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Original article

EFFECTS OF DIFFERENT FORCE MOULTING METHODS ON PERFORMANCE, EGG QUALITY AND PLASMA METABOLITES IN JAPANESE QUAILS

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Summary

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This study investigated the effects of various force moulting methods on egg physical and mechanical characteristics, plasma metabolites and performance of Japanese quails from 26 to 36 weeks of age. The treatments were: T1 (control), T2 (feed restriction), T3 (alfalfa powder), T4 (wheat screening powder, a by-product obtained after harvesting and processing of wheat). Egg production ceased completely with feed restriction and alfalfa treatments by days 4 and 3. Also, birds under feed restriction and alfalfa treatments returned to first egg at day 4 of post-moulting period. No significant differences were found in feed intake, egg mass, egg production, feed conversion ratio (FCR), and mortality of quails in response to experimental treatments after moulting ($P>0.05$). Feed restriction led to significantly higher egg weight in comparison to control and wheat screening treatments ($P<0.01$). No significant effect on egg quality was found by forced-moulting methods ($P>0.05$). The calcium concentration was higher ($P<0.001$) in control birds than in others at the end of moulting. It can be concluded that using alfalfa and to a lesser extent feed restriction may be suitable force-moulting methods in quails.

Key words: egg quality, forced moulting, mechanical properties, performance, quail

INTRODUCTION

At the end of the laying cycle, egg production and quality decline significantly, making some producers to induce a moult in the flocks in an attempt to improve performance. Induced moulting rejuvenates laying hens for a second or third cycle of production, resulting in higher egg production, heavier egg weight, and improvements in egg quality parameters, such as albumen height, shell thickness, and specific gravity (Alodan & Mashaly, 1999; Bell, 2003).

According to Llobet *et al.* (1989), moulting methods can be divided into three groups: pharmacological methods, methods of management and nutritional methods. Pharmacological methods consist in supplementing rations with certain drugs such as nitrothiazole, progesterone; however, these methods are not implemented due to the difficulty of use and the possibility of residual effects of these substances on human health.

Management methods are based on inducing various stressful situations so that the egg production ceases quickly. Usually there is a reduction of the photoperiod with the withdrawal of artificial lighting, feed restriction for a period and sometimes withdrawal of water for a period of up to three days (which is avoided widely due to the fact that birds excrete their metabolites with the urine and the lack of water may cause poisoning) (Bell, 2003).

Feed restriction has been widely used in recent years due to its easy application, economic benefits and acceptable post-moult performance (Bell, 2003). However, due to increasing animal welfare concerns regarding the use of feed restriction, other approaches that use some sort of dietary manipulation for inducing a moult have become attractive alternatives to the egg production industry (Berry, 2003; Park *et al.,* 2004). Moreover, birds undergoing fasting appeared to be more susceptible to troublesome environmental conditions such as diseases (Holt, 2003).

The nutritional methods modify the dietary concentration of certain ions that influence egg production, such as calcium, phosphorus, sodium, potassium, iodine and zinc. These methods can be used separately or together, however with varying efficacy. They have gained special attention for avoiding the purchase of ingredients making and because they are easy to use (Llobet *et al.*, 1989). Other nutritional methods of inducing moulting consist in using alternative ingredients in the diet. Among them we may mention rations of corn or high-energy, low-energy ration, ration of low nutrient density, sorghum, wheat bran, defatted jojoba meal, alfalfa, cotton, rice hulls, brewers rice and rice bran.

Using fibre sources such as alfalfa powder (*ad libitum* access to water and feed) as a better alternative than feed restriction has been evaluated in some studies (Landers *et al.*, 2005a). Moulted hens induced by alfalfa diets exhibited post-moult levels of egg production over a twelve week period which were similar to that of hens moulted by feed withdrawal (Landers *et al.*, 2005a).

All moulting programmes necessitate body weight loss and cessation of egg production (Shippee *et al.*, 1979). Forced moulting of Japanese quails was also studied by Faitarone *et al.* (2008), who found that although the 3-day fasting followed by *ad libitum* feeding resulted in lower egg weight, it promoted better lay percentage, egg mass, and feed conversion ratio.

The mechanical properties of biological materials indicate their strength under different loads regarding some parameters such as rupture force, deformation and toughness (Vursavuş & Özgüven, 2004; Altuntas & Yildiz, 2007). Despite the importance, there is few information related to the mechanical behaviour of quail egg. Large amounts of cracked or broken eggshells at the end of laying period result in a loss in profits for the producer and can affect consumer safety, as eggshells are a barrier to microorganisms, such as *Salmonella* (Donalson *et al.*, 2005). Also, Donalson *et al.* (2005) reported that using alfalfa in moulting diet resulted in higher Haugh units and lower shell breakage compared with control. Some studies have indicated that moulting affected blood parameters such as glucose, calcium and some hormones (Webster, 2003; Dunkley *et al.*, 2007). The purpose of this study was therefore to investigate the effects of various forced-moulting methods on egg physical and mechanical behaviour, plasma indices and performance in Japanese quails.

MATERIALS AND METHODS

Birds and treatments

A total of 160 Japanese quails, 26 weeks of age with the average weight 255.5±6.4 g were used in the present study. Birds were distributed in a completely randomised experimental design into four treatments, with four replicates and 10 birds each. During the experimental period, room temperature was 21 to 23 ^{o}C, relative humidity: 60 to 70%, light regimen: 16 h of light and 8 h of darkness. Each cage compartment (100×80×60 cm) was equipped with a nipple drinker and a trough feeder.

The following treatments were applied to induce moulting: T1 (control, forced moulting was not induced), T2 (feed restriction, birds received 15 g control feed/bird/day for 14 days), T3 (alfalfa powder, birds received *ad libitum* alfalfa powder supplemented with vitamin (0.25%) and mineral premix (0.25%) 4 days and received 10 g control diet/bird/day for 10 days), T4 (wheat screening powder, birds received *ad libitum* screening powder supplemented with vitamin (0.25%) and mineral premix (0.25%) for 14 days.

Wheat screening is a by-product obtained after harvesting and processing of wheat in flour factories, macaroni factories and plant breeding centre and is about 8–12% of annual wheat production in Iran (Golian & Parsaie, 1996; Rajabzadeh, 2001). Wheat screening powder was obtained from a screening factory of Hamadan, Iran.

The control diet (Table 1) was formulated according to recommendations of NRC (1994). Before starting moulting period, all birds received the same diet during one week for adaptation. Moulting period lasted 2 weeks from the 26th to 28th week of age and post-moulting period – from 28th to 36th week of age. After the moulting period, birds were fed control diet until the end of study.

Performance traits

Body weight of the birds was measured at 5, 10 and 14 days of moulting. A lighting programme of 17 hours light was applied and water and feed were offered *ad libitum* during the post moulting period. At the end of moulting period, one bird of each replicate (4/treatment) was randomly selected, and the relative weights (% of body weight) of ovary, oviduct, proventriculus, small intestine, liver, and gizzard were evaluated. The first week of production after moulting was a period of adaptation and data at that time were not considered. After adaptation, egg production and egg weight were recorded daily and feed intake was recorded weekly. Body weights of the birds were measured weekly during the post-moulting period. This information was used to calculate average daily feed intake, egg production, egg mass, and FCR. Egg mass was calculated by multiplying percentage egg production by egg weight for each replicate. The days to cease egg production, days to first egg, and days to 50% egg production were recorded.

Egg quality

Egg quality was measured in 6 eggs per replicate produced the last day of each week, and the average value for each period was used for further analysis. The eggs were individually weighed and the

Table 1. Control diet formulation and composition (%)

Ingredients	Amount
Corn	52.00
Soybean meal	24.85
Wheat screening	15.00
Soybean oil	0.24
Oyster shell	6.34
Dicalcium phosphate	0.59
Sodium chloride	0.28
Vitamin premix[1]	0.25
Mineral premix[2]	0.25
l-Lysine HCl	0.10
dl-Methionine	0.10
Total	100.00
Calculated analysis	
Metabolisable energy (kcal/kg)	2700
Crude protein	18.6
Crude fibre	4.73
Lysine	1.06
Methionine	0.55
Methionine + cysteine	0.67
Sodium	0.16
Calcium	2.40
Available phosphorus	0.36
Threonine	0.69
Determined analysis	
Dry matter	93.70
Crude protein	18.57
Crude fiber	4.68
Ether extract	3.52
Ash	11.90

[1]Supplies per kg diet: 7200000 IU vitamin A; 700000 IU vitamin D_3; 14400 mg vitamin E; 1600 mg vitamin K_3; 720 mg vitamin B_1; 3300 mg vitamin B_2; 12160 mg niacin; 12000 mg Ca-D-pantothenate; 6200 mg vitamin B_6; 600 mg vitamin B_{12}; 400 mg folic acid; 200 mg D-biotin; 20000 mg vitamin C; 50000 mg choline chloride. [2]Supplies per kg diet: 64000 mg manganese; 100000 mg iron; 44000 mg zinc; 16000 mg copper; 200 mg cobalt; 640 mg iodine; 8000 mg selenium.

external and internal quality was determined. The shell was separated from the yolk and albumen and weighed after drying overnight at 60 ^{o}C as indicated by Grobas *et al.* (2001). Shell thickness was measured using a digital micrometer (Echometer 1061, Robotmation Company, Tokyo, Japan), and albumen height was determined with an electronic height gauge (Futura Company, Lohne, Germany). Haugh units were calculated from egg weight and albumen height as indicated by Haugh (1937).

Mechanical properties of egg were measured by a quasi-static compression test and the eggs were compressed via a food texture analyzer (Z wick/Roll Model BT1_FR0.5TH.D14, using X force HP model of load cell with capacity of 500 N, by 2 mV/V characteristics, Germany) and the data were processed by the software test Xpert II. The eggs were compressed until rupture occurred as denoted by a rupture in force-deformation curve. Compression speed was set at 8 mm/min and the test was finished after 30% force shutdown. The eggs were positioned horizontally, with the major axis of the egg perpendicular to the direction of loading. Elasticity modulus, maximum force which egg can support and toughness (area under the force/deformation curve) which performed to this force have been determined. The value of elasticity modulus for each of the specimens was determined based on the tangent of the inclination angle of a straight line.

Plasma metabolites

At the end of moulting (28 weeks of age) and 8 weeks after moulting (36 weeks of age), one bird of each replicate (4/treatment) was randomly selected and bled from the brachial vein using sodium citrate as anti-clotting agent before feed distribution. Blood samples were immediately centrifuged at 2,000×g for 15 min, and plasma samples were stored at −20 °C until further analysis. Glucose, albumin, calcium, phosphorus and alkaline phosphatase have been tested by commercial kits (Pars Azmun., Co. Iran).

Statistical analysis

The experiment was conducted as a completely randomised design with 4 treatments and data were analysed by ANOVA using the GLM procedure of SAS Institute (SAS, 2004). For productive performance traits, age was included in the model as a third factor. When significant interactions between treatment and age were observed, means were compared by the Duncan multiple range test. All differences were considered significant at $P \leq 0.05$.

RESULTS

Performance traits

Table 2 shows the influence of different treatments on days until egg production ceased, days to first egg, and days to 50% of egg production. Egg production has

Table 2. Effect of force moulting treatments on period of time (days) to cease egg production, laying first egg post moult and return to 50% egg production in Japanese quails (mean ± SEM, n=4)

Parameters	Group T1 (control)	Force moulting methods		
		Group T2 (feed restriction)	Group T3 (alfalfa powder)	Group T4 (wheat screening powder)
First day out of production	*	$4.00^a \pm 0.81$	$3.00^b \pm 0.00$	*
Days to first egg post moult	–	4.00 ± 0.57	4.00 ± 0.81	–
Days to return to 50% egg production	–	$9.50^b \pm 1.29$	$11.25^a \pm 0.50$	$4.25^c \pm 0.95$

* Egg production has not ceased. Days to first egg post moult for T1 and T4 and reach days to return to 50% egg production for T1 were not considered; $^{a-c}$ means without a common superscript within a row differ ($P<0.05$).

Table 3. Effects of force moulting treatments on quails weight loss (%) during and after the moulting period (mean ± SEM, n=4)

Parameters	Group T1 (control)	Force moulting methods		
		Group T2 (feed restriction)	Group T3 (alfalfa powder)	Group T4 (wheat screening powder)
Day 5 of moulting	$2.69^{d}\pm2.69$	$24.05^{b}\pm4.23$	$32.37^{a}\pm4.69$	$11.27^{c}\pm2.28$
Day 10 of moulting	$1.77^{c}\pm2.98$	$22.11^{a}\pm5.88$	$25.44^{a}\pm4.09$	$10.69^{b}\pm3.64$
End of moulting	$1.51^{c}\pm2.75$	$22.10^{a}\pm4.99$	$23.31^{a}\pm4.74$	$11.89^{b}\pm3.67$
1 week post moulting	0.95±2.16	5.33±2.19	4.33±4.32	1.60±4.23
2 weeks post moulting	0.01±1.43	1.06±1.65	1.11±4.01	1.58±3.97

$^{a–c}$ means without a common superscript within a row differ (P<0.05).

Table 4. Effects of force moulting treatments on relative weight of some organs of quails (g/100g body weight) (mean ± SEM, n=4)

Parameters	Group T1 (control)	Force moulting methods		
		Group T2 (feed restriction)	Group T3 (alfalfa powder)	Group T4 (wheat screening powder)
Ovary	$1.94^{a}\pm0.77$	$0.69^{b}\pm0.35$	$0.50^{b}\pm0.22$	$0.93^{b}\pm0.26$
Oviduct	$3.40^{a}\pm0.44$	$1.80^{b}\pm0.91$	$1.10^{b}\pm0.59$	$3.16^{a}\pm0.93$
Small intestine	$3.09^{b}\pm0.10$	$4.23^{a}\pm0.68$	$4.24^{a}\pm0.21$	$3.87^{a}\pm0.55$
Proventriculus	0.43±0.07	0.46±0.02	0.43±0.02	0.37±0.06
Liver	$3.33^{a}\pm0.18$	$2.58^{b}\pm0.41$	$2.51^{b}\pm0.51$	$2.81^{ab}\pm0.50$
Gizzard	$2.63^{b}\pm0.16$	$3.28^{a}\pm0.37$	$3.72^{a}\pm0.30$	$3.30^{a}\pm0.63$

^{a,b} means without a common superscript column a row differ (P<0.05).

ceased completely for feed restriction and alfalfa treatments by days 4 and 3, respectively, whereas birds fed control and wheat screening diets did not cease egg production. Also, birds on feed restriction and alfalfa treatments returned to first egg at post-moulting day 4. In addition, birds under feed restriction, alfalfa and wheat screening returned to 50% egg production at post-moulting 9.5, 11.25 and 4.25 days respectively.

Body weight loss of birds with induced forced-moulting (Table 3) was significantly higher than those for control group at days 5, 10 and the end of moulting (P<0.001). Weight loss was the highest for alfalfa treatment, the lowest for control treatment, and intermediate for feed restriction and wheat screening. No significant effect of treatments was observed on weight loss at post moulting weeks 1 and 2 (P > 0.05).

The relative weights of ovary and oviduct of force-moulted quails were lower than respective values in the control group (P<0.01) (Table 4) while the relative weights of gizzard and small intestine of forced-moulted quails were higher vs controls (P<0.05). The effect of different treatments on the relative weights of proventriculus was not significant (P>0.05). Control birds had significantly (P>0.01) higher liver weight when compared with feed restriction and alfalfa groups.

Table 5 demonstrated no significant differences in feed intake, egg mass, egg production, FCR, and mortality of quails in response to experimental treatments (P>0.05). Feed restriction led to significant higher egg weight in comparison to control and wheat screening treatments (P<0.01).

Egg weight, egg mass and egg production were affected by birds' age. Therefore, the effects of treatments on the mentioned traits are shown at post-moulting week 8 (Table 6). At that time egg weight, egg mass and egg production of control birds were lower than those of birds under feed restriction and alfalfa treatments (P<0.05). However, the differences between wheat screening and control groups were not significant (P>0.05).

Egg quality

No significant effect on shell percentage, shell thickness, yolk percentage, albumen percentage and Haugh unit of eggs produced after the moulting period were found in forced-moulted groups as shown in Table 6 (P>0.05). Force-moulting had neither an effect on the mechanical properties of eggs (Table 7). The average values of rupture force, toughness and Young's modulus have not been affected by treatments (P>0.05).

Plasma metabolites

The experimental treatments did not affect plasma concentrations of albumin, glu-

Table 5. Effects of force moulting treatments on laying quails performance (mean ± SEM, n=4)

Parameters	Group T1 (control)	Force moulting methods		
		Group T2 (feed restriction)	Group T3 (alfalfa powder)	Group T4 (wheat screening powder)
Feed intake (g/day)	35.41±2.17	36.93±1.73	36.47±2.03	35.70±2.20
Ehg weight (g)	11.27^{bc}±0.18	12.06^{a}±0.45	11.77^{ab}±0.63	11.17^{c}±0.36
Egg mass (g/day)	7.98±0.74	8.90±2.45	8.63±2.92	8.26±1.60
Egg production (%)	70.81±6.30	73.66±18.81	72.59±23.63	74.18±14.97
FCR* (g/g)	4.43±0.42	3.61±0.56	3.60±0.52	4.07±0.96
Mortality (%)	0.00±0.00	0.62±2.45	1.56±6.27	0.31±1.76

* Net feed conversion ratio was calculated as grammes of feed per gramme of egg mass plus gramme of weight gain or loss; $^{a-c}$ means without a common superscript within a row differ (P<0.05).

Table 6. The effects of treatments on egg weight, egg mass and egg production of laying quails at week 8 after moulting

Parameters	Group T1 (control)	Force moulting methods		
		Group T2 (feed restriction)	Group T3 (alfalfa powder)	Group T4 (wheat screening powder)
Egg production (%)	67.26^{b}±6.35	82.66^{a}±4.82	84.35^{a}±6.55	75.32^{ab}±7.36
Egg weight (g)	11.33^{b}±0.26	12.08^{a}±0.19	12.11^{a}±0.32	11.26^{b}±0.27
Egg mass (g/day)	7.63^{b}±0.84	9.98^{a}±0.55	10.22^{a}±0.9	8.46^{b}±0.7

$^{a-c}$ means without a common superscript within a row differ (P<0.05).

Table 7. Effects of force moulting treatments on egg quality during the post moulting period in laying quails (mean ± SEM, n=4)

Parameters	Group T1 (control)	Force moulting methods		
		Group T2 (feed restriction)	Group T3 (alfalfa powder)	Group T4 (wheat screening powder)
Shell (%)	8.79±0.77	8.57±0.71	8.40±0.58	8.70±0.72
Shell thickness (mm)	0.241±0.01	0.245±0.01	0.239±0.01	0.241±0.02
Yolk (%)	32.41±3.27	32.24±2.95	32.69±2.90	32.83±2.78
Albumen (%)	50.15±5.74	50.96±5.24	50.05±4.01	48.84±6.18
Haugh units	82.13±4.34	81.62±4.73	81.76±4.21	81.90±4.17
Rupture force (N)	10.80±1.75	11.67±1.81	11.28±2.21	11.34±2.20
Toughness (J)	0.0373±0.0212	0.0318±0.0148	0.0380±0.0181	0.0387±0.0142
Young modulus (N/m)	53741±2122	57728±1873	56329±2065	52370±1924

Table 8. Effects of force moulting treatments on blood plasma metabolites in laying quails at the end of moulting (A) and 8 weeks after moulting (B) (mean ± SEM, n=4)

Parameters		Group T1 (control)	Force moulting methods		
			Group T2 (feed restriction)	Group T3 (alfalfa powder)	Group T4 (wheat screening powder)
Albumin (g/L)	A	20.51±1.63	20.96±1.67	40.22±1.95	30.01±1.53
	B	20.83±1.51	20.65±1.70	20.59±1.82	20.54±1.72
Glucose (mmol/L)	A	9.4±1.51	12.22±1.9	7.99±1.05	9.66±2.2
	B	11.79±2.42	8.23±2.33	11.79±1.68	10.78±1.76
Calcium (mmol/L)	A	2.615^a±0.52	1.53^b±0.41	1.61^b±0.2	1.47^b±0.42
	B	2.88±0.53	2.63±0.42	2.88±0.52	2.80±0.55
Phosphorus (mmol/L)	A	1.95±0.35	1.70±0.31	2.50±0.41	1.86±0.41
	B	2.11±0.51	1.80±0.52	1.87±0.53	2.13±0.51
Alkaline phosphatase (U/L)	A	681.2±146	570.4±143	661.7±261	739.4±138
	B	669.5±145	674.7±149	673±121	616.7±213

^{a,b} means without a common superscript within a row differ (P<0.05).

cose, calcium, phosphorous, and alkaline phosphatase at the end of moulting and post-moulting periods except calcium concentration at the end of moulting (P<0.001) that was higher in control than in other groups (Table 8).

DISCUSSION

Generally, induced moulting is economic, particularly when factors such as the declining value of birds' carcasses and availability of fewer processors willing to process them as well as fluctuating egg prices and feed costs are considered (Mcdaniel & Aske, 2000). Biggs *et al.* (2003) have reported that hens fed the wheat middling's diet went completely out of production by the 8th day following initiation of feeding the moult diet. Landers *et al.* (2005b) have reported that hens fed alfalfa meal during moult return to production 14 days after induction. Results of current study were in accordance to the findings of North & Bell (1990) who reported that the sooner birds enter the rest period and cease production, the quicker they will return to production and reach their peak production, which occurs within a month of the moulting period. Body weight loss of birds subjected to induced force-moulting was significantly higher than those for control group at days 5, 10 and the end of moulting. In agreement to our results are those of Landers *et al.* (2005b) who reported a weight loss in forced-moulted compared with unmoulted birds. However, egg weight and egg mass did not increase by wheat screening powder compared to alfalfa powder by the 8th week, which could be related to the higher fibre content of alfalfa powder in comparison to wheat screening powder. Also, wheat screening powder and similar feedstuffs have more energy than alfalfa powder (Rajabzadeh, 2001; Islam *et al.*, 2009). Rijnen *et al.* (1999) have shown that high-fibre low-energy diets can effectively induce moult in a second laying cycle (Donalson *et al.*, 2005). So, it seems that more studies are needed on the use of wheat screening powder in force moulting of quails.

Compared to control, force-moulting treatments decreased the relative weights of ovary and oviduct and increased the relative weights of gizzard and small intestine of quails. Experimental treatments had no effect on the relative weights of proventriculus. In line with these results, Donalson *et al.* (2005) and Landers *et al.* (2005a) have reported that unmoulted control hens had higher ovarian weights than hens on moulted treatments. Brake (1993) has stated that the relative weights of ovary decreased simultaneously with body mass loss due to the regression of the ovaries, directly associated with the rejuvenation process.

In agreement with the results of Donalson *et al.* (2005), control birds had significantly higher liver weights when compared with feed restriction and alfalfa treatments. The loss of liver weight implies a decrease of liver energy sources, such as glycogen and lipids, which are metabolised in the liver (Berry & Brake, 1985). Liver weight loss is also indicative of the loss of oestrogen-dependent egg component synthesis, which is related to stimulation from ovarian steroids. The most common ovarian steroids are the oestrogens whose target organ is the liver, where occurs yolk phospholipoprotein synthesis that is dependent primarily on oestrogens (Berry & Brake, 1985).

Increased intestinal weights of birds fed diet containing dietary fibres was found by Amerah *et al.* (2009) that is in agreement with the increase in small intestine weight observed in birds fed alfalfa and wheat screening diets in the current study. Alfalfa and wheat screening treatments led to an increase in gizzard weights which in consistent with data of Jiménez-Moreno *et al.* (2009) about increase in gizzard weight of broilers fed diet supplemented with dietary fibres.

At the early weeks after moulting, the performance of force-moulted birds was lower than that of controls but by continuing moulting, the feed restriction and alfalfa treatments led to an increase in egg weight, egg mass and egg production than controls. These results are in agreement with the findings of Landers *et al.* (2005b) who stated that alfalfa could be used as a suitable ingredient to induce moult because of improving performance.

The strength of eggshells is critical to avoid cracking and breakage during their transport from farm to market and to preserve safely the embryo during hatching. In other words, the eggshell should be thin enough to exchange gas and weak enough to permit the chick to crack when hatching (Mcdaniel & Aske, 2000). The rupture force, toughness and Young's modulus were not affected by treatments. These mechanical parameters of eggs depended on various egg properties (egg specific gravity, egg mass, egg volume, egg surface area, egg thickness, shell weight, shell percentage (Narushin *et al.*, 2004). These results show that different force-moulting methods somewhat improved the resistance of quail's egg to rupture. Calcium concentration at the end of moulting was lower in forced-moulted birds than in controls. Dunkley *et al.* (2007) reported similar reductions of calcium in forced-moulted birds compared with control. Thus, it has been reported that maximising bone mineral deposition before onset of egg production and after moulting is vital to avoid bone weakness problems and improve eggshell qualities in older laying birds (Park *et al.*, 2004).

CONCLUSION

It can be concluded that using alfalfa and to lesser extent feed restriction may be suitable force-moulting methods in quails. However, after moulting, performance of moulted birds has not been improved by wheat screening. Although our purpose in the current study was simply to compare moulting effectiveness and early post-moult performance of force-moulted quails. Longer periods of postmoult egg production are advised to be examined in future studies to determine long-term effectiveness of used moulting methods.

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