Cracked and shell-less eggs represented 9% of the total egg production during the experimental period. This was lower than the 13-20 % reported by Guinotte and Nys (1990) for the period 20 to 30 weeks. In this study, most of the cracked or shell-less eggs were recorded for treatment with fine particles, indicating that smaller particle sources such as pulverized $CaCo_3$ pass quickly through the digestive tract resulting in the bird not able to sufficiently extract enough calcium to meet its needs. This finding is in agreement with Watkins et al. (1977) who reported that ground limestone produce poor egg shells as opposed to coarse particles.

Egg weight

Egg weight and egg output were not significantly ($P>.05$) influenced by limestone particle size in the diet (Table 3). These findings are in agreement with Cheng and Coon (1987) who concluded that switching from ground limestone to coarse oyster shell resulted in no significant differences in egg weight. Egg weight increased ($P<0.05$) from 19 to 28 weeks of age. These findings confirmed the previous observations that egg weight is lowest at the beginning of the production cycle and increases throughout the laying period (Leeson and Summers, 1982; McDaniel, 1983).

Egg quality

The term "shell quality" is frequently used as a synonym for shell strength and denotes the ability of eggshells to withstand externally applied forces without cracking or breaking (Hamilton, 1982). The most common physical properties associated with egg shell strength are shell thickness and shell specific gravity. Richards and Staley (1967) suggested that shell thickness, shell weight, shell percentage and SWUSA may be classified as shell quality measurements, as these variables are highly significantly ($P<0.01$) correlated with each other.

The influence of limestone particle size distribution on egg volume, egg contents and egg surface area are presented in Table 3. No significant differences occurred in egg volume ($P=0.1310$) and egg surface area ($P=0.1393$). The highest ($P<0.001$) egg contents were recorded where 100 and 75 % fine limestone particles were included in the diet. Although significant differences for shell weight ($P<0.0017$) and shell percentage ($P<0.0001$) occurred, no clear influence of particle size distribution on these characteristics could be detected.

In this study, SWUSA was significantly ($P<0.0142$) different amongst treatments but this was not confirmed by Tukey's test. In accordance with SWUSA no significant ($P> 0.05$) difference in eggshell thickness occurred. The findings of this trial are inconsistent with Watkins et al. (1977) who observed that replacement of two-thirds of fine calcium particles with hen size particles of improved egg-shell strength. Dekalb (1998) suggested that one third of the layer dietary calcium should be supplied in large particle form (2-5 mm). Factors such as the source of calcium and the time of laying period could probably explain these contrary results. Zhang and Coon (1997) stated that the limestone retention of calcium in the gizzard of laying hens for improving shell quality may be dependent upon particle size, porosity of the calcium source and overall *in vitro* solubility of the calcium source.

Conclusions

These results showed that the ratio of fine (<1.0 mm) and coarse (>2.0-3.8 mm) limestone particles in a layer diet does not influence egg production and egg shell quality at 24 weeks of age. However, these results apply only for the specific limestone used in this study and for peak production. The present results suggest that the influence of dietary limestone particle size distributions at a later stage of the laying period on egg production and egg quality warrants further research.

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