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EFFECT OF NON-FEED WITHDRAWAL INDUCED MOLTING TECHNIQUES ON FEATHER MOLT SCORING AND EGG PRODUCTION OF CAGED HENS

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ABSTRACT

This study was conducted to compare the effect of various molting methods on feather molt score and egg production of caged hens. Three hundred twenty four Single Comb White Leghorn (Babcock) commercial layers (60 weeks old) were divided into 27 replicates of 12 layers each. Each treatment comprised of three replicates with 36 hens each. Hens were molted 1) feed deprivation, 2) fortified ground corn, 3) zinc oxide, 4) aluminium oxide, 5) moderate zinc and low calcium, 6) copper sulphate, 7) progesterone, 8) thyroxin and 9) untreated hens served as control. Hens were subjected to respective treatments for two weeks and were offered feed @ 35 g/bird except T1 (no feed) and T9 (full feed). In the following five weeks, hens were given feed @ 45 g/bird except T9 (110 g/bird) and during postmoult period hens were fed @110 g/bird. The results of this study revealed that primary and overall body feathers started shedding in the first week while secondary feather shedding started in second week of molting. Maximum primary and secondary feather scores were observed in T1 and T7 while minimum scores were noted in T9. Similarly, overall body feather score was maximum in T2 and T8 while minimum values were exhibited by T9. Egg production was maximum in T6 followed by T4, T3 and T1 while minimum values were observed for T9. On overall basis, present study revealed that the hens can be molted by non feed withdrawal molting methods (supplemented with minerals) with better egg production as compared to feed deprivation method.

Key words: Molting, methods, feather scoring, egg production

INTRODUCTION

Poor plumage condition and the consequent reduced insulation increases heat loss and accordingly the energy requirements (Tauson and Svensson, 1980), resulting in decreased laying efficiency (Leeson and Morrison, 1978). Good feather condition could be restored by induced molting (Herremans, 1988). The process of molting consisted of the replacement of feathering following endogenous stimulation in which the new feather generation induced the loss of the previous generation (Watson, 1963; Herremans, 1986).

Molting in avian species is defined as the periodic shedding and replacement of feathers (Berry, 2003). Induced molting in chickens dates back to early nineteenth century (Rice, 1905; Rice *et al.*, 1908). The scientists investigated different methods for molt induction due to which this practice gained popularity during 1930s. However, most of the egg producers in the California adopted induced molting in 1950s. The practice of molting continued to increase as indicated by an increase in the number of research papers being published in 1960s and 1970s. Similarly, induced molting spread in most of the egg producing regions of the world with the passage of time as a tool to rejuvenate the spent hens (Bell, 2003).

Different methods of induced molting have been practiced to recycle laying hens. To achieve maximum egg production during post molt period, it is recommended that weight loss should be in range of 25-35%. The conventional feed withdrawal/deprivation procedure is most widely used in poultry production because it is simple, practicable and economical technique that can be used in combination with light and/or water restriction (Hussein, 1996; Yousaf, 1998; Koelkebeck *et al.*, 2001; Yousaf, 2002; Bell, 2003; Biggs *et al.*, 2003: Biggs *et al.*, 2004; El-Deek and Al-Harthi, 2004; Oguike *et al.*, 2004; Khoshoei and Khajali, 2006). Mineral induced molting procedures, such as the use of high levels of either aluminium salt (Hussein and Dagir, 1996; Yousaf, 2004; Yousaf and Ahmad, 2006) or dietary zinc (Cantor and Johnson, 1984; Hussein *et al.*, 1988; Yousaf, 1998; El-Deek and Al-Harthi, 2004; Yousaf and Ahmad, 2006; Koelkebeck and Anderson, 2007) have been successfully practiced. However, supplementing low levels of dietary zinc combined with reduced calcium levels in the diet have induced molting successfully in laying hens (Breeding *et al.*, 1992a; Yousaf, 1998; Ricke *et al.*, 2001). The use of low sodium diet (Naber *et al.*, 1984) is equally effective as a feed restriction technique as a means in inducing molt. Mineral induced moulting at low levels presents opportunity as non feed withdrawal method for the industry.

However, in recent years, induced molting by feed withdrawal has become more of a concern to poultry industry due to welfare and food safety reasons (Bell, 2003). Feed withdrawal results in severe stress,

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lowered immunity and increased mortality rate in hens. Mortality rate is greater during the molting period when the hens are deprived of feed. The initiative taken by the United Egg Producers (UEP) to encourage U.S. egg producers to cease molting flocks by feed withdrawal has led to the development of practical non-feed withdrawal molting programmes which allow hens to eat maintenance diet during molting period when egg production must be stopped. Non feed withdrawal molting techniques seems to be safer, animal friendly and will be the methods of choice in future.

MATERIALS AND METHODS

This research was conducted at Poultry Research Center, University of Agriculture, Faisalabad. Three hundred twenty four Single Comb White Leghorn (Babcock) commercial layers (60 weeks of age) were randomly selected from the flock and were divided into 27 replicates of 12 layers each. Each treatment comprised of three replicates consisting of 36 hens in each treatment. Two hens per partition with dimensions of 16//x16//x16// were kept in single tier batteries. Hens were molted by feed deprivation, fortified ground corn, zinc oxide, aluminum oxide, moderate zinc and low calcium, copper sulphate, progesterone, thyroxin and untreated served as control. These treatments were designated as T1, T2, T3, T4, T5, T6, T7, T8 and T9 (control) as shown in Table 2. Hens in all treatment groups were subjected to respective treatments for duration of 14 days and were offered maintenance diet (35 g/bird) except T1 (no feed) and T9 (full feed). After two weeks, hens in all treatment groups were given feed @ 45 g /bird for the next five weeks and then were maintained on 110 g feed /hen for the entire postmolt production period Describe why daily feed changed from 35 to 45 and 110g & why 5 weeks and not more or less?. Daily feed was changed from 35 to 45 g/bird to build body reserves and normally the hens are offered feed @110 g/bird as per layer guide books. The reproductive system of hen rejuvenates effectively in 5 weeks duration, the period less than five weeks can be reduced to 4 weeks but beyond 5 weeks it is uneconomical. Water was supplied throughout the experimental period feed was offered in mash form. Temperature ranged from 9.54 to 31.14 ^{o}C (dry bulb reading) while relative humidity values ranged from 71.07 to 82.29. At the start of molting, photoperiod was reduced to 12 hours (week 61 to 66), increased to 14 hours thereafter (week 67) and finally 16 hours (week 68) for all treatments (weeks 68-96) as given in Table 1. Cleaning, watering, feeding, egg collection, mortality if any, was done on daily basis and moult scoring was executed on weekly basis. The total duration of the experiment was 37 weeks.

Feather molt scoring:

Primary, secondary and overall body feather scoring was done weekly for 8 consecutive weeks (commencing from start of molt). Three hens from the same cages were sampled from each treatment and were scored on weekly basis. The procedure used for feather scoring is as under;

a) Primary feather score (PFS).

Primary feather score was obtained by summing up the individual score (1-10) for the innermost 10 primaries of the left wing. If an obvious asymmetry was encountered, the score for the two wings was averaged. Each of the 10 primaries was assigned one of the following score:

0	2	3	4-9	10
Old	dropped new	pin stage	brush stage	growing

To calculate PMS, values from ten primaries were summed up. In this way PMS was calculated for three birds from each experimental unit and then averaged.

b) Secondary feather score (SFS).

SFS was obtained by summing up the individual score for the innermost 15 secondaries of both the wings. Each of the 15 secondaries was assigned one of the following values:

0	1	2	3	4-9	10
Old	dropped new	pin stage	brush stage		growing

SFS was calculated by summing up the score of 15 secondaries for each bird. SFS was calculated for three birds per experimental unit.

c) Overall body feather score (BFS).

BFS was determined by scoring 6 of the feather tracts, the cervical, pectoral, abdominal, femoral, dorsal and alar. From each feather tract, 10 feathers were counted and the growth pattern was noted at weekly intervals, for eight successive weeks. The intensity of molt was judged by scoring the fraction of feathers in each tract involved in molt as follows:

0	1	2	3-4	5
Old	pin stage	brush stage	growing	full grown

For the calculation of BFS scores given to each of ten feathers in each body tract was summed and divided by total number of body tract, as follows:

$$BPS = \frac{\Sigma X_{ij}}{X_i}$$

Where,

X_{ij} is the score given to ith feather (1,2... 10) and jth body tract

$_j$= is the j[th] body tract (l,2...6).
6 feather tracts i.e., cervical, pectoral, abdominal, femoral, dorsal and alar were scored weekly and ten feathers of the respective feather tract were scored.

Egg Production:
Egg production data of all the treatments was taken on daily basis through out the experiment. The data for 28 post-moult weeks were taken on the computerized sheets and were analyzed for seven periods of 4 weeks duration.

Statistical Analysis
The experimental design was Completely Randomized Design. Analysis of variance technique was carried out and means were compared by Least Significant Difference Test as described by Snedecor and Cochran, 1991.

RESULTS AND DISCUSSION

Egg production
During premolt period hens produced 70.46 % eggs on hen day egg production basis. In all treatment groups egg production ceased during molting period (except T9). Egg production resumed after feed allocation was increased to 110 g feed/hen/day. Induced molting showed significant ($P<0.05$) effect on egg production of caged as shown in Table 3. Maximum number of eggs produced by treatment T6 (76.06±2.94 %) in postmolt period followed by T4 (74.44±3.63 %), T1 (74.08±4.25 %) and T8 (73.82±3.94 %). However, minimum egg production was observed in T9 (64.35±1.03). Findings of this study revealed that hens induced to molt produced more number of eggs as compared to non molted birds in the post molt period. Similarly, scientists have reported increased egg production in the post molt period (Naber *et al.,* 1984; Hussein *et al.,* 1988; Breeding *et al.,* 1992a; Hussein, 1996; Koelkebeck *et al.,* 2001; Ricke *et al.,* 2001; Bell, 2003; El-Deek and Al-Harthi, 2004; Oguike *et al.,* 2004; Yousaf, 2004; Khoshoei and Khajali, 2006; Yousaf and Ahmad, 2006; Koelkebeck and Anderson, 2007). Hens in T6 proved best in this research study in comparison to feed deprivation/withdrawal method. The results are same to the findings of Yousaf (1998 who reported better egg production in copper sulphate supplemented hens as compared to feed deprivation. It is evident from this study that non feed removal induced molting (supplemented with minerals) is an effective alternative for future molting of poultry birds.

Feather Scoring
The effect of various molting methods on PFS, SFS and BFS is shown in Table 4, 5 and 6, respectively. The treatment groups T1, T2, T3, T4, T5, T6, T7, T8 and T9 showed significant differences in PMS values while T1 and T7 were non significant among themselves. Hens in treatment T1 (15.26±5.12) and T7 (14.96±4.46) exhibited maximum PFS values while minimum PFS was noted in T9 (0.29±0.12). Weekly data (at 68[th] week) exhibited maximum mean values of PFS in T1 (38.49) and T7 (31.39), respectively, however, minimum PFS was observed in T9 (0.82). Maximum mean values of SFS were noted in T1 (14.43±2.98) and T7 (7.20±1.91), respectively, however, minimum SFS was observed in T9 (0.00). Hens in treatment T1 (26.66) showed maximum SFS values (at 68[th] week) followed by T6 (14.36) while minimum SFS was noted in T9 (0.00±0.00). Higher values of both primary and secondary feather scoring in T1 and T7 might be due to earlier feather endogenous stimulation in which new feather generation induced the loss of the previous generation being confirmed by Watson (1963) and Herremans (1986).

Hens in T8 exhibited maximum (32.28±5.30) BFS mean value followed by T2 (30.52±5.54) while minimum BFS was noted in T9 (0.85±0.32). Weekly data exhibited maximum values of BFS (at 68[th] week) in T8 (48.70) followed by T2 (48.07), respectively, however, minimum BFS was observed in T9 (3.23). Highest values of BFS might be due to thyroxin levels which activated the feather papillae and the formation of an underlying new feather and ultimately expelled its predecessor. As induced molting is accompanied by increased in T_4 and the mechanism of this feather replacement could be expressed as the ovary became resulting in decreased release of oestrogen which discontinued the existing suppressed activation of feather papillae as confirmed by Verheyen *et al.* (1983). Thyroxin / progesterone activated the feather papillae in the formation of an underlying new feather that ultimately expelled its predecessor. On overall basis, at the age of 68[th] week PMS, SFS and BFS values were 30.3, 10.9 and 36. respectively which showed that maximum feather replacement took place in BFS followed by PMS and minimum feather replacement was noticed in SFS at the end of 68[th] week. Weekly data regarding primary, secondry and body moult scoring exhibited significant differences as shown in tables 4, 5 and 6. Hens exhibited higher primary and body moult scoring was as compared to secondry moult scoring during the moulting period.

In the present study, hens started feather shedding during the first week. The findings of present study are not inline to the findings of Rose (1997) who reported that feather shedding started 15 days from the beginning of molting. The shedding of feathers was more in T1 because due to feed removal, oviduct regression started rapidly due to which hormonal profile of the hens changed accordingly resulting in initiation of feather as confirmed by Himeno and Tanabe (1957) and Odensi *et al.* (2002).

The findings of this study are in line to the findings of Stevenson and Jackson (1984) who stated that copper was superior to the traditional forced molting technique. The layers induced to molt by minerals supplementation showed lower feather scoring than T1 but produced higher number of eggs. The probable reason might be that hens in non feed withdrawal (NFW) treatments produced more eggs during the molting period when the feed withdrawal treatment hens ceased egg production earlier. Additionally, hens in NFW treatments reduced less weight, were exposed to less stressful conditions, therefore, resulting in higher egg production. The findings of the present are contrary to the observations of Krueger *et al.,* (1977); Herremans (1986); (Oguike *et al.,* 2004) who reported that the performance of the molted birds was directly related to the growth of the feathers. The probable reason for lower feather scoring and higher production might be that birds in NFW treatments replaced their feathering moderately, efficiently utilized body fat reserves and a sequential regression of reproductive organs as compared to T1 in which the hens were subjected to severe stressful conditions, rapid feathering, immediate body reserves utilization and rapid regression of the reproductive organs.

CONCLUSIONS AND RECOMMENDATIONS

The present study revealed that hens with lower values for feather scoring performed better as regards egg production as compared to hens having more feather scoring. It is therefore, recommended that induced molting can be effectively practiced with better egg production by non feed removal molting methods especially by mineral supplementation either copper sulphate or aluminium oxide at prescribed levels.

Table I ***Induced molting schedule***

Age (Weeks)	Stage	Medication/ Vaccination	Feed (g/bird/d)	Water	Light
60	Premolt	Deworming, Antibiotic Course, IB+ND Vaccine	Ad lib	Ad lib	16 h
61-62	Molt	-	35 except T1 and T9	Ad lib	12 h
63-66	Rest Period	ND Live Vaccine	45	Ad lib	12 h
67	Rest Period	-	45	Ad lib	14 h
68-96	Production	NDV Lasota each month	110	Ad lib	16 h

Table II ***Induced molt treatments***

No.	Treatments	Particulars format?
T1	Feed Deprivation	None
T2	Fortified Ground Corn	Ground Corn with 1 % Ca
T3	Zn Oxide	5 g/kg of feed
T4	Aluminum Oxide	4 g/kg of feed
T5	Moderate Zinc and low Calcium	3.75 g $ZnSO_4$ & 1 g Ca/kg of feed
T6	Copper Sulphate Is it S or Cu effect? Combine	3.5 g/kg of feed
T7	Progesterone	30 mg/bird (intra muscular)
T8	Thyroxin	35 mg bird (feed)
T9	Control	Untreated

The feed composition is as under

Composition of commercial feed fed during moulting and post moult period	
Energy	2720 K cal/kg
Crude Protein	16.5 %
Fat	3.76 %
Fibre	4.39 %
Linoleic acid	1.23 %
Calcium	3.65 %
Phosphorous	0.4 %
Sodium	0.14 %
Lysine	0.82 %
Methionine	0.38 %
Threonine	0.67 %

Available Lysine: 0.67 %
Available Methionine: 0.35 %
Available Threonine: 0.44 %
Avaialable Tryptophan: 0.13 %

Table III ***Effect of induced molt methods on egg production (percent) during second production cycle***

Treatments	Mean
Feed Deprivation	74.08 ± 4.25^{b}
Fortified Ground Corn	72.96±2.68^{c}
Zn Oxide	74.17±3.34^{b}
Aluminum Oxide	74.44±3.63^{b}
Moderate Zn & low Ca	71.31±2.26^{c}
Copper Sulphate	76.06±2.94^{a}
Progesterone	72.92±3.13^{c}
Thyroxin	73.82±3.94^{bc}
Control	64.35±1.03^{d}

Means with different letters differ significantly (P≤0.05)

Table IV ***Effect of induced molt methods on primary feather score of layers kept in cage system.***

Treatments	Weeks								Mean
	61	62	63	64	65	66	67	68	
Feed Deprivation	5.42	6.89	13.05	23.58	31.48	45.86	52.01	60.65	29.86±7.49^{A}
Fortified Ground Corn	2.38	6.11	8.41	11.82	16.92	18.33	21.91	28.39	14.28±3.07^{CD}
Zn Oxide	1.94	2.57	10.32	12.06	14.29	17.49	22.28	24.14	13.14±2.90^{D}
Aluminum Oxide	0.00	0.00	8.88	11.07	14.49	19.51	23.84	25.53	12.91±3.48^{E}
Moderate Zn & low Ca	0.00	0.00	1.67	3.34	7.59	11.33	21.58	27.17	9.08±3.64^{H}
Copper Sulphate	0.74	4.17	9.66	12.03	16.12	19.83	23.09	27.44	14.14±3.26^{C}
Progesterone	0.00	7.55	15.39	19.26	26.85	29.88	48.61	53.40	25.12±6.61^{B}
Thyroxin	0.00	1.50	4.27	7.47	15.82	21.52	23.89	25.27	12.47±3.67^{E}
Control	0.00	0.00	0.00	0.00	0.54	0.67	1.07	1.11	0.42±0.17^{F}
Mean	1.2^{h}	3.2^{g}	7.9^{f}	10.7^{e}	16.0^{d}	20.5^{c}	26.5^{b}	30.3^{a}	

Means with different letters differ significantly (P≤0.05)

Table V ***Effect of induced molt methods on secondary feather score of layers kept in cage system.***

Treatments	Weeks								Mean
	61	62	63	64	65	66	67	68	
Feed Deprivation	0.00	8.19	10.94	12.60	15.79	18.77	22.51	26.66	14.43 ± 2.98^{A}
Fortified Ground Corn	0.00	0.00	0.00	1.33	2.22	2.91	3.15	8.61	2.27 ± 1.01^{CD}
Zn Oxide	0.00	0.00	0.00	0.22	4.35	6.89	8.17	12.47	4.78 ± 1.69^{C}
Aluminum Oxide	0.00	0.00	0.15	0.42	2.18	3.81	5.55	9.43	2.69 ± 1.21^{CD}
Moderate Zn & low Ca	0.00	0.00	0.00	0.49	1.37	2.27	4.50	6.70	1.91 ± 0.8^{8CD}
Copper Sulphate	0.00	0.00	0.00	1.39	4.46	8.19	12.03	14.36	5.05 ± 2.05^{BC}
Progesterone	0.00	2.20	2.98	4.98	9.20	10.32	13.71	14.24	7.20 ± 1.91^{B}
Thyroxin	0.00	0.00	0.00	1.00	1.91	3.10	4.70	6.29	2.12 ± 0.84^{CD}
Control	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00 ± 0.00^{E}
Mean	0.00^{d}	1.15^{d}	1.56^{d}	2.49^{cd}	4.61^{c}	6.25^{b}	8.26^{b}	10.9^{a}	

Means with different letters differ significantly ($P\leq0.05$)

Table VI ***Effect of induced molt methods on overall body feather score of layers kept in cage system.***

	Weeks								Mean over trial
	61	62	63	64	65	66	67	68	
Feed Deprivation	12.73	13.21	22.40	26.20	31.89	37.42	40.18	43.98	28.50 ± 4.21^{AB}
Fortified Ground Corn	4.36	14.13	22.22	31.10	37.21	41.74	45.37	48.07	30.52 ± 5.54^{B}
Zn Oxide	7.25	9.61	12.06	15.36	20.70	23.54	27.59	32.46	18.57 ± 3.17^{E}
Aluminum Oxide	9.94	11.65	14.97	23.55	28.34	33.23	35.40	39.48	24.57 ± 4.02^{D}
Moderate Zn & low Ca	7.32	10.17	13.35	16.08	20.57	23.15	25.42	30.39	18.30 ± 2.81^{EF}
Copper Sulphate	11.31	16.50	21.84	24.42	25.73	28.76	31.53	35.54	24.45 ± 2.79^{DE}
Progesterone	7.37	13.64	20.73	25.36	30.49	36.82	42.58	46.10	27.88 ± 4.85^{C}
Thyroxin	4.20	18.37	28.75	32.14	38.63	41.72	45.73	48.70	32.28 ± 5.30^{A}
Control	0.00	0.00	0.00	0.00	2.86	2.96	3.03	3.23	1.51 ± 0.57^{F}
Mean	7.16^{g}	11.9^{f}	17.3^{e}	21.5^{d}	26.2^{c}	29.9^{bc}	32.9^{b}	36.4^{a}	

Means with different letters differ significantly ($P\leq0.05$)

REFERENCES

Bell, D.D. 2003. Historical and current molting practices in the U.S. table egg industry. Poult. Sci. 82: 965-970.

Berry, W.D. 2003. The physiology of induced molting. Poult. Sci. 82:971-980.

Biggs, P.E., M.W. Douglas, K.W. Koelkebeck and C.M. Parsons. 2003. Evaluation of non feed removal methods for molting programs. Poult. Sci. 82: 749-753.

Biggs, P.E., M.E. Persia, K.W. Koelkebeck and C.M. Parsons. 2004. Further evaluation of non feed removal methods for molting programs. Poult. Sci. 83: 745-752.

Breeding, S.W., J. Brake and J.D. Garlich. 1992a. Molt induced by dietary zinc in a low calcium diet. Poult. Sci. 71: 168-180.

EL-Deek, A.A. and M.A. AL-Harthi. 2004. Postmolt performance of broiler breeder hens associated with molt induced by feed restriction, high dietary zinc and fasting. Int'l. J. Poult. Sci. 3(7): 456-462.

Herremans, M. 1986. A new method of recording molting in the fowl. Brit. Poult. Sci. 27: 177-194.

Herremans, M. 1988. Age and strain differences in plumage renewal during natural and induced molting in hybrid hens. Brit. Poult. Sci. 29: 825-835.

Hussein, A.S. 1996. Induced molting procedures in laying fowl. World's Poult. Sci. J. 52: 175-187.

Hussein, A.S., A.H. Cantor and T.H. Johnson 1988. Use of high dietary levels of aluminium and zinc for inducing pauses in egg production of Japanese quails. Poult. Sci. 67: 1157-1165.

Hussein, A.S. and N.J. Daghir. 1996. Effect of two force molting procedures on egg production and eggshell quality of laying hens. Department of Animal Production. United Arab Emirates University P.O. Box 17555. Al-An. U.A.E.

Khoshoei E.A. and F. Khajali. 2006. Alternative induced-molting methods for continuous feed withdrawal and their influence on postmolt performance of laying hens. Int'l. J. Poult. Sci. 3(7): 47-50.

Koelkebeck, K.W., C.M. Parsons, M.W. Douglas, R.W. Leeper, S. Jin, S. Wang, Y. Zhang and S. Fernandez. 2001. Early postmolt performance of laying hens fed a low-protein corn molt diet supplemented with spent hen meal. Poult. Sci. 80: 353-357.

Koelkebeck, K.W. and K.E. Anderson. 2007. Molting layers-alternative methods and their effectiveness. Poult. Sci. 86: 1260-1264.

Krueger, K.K., T.M. Ferguson, J.A. Owen and C.E. Krueger. 1977. The influence of feather loss on subsequent egg production in force molted Turkey hens (SAAS Abst.). Poult. Sci. 56: 1351.

Leeson, S. and W.D. Morrison. 1978. Effect of feather cover on feed efficiency in laying birds. Poult. Sci. 57: 1094-1096.

Naber, E.C., J.D. Latshaw and G.A. Marsh. 1984. Effectiveness of low sodium diets for recycling of egg production type hens. Poult. Sci. 63: 2419-2429.

Oguike, M.A., G. Igboeli, S.N. Ibe and M. Uzoukwu. 2004. Effect of day length and feed/water regime on induction of feather molt and subsequent laying performance in the domestic fowl. Int'l. J. of Poult. Sci. 3(8): 507-512.

Odunsi, A.A., G.O. Farino and V.A. Togun. 2002. Diet manipulation and post-molting responses in caged laying hens. Nigerian J. Anim. Prod. 29: 11-15.

Rice, J.E. 1905. In The Feeding of Poultry, The Poultry Book. W.D. Johnson and G.O. Brown, ed. Doubleday, New York.

Rice, J.E., C. Nixon and C.A. Rogers. 1908. The molting of fowls. Bull. No. 258. Cornell Univ., Ithaca, NY.

Ricke, S.C., Y.M. Kwon, C.L. Woodward, J.A. Byrd, D.J. Nisbet and L.F. Kubena. 2001. Limitation of Salmonella enteritidis colonization by diets containing low calcium and low zinc. Poult. Sci. 80 (suppl. 1): 262 (abstract).

Rose, S.P. 1997. Principles of Poultry Science. CAB. International. Wallingford. UK.

Snedecor, G.W. and W.G. Cochran. 1991. Statistical Methods (8th Ed.) Iowa State Univ. Press /AMES.

Stevenson, M.H. and N. Jackson. 1984. Comparison of dietary hydrated copper sulphate, dietary zinc oxide and a direct method for inducing a molt in laying hens. Brit. Poult. Sci. 25: 505-517.

Tauson, K. and S.A. Svensson. 1980. Influence of plumage condition on the hen's feed requirement. Swed. J. of Agric. Res. 10: 35-39.

Verheyen, G., E. Decuypere, E.R. Kuhn, G. Fontaine and G.DE. Groote 1983a. Moult induction in the hen. Effect of different methods on some performance traits and on thyroid hormone, prolactin. Ca, P, Na, and protein concentrations in blood serum. Reeub de I, Agric. 36: 1535-1559.

Watson, G.E. 1963. The mechanism of feather replacement during natural molt. Auckland. 80: 486-495.

Yousaf, M. 2002. The impact of mineral supplementation and feed deprivation on plumage renewal of commercial layers kept on litter floor system. 33rd All Pak. Sci. Conf. 25th to 28th December, 2002 at Univ. Agric., Faisalabad. pp.16.

Yousaf, M. 2004. Influence of different copper and aluminum levels on feather renewal and production characteristics of the layers in the second production cycle. Research project report submitted to Pakistan Science Foundation, Islamabad, Pakistan.

Yousaf, M. and N. Ahmad, 2006. Influence of different copper and aluminum levels on organ weights, feather renewal and production performance of molted layers. Pak. J. Arid Agric. 9 (1): 35-39.

Yousaf, M. 2006. Induced molting: Tips for success. Poultry International p: 36-40.

Yousaf, M. 2005. Secrets of Feather Development. World Poult. 21(3):36-38.

Yousaf, M. 1998. Comparative study of induced molt methods in relation to plumage renewal and productive performance of layers under cage and litter floor systems. Ph.D. thesis, Deptt. Poult. Sci., Univ. Agric., Faisalabad, Pakistan.