RURAL INDUSTRIES RESEARCH AND DEVELOPMENT CORPORATION

FINAL REPORT

Project Title: Improvement in egg shell quality at high temperatures

RIRDC Project No.: US-43A

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PROJECT SUMMARY

Objectives: To improve egg shell quality from hens at high ambient temperatures by manipulating the diet to overcome physiological problems associated with respiratory alkalosis.

Background: Poor egg shell quality remains a consistent and major source of economic loss to egg producers. A major cause of poor egg shell quality is high ambient temperature and the associated heat stress. The provision of supplementary calcium under these conditions has not alleviated the problem. High temperatures induce respiratory alkalosis in birds and this reduces the availability of bicarbonate in the lumen of the shell gland. This is turn limits the production of carbonate ions, essential for the formation of the egg shell.

Research: Egg production and egg shell quality measurements were made at 8-week intervals, between 22 and 62 weeks of age, using laying hens fed either a conventional layer diet or this diet supplemented with 1% sodium bicarbonate ($NaHCO_3$) and housed at 32°C in either a conventional 16 h light : 8 h dark (16L:8D) or an intermittent 3L:1D lighting regimen.

Outcomes: The intermittent lighting regimen significantly improved feed intake, egg weight, egg shell breaking strength and egg shell thickness. Consistent improvements in shell breaking strength were observed with the $NaHCO_3$ supplement. The response was small in the 16L:8D regimen (3%) compared with the 3L:1D regimen (7%), the latter being additional to a 14% improvement resulting from the use of the 3L:1D lighting.

Implications: Egg shell quality can be improved at high temperatures by using intermittent lighting and dietary $NaHCO_3$ supplementation.

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Background

Poor egg shell quality remains a consistent and major source of economic loss to egg producers. While it is generally thought that egg shell defects occur in approximately 8 per cent of all eggs produced by commercial flocks this is an underestimate based on information obtained from egg packing stations. Recent estimates of losses from egg shell defects in the USA and Australia approximate 20 per cent of all eggs produced when on-farm losses and damaged eggs at retail sales outlets are included. A major cause of poor egg shell quality is high ambient temperature and the associated heat stress and the provision of supplementary calcium under these conditions has not alleviated the problem. High temperatures induce respiratory alkalosis in birds and this reduces the availability of bicarbonate in the lumen of the shell gland. This is turn limits the production of carbonate ions, essential for the formation of the egg shell. The major egg producing regions of Australia experience high ambient temperatures for a considerable part of the production year. While production measures such as rate of lay and egg weight can be improved by a number of feeding and management strategies egg shell quality is primarily affected by heat stress *per se*. Accordingly, egg shell quality and economic returns to egg producers are adversely affected by high ambient temperatures.

Objectives

To improve egg shell quality from hens at high ambient temperature.

Technical Information

Estimates of losses from egg shell defects from the USA and Australia indicate overall losses of approximately 20 per cent of all eggs laid. This loss is greatest in the case of hens under heat stress.

The results of recent Camden studies at high temperatures have indicated a 10 per cent improvement in the shell breaking strength of eggs from hens fed $NaHCO_3$ supplements. Other attempts to improve egg shell quality through supplementation of the diet or drinking water with sodium bicarbonate have been equivocal. While positive responses have been observed by some researchers, others have reported no benefits and yet others have reported benefits only under specific conditions.

The inconsistent responses to bicarbonate may reflect the fact that under a conventional daily 16 h photoperiod the bicarbonate is not consumed during the dark period, the time at which most egg shell formation occurs. Therefore, the use of a continuous lighting regimen or one involving repetitive short light:dark periods should allow the synchronisation of egg shell formation with supplementary bicarbonate intake by the hen. In addition, the use of such lighting regimes may also improve egg shell quality by allowing the hen access to dietary calcium during the period of egg shell formation. This approach has not been used previously when attempts have been made to utilize sodium bicarbonate to improve egg shell quality at high temperatures.

Methodology

Continuous lighting over an extended period of lay is unacceptable from an animal welfare point of view in that it does not allow the hens periods of darkness for rest and sleep. The alternative is to use a repetitive intermittent lighting regimen, such as the 3L:1D schedule used in this study. Therefore, the basic design of this study involved maintaining laying hens in a conventional (16L:8D) or intermittent (3L:1D) lighting regimen and feeding a conventional diet (199 g crude protein and 12.0 MJ of ME/kg) without or with 1% $NaHCO_3$.

Point-of-lay pullets were placed in double-bird cages in two temperature controlled rooms maintained at 32°C. From 20 weeks of age the hens in one room were given a 16L:8D lighting schedule and those in the other room a 3L:1D repetitive lighting schedule. Production and shell quality measures were made at 8 weekly intervals commencing at 22 weeks of age (10% rate of lay) and finishing at 62 weeks of age. The data were analysed as a 2x2 factorial ANOVA with repeated measures. The effects of lighting regimen, diet and age and the interactions between these main factors were examined.

Results

The main effects of age, light and diet on feed intake, egg production, egg weight, egg mass and feed conversion are shown in Table 1. Age had a significant effect on all measures. Maximum feed intake was attained between 30-46 wk of age after which there was a significant decrease. Rate of lay and egg mass output showed continuing declines in each period after 38 wk of age although egg weight continued to increase until 54 wk of age. Feed conversion was poor during the first 8 wk of lay when overall egg production and egg mass were low. Feed conversion improved significantly between 30 and 38 wk of age, the period associated with improved egg production and egg mass output. Thereafter, there was a continuous decline in feed conversion efficiency with increasing age.

The 3L : 1D light regimen significantly improved feed intake with hens on this lighting regimen eating 6.4 g more feed per day than those on the 16L : 8D conventional lighting. Hens in the 3L : 1D lighting regimen produced significantly larger eggs and 2.0 g more egg mass daily which was near the significance level (P=0.062), but no significant differences were observed between the 16L : 8D and 3L : 1D lighting regimens with respect to rate of lay and feed conversion. Also, there were no significant differences due to diet.

There were significant age x light interactions on feed intake, egg production and egg mass (Table 2). The feed intake of hens on the 3L : 1D lighting regimen was significantly greater to 46 wk of age but, thereafter, there was no significant effect of light. The maximum improvement achieved in the 3L : 1D regimen was 11 g/d between 38 and 46 wk of age. Hens in the 3L : 1D lighting regimen had a numerically higher rate of lay than hens on 16L : 8D between 30 and 46 wk of age although no significant differences were observed at any age. After 46 wk of age no significant differences in egg production were observed between the two lighting regimens although there was a tendency for more eggs to be laid by hens in the 16L : 8D environment. Hens in the 3L : 1D regimen produced significantly more daily egg mass than hens on the 16L : 8D regimen between 30 and 46 wk of age but differences due to lighting regimen at other times were small and non significant.

The main effects of age, light and diet on the eggshell quality measures are shown in Table 3 and Figure 1. All eggshell quality measures were affected significantly by age. The shell breaking strength was greatest during early lay at 30 and 38 wk of age but declined thereafter. Eggs from hens in the 3L : 1D regimen had a significantly greater shell breaking strength than eggs from hens in the 16L : 8D regimen. Apart from hens in the 16L : 8D regimen at 30 wk of age dietary supplementation with $NaHCO_3$ consistently improved shell breaking strength (Figure 1). This response was greater in the 3L : 1D than in the 16L : 8D regimen although no significant interactions were observed. The shell breaking strength of eggs from hens in the 16L : 8D regimen was improved by 1.0 Newton, from a mean overall value of 32.2 Newtons to 33.2 Newtons, by the use of the $NaHCO_3$ supplement whereas the improvement was much greater in eggs from hens in the 3L : 1D regimen (36.8 to 39.4 Newtons). The 7 percent improvement in the 3L : 1D regimen occurred in addition to the significant 14 percent improvement (36.8 vs 32.2 Newtons) resulting from the use of the 3L : 1D regimen.

Numerical improvements in shell weight percentage and in shell thickness were observed in eggs from hens in the 3L : 1D regimen, the shell thickness effect being significant and the shell weight percentage effect approaching significance (P=0.057). Although the effect of diet was not significant there was a tendency for both measures to be improved in hens fed the $NaHCO_3$ diet in the 3L : 1D regimen. Consistent improvements were obtained in the 3L : 1D regimen but not in the 16L : 8D regimen although no significant interactions were observed.

Discussion

Apart from a significant improvement in the feed intake of these heat-stressed hens in the 3L : 1D regimen the only other significant effect of light or diet on production responses was the improved egg weight from hens in the 3L : 1D regimen. However, significant age x light interactions were observed on feed intake, egg production and egg mass. Hens in the 3L : 1D regimen ate significantly more food to 46 wk of age and this was reflected in a numerically greater rate of lay and significantly greater egg mass output. However, after 46 wk of age feed intake, egg production and egg mass output were similar in both lighting environments. These results at heat-stress temperatures contrast with the results obtained by others who have examined the effects of intermittent lighting on layer performance in non-heat stress environments. The results of these latter studies have consistently found intermittent lighting to decrease feed intake and egg production although egg weight improves with intermittent lighting, as evidenced in the current study.

The use of intermittent lighting at non-heat stress temperatures has been found by others to improve eggshell quality. The present results extend these observations to the prolonged use of intermittent lighting at heat stress temperatures and confirm the benefits of a 3L : 1D regimen on shell breaking strength, shell thickness and shell weight percentage. In fact, as far as the current author is aware this is the first time that the effect of repetitive intermittent lighting on production and eggshell quality has been evaluated at high ambient temperatures. The present results suggest that the use of intermittent lighting is more beneficial at high, compared to thermoneutral or low, temperatures.

It is generally accepted that dietary $NaHCO_3$ supplementation should play an important role in maintaining good eggshell quality. However, attempts to improve eggshell quality in this way have been equivocal and, apart from recent studies at Camden, only two other reports have shown a beneficial response to $NaHCO_3$ at high temperatures. In the current experiment no significant differences in eggshell quality were observed between the dietary treatments. However, the $NaHCO_3$ supplement given to hens in the 3L : 1D lighting regimen consistently improved shell breaking strength (overall mean 7%) in addition to the 14% improvement resulting from the use of the 3L : 1D regimen. Providing the $NaHCO_3$ to the hens in the 16L : 8D regimen only induced a 3% improvement in SBS. These improvements in shell breaking strength at 32°C in the 3L : 1D regimen are similar in extent to those reported previously at Camden for hens maintained in continuous light at 30-35°C. In this earlier work improvements of 15% resulting from feeding 1% $NaHCO_3$ at the same time as increasing the daylength from 16 to 24 h, and improvements of 9% due to feeding 1% $NaHCO_3$ to hens acclimated to continuous light, were significant. The results confirm the original hypothesis examined in that a supplement of 1% $NaHCO_3$ to laying hens at high temperatures is a means of improving eggshell quality as long as hens consume the additional bicarbonate during the period of active shell formation. The use of a repetitive intermittent lighting regimen such as the 3L : 1D used in the current study allows for desynchronisation of ovulation patterns which may be important to the improvements noted in egg weight and shell breaking strength.

Implications and Recommendations

The results of this short-term project confirm the advantages arising from supplementing the diet of laying hens at high temperatures with sodium bicarbonate. The major benefit was observed with egg shell quality and this was achieved without any loss in production. In addition, the use of intermittent lighting exerted positive effects on food intake, egg weight, egg mass output and egg shell quality during the first half of lay with no significantly adverse effects thereafter.

It appears that:

1) Sodium bicarbonate supplementation of diets for laying hens at high temperatures improved egg shell quality.
2) Where appropriate, producers should consider the merits of intermittent lighting for laying hens.
3) Further work is required to identify the optimum concentrations of sodium bicarbonate and the optimum intermittent lighting patterns to use at varying ambient temperatures.

Intellectual Property

Not applicable.

Table 1. Main effects of age, light and diet on production measures from 22 to 62 weeks of age

Values within a main effect with no similar superscripts are significantly different at the level of significance shown.

Main Effect		Feed intake (g)	Weight gain (g)	Egg production (%)	Egg weight (g)	Egg mass (g/day)	Feed:Gain (g:g)
Age (weeks)	22-30	89.6b	11.6d	69.9c	50.1c	35.9c	2.52ab
	30-38	93.7a	93.6c	83.4a	52.3b	43.7a	2.15d
	38-46	95.3a	180.4b	76.2b	54.1a	41.3a	2.31cd
	46-54	88.9b	197.2ab	67.2c	55.1a	37.1c	2.42bc
	54-62	85.0c	229.0a	58.4d	55.0a	32.4d	2.65a
s.e.m.		0.60	9.28	0.89	0.25	0.55	0.039
Significance		***	***	***	***	***	***
Light	16L : 8D	87.3b	111.2b	70.9	51.9b	37.1	2.46
	3L : 1D	93.7a	174.6a	71.0	54.7a	39.1	2.54
s.e.m.		1.11	15.78	1.17	0.34	0.73	0.048
Significance		***	**	n.s.	***	n.s.	n.s.
Diet	Control	89.8	130.4	70.6	53.4	38.0	2.64
	$NaHCO_3$	91.2	154.4	71.3	53.3	38.2	2.66
s.e.m.		1.11	15.78	1.17	0.34	0.73	0.048
Significance		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

**P<0.01; ***P<0.001; n.s. non significant.

Table 2. Interaction effects of age and lighting regimen on feed intake, egg production and egg mass from 22 to 62 weeks of age

Values within a main effect with no similar superscripts are significantly different at the level of significance shown.

Age (weeks)	Light	Feed intake (g)	Egg production (%)	Egg mass (g/day)
22-30	16L : 8D	85.4d	71.1de	35.3ef
22-30	3L : 1D	93.9bc	68.8de	36.5de
30-38	16L : 8D	89.9cd	81.8ab	41.7bc
30-38	3L : 1D	97.4ab	85.1a	45.8a
38-46	16L : 8D	89.8cd	74.1cd	39.0cd
38-46	3L : 1D	100.8a	78.2bc	43.6ab
46-54	16L : 8D	87.1d	67.9e	36.6de
46-54	3L : 1D	90.7cd	66.6e	37.7de
54-62	16L : 8D	84.4d	60.6fg	32.8f
54-62	3L : 1D	85.5d	56.2g	32.0f
s.e.m.		0.84	1.26	0.77
Significance		***	**	**

**P<0.01; ***P<0.001.

Table 3. Main effects of age, light and diet on egg shell quality measures from 22 to 62 weeks of age

Values within a main effect with no similar superscripts are significantly different at the level of significance shown.

Main effect		Shell strength (Newtons)	Shell weight (%)	Shell thickness (µm)
Age (weeks)	30	36.95ab	9.71a	372a
	38	37.29a	9.69a	375a
	46	33.87b	9.64ab	368ab
	54	34.08ab	9.29bc	361b
	62	34.87ab	8.93c	349c
s.e.m.		0.712	0.081	1.9
Significance		***	***	***
Light	16L:8D	32.70b	9.33	360b
	3L:1D	38.13a	9.58	372a
s.e.m.		0.787	0.091	2.2
Significance		***	n.s.	**
Diet	Control	34.51	9.46	366
	$NaHCO_3$	36.32	9.45	366
s.e.m.		0.787	0.091	2.2
Significance		n.s.	n.s.	n.s.

**P<0.01; ***P<0.001; n.s. non significant.