The Effect of Disease, Nutrition and Management on Egg and Eggshell Quality in Laying Hens

J.R. Roberts, R. Chubb*, J. Nolan, S. Robinson**, W. Ball** and A. Leary**

Department of Physiology, University of New England, Armidale, NSW 235 1.

* Department of Biochemistry, Microbiology and Nutrition, University of New England, Armidale, NSW 235 1.

** Department of Animal Science, University of New England, Armidale, NSW 235 1.

Summary

Egg and eggshell quality were assessed under three different circumstances: challenge with infectious bronchitis virus (IBV) of complete-fed and choice-fed Isa Brown laying hens; the provision of calcium supplement in the form of either oyster shell or limestone chips and either choice-fed or included in a complete ration; a comparison of three different strains before, during and after an induced moult. The Isa Brown hens did not learn to choice-feed successfully. As a result, the choice-fed birds, which consumed protein concentrate in excess of feeding recommendations, laid heavier eggs with reduced eggshell quality and darker yolks. The eggshells of the complete-fed birds were darker and there was a significant transient decrease in the depth of the shell pigment in response to the IBV challenge. Calcium supplementation with ground oyster shell gave better eggshell quality than ground limestone and there were improvements in shell quality with higher levels of inclusion. There were strain differences in eggshell quality in the moult experiment. All strains showed a deterioration in eggshell quality as the birds were going out of production at the start of the induced moult. Eggshell quality improved following the moult, as evidenced by a significant increase in eggshell breaking strength.

Introduction

Many factors are known to affect egg and eggshell quality in laying hens: genetics, nutrition, environment (temperature, lighting, water availability), housing, management practices, disease, and dietary contaminants. Disease, nutrition and management (induced moulting) are considered in this paper.

A range of diseases, including infectious bronchitis virus (IBV) has been shown to affect egg and eggshell quality (Spackman, 1987). IBV can lead to watery albumen which provides a poor template for eggshell formation and results in wrinkled or corrugated eggshells (Solomon, 199 1). There have also been reports from Europe that IBV exposure is associated with a reduction in the depth of the pigment in brown-shelled eggs (Chubb, R.C. pers. comm.). In the present study (Experiment 1), vaccinated brown egg layers were challenged with IBV to assess the impact of an intercurrent infection on egg and eggshell quality.

Laying hens must have an adequate supply of calcium for eggshell formation. It appears that the laying hen has an appetite for calcium, particularly late in the day (Mongin and Sauveur, 1974). Also, there is evidence that the hen is able to self-select calcium. Blair and coworkers (1973) concluded that allowing hens to self-select a calcium supplement may prevent the over-consumption of other feed ingredients and there is potential, under practical conditions, for cost savings in large sheds (Home, pers. comm.). Experiment 2 of the present study investigated the effect, on egg production and eggshell quality, of allowing laying hens to select from either oyster shell or limestone chips.

The management practice of induced moulting has been shown to improve eggshell quality and even egg production in an ageing flock (Karunajeewa et al., 1989). The mechanisms by which an induced moult improves eggshell quality are not completely understood. However, it appears that best results are achieved if there is a complete cessation of lay for 4-8 weeks, a loss of approximately 50% of primary feathers and a 27-3 1% loss of body weight (Baker et *al.,* 1983; Brake, 1993). Experiment 3 of the present study examined eggshell quality in three strains of layers prior to an induced moult, during the moult (as birds were going out of production), and at different intervals after the birds resumed production.

Materials and Methods

Experiment 1

Exposure of Vaccinated Hens Complete or Choice Fed to Challenge with Infectious Bronchitis Virus

Ninety-six Isa Brown layers (66 weeks of age) were obtained from a commercial farm in the Tamworth region. The birds had been receiving a commercial complete diet and had not been trained to choice-feed. The hens were divided into 4 groups, each of 24 birds. Two groups (Groups 1 and 2) were placed into positive-pressure isolation sheds and two groups (Groups 3 and 4) were placed into identical sheds which were maintained at ambient pressure. Birds were placed, two to a cage, so that there were 12 cages in each of the isolation sheds. All birds had been vaccinated previously, according to standard commercial practice. The treatment groups were as follows:

Group	Feeding Regimen	Infection Status
Group 1	Complete ration	Not challenged with IBV
Group 2	Choice Fed	Not challenged with IBV
Group 3	Complete ration	Challenged with IBV
Group 4	Choice Fed	Challenged with IBV

Birds were allowed to acclimatise for 2-3 weeks to ensure that the egg laying cycle had stabilised and to train the birds in groups 2 and 4 to choice feed. Eggs were collected on day 1 of the experiment and the birds in Groups 3 and 4 were challenged with T-strain infectious bronchitis virus (IBV) by eye-drop at 10-7/ mL. The control birds were given a sham treatment. The birds were observed for 4 weeks post-challenge. Blood samples were taken from birds on arrival, at challenge and 3 weeks post challenge.

The following were measured or recorded prior to the challenge of Groups 3 and 4 and, daily, for 3 weeks following challenge with IBV: feed and water intake, egg production, egg weight, gross egg shell defects, egg shell pigmentation (by reflectivity), egg specific gravity (Archimedes principle), egg shell breaking strength (by quasi-static compression), albumen height (Haugh Units), yolk colour (Roche fan), shell weight, shell thickness (dial comparator gauge).

Experiment 2

Comparison between Oyster Shell and Limestone as Supplementary Dietary Calcium.

Forty-eight SIRO CB laying hens (32 weeks of age), which had been trained to choice fed from 5 weeks of age, were housed two per cage in an open shed at the University of New England's "Laureldale" poultry farm. Birds were assigned to one of three treatments for each Ca source (4 cages per treatment). For treatments l-3, limestone was finely ground and mixed into a Ca-deficient diet to produce three diets containing 37, 43 and 50 g Ca/kg, respectively. Treatments 4-6 were similar to Treatments l-3 except that ground oyster shell was substituted for limestone. Feed intake, egg production and eggshell quality were recorded for 12 weeks.

Experiment 3

Effect of an Induced Moult

Twenty birds of each of three strains (Hy-Line tinted bird, SIRO-CB, Isa Brown) were housed in individual cages in a layer shed at the University of New England's "Laureldale" farm. These birds were from the same flock as the birds used in Experiment 2. Moult was induced according to the commercial "Code of Welfare" and resulted in a reduction in egg production within 48 hours. All birds had gone out of lay within 8 days. Birds were monitored to assess the effect of the moult on eggshell quality. All eggs laid by the birds were collected for one week prior to the induction of moult (Period 1), for the 8 days as they went out of production (Period 2), for the first two weeks after birds came back into production (Period 3), and then after a further one month (Period 4) and two months (Period 5) had elapsed. Egg production was assessed and egg and eggshell quality measured as described in Experiment 1 above.

Results

Experiment 1

Exposure of Vaccinated Hens Complete or Choice Fed to Challenge with Infectious Bronchitis Virus

The birds challenged with IBV consumed more water and had wetter droppings than did the control birds. The percentage egg production was highest in the choice-fed birds although this was accompanied by a decrease in the proportion of good eggshells laid. The proportion of pimpled eggshells laid increased 4 days after the IBV challenge in the complete-fed birds but not in the choice-fed. However, exposure to IBV did not increase the incidence of wrinkled or corrugated eggshells.

The reductions in Haugh Units and egg specific gravity in all groups on days 5-7 of the experiment were most likely the result of increased ambient temperature on those days.

Egg weight was significantly different between groups but was not significantly affected by the IBV exposure (Fig. la). The choice-fed birds laid eggs which were generally heavier than for the complete-fed birds. However, the reverse was true for % shell and shell thickness which were significantly different between groups but not affected by IBV infection. The choice-fed birds had a lower % shell (Fig. lb) and shell thickness (Fig. 1c). Shell breaking strength was significantly different between groups with the complete-fed hens laying stronger shells (Fig. 1d). However, breaking strength did not change over the course of the experiment for any group.

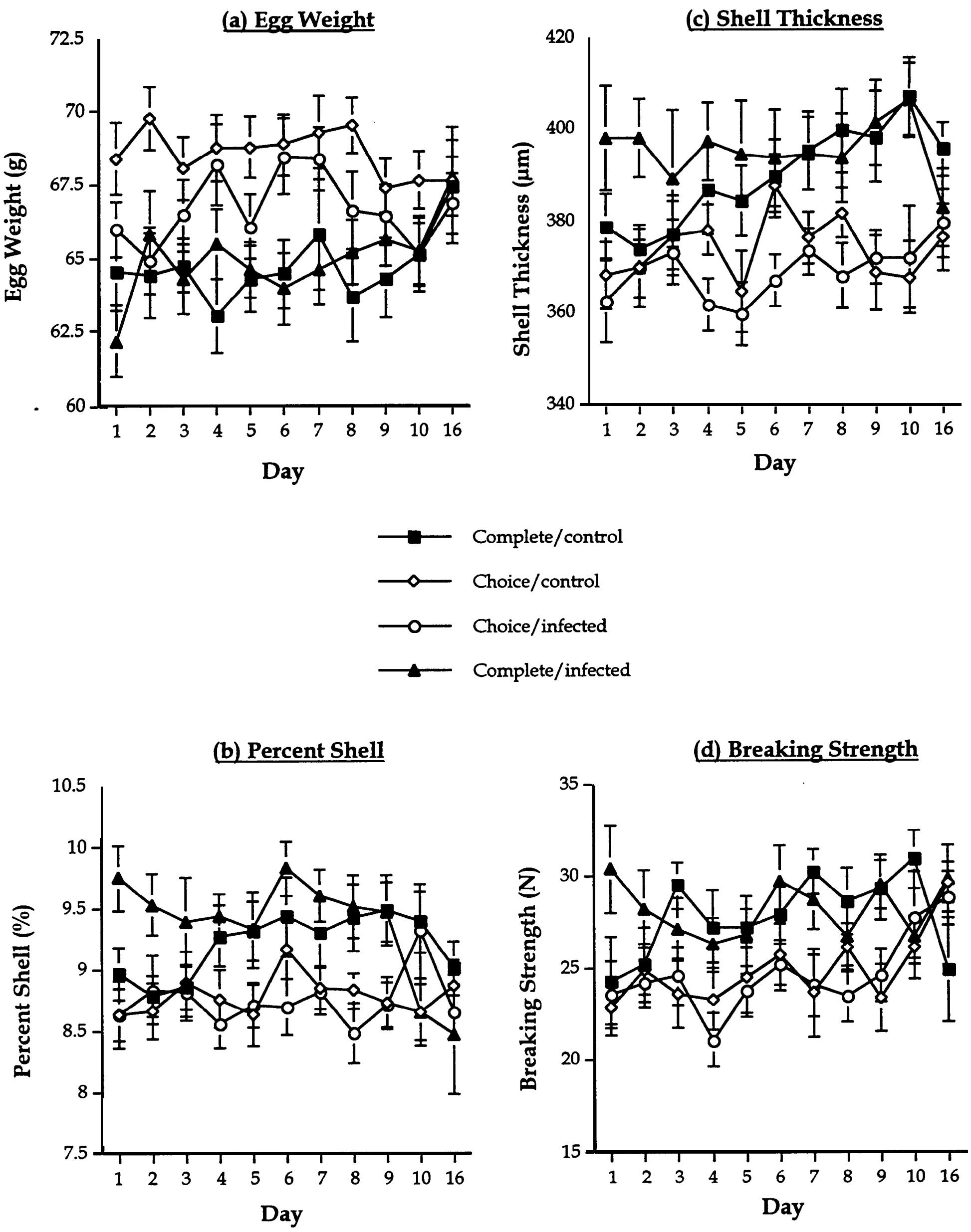
Both the depth of colour of the shells (Fig. 2a) and the colour of the yolks of the eggs (Fig. 2b) were significantly different between groups and over the course of the experiment. There was a significant group x time interaction for the yolk pigment but not for shell colour. The eggshells of the complete-fed birds were generally darker than those of the choice-fed group. In addition, exposure to IBV resulted in a significant transient decrease in the depth of shell colour in the complete-fed birds but not in the choice-fed birds. Yolk colour was consistently darker in the choice-fed birds. Haugh Units (Fig. 2c) and egg specific gravity (Fig. 2d) were significantly affected by both group and date although there were no significant group x time interactions. Both these measures were at their lowest 4 days following exposure of Groups 3 and 4 to IBV.

Experiment 2

Comparison between Oyster Shell and Limestone as Supplementary Dietary Calcium,

There were no mortalities over the 12-week period and production was excellent (>93%, hen housed basis) for both Ca sources, at all three levels of dietary Ca inclusion. Food conversion ratio did not differ between treatments. There were, however, statistical differences in egg and egg shell characteristics between the ground Ca sources (Table 1). Egg weight was significantly greater in the birds receiving oyster shell. For birds receiving limestone, egg weight

Figure 1



decreased as the level of limestone in the diet increased. Egg mass production was unaffected by Ca source and level of inclusion. The shell weight:egg weight ratio was unaffected by source of Ca but was increased at the highest levels of limestone in the diet. Shell thickness was higher in birds given oyster shell or when ground limestone was included in the diet at 50 g/kg. Egg specific gravity was greatest at the highest level of dietary Ca.

Experiment 3

Effect of an Induced Moult

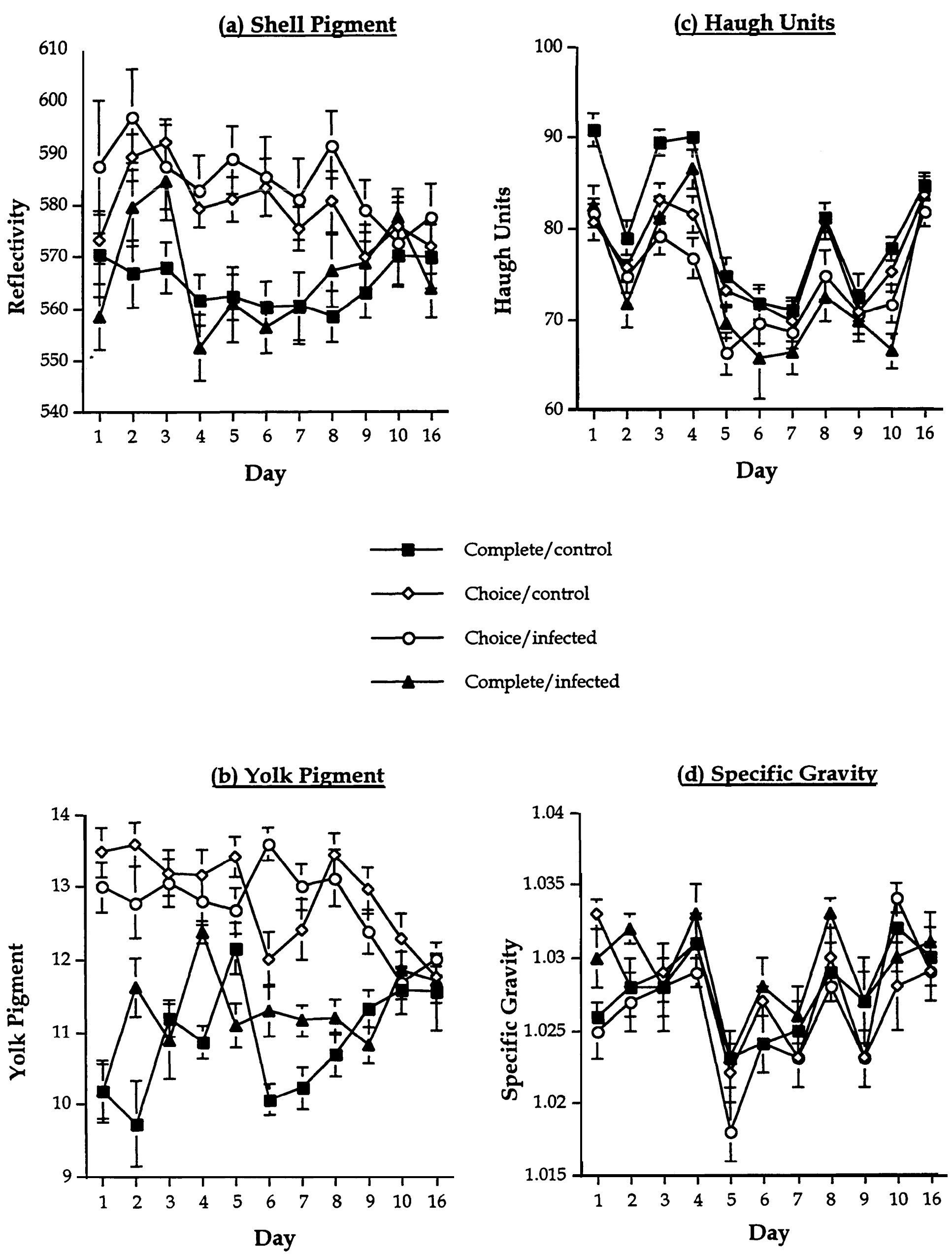
Prior to the induced moult, the Isa Brown hens (Isa) laid the largest eggs with the heaviest and thickest shells and the greatest percentage shell present (Table 2). However, the Hy-Line tinted birds (white) had the and thickness following the moult were the same as they had been prior to the moult for all three strains although eggshell breaking strength was improved. The incidence of some superficial shell defects (pimpled, wrinkled, speckled eggshells) was higher following the moult in all strains.

In Table 2, Period 1 is pre-moult, Period 2 is when the birds are going out of production, Period 3 is the first 2 weeks of production following the moult, Period 4 is 1 month after the return to production and Period 5 is 2 months after the return to production.

Discussion

In Experiment 1, the Isa Brown birds in Groups 2 and 4 did not learn to choice feed successfully. The hens tended to over-consume the protein concentrate.

Figure 2



This may have been the result of the short period of training (2-3 weeks) although subsequent experiments have led to the conclusion that this strain is not well-suited to choice feeding.

The failure of the birds in Groups 2 and 4 to adapt to choice feeding is the most likely cause of the differences observed between complete-fed and choice-fed birds. The choice-fed birds laid bigger eggs but these eggs had poorer shell quality. The eggs laid by the choice-fed birds had darker yolks but lighter-coloured eggshells. The reduction in the depth of the colour of the eggshell pigment in the complete-fed birds, following the IBV challenge, is in accord with the European findings. However, this trend was not seen in the choice-fed birds, presumably because their eggshells were consistently lighter in colour. The colour of the pigment in the shells of the complete-fed challenged birds returned to normal by 3 days post-challenge.

Oyster shell proved to be a better calcium source than limestone. Eggs were heavier and shell thickness was greater. Increasing the level of calcium in the diet had a positive effect on eggshell quality, resulting in the production of eggs with thicker shells and greater shell weight:egg weight ratios (% shell). Specific gravity was significantly higher at the 5% calcium level. The improved eggshell quality in hens receiving oyster shell may result from the greater solubility of oyster shell (78%) as compared with limestone (47%) (Keshavarz et *al.,* 1993). However, oyster shell is more expensive than limestone so an economic analysis would be needed to determine if the added benefit in terms of egg and shell improvement was outweighed by price.

Experiment 3 documented different responses to a moult among the three strains. The Isa Brown hens laid the biggest eggs with the heaviest and thickest shells and the greatest shell weight:egg weight ratios (% shell). Egg specific gravity was also greatest in this strain. The shells of the Isa Brown strain had the darkest colour (the lowest % reflectivity). However, the shell breaking strength of the Isa Brown birds was intermediate between the other two strains. All three strains laid lighter eggs with poorer shell quality as they were going out of production at the start of the induced moult.

Egg weight increased following the moult in the white and black birds but was not significantly different before and after the moult for the Isa strain. The greatest improvement in shell weight as the result of the moult was for the white birds. All strains showed significant improvement in eggshell breaking strength, following the moult. An induced moult can improve some aspects of eggshell quality. However, this advantage needs to be assessed in relation to the cost of having the birds out of production for 1-2 months.

Table 1 ***Experiment*** 2 Effect of calcium source and level of dietary inclusion on egg production and egg characteristics. Values given are Mean (±SEM)

	Egg Weight g	Egg Mass Production (g/b/d)	Egg Specific Gravity	% Shell	Shell Thickness (µm)
Source					
Limestone	56.3 (0.3)	52.3 (0.0003)	1.084	9.22 (0.05)	363 (1.7)
Oyster Shell	59.2 (0.3)	55.4	1.085 (0.0003)	9.21 (0.05)	369 (1.7)
Significance	***	NS	NS	NS	*
Level					
37 g/kg	59.1 (0.4)	55.3 (0.0004)	1.083	9.03 (0.06)	362 (2.0)
43 g/kg	57.5 (0.4)	55.4	1.083 (0.0004)	9.18 (0.06)	363 (2.9)
50 g/kg	56.7 (0.4)	52.8 (0.0004)	1.086 (0.06)	9.42 (2.1)	372
Significance	***	NS	***	***	***

*P<0.005, ***P<0.001

Table *2:* ***Experiment 3:*** Effect of induced moult on egg and eggshell quality in three strains of laying hen. Values given are Mean ± SEM.

	Strain	Period					Strain	Period	Strai * Peri
		1	**2**	**3**	**4**	**5**			
Egg Weight g	Isa	**67.4** ± 0.4	**65.7** ± 0.5	**68.5** ± 0.3	**67.3** ± 0.4	**67.6** ± 0.8	<.0001	<.0001	.02
	White	**61.7** ± 0.5	**60.8** ± 0.6	**65.1** ± 0.3	**63.8** ± 0.4	**64.4** ± 0.7			
	Black	**62.7** ± 0.4	**59.7** ± 1.0	**63.6** ± 0.3	**63.4** ± 0.4	**64.3** ± 0.6			
Shell Weight g	Isa	**6.18** ± 0.05	**5.19** ± 0.11	**6.23** ± 0.04	**6.10** ± 0.0739	**6.13** ± 0.09	<.0001	<.0001	.04
	White	**5.38** ± 0.04	**4.55** ± 0.11	**5.72** ± 0.03	**5.70** ± 0.05	**5.57** ± 0.08			
	Black	**5.41** ± 0.05	**4.66** ± 0.09	**5.69** ± 0.04	**5.58** ± 0.06	**5.47** ± 0.10			
Shell Thickness µm	Isa	**391.9** ± 2.8	**341.7** ± 5.8	**389.4** ± 2.0	**390.4** ± 3.9	**386.0** ± 4.2	<.0001	<.0001	N
	White	**360.9** ± 2.6	**313.2** ± 5.8	**362.2** ±1 .9	**369.0** ± 2.5	**359.2** ± 3.6			
	Black	**356.4** ± 2.7	**318.6** ± 5.2	**364.5** ± 1.6	**360.6** ± 2.5	**353.9** ± 4.7			
Reflectivity %	Isa	**65.4** ± 0.4	**67.9** ± 0.5	**65.6** ± 0.3	**65.9** ± 0.4	**64.9** ± 0.6	<.0001	<.0001	.00
	White	**79.0** ± 0.2	**78.9** ± 0.3	**79.0** ± 0.1	**78.3** ± 0.2	**78.5** ± 0.3			
	Black	**72.5** ± 0.2	**73.9** ± 0.3	**72.3** ± 0.2	**72.1** ± 0.2	**71.8** ± 0.4			
Breaking Strength Newtons	Isa	**24.3** ± 0.7	**22.3** ± 1.1	**26.4** ± 0.5	**26.3** ± 0.8	**26.7** ± 1.0	.0347	<.0001	N
	White	**23.9** ± 0.7	**21.7** ± 1.3	**25.3** ± 0.5	**26.8** ± 0.8	**26.3** ± 0.9			
	Black	**24.9** ± 0.6	**22.0** ± 1.0	**28.2** ± 0.4	**28.8** ± 0.7	**27.0** ± 1.1			
Specific Gravity	Isa	**1.034** ± 0.001	**1.025** ± 0.001	**1.034** ± 0.001	**1.032** ± 0.001	**1.033** ± 0.002	<.0001	<.0001	.01
	White	**1.027** ± 0.001	**1.018** ± 0.001	**1.031** ± 0.000	**1.029** ± 0.001	**1.031** ± 0.001			
	Black	**1.026** ± 0.001	**1.017** ± 0.001	**1.031** ± 0.000	**1.029** ± 0.001	**1.030** ± 0.002			
Shape Index %	Isa	**75.1** ± 0.2	**74.3** ± 0.3	**76.2** ± 0.2	**75.0** ± 0.3	**74.6** ± 0.4	<.0001	.0149	<.00
	White	**73.9** ± 0.3	**73.5** ± 0.3	**74.0** ± 0.2	**74.1** ± 0.2	**74.0** ± 0.4			
	Black	**75.7** ± 0.3	**75.7** ± 0.4	**75.3** ± 0.2	**76.0** ± 0.3	**75.0** ± 0.4			
% Shell	Isa	**9.21** ± 0.06	**7.92** ± 0.16	**9.09** ± 0.05	**9.07** ± 0.10	**9.07** ± 0.12	<.0001	<.0001	.00
	White	**8.69** ± 0.07	**7.47** ± 0.15	**8.83** ± 0.04	**8.94** ± 0.06	**8.66** ± 0.09			
	Black	**8.63** ± 0.07	**7.75** ± 0.13	**8.92** ± 0.04	**8.79** ± 0.06	**8.51** ± 0.13			

Conclusions

Egg and eggshell quality are influenced by a range of factors. In the commercial situation, effects may have multiple causes and it is important to be able to distinguish between, for example, the effects of changed feed composition and the appearance of an intercurrent infection.

Acknowledgments

The support of the Egg Industry Research and Development Council is gratefully acknowledged. Mr. Grahame Chaffey, Mr. Allan Rummery, Mr. Evan Thomson and Mr. Mark Porter assisted with some of the experiments.

References

BAKER, J.R., BRAISE, J., and McDANIEL, G.R. (1983) The relationship between body weight loss during induced molt and postmolt egg production, egg weight, and shell quality in caged layers. *Poultry Science,* **62: 409-4** 13.

BLAIR, R., DEWAR, W.A. and DOWNIE, J.N. (1973) Egg production responses of hens given a complete mash or unground grain together with concentrate pellets. *British Poultry Science,* **14: 373-377.**

BRAKE, J. (1993) Recent advances in induced molting. *Poultry Science, 7:* **929-93** 1.

KARUNAJEEWA, H., ABU-SEREWA, S. and HARRIS, P.A. (1989) Effects of an induced pause in egg production and supplementation of the diet with iron on egg shell colour, quality and performance of brown egg layers. *British Poultry Science, 30: 257-264.*

KESHAVARZ, K., SCOTT, M.L. and BLANCHARD, J. (1993) The effect of solubility and particle size of calcium sources on shell quality and bone mineralisation. *Journal of Applied Poultry Research, 2:* 259-267.

MONGIN, P. and SAUVEUR, B. (1974) Voluntary food and calcium intake by the laying hen. *British Poultry Science,* **15: 349-359.**

ROBINSON, S.M., BALL, W.J., THOMSON, E.S. and NOLAN J.V. (1995) Oyster shell versus limestone as sources of calcium for layers. *Proceedings of the Australian Poultry Science Symposium, 7: 195.*

SOLOMON, S..E. (1987) Egg shell pigmentation, in: WELLS, R.G. and BELYAVIN, C.G. (Ed.) *Egg Quality - Current Problems and Recent Advances.* Poultry Science Symposium No.20, pp. 147-1 58 (Butterworths, London).

SOLOMON, S.E. (1991) *Egg and Eggshell Quality.* (Wolfe Publishing Limited, London).

SPACKMAN, D. (1987) The effect of disease on egg quality., in: WELLS, R.G. and BELYAVIN, C.G. (Ed.) *Egg Quality - Current Problems and Recent Advances.* Poultry Science Symposium No. 20, pp. 255-282 (Butterworths, London).