EFFECT OF FORCE MOLTING INDUCED CONVENTIONALLY OR BY HIGH DIETARY ALUMINUM ON EGG AND SHELL QUALITY OF LAYING HENS

A. A. Alsobayel[1] and N. A. Alkhateeb

Department of Animal Production, College of Agriculture
King Saud University, Riyadh 11451, Saudi Arabia

Summary

Eggs used in this study were obtained from Saudi Arabian Baladi laying hens which were divided into four experimental groups and subjected to the following treatments: Commercial laying ration (17% CP, 3.6% Ca and 0.343% available P) fed *ad libitum* as a control (C); Conventional force molting, feed removal for 10 days followed by 18 days full-feed of cracked corn (F); 15 days *ad libitum* intake of the control ration supplemented, to initiate forced-molt, with 0.35% aluminum as the sulfate (ALS) or the chloride (ALC). The hens were in production for 52 weeks and 17 months of age at the start of the trial and the post-treatment period lasted 36 weeks.

During the treatment period F and AL treated groups had similar egg and shell weight, egg surface area, shell thickness and shell weight per unit of surface area but significantly ($p < 0.05$) lower than the control. F had significantly ($p < 0.05$) the highest and the control the lowest Haugh unit values whereas AL fed groups had significantly ($p < 0.05$) lower meat spot incidence compared with the control which tended to have higher value than F group. ALC and F had significantly ($p < 0.05$) the lowest yolk color grade whereas ALC had significantly ($p < 0.05$) lower egg index than ALS and the control.

During the post-treatment period the control had significantly ($p < 0.05$) the highest egg index and blood spots incidence and ALS the lowest shell diensity compared with other groups. ALS had significantly ($p < 0.05$) lower shell weight than ALC and the control whereas F and AL treated hens had significantly ($p < 0.05$) the highest Haugh unit values and yolk color grades respectively. F had significantly ($p < 0.05$) lower meat spots incidence than ALC and the control. The same results were observed for ALS compared with the control.

(**Key Words**: Saudi Arabian Baladi Hen, Force Molting, Aluminium, Egg Quality)

Introduction

Force molting has been studied for many years as a possible way of rejuvenating laying hens to increase egg production and improve egg and shell quality. Force molting methods and their effect on laying performance and egg quality have been reviewed by several investigators (Wakeling, 1977; Miller, 1983; North, 1984; Wolford, 1984).

Excessive dietary aluminum has been recently viewed as a possible means of force molting by Hussein et al. (1989) and Alkhateeb (1990). However, informations on the effect of high dietary aluminium on egg and shell quality are very limited. Nyholm (1981) reported on an adverse effect of aluminium on apatite deposition and/or mobilization in bone marrow which could account for the production of poor shell quality of wild passerine birds. Hussein et al. (1988) showed that high dietary aluminium levels (0.15 to 0.30% as the sulfate) fed for seven days negatively affected egg shell breaking strength of Japanese quail. However the same authors (1989) reported no differences among hens treated with dietary aluminium and those force-rested conventionally in shell breaking strength during the post-treatment period.

To our knowledge reports on the effect of high dietary aluminium as a force molting agent on egg and shell quality are almost lacking. The present study was therefore conducted to investigate in Saudi Arabian Baladi laying hens the following aspects: 1) the effect of high dietary aluminium (as the sulfate or chloride) as a force molting agent upon egg and shell quality and

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[1] Address reprint requests to Dr. A. A. Alsobayel Department of Animal Production, College of Agriculture, King Saud University, P. O. Box 2460, Riyadh 11451, Saudi Arabia.

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2) to compare the post-molt egg and shell quality of aluminium treated hens with that of the control and hens subjected to conventional fasting procedure.

Materials and Methods

A total of 416 leg-banded Baladi laying hens were used in this study. The hens were obtained from Saudi Arabian Baladi flock which has been randomly bred for several years in the experimental poultry and live-stock farm of the animal production department, King Saud University. Baladi is an endogenous breed characterized by its relatively small adult body weight (1.34 kg), low egg production (175 egg/year) and small egg weight (45.03 g) as reported by Al-Ogaily (1989) and Alsobayel et al. (1991). The experimental birds were randomly alloted to 16 floor pens in an environmentally controlled house, 26 birds in each pen and divided into four experimental groups of four floor pens. Average house temperature and relative humidity were 24.5°C and 47% during the treatment period, respectively. The birds were in production for 52 weeks and 17 months of age at the beginning of the experimental period. The different experimental groups were randomly assigned to each of the following dietary treatments:

1- Commercial laying ration (table 1) during the entire experimental period as a control (C).

2- Conventional force molting: feed removal for 10 days followed by 18 days full feed of carcked corn (F) and water was offered *ad libitum* as for the other groups.

3- 15 days *ad libitum* intake of the control laying ration supplemented, to initiate forced-molt, with 0.35% aluminium as the sulfate "$Al_2(SO_4)_3$ $18H_2O$" (ALS) or the chloride "$AlCl_3$" (ALC).

The level of aluminium (0.35%) was approximately equal to the calculated level of available phosphorus (0.343%). Light was maintained constantly at 15h light: 9 h dark for all of the groups during the whole experimental period. After the termination of the treatments, experimental birds in each group received the commercial laying ration described in table 1 and the post-molt period lasted thereafter 36 weeks divided into nine, 28 days production periods.

Five eggs of each replicate were collected three consecutive days at the start of the 1st and 2nd week of the treatment period, thereafter on the 14th, 15th and 16th day of each 28 days production period. The eggs were stored at 10-12°C and 55-60% relative humidity for not more than two days. On the third day, the index of each egg was calculated as the ratio of width/length × 100 (w/l × 100). Eggs were individually weighed to the nearest gram, broken-out and the presence of blood and meat spots (BS and MS) was visually determined. Haugh unit values (HU) (Haugh, 1937) were directly estimated using micrometer adjustable to egg weight and albumen

TABLE 1. COMPOSITION OF THE COMMERCIAL LAYING RATION[1]

Ingerdient	(%)
Alfalfa (17%)	1.50
Yellow corn	39.25
Soybean meal (48%)	18.77
Wheat (12.5%)	14.54
Wheat bran	9.35
D. C. P.	0.67
Local limestone (28-30% Ca)	11.38
Fat	1.21
Salt	0.29
Fish meal (61%)	2.50
Vitamin-mineral premix[2]	0.40
Red carrotin (Kemoglo Red)	0.10
Methionine	0.07
Calculated nutrient composition:	
ME (kcal/kg)	2585
Crude protein (%)	17.48
Crude fat (%)	4.23
Crude fiber (%)	3.10
Calcium (%)	3.60
Total phosphorus (%)	0.60[3]
Available phosphorus (%)	0.34

[1] Manufactured by: Grain Silos and Flour Mills Organization, Riyadh.

[2] Provided the following per kilogram diet; Vitamin A, 10,000 IU; Vitamin D_3, 3,000 ICU; Vitamin E, 20 IU; Vitamin K, 2 mg; Vitamin B_1, 2 mg; Vitamin B_2, 5 mg; Vitamin B_6, 1 mg; Vitamin B_{12}, 10 mcg; Nicotinic Acid, 25 mg; Panthothenic Acid, 10 mg; Folic Acid, 1 mg; Biotin, 0.1 mg; Choline, 500 mg; Vitamin C, 100 mg; Iron, 40 mg; Manganese, 100 mg; Zinc, 60 mg; Iodine, 1 mg; Cobalt, 0.25 mg; Selenium, 0.2 mg.

[3] Analysed 0.585% (Association of Offical Analytical Chemists, 1984).

height and directly gives Haugh unit values (USDA, 1977). Yolk color grade (YC) was measured by Roch Color Fan, which has 15 color gradations from pale yellow to dark orange (North, 1984). Shell thickness (ST) was measured at the middle part of the egg shell with membranes using "Ames Thickness Measure" to the nearest 0.001 inch and converted to microns after statistical analysis. Shell weight with membranes (SW) of each egg was measured to the nearest 0.01 gram after it was carefully washed and left to dry for 24 hours and shell weight percent (SWP) was also calculated (dried shell weight/egg weight × 100). Egg surface area (SA) and shell weight per unit of egg surface (SWUSA) were obtained for each egg using the following equations suggested by Nordstorm and Ousterhout (1982):

$SA = 3.9782 \times \text{egg weight}^{0.7056}$

$SWUSA = \text{shell weight (mg)/surface area (cm}^2)$

Shell density in gm/cm^3 (SD) was estimated for each egg according to the following equation suggested by Curtis et al. (1985): $SD = \text{shell weight (gm)/surface area (cm}^2) \times \text{shell thickness (cm)}$ Data collected were subjected to statistical analysis using SAS general linear model (GLM) procedure, KSU computer center, according to the following model:

$Y_{ij} = \mu + T_i + e_{ij}$

where the Y_{ij} is the jth observation of the ith treatment, μ is the general mean and e_{ij} is the random error associated with Y_{ij} observation (SAS, 1980).

Results

Statistical analysis indicated a significant treatment effect upon most studied traits during and post-molt period (tables 2 and 3). During the force molting period, feed restricted and AL treated hens had similar egg and shell weights, egg surface area, shell thickness and shell weight per unit of surface area but significantly ($p < 0.05$) lower than those of the control (table 2). However there were no significant differences between the different experimental groups with regard to shell weight percent, shell density and blood sports incidence (table 2). Feed restricted hens had significantly ($p < 0.05$) the highest and the control the lowest Haugh unit values. On the other hand, AL fed groups had significantly ($p < 0.05$) lower meat spot incidence than the control which tended to have higher value than feed restricted hens (table 2). ALC and feed restricted groups had significantly ($p < 0.05$) the lowest yolk color grades whereas ALC had significantly ($p < 0.05$) lower egg index compared with ALS and the control (table 2).

As it is shown in table 3, the different experimental groups had similar egg weight, shell thickness, shell weight percent, egg surface area and shell weight per unit of surface area during the post-molt period. However, the control had significantly ($p < 0.05$) the highest post-molt egg index and blood spots incidence and ALS the lowest shell density compared with other experimental groups (table 3). ALS had also significantly ($p < 0.05$) lower shell weight than ALC and the control. On the other hand, F and significantly ($p < 0.05$) the highest post-molt Haug unit values whereas AL treated hens had significantly ($p < 0.05$) the highest yolk grades. With regared to post-molt meat spot incidence, F had significantly ($p < 0.05$) lower values compared with ALC and the control (table 3).

Discussion

Fasted group (F) completely ceased egg production 10 days following feed withdrawel whereas ALS and ALC were producing at 10.32 and 14.42% at the end of the treatment period, respectively (Alkhateeb, 1990). The same auther also observed that F, ALS and ALC groups had significantly lower post-molt egg production than the control (C) and the means were 34.9, 34.6, 31.1 and 38.7% for the different groups, respectively.

During the force molting period, feed-restricted hens had significantly ($p < 0.05$) lower egg and shell weights, shell thickness, egg surface area, shell weight per unit of surface area and yolk color grades compared with the control. These results might be attributed to feed deprivation. Polin and Sturkie (1954) reported that 1-2 days feed starvation caused a 20% decrease in egg shell weight. Bierer et al. (1965) also indicated that egg shell weights were lighter after 24-48 hours of starvation suggesting that production of normal strong-shelled eggs depends to a degree on the

TABLE 2. EFFECT OF FORCE MOLTING INDUCED CONVENTIONALLY (F) OR BY HIGH DIETARY AL AS THE SULFATE (ALS) OR CHLORIDE (ALC) ON EGG WEIGHT (EW), EGG INDEX (EI), SHELL WEIGHT (SW), SHELL THICKNESS (ST), SHELL WEIGHT PERCENT (SWP), EGG SURFACE AREA (SA) SHELL WEIGHT PER UNIT OF SURFACE AREA (SWUSA), SHELL DENSITY (SD), HAUGH UNIT (HU), BLOOD AND MEAT SPOTS INCIDENCE (BS & MS) AND YOLK COLOR GRADES (YC) DURING THE TREATMENT PERIOD

		EW (g)	EI (w/1×100)	SW (g)	ST (μm)	SWP (%)	SA (cm³)	SWUSA (mg/cm²)	SD (g/cm³)	HU	BS (%)	MS (%)	YC
Treatment	:	**	*	**	*	n.s.	**	*	n.s.	**	n.s.	*	**
F	:	47.81^{a}	73.71^{ab}	4.33^{a}	327^{a}	8.89	60.88^{a}	71.06^{a}	2.15	71.62^{a}	10.42	13.75^{ab}	6.53^{a}
ALS	:	48.30^{a}	74.55^{ab}	4.42^{a}	331^{a}	9.18	61.30^{a}	72.13^{a}	2.12	65.88^{bc}	3.85	9.23^{a}	7.46^{b}
ALC	:	48.25^{a}	73.72^{a}	4.38^{a}	328^{a}	8.89	61.27^{a}	71.45^{a}	2.14	66.61^{b}	13.26	11.49^{a}	7.01^{a}
C	:	49.97^{b}	74.86^{b}	4.68^{b}	352^{b}	9.32	62.81^{b}	74.62^{b}	2.12	63.71^{c}	11.62	21.67^{b}	7.33^{b}
SEM	:	± .20	+ .38	± .03	± 1.65	+ .32	± .18	± .46	± .01	± .45	± 1.47	± 1.75	± .06

[a,b,c] Means within the same column with different superscript letters differ significantly.

* *Significant* ($p < 0.05$).

** Highly significant ($p < 0.01$).

[ns] Not significant.

TABLE 3. EFFECT OF FORCE MOLTING INDUCED CONVENTIONALLY (F) OR BY HIGH DIETARY AL AS THE SULFATE (ALS) OR CHLORIDE (ALC) ON EGG WEIGHT (EW), EGG INDEX (EI), SHELL WEIGHT (SW), SHELL THICKNESS (ST), SHELL WEIGHT PERCENT (SWP), EGG SURFACE AREA (SA) SHELL WEIGHT PER UNIT OF SURFACE AREA (SWUSA), SHELL DENSITY (SD), HAUGH UNIT (HU), BLOOD AND MEAT SPOTS INCIDENCE (BS & MS) AND YOLK COLOR GRADES (YC) DURING THE POST-MOLT PERIOD

		EW (g)	EI (w/1×100)	SW (g)	ST (μm)	SWP (%)	SA (cm³)	SWUSA (mg/cm²)	SD (g/cm³)	HU	BS (%)	MS (%)	YC
Treatment	:	n.s	**	*	n.s.	n.s.	n.s.	n.s.	**	**	**	*	*
F	:	48.92	74.88^{a}	4.67^{a}	375	9.61	61.85	75.34	2.02	71.79^{b}	5.68^{a}	7.69^{a}	8.41^{ab}
ALS	:	48.68	74.58^{a}	4.60^{a}	377	9.46	61.66	74.60	1.98	70.42^{a}	4.76^{a}	8.11^{ba}	8.44^{a}
ALC	:	48.98	74.46^{a}	4.68^{b}	377	9.56	61.59	75.50	2.01	70.04^{a}	7.39^{a}	11.59^{cb}	8.44^{a}
C	:	48.96	75.19^{b}	4.69^{b}	378	9.57	61.92	75.63	2.01	69.78^{a}	11.39^{b}	12.35^{c}	8.29^{b}
SEM	:	± .08	± .07	± .01	± 1.00	± .02	± .07	± .16	± .00	± .20	± .57	± .65	± .02

[a,b,c] Means within the same column with different superscript letters differ significantly.

* Significant ($p < 0.05$).

** Highly significant ($p < 0.01$).

[ns] Not significant.

feed consumed daily. The same authors observed thinner egg shells and increased in the number of cracked and soft-shelled eggs 24-48 hours following starvation. Similarly was observed by Polin and Sturkie (1954) who attributed that to the decrease in total plasma calcium. On the opposite, Haugh unit values were significantly ($p < 0.05$) higher than those of the control. This finding is consistent with that of Nordstrom (1980) who reported dramatic increase in Haugh unit values in the eggs laid during the feed withdrawal (molt) period which lasted for 7 days without water restriction. Sturkie and Polin (1954) reported that when the developing egg enters the shell gland during egg formation, albumen height is greater than 18-20 hours later when the egg is laid. Austic (1977) indicated that during the first 5 hours the egg is in the shell gland, albumen weight doubles due to the addition of water (plumping). The same author observed dilution of the albumen by water as well as an unexplained reduction in the total amount of ovomucin present after plumping which appear to be involved in the decline in albumen quality within the shell gland prior to oviposition. Bierer et al. (1965) have observed that water consumption declined when laying hens were deprived of feed. Hill and Powell (1977) and Savory (1978) concluded that feed intake and water consumption are colsely correlated overtime. Thus, the significant increase in Haugh unit values of eggs laid during the force molting period in the present study may be due to decreased water intake during feed withdrawal. Similar results were observed for AL treated hens with regard to egg weight, shell thickness and egg surface area which might be also due to reduced feed intake compared with the control (Alkhateeb, 1990).

During the post-molt period, hens in the feed-restricted group had similar egg weight and other shell quality parameters (ST, SW, SWP, SA, SWUSA and SD) as the control. These results are consistent with those of many investigators with respect to egg weight (Len et al., 1964; Noles, 1966; Wilson et al., 1967; Hurwitz et al., 1975; Nesbeth et al., 1976; Smith, 1980; Lee, 1982; Roland and Brake, 1982) and Shell thickness (Shippee et al., 1979). On the other hand, many others reported improved post-molt egg weight (Berg and Bearse, 1947; Safi and Miller, 1969; Hurwitz et al., 1975; Roland and Bushong, 1978; Swanson et al., 1978; Nordstrom, 1980) and shell thickness (Berg and Bearse, 1947; Hansen, 1960; Hamm and Welter, 1965; Safi and Miller, 1969; Lee, 1982; Garlich et al., 1984). However, Len et al. (1964) and Roberson and Francis (1979) found that post-molt increase in shell thickness was temporary and declined with age. Contrary to our results Hurwitz et al. (1975) reported increased post-molt shell weight and shell weight per unit of surface area compared with the control. Similarly was reported for shell weight by Roland and Brake (1982). Improved Haugh unit values were observed for feed-restricted hens in comparison with the control. These results are supported by those of many investigators (Len et al., 1964; Hamm and Welter, 1965; Roberson and Francis, 1979; Hembree et al., 1980 and Smith, 1980). However, some others did not detect any significant differences in Haugh unit values of molted and nonmolted hens (Wilson et al., 1967; Zeelen, 1975; Miller, 1983). In our study feed-restricted hens had significantly ($p < 0.05$) lower incidence of blood and meat spots compared with the control. However, Wilson et al. (1967) concluded that blood and meat spots incidence did not seem to be increased by force molting as previously reported by Marble (1963).

During the treatment period, AL treated hens had significantly ($p < 0.05$) lower EW, SW, ST, SA, SWUSA and MS compared with the control but similar to those of feed restricted hens. However the results on EI, HU, BS and YC are inconsistent. ALS had similar EI and HU values whereas ALC had higher HU and lower EI values than the control. ALC had also lower YC compared with the control and ALS the lowest BS among all treatments.

The results of this study also showed that AL treated hens had significantly ($p < 0.05$) lower post-molt values of blood spots and egg index, and higher yolk color grades compared with the control but similar to those of feed-restricted hens. On the other hand, the effect of AL treatment on post-molt meat spots incidence, shell weight and shell density are inconsistent. Hens fed AL as the sulfate had significantly ($p < 0.05$) lower values whereas those fed AL as the chloride had similar values compared with the control. With regard to post-molt egg weight and other shell quality parameters (ST, SWP, SA and SWUSA) there were no significant differences among the treatments. However the informations on subsequent egg and shell quality characterstics are very sparse. Nyholm (1981) reported on an adverse effect of AL on apatite formation in bone marrow and poor shell quality of wild passerine birds. Hussein et al. (1988) reported that high dietary AL level fed for 7 days negatively affected shell breaking strength of Japanese quail. However, the same authors (1989) observed no significant differences in egg shell breaking strength of feed-restricted and AL treated hens during and upto 8 weeks following the treatment.

Our results suggest that AL treatment positively affected post-rest blood spots incidence and yolk color grades and negatively affected egg index. On the other hand, feed restriction caused a significant improvement in Haugh unit values and blood and meat spots incidence, whereas other egg and shell quality parameters did not seem to be influenced by aluminium and feed restriction treatments.

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