Effects of dietary minerals on postmolt performance of laying hens

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Abstract

Four hundred and fifty Single Comb White Leghorn commercial layers (66-67 weeks-old) were housed 2 birds per cage for the molting procedure. The hens were divided into 5 treatment groups with 90 layers per treatment and 30 layers in each replicate per treatment group following completely randomized design. During molt period (2 Weeks), experimental birds were randomly assigned to five-treatment groups viz., A (15 ppm copper sulphate), B (20 ppm zinc oxide), C (20 ppm aluminium oxide), D (balanced layer diet without added minerals) and E (without induced molting as control). The birds in groups A, B, C and D were offered respective experimental diets at the rate of 30 g/bird except bird's in-group E (ad libitum) and lighting program was followed as 12L: 12D. During rest period (3 Weeks) the birds in groups A, B, C and D were given respective experimental diet at the rate of 50 g/bird for first 2 weeks of the rest period. During 3rd week of rest period the birds in groups A, B, C and D were given experimental diets at the rate of 60 g/bird and were placed on lighting program of 14L:10D. During production phase, the birds of all groups were fed a balanced layer diet (ad libitum) and birds were placed again on lighting program of 16L:8D. The results showed that the birds fed diets A, B and C showed greater (p<0.05) percentages of body mass loss than those fed the diet D. The birds fed diet E (Full feed-non molted group) exhibited the least amount of body mass loss when compared with all other treatments of molted hens. Un-supplemented mineral group and un-molted hens had higher (p<0.05) ovarian weights than hens on all other molted treatments. No significant differences (p>0.05) in ovarian weights were found among minerals supplemented groups A, B and C. The non-molted birds (group E) exhibited the greatest (p<0.05) feed intake over the 2 weeks molt whereas birds on minerals supplemented diets ate the least (p<0.05) feed. On average non-molted hens fed a balanced layer diet and molted hens fed without minerals diet had lower (p<0.05) egg production when compared with molted hens fed mineral added diets after 20 weeks post molt. However, molted hens fed without minerals diet had significantly higher egg production than that of non-molted hens fed a balanced layer diet. Egg shell quality and Haugh unit score improved (p<0.05) in molted hens compared to non-molted hens. Based on the results of this study, mineral feeding appears to be the best alternative to without mineral feeding in molting methods and yield comparable results. Key words: Zinc oxide, copper sulphate, aluminium sulphate, performance.

Introduction

The commercial egg industry commonly uses induced molt procedures to rejuvenate flocks for a second or third laying cycle. According to Holt (2003), 75 to 80 percent of commercial laying facilities in the United States use an induced molt program to rejuvenate flocks for increased productivity. The main purpose of molting is to cease egg production in order for the hens to enter a non-reproductive state, which increase egg production and egg quality postmolt (Webster, 2003). Body mass loss during molting process has been shown to be directly related to postmolt performance.

To optimize postmolt performance, a body mass loss of 25 to 30% should be achieved (Baker *et al.*,

induced molt rejuvenates hens' reproductive tract to produce higher quality eggs, which are more marketable (Keshavarz and Quimby, 2002). There are several programs used for successfully

1983). In addition to increased profit margins, an

molting laying hens such as by feed removal and photoperiod reduction to obtain a total cessation of egg production (Hussen, 1996). In recent years, there is growing global concern for animal rights and welfare, hens during molt has been questioned when feed removal is used (Gast and Ricke, 2003). Molting by feed deprivation has also been identified by researchers and public health authorities as a significant risk factor for the infection of laying flocks with *Salmonella Enteritidis*, the most important pathogen inside eggs and known to be transmitted to

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Ingredients	Stages of induced molting				
	Pre-molt	Molt*	Post-molt		
Corn, yellow	567.18	170.15	567.00		
Soyabean meal	316.33	94.90	316.51		
Alfalfa meal	-	700.00	-		
Vegetable Oil	76.82	23.05	76.50		
Di-calcium phosphate	16.86	5.06	17.18		
Calcium Carbonate	15.62	4.69	15.62		
Methionine (98 %)	1.69	0.51	1.69		
Vitamin premix ¹	2.50	0.99	2.50		
NaCl	2.50	0.75	2.50		
Trace mineral premix ²	0.50	-	0.50		
Total	1,000.00	1,000.00	1,000.00		

Table_1	Composition	of Experimental	Diets (a/ka)
laple-1.	composition	or Experimental	Diets (g/ kg)

1. Provided milligrams per kilogram of diet unless otherwise noted: vitamin A, 8.818 IU; vitamin D, 2.208 IU; vitamin E, 5.86 IU; vitamin K, 2.2 IU; thiamine, 1.1 IU; riboflavin, 4.4IU; niacin, 22 IU; choline, 500 IU; B₁₂, 0.013 IU; Biotin, 0.055 IU.

2. Trace mineral premix provided milligrams per kilogram of diet unless otherwise noted: Mn, 68.2; Zn, 55; Cu, 4.4; I, 1.1; Se, 0.1.

*molting layer diet divided into three treatments; A: 15 ppm copper sulphate; B: 20 ppm zinc oxide; C: 20 ppm aluminium oxide

humans (Gast and Ricke, 2003). It seems that mineral supplementation molting methods would be given priority in the coming years. These methods have lower mortality rates in the hot climates as compared to the feed deprivation and feed restriction methods.

Inductions of molt through dietary mineral additives such as Cu, Zn (Stevenson and Jackson, 1984), or Al (Hussein et al., 1989) have been practiced by various scientists in the past to enhance the post-molt production. Uses of high levels of either aluminium salt (Yousaf and Ahmad, 2006) or dietary zinc (Yousaf and Ahmad, 2006) have been successfully used. However, supplementing low levels of dietary zinc combined with reduced calcium levels in the diet have also induced molting successfully in laying hens (Ricke et al., 2001). Copper is used as an effective molting agent (Stevenson and Jackson, 1984). Supplementation of minerals has resulted in better postmolt production performance in laying hens as compared to a control group. However, induced molting by high dietary minerals has raised public health concerns regarding the potential residues of these minerals in eggs and meat, which may have implications for human health. These risks of high mineral residues can be minimized by using low mineral diets and yet induce molting in egg laying hens.

The objective of the current experiment was to evaluate the effectiveness of different minerals at low levels combined with layer ration on the induction of a molt, postmolt production and postmolt egg quality.

Materials and methods

Experimental birds: Four hundred and fifty Single Comb White Leghorn commercial layers (66-67 weeks-old) were randomly picked up from the flock

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raised at Breeding and Incubation Section, Poultry Research Institute, Rawalpindi. Birds were housed one per cage and allowed 3 weeks for acclimation. After acclimation, layers were placed 2 birds per cage for the molting procedure. The hens were divided into 5 treatment groups with 90 layers per treatment and 30 layers in each replicate per treatment group following completely randomized design.

Pre-molt period: The layers were vaccinated against newcastle disease and were treated with oxytetracycline (1 ml/liter of drinking water) and vitamins for a period of three weeks during which feed and drinking water were given *ad libitum*. During this period, the birds were fed a complete layer diet (Table 1) *ad libitum* and allowed full access to water. Hens were placed on lighting program of 16L:8D. Egg production was monitored to ensure that all hens were healthy and actively producing. Induced molting Schedule is given in Table-3.

Molt period (2 Weeks): During this period, experimental birds were randomly assigned to five treatment groups' viz., A, B, C, D and E. The experimental birds of groups A, B and C were fed a molted layer diet (Table 1) that was contained different minerals added. The experimental diet "A" contained 15 ppm copper sulphate (Yousaf, 2006). The diet "B" contained 20 ppm zinc oxide (North and Bell, 1990). The diet "C" contained 20 ppm aluminium oxide (Yousaf and Ahmad, 2006). However, diet "D" was balanced layer diet without added minerals. The bird's in-group E (without induced molting as control) was fed balanced layer diet. These diets were prepared at Nutrition Section, Poultry Research Institute, Rawalpindi. The birds in groups A, B, C and D were offered respective experimental diets at the rate of 30 g/bird, whereas birds in group E were fed ad libitum feed throughout

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Table-2. Nutrient composition of diets offered at various stages of induced molting							
Ingredients	Stages of induced molting						
-	Pre-molt	Molt*	Post-molt				
Dry matter	90.10	91.50	91.00				
Crude protein	16.75	14.00	17.00				
Ether extract	2.93	2.79	3.00				
Crude Fiber	4.78	10.00	4.60				
Ash	9.00	10.25	9.10				
Calcium	3.00	0.90	3.00				
Phosphorus (Available)	0.25	0.22	0.25				
Metabolizable Energy (Kcal Kg-1)	2872	1387	2850				

the period and kept as control. Water was given *ad libitum* to the birds of all groups. During this phase, lighting program was followed as 12L: 12D.

Rest period (3 Weeks): The birds in groups A, B, C and D were given respective experimental diet at the rate of 50 g/bird for first 2 weeks of the rest period. Water was offered *ad libitum* to the birds of all groups. The birds of all groups were vaccinated against Newcastle Disease with Lasota.

During 3rd week of rest period the birds in groups A, B, C and D were given experimental diets at the rate of 60 g/bird, however birds in group E were fed *ad libitum*. During this week, hens were placed on lighting program of 14L:10D. The schedule for induced molting is illustrated in the Table 3. Molting phase lasted for 35 days in months of June-July.

Production Phase: During this phase, the birds of all groups were fed a balanced layer diet (Table 1). They were fed *ad libitum* and had free access to clean and fresh drinking water. Hens were placed again on lighting program of 16L:8D. Production data was recorded for 20 weeks after molting.

Each diet was analyzed as described methods in AOAC (2000) for proximate composition, minerals and aflatoxin at Feed Testing Laboratory, Poultry Research Institute, Rawalpindi (Table 2). All analyses and determinations were done in triplicate.

Parameter measured: At the end of the molt, 15 birds per treatment were euthanized with CO_2 gas and the ovaries, oviducts, kidneys, hearts, livers and spleens were excised aseptically and weighed and expressed as relative weights (%of body weight). During molt, bird weights were monitored at d 1, 5, 9

and 14. Feed intake was measured by weighing each diet prior to the start of the molt and after the molt period. Feed efficiency was calculated on the basis of feed intake/dozen eggs during production period. Egg production was measured daily (%of hen-day assuming 1 egg per day = 100%), whereas egg quality parameters were measured once per week. Egg weight was measured with electronic balance and recorded to the nearest 0.01 g. Shell thickness, egg length and albumen height were measured with a caliper and recorded to the nearest 0.1 mm. Haugh units were calculated taking into account egg length and albumen height as an indicator of interior egg quality (Silversides et al., 1993). Egg production and quality were measured for 20 weeks after molting. Daily mortality and etiology of the dead birds, if any, was recorded after conducting the post-mortem examination.

Statistical analysis: All data were analyzed using procedure of SAS software (2001). Differences in parameters (egg production, feed intake, g of body weight loss, % of body weight loss, organ weights, internal egg quality and external egg quality) among treatment groups, when significant, were compared using Duncan's multiple range test. The level of significance used in all results was p<0.05.

Results

Molting phase: The birds fed diets A, B and C showed significantly greater (p<0.05) percentages of body mass loss (25.89, 25.69 and 25.25%, respectively) than those fed the diet D (20.04%). The birds fed diet E (Full feed-non molted group) exhibited

Table-3. Induced Molting Schedule

Age (Weeks)	Stage	Medication/ Vaccination	Feed	Water	Light
65	Premolt	Deworming, Antibiotic Course IB+ND Vaccination	Ad libitum	Ad libitum	16 h
66-67	Molt	-	30 g/ bird except feed deprivation	Ad libitum	12 h
68-71	Rest Period	ND Live Vaccine	50 g/bird	Ad libitum	12 h
72	Rest Period	-	60 g/bird	Ad libitum	14 h
73-92	Production	NDV Lasota each month	Ad libitum	Ad libitum	16 h
			IB=Infectious bronchitis: NE)= Newcastl	e disease

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Table-4. Effects of copper sulphate, zinc oxide, aluminium oxide, without mineral molt diets and a non-molt diet on feed intake, body weight loss and percentage of body weight loss during molting period

Groups*	Feed Intake (g/bird)	Body weight loss (g/bird)	Body weight loss (%)
A	280.5° <u>+</u> 22.3	380.6° <u>+</u> 10.8	25.89 ^ª <u>+</u> 0.017
В	257.8° +27.7	390.5° +11.7	25.69° +0.010
С	274.3° +31.6	386.3° +9.7	25.25° +0.015
D	450.6 ^b +21.5	255.4 ^b +17.4	20.04 ^b +0.012
E	739.5° <u>+</u> 15.4	79.5° <u>+</u> 0.7	5.25° <u>+</u> 0.10

 $^{a-d}$ means with the different superscript within columns are significantly different (P< 0.05)

*A: 15 ppm copper sulphate; B: 20 ppm zinc oxide; C: 20 ppm aluminium oxide; D: without minerals; E: without inducing molting as control.

the least amount of body mass loss (5.25%) when compared with all other treatments of molted hens (Table 4). No significant differences in ovarian weights were found among minerals supplemented groups A (0.75% BW), B (0.55% BW) and C (0.65% BW; Table 5). All treatments exhibited differences (p<0.05) in feed intake during the molt. The nonmolted birds (group E) exhibited the greatest feed intake (739.5 g/bird over the 2 weeks molt), whereas birds on group D ingested 450.6 g/bird (Table 5). Birds on minerals supplemented diets ate the least feed (280.5, 257.8 and 274.3 g/bird for groups A, B and C, respectively).

Post-molting phase: On average non-molted hens fed a balanced layer diet and molted hens fed without minerals diet had significantly lower (p<0.05) egg production (60.16 and 65%, respectively) when compared with molted hens fed mineral added diets (71.80, 74.50 and 72.15% for groups A, B and C, respectively) after 20 weeks postmolt (Table-6). However, molted hens fed without minerals diet had significantly higher egg production than those of nonmolted hens fed a balanced layer diet. In the present study, egg weight at the peak of postmolting production was not significantly different between the molted and non-molted hens (Table 6).

In this study, egg shell quality improved (p<0.05) in molted hens compared to non-molted hens (Table-6). However, there was non-significant (p>0.05) difference found among the molted hens with

or without mineral added diets. The molted birds showed higher (p<0.05) Haugh unit score values (85.08, 86.11, 85.08 and 84.27 for groups A, B, C and D, respectively) compared to non-molted birds (82.00 for group E, Table 6).

Discussion

Molt induction to rejuvenate the egg laying performance of commercial laying hen flocks is an important practice in many parts of the world, often being necessary to make a flock profitable under certain market scenarios. The first objective of an induced molt program is to cause hens to cease egg production and enter a non-reproductive state that cause body weight losses.

Hussein *et al.*, (1988) reported that supplementation of aluminium sulphate in molted diet led to a significant reduction in body weight and feed intake of birds. Approximately 25% of the body mass loss was attributed to decreases in liver and reproductive organ weights (Berry and Brake, 1985). The body weight reduction in the minerals supplemented groups was shown to be 25.89-25.69%. Therefore, it can be suggested that the termination of fasting should be determined on body weight basis rather than days-offasting. The weight loss exhibited by non-molted birds could be explained by the reduced photoperiod, because photoperiod and nutrient deprivation have similar modes of action on the hypothalamic hypophyseal axis causing an inhibition of circulating

Table-5. Effects of copper sulphate, zinc oxide, aluminium oxide, without mineral molt diets and a non-molt diet on post molt organ weights (as % of body weight)¹

Groups*	Ovary(%)	Oviduct(%)	Heart(%)	Liver(%)	Spleen(%)
A	0.75 <u>+</u> 0.09°	1.77 <u>+</u> 0.06°	0.46 <u>+</u> 0.01	1.55 <u>+</u> 0.08°	0.10 <u>+</u> 0.005
В	$0.55 \pm 0.07^{\circ}$	$1.55 \pm 0.07^{\circ}$	0.46 ± 0.01	1.49 <u>+</u> 0.03°	0.09 ± 0.005
С	0.65 + 0.04°	1.69 + 0.14°	0.46 + 0.01	1.60 + 0.06°	0.10 + 0.007
D	1.25 + 0.10 ^b	2.10 + 0.09 ^b	0.47 ± 0.01	1.80 <u>+</u> 0.09 ^b	0.10 + 0.006
E	2.16 <u>+</u> 0.22 ^ª	3.96 <u>+</u> 0.21 [°]	0.48 <u>+</u> 0.01	2.26 <u>+</u> 0.05 [°]	0.11 <u>+</u> 0.008

a-c. means with the different superscript within columns are significantly different (P < 0.05).

1. Relative organ weight (%) = (organ weight/100 g of body weight) x 100.

*A: 15 ppm copper sulphate; B: 20 ppm zinc oxide; C: 20 ppm aluminium oxide; D: without minerals; E: without inducing molting as control.

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Table-6.	Effects	of	Minerals	Supplementation	on	performance	of	molted	Commercial	layers	in
second p	roductic	on c	ycle								

Variables			Groups*		
	A	В	С	D	E
Egg Production (%)	71.80° <u>+</u> 0.015	74.50° <u>+</u> 0.01	72.15° <u>+</u> 0.01	65.00 ^b +0.01	60.16° <u>+</u> 0.01
Egg weight (g)	64.17 <u>+</u> 0.039	64.00 <u>+</u> 0.021	64.15 <u>+</u> 0.062	63.99+0.060	63.97+0.015
Feed Intake (Kg)	16.80+0.050	16.82+0.015	16.9+0.021	17.1 +0.016	17.8 +0.021
Feed Efficiency	3.28°+0.025	3.08°+0.053	3.15 [°] +0.044	5.20 ^b +0.028	5.38°+0.153
(feed /dozen eggs)	—	—	—	—	—
Eag shell thickness (mm)	0.351°+0.002	0.357°+0.005	0.352°+0.001	0.350°+0.007	0.342 ^b +0.003
Haugh unit score	85.08° <u>+</u> 1.93	86.11° <u>+</u> 1.95	85.08° <u>+</u> 1.68	84.27 ^ª <u>+</u> 2.14	82.00 ^b <u>+</u> 2.10

reproductive hormone concentrations with subsequent ovary regression and weight loss (Berry, 2003). The reduced photoperiod also provides fewer day light hours for feeding, which decreases feed intake and causes weight loss as exhibited by all birds (Andew *et al.*, 1987). Birds on A, B and C lost more body weight than birds on groups D and E due to a decreased feed intake, which could be attributed to several factors including supplementation of minerals in the diet.

Ovarian weight loss occurs simultaneously with body mass loss due to the regression of the ovaries that is directly associated with the rejuvenation process. Maximum involution of the reproductive organs is essential for optimum postmolt performance (Baker *et al.*, 1981).

Un-supplemented mineral group and un-molted hens had higher (p<0.05) ovarian weights than hens on all other molted treatments (1.25 and 2.16 % BW, respectively). Similar results were published by Stevenson and Jackson (1984); ovarian weights of hens fed diet supplemented with copper sulphate were significantly reduced from ovarian weights of hens fed non-supplemented mineral diet. Loss of gonadotropin support during induces molting causes involution of the ovary. Follicles in the maturational hierarchy become atretic and the yolk material is resorbed. Ovary weight declines as follicles become atretic. Reduction in ovary weight is initially dependent on the duration of fasting and rate of body weight loss. Beyond 25% body weight loss, the ovary is fully regressed (Heryanto et al., 1997). In the present study, hens lost more than 25% body weight in mineral supplemented groups showing more declined in ovary weight compared to other groups. Involution of the oviduct follows the loss of ovarian steroidal support. Regression of the oviduct is a true re-modeling of the tissue rather than a decline in the size of cells or shrinkage of the tissue. Apoptosis removes cells of the glandular epithelium during regression (Heryanto et al., 1997). Zinc has an inhibitory effect on ovarian function; it causes oviposition to cease without greatly depressing feed consumption (Breeding et al., 1992).

No differences (p < 0.05) were found among treatments when comparing heart and spleen weights. Unsupplemented mineral group and un-molted birds had significantly higher liver weights when compared with all other treatments (1.80 and 2.26% BW, respectively), whereas mineral-treated birds had significantly lower liver weights (1.55, 1.49 and 1.60% BW for groups A, B and C, respectively) than those of control groups. Liver weight loss indicates a loss of liver energy sources, such as glycogen and lipids, which are metabolized in the liver (Berry and Brake, 1985). Weight loss from the liver is also indicative of the loss of estrogen-dependent egg component synthesis, which is dependent on stimulation from ovarian steroids (Berry and Brake, 1985). The most common ovarian steroids are the estrogens whose target organ is the liver where yolk phospholipoprotein synthesis occurs and is dependent primarily on estrogens (Berry and Brake, 1985).

The reduction in feed intake could have been due to some factors, including appetite suppression with minerals supplementation, decreased feeding stimulation with reduced daylight hours (Andews et al., 1987). Dietary aluminium has been tried as a molting agent (Hussein et al., 1989). They reported that dietary aluminium causes reduced feed intake by hens. Pearce et al., (1983) reported that supplementing copper sulphate (2000 mg Cu/kg) reduced feed intake of bird's upto 30%. Increasing levels of dietary zinc caused progressive declined in feed consumption (Breeding et al., 1992) such that hens given 20,000 ppm zinc oxide in an otherwise typical layer ration virtually begin fasting. Whether there is a specific metabolic function of zinc in inducing a forced rest is not certain at this time.

The goal of a viable molting program is to increase post molt egg production and quality. Hussein *et al.*, (1989) and Hussein, (1996) reported that egg production of hens was increased in postmolting performance by supplementing of aluminium acetate in the diets of molted birds. After the molting period, hens improve their egg production due to the all as 1%

rejuvenation of the reproductive organs and overall body weight loss (Ocak et al., 2004). Hens that lost the greatest amount of weight exhibited the greatest improvement in highest egg production after molting (Baker et al., 1981). One of the major reasons for increased postmolt egg production was decreased postmolt production of shell less eggs. Increased egg production can relate to profits for the industry depending on bird prices, feed prices and egg demand (McDaniel and Aske, 2000). A change in supply as small as 1% can result in a 6% opposite change in egg prices, which can cost or make a producer with a typical operation \$1.46 million annually (McDaniel and Aske, 2000). Yousaf, (2006) reported that molted hens treated by aluminium oxide in the second production cycle produced maximum number of eggs followed by copper sulphate treatment. Similar findings have been reported by Hussein et al. (1989), who reported that the birds induced to molt by minerals supplementation performed better than feed deprivation method. North et al. (1990) and Yousaf (2006) who reported that different induced molting programs did not significantly affect egg weight when compared to the non-molted birds.

Hens that lost more weight exhibited the best improvement in highest egg shell quality after molting (Baker et al., 1981). Improved shell gland function following induced molting may be due to remodeling at the cellular level. Cellular proliferation in the oviduct replaces cells lost during the regression, as evidenced by increased staining of the proliferating cells for proliferating cells nuclear antigen, a marker of cell proliferation (Heryanto et al., 1997). Remodeling of shell gland tissue may also be responsible for removing substances that interfere with shell gland function. The uterine glandular epithelium which is the site of egg shell calcium transport and deposition contain quantities of intracellular lipid visibly detectable by histological staining. Roland et al. (1977) reported that hens laying shell-less eggs have significantly higher uterine lipid levels compared to hens producing normal egg shells. Further reports by Baker et al. (1981) indicated that induced molting halts the incidence of shell-less eggs and removes lipid accumulation in the uterus. Berry and Brake, (1987) reported that molting increases tissue receptivity to 1,25(OH) dihydroxyvitamin D₃. The location of the cytosolic receptors for 1,25(OH) dihydroxyvitamin D₃ in shell gland glandular cells coincided with the reported location of calcium binding protein. Brake et al. (1981) and Baker et al. (1983) have reported that optimum postmolting performance was achieved when body weight loss was greater than 25%. They reported that uterine lipid was not lost until body weight decreased to that point which coincided with maximum oviductal regression. Duodinal weight decreased during fasting and returns to original size upon refeeding (Donalson *et al.*, 2005). Following the molt, intestinal calcium binding protein concentration increases compared to unmolted hens. Intestinal uptake of calcium also improves following molt (Al-Batshan *et al.*, 1994). Higher eggshells thickness of molted birds is a desirable characteristic for the egg industry (Keshvarz and Quimby, 2002).

The Haugh unit is a measure of the internal quality of an egg. Haugh unit score were improved by forced molt. Karunajeewa *et al.*, (1989) reported higher (p<0.05) Haugh units of eggs from hens molted by fasting than from hens fed 10 ppm ZnO. However, in the present experiment, higher Haugh units of eggs from hens molted by feeding ZnO than from hens molted by non-mineral diets. This difference is due to use of high level of ZnO (20 ppm) than above study.

In conclusion, this study shows that mineral feeding appears to be the best alternative to without mineral feeding in molting methods and yield comparable results.

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References

- 1. Al-Batshan, H.A., *et.al.* (1994). Duodenal calcium uptake, femur ash and egg shell quality decline with age and increase following molt. *Poultry Sci.* 73: 1590-1596.
- Andews, D.K., Berry, W.D. and Brake, J. (1987). Effect of lighting program and nutrition on reproductive performance of molted single comb white leghorn hens. *Poultry Sci.* 66: 1298-1305.
- Association of Official Analytical Chemist. (2000). Official Methods of Analysis. 3rd ed. Association of Official Analytical Chemists, Washington, D C.
- Baker, M., Brake, J. and McDaniel, G.R. (1981). The relationship between body weight loss during a forced molt and postmolt reproductive performance of caged layers. *Poultry Sci.* 60: 1595. (*Abstr.*).
- Baker, M., Brake, J. and McDaniel, G.R. (1983). The relationship between body weight loss during an induced molt and postmolt egg production, egg weight and shell quality in caged layers. *Poultry Sci.* 62: 409-413.
- Berry, W.D. (2003). The physiology of induced molt. *Poultry* Sci. 82: 971-980.
- Berry, W.D. and Brake, J. (1985). Comparison of parameters associated with molt induced by fasting, zinc and low dietary sodium in caged layers. *Poultry Sci.* 64: 2027-2036.

- Berry, W.D. and Brake, J. (1987). Postmolt performance of laying hens molted by high dietary zinc, low dietary sodium and fasting. Egg production and egg shell quality. *Poultry Sci.* 66: 218-226.
- 9. Brake, J., Baker, M. and Mannix, J.G. (1981). Weight loss characteristics of the body, liver, ovary, oviduct and uterine lipid during a forced molt and their relationship to postmolt performance. *Poultry Sci.* 60: 1628 (Abstr.).
- Breeding, S. W., Brake, J., Garlich, J.D. and Johnson, A.L. (1985). Molt induced by dietary zinc in a low-calcium diet. 1992. *Poultry Sci.* 71: 168-180.
- Donalson, L.M., Kim, W.K., Woodward, C.L., et.al. (2005). Utilizing different ratios of alfalfa and layer ration for molt ininduction and performance in commercial laying hens. *Poultry Sci.* 84: 362-369.
- 12. Gast, R.K., Ricke, S.C. (2003). Symposium: Current and future prospects for induced molting in laying hens. *Poultry Sci.* 82:964.
- 13. Heryanto, B., Yoshimura, Y. and Tamura, T. (1997). Cell proliferation in the process of oviducal tissue remodeling during induced molting in hens. *Poultry Sci.* 76: 1580-1586.
- 14. Holt, P.S. (2003). Moulting and Salmonella Enterica Serovar Enteritidis infection the problem and some solutions. *Poultry Sci.* 82: 1008-1010.
- 15. Hussein, A.S. (1996). Induced moulting procedures in laying fowl. *World's Poultry Sci.* 52: 175-187.
- Hussein, A.S., Cantor, A.H. and Johnson, T.H. (1988). Use of high dietary levels of aluminium and zinc for inducing pauses in egg production of Japanese quails. *Poultry Sci.* 67: 1157-1165.
- Hussein, A.S., Cantor, A.H. and Johnson, T.H. (1989). Comparison of the use of dietary aluminium with the use of feed restriction for forced molting laying hens. *Poultry Sci.* 68: 891-896.
- Karunajeewa, H., Abuserewa, S. and Harris, P.A. (1989). Effects of an induced pause on egg production and supplementation of the diet with iron on egg shell colour, quality and performance of brown egg layers. *Brit. Poultry Sci.* 30: 257-264.
- Keshavarz, K. and Quimby, F.W. (2002). An investigation of different molting techniques with an emphasis on animal

welfare. J. Applied Poultry Res. 11: 54-67.

- McDaniel, B.A. and Aske, D.R. (2000). Egg prices, feed costs and the decision to molt. *Poultry Sci.* 79, 1242-1245.
- 21. North, M.O. and Bell, D.D. (1990). Commercial chicken production manual. AVI Publishing Inc., NewYork, USA.
- Ocak, N., Sarica, M., Erener, G. and Garipoglu, A.V. (2004). The effect of body weight prior to moulting in brown laying hens on egg yield and quality during second production cycle. *Intern. J. Poultry Sci.* 3: 768-772.
- Pearce, J., Jackson, N., Stevenson, M.H. (1983). The effects of dietary intake and of dietary concentration of copper sulphate on the laying domestic fowl: effects on some aspects of lipid, carbohydrates and amino acid metabolism. *Brit. Poultry Sci.* 24: 337-348.
- 24. Ricke, S.C., *et.al.* (2001). Limitation of *Salmonella enteritidis* colonization by diets containing low calcium and low zinc. *Poultry Sci.* 80 (1): 262 (Abstr.).
- Roland, D.A. Sr, Holcombe, D.J. and Harms, R.H. (1977). Further studies with hens producing a high incidence of non-calcified or partially calcified eggs. *Poultry Sci.* 56: 1232-1236.
- SAS Institute. (2001). SAS/STAT Users Guide: Statistics. Release 8.2. SAS Institute Inc., Cary; NC.
- Stevenson, M.H. and Jackson, N. (1984). Comparison of dietary hydrated copper sulphate, dietary zinc oxide and a direct method for inducing moult in laying hens. *Brit. Poultry Sci.* 25: 505-517.
- Silversides, F.G., Twizeyimana, F., Villeneuve, P. (1993). Research note: A study relating to the validity of the haugh unit correction for egg weight in fresh eggs. *Poultry Sci.* 72: 760-764.
- Webster, A.W. (2003). Physiology and behavior of the hen during induced moult. *Poultry Sci.* 82: 992-1000.
- Yousaf, M. (2006). Influence of different copper and aluminium levels on organ weight, feather renewal and production performance of the moulted layers. *Pakistan J. AridAgric.* 9(1): 35-39.
- Yousaf, M., Ahmad, N. (2006). Effects of Housing systems on productive performance of commercial layers following induced molting by aluminium oxide supplementation. *Pakistan Vet. J.* 26(3): 101-104.
