The Significance of Wet Droppings in Laying Hens

A report for the Rural Industries Research & Development Corporation

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PREFACE

The project was initiated because there were numerous complaints from egg producers about the problem of wet droppings in terms of its implications for increased dirty eggs and cages, and other shed hygiene-related problems. The focus of the project was to examine wet litter problems from nutritional perspectives and to develop strategies minimising the problem. During the project, however, it was convenient to collect data on egg production (breaking it into broken, cracked, dirty and malformed eggs), and egg and egg shell quality. Therefore the report contains large amounts of significant data on these parameters. This report also contains some data linking intestinal spirochaetes with wet litter problems. These data were obtained collaboratively with Ms Carol Stephens and Dr David Hampson of Murdoch University.

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EXECUTIVE SUMMARY

The project was undertaken to investigate the genetic and nutritional basis for watery and sticky droppings in layers and to develop strategies minimising it. The project was conducted two phases, firstly to identify the problem and secondly to develop strategies minimising it. A total of six experiments were conducted. The first experiment examined strain differences in excreta moisture. For the other five experiments, excreta moisture as well as saleable and non-saleable egg production and egg and egg shell quality were measured to examine: (a) the effect of different cereal bases in commercial layer diets; (b) the influence of high levels of chloride and magnesium levels; (c) the efficacy of 4 different enzyme products in 4 strains of birds fed diets based on three different cereals (barley, wheat and triticale). Links between intestinal spirochaetes and wet droppings in chickens were also determined in conjunction with another project funded by RIRDI and carried out by Murdoch University.

1. Genetic differences:

There were clear genetic differences in the excreta moisture content of laying hens. Isa Brown and HiSex strains had significantly ($P<0.01$) wetter excreta compared with Hy-Line CB.

2. Effect of different cereal grains on excreta moisture contents, egg production, egg and egg shell quality in Isa Brown layers:

Formulation of diets using sorghum, barley, wheat or triticale as the main energy source produced significantly ($P<0.05$) different excreta moisture contents with barley causing the wettest excreta. Total rate of lay was similar regardless of the cereal base, but the percentage of non-saleable eggs (broken, visibly cracked, malformed eggs) differed widely. Barley, wheat and triticale produced significantly ($P<0.05$) higher numbers of non-saleable eggs than sorghum and standard commercial diets. This difference was due to markedly ($P<0.001$) poorer egg shell quality in birds fed barley, wheat and triticale diets.

3. Elevated levels of chloride and magnesium:

There was no effect on excreta moisture content when up to three times the NRC recommendations for chloride and magnesium were included in layer diets. Total egg production and egg and egg shell quality were also not affected by high levels of chloride and magnesium. Non-saleable egg production tended to be elevated as chloride and magnesium levels were increased.

4. Effect of feed enzymes in four strains of layers fed barley-, wheat- or triticale-based diets:

Three separate experiments were conducted to examine the effect of four different enzymes on wet droppings, egg production, egg and egg shell quality in four strains of layers fed barley, wheat or triticale diets. In barley diets, enzymes can alleviate the problems with wet droppings and reduce feed intake without affecting production. There was a significant ($P<0.01$) strain x enzyme interaction in all three experiments. Different enzyme products may be highly effective in one strain, but may not work in a different strain. The number of broken and cracked eggs increases as the flock ages; some enzymes alleviated this problem whilst others worsened it. Enzymes improved ($P<0.01$) egg and egg shell quality in birds fed barley, wheat or triticale diets.

5. Links between intestinal spirochaetes and wet droppings:

There is a strong link between the occurrence of intestinal spirochaetes and wet litter problems with chickens colonised with spirochaetes generally producing significantly wetter excreta.

It is concluded that the problems with wet droppings can be avoided, to a large extent, by selecting the appropriate strains of birds, using low-NSP grains and supplementing the diet with an appropriate dosage of glycanases. But intestinal spirochaetes can influence the incidence of wet droppings, perhaps independent of nutrition. A spin off of this project is the identification of the effect of different cereal grains on non-saleable egg production and egg shell quality. Appropriate enzymes can alleviate egg shell quality problems associated with using high levels of barley, triticale or wheat in layer diets.

INTRODUCTION

Watery and sticky droppings in layers have been a problem in the egg industry for years. The major loss to the industry is through increased percentage of dirty eggs and shed problems, although management and hygiene problems may also be significant. In tiered cage systems fitted with deflectors or scrapers, wet droppings can be particularly problematic. It is well understood in broilers that increased dietary non-starch polysaccharides (NSPs) cause watery and sticky droppings due to their ability to increase gut viscosity and to hold a large amount for water. Nowadays, glycanases (carbohydrate-degrading enzymes) are used in broiler diets to improve the nutritive value of rations, and in the meantime, largely overcoming watery and sticky dropping problems. In layers, however, the problem is multifaceted. A number of factors other than nutrition appear to be important. These include excessive drinking (Lintern-Moore, 1972), an inappropriate amount of Ca and electrolyte balance in the diet (Osbaldiston, 1969; Roberts and Balnave, 1992), strain differences in mineral requirements, kidney damage from infectious bronchitis or mycotoxins (Glahn and Wideman, 1987; Hnatow and Wideman, 1985) and contaminants in the water. Whilst paying attention to non-nutrition related problems that contribute to wet droppings in layers, the current project has examined the problem from a nutritional management perspective.

BACKGROUND

Dirty eggs represent approximately 4% of the total egg production, which accounts for an estimated lost revenue of $10 million per annum. In addition, sticky and watery excreta can make cage and shed cleaning difficult and time-consuming. There are also concerns that wet droppings may lead to increased gas production in the shed, hence an elevated odour problem for the surrounding environment. It is therefore obvious that the identification of the problem and development of strategies to minimise it will not only increase direct economic gains to the egg industry, but also will lead to improved hygiene in the shed and a better working environment for the staff.

A total of six experiments were conducted. The first experiment examined strain differences in excreta moisture. For the other five experiments, excreta moisture as well as saleable and non-saleable egg production and egg and egg shell quality were measured to examine: (a) the effect of different cereal bases in commercial layer diets; (b) the influence of high levels of chloride and magnesium levels; and, (c) the efficacy of 4 different enzyme products in 4 strains of birds fed diets based on three different cereals (barley, wheat and triticale). The findings are presented in four separate Sections.

SECTION ONE.

EFFECTS OF DIFFERENT CEREAL GRAINS ON WET DROPPINGS, EGG PRODUCTION, AND EGG AND EGG SHELL QUALITY

INTRODUCTION

Cereal grains differ widely in their nutritive value as well as in their effect on excreta consistency and moisture levels. Most cereal grains have a similar macronutrient content, but their fibre (non-starch polysaccharides; NSPs) level varies. It is thought that NSPs can influence the level of moisture through their ability to modify gut physiology and their water holding capacity (1 g NSPs can hold up to 10 g of water). However, whether or not these cereals affect egg shell quality is not clear despite claims that problems with egg shell quality in broiler breeders result from the use of rations based on certain grains.

This experiment was conducted to examine the effect of different cereals on wet droppings together with egg production and egg shell quality in Isa Brown layers.

MATERIALS AND METHODS

1. Excreta moisture levels in six strains of laying hens fed a commercial diet during the early laying period

This experiment was conducted to determine whether the excreta moisture levels would vary due to genetic differences. Six strains of layers, Tegel Super Brown, Hy-Line Brown, Isa Brown, Lohmann, Hy-Line CB and Tegel HiSex, at early lay were used for the trial. Excreta samples were collected over two consecutive weeks using aluminium trays mounted under 2-bird cages. The excreta were dried in a forced-drought oven at 80^{o}C.

2. Excreta moisture, production levels and egg shell quality in peak-of-lay Isa Brown birds fed five different diets

Four diets based on sorghum, wheat, barley, or triticale were formulated and pelleted at Ridley AgriProducts (Fielders), Tamworth. Diet 1 was the commercial layer ration regularly used at the farm (Millmaster Layer diet; composition not shown, measured NSP levels (% as fed): soluble – 1.44, insoluble – 9.12 and total – 10.56). A total of 500 Isa brown birds were allocated to 5 diets with 50 replicates of 2 birds per treatment. Diets were fed to the birds for 12 weeks, with the first two weeks serving as an adaptation period. For the following ten weeks, feed intake and excreta moisture were measured weekly, eggs were counted twice a week and categorised as good, dirty and broken. Egg weight was measured every second week of the trial. During Week 10, ME of the diets was determined and sixty eggs per diet were collected for egg shell quality measurements (egg weight, gross egg shell defects, egg shell pigmentation by reflectivity, egg length and breadth, eggshell breaking strength by quasi-static compression, shell weight and shell thickness using a dial comparator gauge. Shape index (breadthx100/length) and percentage shell (shell weight x100 / egg weight) were calculated. Internal egg quality was assessed by measuring the Haugh units of the albumen and the Roche score of the yolk.

Table 1.1. Experimental diets - Sorghum and Wheat diets

Sorghum-based diet		**Wheat-based diet**	
Ingredients	**Inclusion (%)**	**Ingredients**	**Inclusion (%)**
Sorghum 10%	59.700	Wheat 10	61.817
Meat meal 50	8.600	Meat meal 50	9.600
Tallow	1.867	Tallow	1.933
Canola meal 38	6.000	Canola meal 38	6.000
Cottonseed meal 38	4.000	Cottonseed meal 38	4.000
Soybean meal 48	3.067	Soybean meal 48	2.500
Rice pollard 13	4.533	Rice pollard 13	7.067
Lucerne meal 15	4.867	Lucerne meal 15	0.000
Limestone	6.833	Limestone	6.634
Salt	0.170	Salt	0.173
Choline chloride 75	0.050	Choline chloride 75	0.033
Lysine	0.020	Lysine	0.000
Alimet	0.173	Alimet	0.123
Layer premix	0.120	Layer premix	0.120
Total	100.000	Total	100.000
Calculated nutrient levels		**Calculated nutrient levels**	
Protein	16.983	Protein	16.974
ME	11.551	ME	11.591
Fat	5.701	Fat	5.694
Fibre	4.614	Fibre	3.580
Linoleic acid	1.381	Linoleic acid	1.381
Na	0.165	Na	0.160
Salt	0.439	Salt	0.416
Ca	3.644	Ca	3.646
Available P	0.499	Available P	0.576
Lysine	0.750	Lysine	0.773
Methionine	0.380	Methionine	0.353
Threonine	0.572	Threonine	0.563
Tryptophan	0.171	Tryptophan	0.163
Choline	1217.68	Choline	1227.778
Na+K+Cl	182.27	Na+K+Cl	181.669
Measured NSP levels (% as fed)		**Measured NSP levels (% as fed)**	
Soluble	0.71	Soluble	1.59
Insoluble	8.28	Insoluble	10.29
Total	8.99	Total	11.88

Table 1.2. Experimental diets - barley and triticale diets

Barley-based diet		**Triticale-based diet**	
Ingredients	Inclusion (%)	Ingredients	Inclusion (%)
Barley 9.5	69.950	Triticale 10	64.140
Meat meal 50	16.334	Meat meal 50	9.900
Tallow	2.667	Tallow	2.400
Soybean meal 48	0.867	Canola meal 38	6.000
F/F Soybean 37	0.500	Cottonseed meal 38	4.000
Rice pollard 13	4.700	Soybean meal 48	2.500
Limestone	4.500	Rice pollard 13	3.966
Salt	0.033	Limestone	6.567
Na-bicarbonate	0.053	Salt	0.147
Choline chloride 75	0.030	Na-bicarbonate	0.053
Methionine	0.100	Choline chloride 75	0.070
L-threonine	0.033		
Alimet	0.113	Alimet	0.137
Layer premix	0.120	Layer premix	0.120
Total	100.000	Total	100.000
Calculated nutrient levels		**Calculated nutrient levels**	
Protein	16.183	Protein	16.961
ME	11.356	ME	11.648
Fat	6.763	Fat	5.834
Fibre	5.098	Fibre	3.806
Linoleic acid	1.395	Linoleic acid	1.402
Na	0.167	Na	0.160
Salt	0.363	Salt	0.390
Ca	3.536	Ca	3.647
Available P	0.834	Available P	0.561
Lysine	0.771	Lysine	0.786
Methionine	0.408	Methionine	0.365
Threonine	0.546	Threonine	0.584
Tryptophan	0.155	Tryptophan	0.171
Choline	1218.18	Choline	1231.88
Na+K+Cl	158.887	Na+K+Cl	179.653
Measured NSP levels (% as fed)		**Measured NSP levels (% as fed)**	
Soluble	3.64	Soluble	1.57
Insoluble	11.17	Insoluble	11.00
Total	14.81	Total	12.57

RESULTS

1. Genetic differences in excreta moisture levels:

Among the six strains (Tegel Super Brown, Hy-Line Brown, Isa Brown, Lohmann, Hy-Line CB and Tegel HiSex) tested, the Hy-Line CB had the driest excreta (63.8% moisture), whereas the Isa Brown and Tegel HiSex had the wettest excreta (68.4% moisture) ($P<0.01$). The excreta moisture contents for Hy-Line Brown, Tegel Super Brown and Lohmann did not differ significantly. The values were 65.8%, 66.3% and 67.8 %, respectively.

2. Effect of cereals:

Excreta moisture, feed intake and ME: The moisture content of excreta from birds fed the barley-based diet was higher ($P<0.05$) than those fed the other diets. It was also visibly runny and stuck to the bottom of the cages. The average daily intake of the birds was higher ($P<0.05$) in birds fed the barley, wheat and triticale-based diets than those fed the commercial and sorghum diets. The ME value of the sorghum-based diet was higher ($P<0.05$) than that of the commercial and the barley-based diets. The data are shown in Table 1.3.

Table 1.3. Effect of using different cereal bases in commercial layer diets on excreta moisture, feed intake and apparent metabolisable energy (AME) values in Isa brown layers at peak of lay

Diet	Excreta Moisture (%)	Feed Intake (g/d)	AME (MJ/kg)
Sorghum	74.7(0.7)^a	112.4 (0.8)^b	11.5 (0.2)^a
Commercial	73.6(1.5)^a	114.4 (1.1)^b	10.9 (0.2)^b
Barley	77.5(1.4)^b	121.9 (1.7)^a	10.9 (0.1)^b
Triticale	74.4(1.5)^a	120.4 (1.1)^a	11.2 (0.1)^{ab}
Wheat	74.2(1.4)^a	123.9 (1.5)^a	11.2 (0.2)^{ab}

^{ab} Means (SE in brackets) within a column followed by the same superscript letters do not differ significantly ($P<0.05$).

Total egg production, non-saleable percentage and egg mass: There were no significant differences between the number of eggs produced, but the number of non-saleable eggs differed widely ($P<0.01$) amongst treatments. Birds fed the sorghum-based diet produced the lowest percentage of non-saleable eggs (6.6%), whereas the triticale produced the highest (12.7%). Egg weight was the highest (64.1g) in birds fed the wheat-based diet and the lowest in those fed the triticale-based diet (62.0g). The data are shown in Table 1.4.

Table 1.4. Effect of using different cereal bases in commercial layer diets on total and non-saleable egg (broken, dirty and malformed eggs) production, and egg weight in Isa brown layers at peak of lay

Diet	Total Production (%)	Non-saleable %	Egg wt (g)
Sorghum	96.0 (1.5)	6.6 (0.7)^{a}	62.7 (0.5)^{b}
Commercial	95.2 (1.4)	9.3 (1.5)^{ab}	62.8 (0.3)^{b}
Barley	96.2 (2.3)	11.1 (1.4)^{b}	63.3 (0.6)^{ab}
Triticale	97.2 (1.5)	12.7 (1.5)^{b}	62.0 (0.4)^{b}
Wheat	93.3 (1.4)	12.3 (1.4)^{b}	64.1 (0.5)^{a}

^{ab} Means (SE in brackets) within a column followed by the same superscript letters do not differ significantly (P<0.05).

Egg shell quality parameters: The sorghum diet produced the shells with the greatest breaking strength whereas the weakest shells occurred on the barley diet. Shell weight and shell thickness were greatest on the control and sorghum diets and lowest on the triticale and barley diets. A similar trend occurred with the percentage shell (shell weight : egg weight ratio). Yolk colour was greatest for the control and sorghum diets and lowest for the barley diet. Shell reflectivity (colour) and Haugh Units were not significantly different between diets (Table 1.5).

Table 1.5. Egg and egg shell quality for diets based on different cereal grains

	Control	Sorghum	Triticale	Barley	Wheat	P Value
Shell Reflectivity %	35.6 (0.6)	36.5 (0.8)	37.0 (0.7)	36.4 (0.5)	36.2 (0.8)	NS
Breaking Strength N	31.0 ^{ab} (1.3)	32.5 ^{a} (1.3)	28.3 ^{bc} (1.1)	26.8 ^{c} (1.1)	29.2 ^{abc} (1.1)	<0.001
Shell Wt g	5.97 ^{a} (0.06)	5.96 ^{a} (0.08)	5.34 ^{c} (0.07)	5.60 ^{b} (0.06)	5.85 ^{a} (0.06)	<0.001
Shell Thickness µm	384.7 ^{a} (3.4)	386.6 ^{a} (4.2)	356.9 ^{c} (3.6)	361.9 ^{c} (3.4)	373.9 ^{b} (3.2)	<0.001
% Shell	9.42 ^{a} (0.11)	9.49 ^{a} (0.10)	8.78 ^{b} (0.10)	8.86 ^{b} (0.09)	9.01 ^{b} (0.08)	<0.001
Yolk Colour	11.6 ^{a} (0.08)	11.7 ^{a} (0.09)	10.6 ^{b} (0.15)	9.9 ^{c} (0.13)	10.7 ^{b} (0.11)	<0.001
Haugh Units	79.1 (1.5)	80.1 (1.3)	77.7 (1.6)	77.0 (1.4)	77.5 (1.4)	NS

^{abc} Means (SE in brackets) within a row followed by the same superscript letters do not differ significantly (P<0.01).

DISCUSSION

Different strains of layers fed the same commercial diet had significantly different faecal moisture levels, which ranged from 63.8% to 68.4%. The Isa Brown strain, which had the wettest excreta in Experiment 1, was chosen for Experiment 2 to examine the effect of including different cereal grains (wheat, sorghum, barley, triticale) in the diet on wet droppings as well as egg production and egg and egg shell quality. The barley-based diet produced the highest excreta moisture (77.5%) whereas the other four diets produced excreta which were approximately 3% lower in moisture content. This is expected as barley contains a high level of soluble NSPs which increase the moisture content of excreta in broiler chickens (Gohl *et al*., 1978). An increase in excreta moisture content from 74% to 78% will make excreta from very wet to runny. Therefore even the control diet used in this experiment resulted in a higher excreta moisture content than is desirable.

The rate of lay was high in all birds, but the saleable egg percentage differed widely with the sorghum-based diet giving the least number of non-saleable eggs and barley, triticale and wheat producing significantly more non-saleable eggs. The latter three grains are so-called viscous grains due to their high soluble NSP contents, which inhibits digestion and absorption of nutrients including essential minerals. Thus, despite small differences in the ME values of the diets (not more than 0.5MJ), birds fed the barley-, wheat- and triticale-based diets ate significantly more than the birds fed the commercial control or the sorghum-based diet, presumably in order to obtain essential nutrients from diets which contained elevated levels of soluble NSPs. The reason for the markedly higher egg weight of birds fed the wheat-based diet compared with that of birds fed the commercial, sorghum- and triticale-based diets is not known.

A range of egg and shell quality parameters including shell reflectivity, breaking strength, shell weight, shell thickness, yolk colour and Haugh unit were measured during the second experiment. The sorghum diet produced shells with the greatest breaking strength whereas the weakest shells occurred on the barley diet. Shell weight and shell thickness were greatest on the control and sorghum diets and lowest on the triticale and barley diets. A similar trend occurred with the percentage shell (shell weight : egg weight ratio). Yolk colour was greatest for the control and sorghum diets and lowest for the barley diet. Shell reflectivity (colour) and Haugh Units were not significantly different between diets. These results indicate that the type of cereal grain on which a layer ration is based can affect egg shell quality. The amount of yolk pigment added to the ration needs to be adjusted in accordance with the type of cereal grain in order to optimise yolk colour.

IMPLICATIONS

1. There are strain differences in the extent of wet droppings in layers.
2. Use of barley-based diets without appropriate enzymes can lead to significantly wetter excreta.
3. Although a similar level of egg production may be achieved using sorghum, wheat, barley or triticale, the saleable egg percentage and egg shell quality can differ widely due to the type of grain is used as the energy source in the diet.

SECTION TWO.

INFLUENCE OF ELEVATED LEVELS OF CHLORIDE AND MAGNESIUM ON EXCRETA MOISTURE CONTENTS, EGG PRODUCTION, EGG AND EGG SHELL QUALITY IN LAYING HENS

INTRODUCTION

Some commonly used mineral sources contain high levels of chloride and/or magnesium, which are quite often overlooked by practical feed formulators. Electrolyte imbalances caused by unchecked mineral elements such as chloride and magnesium in layer rations are believed to contribute to problems with wet droppings and poor egg shell quality. This experiment investigated the effect of including chloride or magnesium at two and three times the normal level on excreta moisture and egg shell quality.

MATERIALS AND METHODS

Six diets were formulated to investigate the effect of increased levels of chlorine and magnesium in feed on the water content of the droppings. Diet 1 was the commercial layer diet used routinely on the farm (Millmaster Standard Layer Ration); Diet 2 had twice the recommended level of chlorine; Diet 3 was three times the recommended level of chlorine; Diet 4 was the experimental control diet; Diet 5 was twice the recommended level of magnesium; Diet 6 was three times the recommended level of magnesium. The diets, except Diet 1 which was the Millmaster layer diet used regularly at the farm, were formulated by Ridley AgriProduct using commercial specifications (Table 2.1). The birds were Isa Brown hens of 70 weeks of age, 20 birds per treatment for the experimental diets, housed two to a cage. Birds were allowed one week to adjust to the diets and then received the diets for three more weeks. Feed intake, total eggs and non-saleable eggs (broken, dirty and malformed eggs) were measured for three weeks. During the fourth week of the experiment, excreta moisture was determined and all eggs laid on the last two days were collected for detailed analyses of egg and egg shell quality.

Table 2.1. Ingredients of experimental control diet

Ingredient	%
Wheat 12.5	46.76
Sorghum 9.0	20.00
Meat Meal 50	8.00
Cottonseed meal 38	5.00
Soybean meal 48	4.00
Rice pollard 13	8.00
Limestone	7.50
Salt	0.18
DL-Methionine	0.04
L-Lysine	0.02
Layer premix	0.50
Nutrient Contents (calculated)	
Protein	16.55
ME	11.53
Available P	0.52
Methionine	0.28
Lysine	0.70
Threonine	0.53
Na	0.16
K	0.53
Cl	0.23
Na+K+Cl (meq/kg)	180.00

The chloride and magnesium levels were elevated as follow:

Diet 2 (x 2 Chlorine)	Add 0.3% Calcium chloride in place of the limestone.
Diet 3 (x 3 Chlorine)	Add 0.6% Calcium chloride in place of the limestone.
Diet 5 (x 2 Magnesium)	Add 0.5% Magnesium sulphate in place of the wheat.
Diet 6 (x 3 Magnesium)	Add 1% Magnesium sulphate in place of the wheat.

RESULTS AND DISCUSSION

The original plan was to examine the effect of chloride on wet droppings, but some commercial producers expressed concern that use of high magnesium limestone may also contribute to the problem with wet droppings in layers. So the current experiment was conducted to examine whether elevated levels of chloride and magnesium would increase the incidence of wet droppings in ISA Brown layers. Egg weight, total egg production, and non-saleable egg production did not differ significantly (P>0.05) due to elevated levels of either chloride or magnesium in the diet. There was a trend for non-saleable egg percentage to increase as chloride or magnesium level in the diet was elevated (Table 2.2). The number of non-saleable eggs was alarmingly high in this experiment. Although the birds were over 70 weeks of age, it was unexpected to find up to 20% of non-saleable eggs on a commercial standard diet. There are, however, no comparable data readily available to confirm this finding.

Table 2.2. Effect of elevated levels of chloride and magnesium on egg weight, total eggs and non-saleable egg production

Diet	Egg Weight (g)	Total Eggs (%)	Non-saleable Eggs (%)
1 (Commercial control)	65.1	66.0	18.9
2 (Cl x 2)	67.4	69.5	23.7
3 (Cl x 3)	68.4	62.6	35.7
4 (Experimental control)	67.9	69.3	20.5
5 (Mg x 2)	66.5	70.5	36.2
6 (Mg x 3)	68.1	69.0	31.4

The birds ate similar amounts of feed regardless of the chloride or magnesium levels. Also there was no difference in the excreta moisture contents of birds fed the various diets (Table 2.3).

Table 2.3. Effect of elevated levels of chloride and magnesium on feed intake and excreta moisture contents

Diet	Feed Intake (g/b/d)	Excreta Moisture (%)
1 (Commercial control)	107.5	71.3
2 (Cl x 2)	107.0	72.9
3 (Cl x 3)	105.8	73.9
4 (Experimental control)	108.3	72.2
5 (Mg x 2)	110.3	71.4
6 (Mg x 3)	111.2	73.4

There were no significant differences among treatments for any measure of egg shell quality (Table 2.4). However, shell colour tended to show some differences (P=0.10) although these were not consistently related to the treatments. Yolk colour was significantly higher (P=0.0016) for Diets 2 and 3. There was a trend (P=0.0774) for differences among groups for Haugh Units. Haugh Units were highest for Diets 2 and 5. There appear to be no deleterious effects on egg and egg shell quality of levels of chloride and magnesium in layer rations at two and three times the recommended levels of inclusion.

Table 2.4. Effect of high levels of chloride and magnesium on egg and egg shell quality

Measurement	1 (Control)	2 (Cl x 2)	3 (Cl x 3)	4 (Control)	5 (Mg x 2)	6 (Mg x 3)	P Value
Shell Reflectivity (%)	37.36	35.92	35.92	40.00	38.68	38.08	NS
	(1.00)	(1.24)	(1.05)	(1.29)	(1.48)	(1.13)	
Albumen Height (mm)	5.23	6.43	6.03	5.99	6.61	6.04	NS
	(0.32)	(0.34)	(0.38)	(0.29)	(0.32)	(0.37)	
Haugh Units	65.82	75.12	71.31	71.97	77.89	73.00	NS
	(2.88)	(2.52)	(3.48)	(2.43)	(2.26)	(2.69)	
Yolk Colour	10.43	11.28	11.15	10.76	10.79	10.60	0.002
	(0.23)	(0.12)	(0.09)	(0.17)	(0.12)	(0.15)	
Shell Breaking Strength (N)	29.01	28.86	30.72	30.46	30.52	31.05	NS
	(2.00)	(1.87)	(1.49)	(1.62)	(1.90)	(1.38)	
Shell Wt (g)	5.74	5.84	5.82	6.04	5.95	5.82	NS
	(0.12)	(0.18)	(0.12)	(0.14)	(0.16)	(0.10)	
Shell Thickness (µm)	377.2	376.0	379.6	387.7	382.8	378.7	NS
	(7.2)	(9.5)	(7.0)	(7.5)	(7.5)	(5.8)	
% Shell	8.80	8.57	8.73	8.91	9.06	8.93	NS
	(0.19)	(0.29)	(0.19)	(0.18)	(0.21)	(0.20)	

IMPLICATIONS AND RECOMMENDATIONS

The current study suggested that problems with wet droppings in layers were not related to elevated levels of chloride or magnesium in the diet although these may adversely affect saleable egg production.

SECTION THREE.

EFFECTS OF COMMERCIAL ENZYMES ON EXCRETA MOISTURE CONTENT, EGG PRODUCTION, EGG AND EGG SHELL QUALITY IN FOUR STRAINS OF LAYERS FED DIETS BASED ON BARLEY, WHEAT OR TRITICALE

INTRODUCTION

Watery and sticky droppings in layers have been a problem in the egg industry for years. The major loss to the industry is through an increased percentage of dirty eggs and shed problems such as increased odours and sticky faeces, although management and hygiene problems may also be significant. In tiered cage systems fitted with deflectors or scrapers, wet droppings can be particularly problematic. The problems with wet droppings in layers are multifaceted. Factors including nutrition, diuresis, bird strain, kidney damage from infectious bronchitis or mycotoxins, contaminants in the water and leakage in water troughs all contribute to wet droppings in layer sheds. It is well understood in broilers that increased dietary non-starch polysaccharides (NSP) cause watery and sticky droppings because these polymers increase gut viscosity and hold a large amount for water. Nowadays, NSP-degrading enzymes are used in broiler diets to improve the nutritive value of rations and to alleviate watery and sticky dropping problems (Bedford and Classen, 1992; Choct *et al.*, 1995). The use of enzymes in layer diets is not as widespread as in broilers since increases in egg production due to enzyme supplementation are not often noted. However, many layer farmers are starting to use enzymes to address wet dropping problems, especially where a tiered cage system is used and the birds are fed diets based on viscous grains (wheat, barley and triticale).

In the current study, three experiments were conducted to examine the efficacy of commercially available feed enzymes in reducing excreta moisture levels and enhancing egg production in four strains of laying hens fed barley-, wheat-, or triticale-based diets.

MATERIALS AND METHODS

Three experiments were conducted using a 5 x 4 factorial design with five diets (basal, enzymes 1 to 4) and four strains of birds (Isa Brown, Hy-Line CB, Tegel SB2, Tegel HiSex). There were thirty replicates of two birds per dietary treatment and the experiment lasted 5 weeks with the first week allowing the birds to adapt to the diets. Weekly excreta moisture was determined by collecting droppings twice a week and drying them at 80^{o}C in a force-draught oven. Saleable eggs, broken (including eggs that were visibly cracked), malformed and dirty eggs were separately recorded daily for total egg production. Weekly feed intake was determined by measuring residual feed residues in the feeders once a week. Sixty eggs from each of the five diets (a total of 300 eggs) were collected for detailed analysis of egg and egg shell quality including egg weight, gross egg shell defects, egg shell pigmentation (by reflectivity), egg length and breadth, eggshell breaking strength (by quasi-static compression), shell weight and shell thickness (using a dial comparator gauge). Shape index (breadthx100/length) and percentage shell (shell weight : egg weight) were calculated.

Internal egg quality was assessed by measuring the Haugh units of the albumen and the Roche score of the yolk.

The enzymes were supplied by four different commercial companies. Activities of the enzymes are presented in Table 3.1. The diets were formulated and manufactured by Ridley AgriProducts, Tamworth (Tables 3.2-3.4).

Table 3.1. Enzyme activities of commercial enzyme products

Code	**Inclusion** (g/tonne)	**Activity** (U/g)
Enzymes used for barley diets		
Enzyme 1	250	Amylase 100; ß-Glucanase 430; Xylanase 500
Enzyme 2	1000	Amylase 1400; ß-Glucanase 6000; Cellulase 3500; Protease 450
Enzyme 3	100	ß-Glucanase 21400; Xylanase 37700; Cellulase 10800; Pectinase 177
Enzyme 4	1000	ß-Glucanase 210; Xylanase 260
Enzymes used for wheat/triticale diets		
Enzyme 1	250	Xylanase 1000
Enzyme 2	1000	Xylanase 20000; Amylase 400; ß-Glucanase 2350; Cellulase 4000; Protease 450
Enzyme 3	100	ß-Glucanase 21400; Xylanase 37700; Cellulase 10800; Pectinase 177
Enzyme 4	1000	Xylanase 2000

Table 3.2. Composition of the barley-based diet (g/kg)

Barley 10	633.4	Meat Meal 50	110.0
Tallow	20.0	Canola Meal 36	16.7
Cottonseed Meal 41	40.0	Soybean Meal 48	40.0
Rice Pollard 13	75.0	Limestone	61.7
Salt	1.2	Choline Chloride 75	0.3
Alimet	0.5	Premix	1.2
Calculated ME value and key nutrients			
ME (MJ/kg)	11.2	Protein	170.0
Calcium	36.0	Available P	6.9

Table 3.3. Composition of the wheat-based diet (g/kg)

Wheat 12	672.3	Meat meal 50	100.0
Tallow	50.0	Canola meal 36	20.0
Cottonseed meal 41	40.0	Soybean meal 48	20.0
Rice Pollard 13	75.0	Limestone	65.0
Salt	1.2	Choline chloride 75	0.3
Alimet	0.05	Premix	1.2
Calculated ME value and key nutrients			
ME (MJ/kg)	11.6	Protein	173.7
Calcium	36.1	Available P	6.4

Table 3.4. Composition of triticale-based diet (g/kg)

Triticale	660.0	Meat meal 50	85.0
Tallow	5.0	Canola meal 36	60.0
Cottonseed meal 41	40.0	Soybean meal 48	20.0
Rice Pollard 13	55.0	Limestone	71.7
Salt	1.7	Choline chloride 75	0.47
		Premix	1.2
Calculated ME value and key nutrients			
ME (MJ/kg)	11.6	Protein	173.7
Calcium	36.1	Available P	6.4

RESULTS AND DISCUSSION

1. Barley-based diets

This trial was conducted when the birds were between 37-42 weeks of age. Average total egg production was 89.8% and was not affected by any of the treatments. The experiment was conducted in May/June, thus the barley used in the diets was already 6-7 months old. Analysis of the NSP composition revealed that its β-glucan content was very low (<2%). The gradual degradation of the soluble NSPs can occur under normal storage of grains and it has been linked with the endogenous glycanase activities (Choct and Hughes, 1997). Therefore, the barley supported excellent egg production without requiring exogenous enzyme supplementation. Daily feed intake was markedly ($P<0.01$) influenced by both diet and breed. Birds fed the control diet consumed a larger amount of feed than those fed the enzyme-containing diets. Hy-Line CB consumed less feed than all the other strains. The percentage of dirty eggs was 2.4% and was not influenced by diet and breed. The percentage of broken eggs was 6.5% of the total and was markedly affected by diet ($P<0.01$) as well as by breed ($P<0.05$). There was also a significant ($P<0.01$) diet x breed interaction with responses of enzymes differing due to breeds of birds. The excreta moisture content differed widely ($P<0.01$) due to both diet and breed. There was a significant ($P<0.01$) diet x breed interaction on this variable as well, with some breeds of birds responding differently depending on the enzyme used. All data are shown in Table 3.5.

2. Wheat-based diets

This trial was conducted when the birds were between 44-49 weeks of age. Average total egg production was 81.8% and was not affected by any of the treatments. Daily feed intake was markedly ($P<0.01$) influenced by both diet and breed with birds fed the Enzyme 2 diet consuming a larger amount of feed than those fed all the other diets except the Enzyme 4 diet. Tegel SB2 consumed more feed than Isa Brown birds. The percentage of dirty eggs was influenced by diet but not by breed with Enzyme 2 significantly increasing it from 2.3% in the Control to 4.0%. The percentage of broken eggs averaged 8.3% and was markedly affected by diet ($P<0.01$) as well as by breed ($P<0.05$). Thus, it ranged from 7.4% in birds fed the control diet to 11.2% in those fed Enzyme 2 diet; and 6.5% in Hy-Line CB to 10.2% in Tegel SB2. There was also a significant ($P<0.05$) diet x breed interaction with responses to enzymes differing due to breeds of birds. The excreta moisture content differed significantly ($P<0.01$) due to both diet and breed although the magnitude of differences was within 1%. There was a significant ($P<0.01$) diet x breed interaction on this parameter as well with same breeds of birds responding differently depending on the enzyme source. All data are shown in Table 3.6.

3. Triticale-based diets

This trial was conducted when the birds were between 51-56 weeks of age. Average total egg production was 80.6%. A significant strain effect on egg production was observed in this trial with the production of Hy-Line CB starting to decline, but diet had not effect. Some strains responded to enzymes differently, leading to a significant diet x breed interaction. Daily feed intake was not influenced either by diet or by breed. The percentage of broken eggs was generally high and was significantly affected by diet. Enzyme 2 increased broken eggs from 9.8% in the Control to 15.5%. The percentage of dirty eggs was not influenced by diet, but differed significantly between strains with the Hy-Line CB producing the lowest percentage (2.3%) of dirty eggs. The excreta moisture content differed significantly ($P<0.01$) due to both diet and breed. Again there was a significant diet x strain interaction on excreta moisture. All data are shown in Table 3.7.

Table 3.5. Responses in total, broken and dirty egg production, feed intake (g/d/bird) and excreta moisture (EM) levels of four strains of birds fed a barley-based diet with four commercial enzyme products (37-42 weeks of age)

		Total Lay %	Broken%	Dirty%	Intake	EM%
Diet						
	Control	89.7^{a}	6.5^{b}	2.4^{a}	110.8^{a}	72.1^{a}
	Enzyme 1	90.7^{a}	5.1^{b}	2.1^{a}	106.2^{b}	70.8^{c}
	Enzyme 2	89.9^{a}	8.4^{a}	2.6^{a}	106.0^{b}	71.7^{ab}
	Enzyme 3	89.9^{a}	6.7^{ab}	2.5^{a}	108.4^{b}	71.6^{ab}
	Enzyme 4	88.3^{a}	5.7^{b}	2.4^{a}	105.8^{b}	71.2^{bc}
Breed						
	Isa Brown	89.4^{a}	7.5^{a}	2.2^{a}	107.5^{a}	71.4^{b}
	Hy-Line CB	89.5^{a}	5.3^{b}	2.4^{a}	104.9^{a}	71.2^{b}
	Tegel SB2	90.0^{a}	6.9^{a}	2.5^{a}	108.8^{a}	71.0^{b}
	Tegel HiSex	88.8^{a}	6.4^{ab}	2.4^{a}	109.2^{a}	72.2^{a}
Diet x Breed						
Control	Isa Brown	89.5	9.2	2.4	113.9	72.2
	Hy-Line CB	90.8	3.8	2.0	106.6	71.8
	Tegel SB2	89.5	7.9	2.3	108.0	71.1
	Tegel HiSex	88.8	5.3	2.8	114.5	73.1
Enzyme 1	Isa Brown	91.0	4.0	1.1	103.6	70.5
	Hy-Line CB	91.4	5.5	2.0	105.4	69.9
	Tegel SB2	89.1	6.5	3.2	108.0	70.5
	Tegel HiSex	91.3	4.7	2.0	107.8	72.4
Enzyme 2	Isa Brown	90.0	8.0	1.5	103.2	70.6
	Hy-Line CB	91.6	10.5	2.8	105.3	71.6
	Tegel SB2	88.3	8.4	3.5	109.7	72.8
	Tegel HiSex	89.7	7.0	2.4	105.8	71.7
Enzyme 3	Isa Brown	89.6	7.9	3.0	107.3	71.5
	Hy-Line CB	90.4	3.1	1.9	104.1	72.1
	Tegel SB2	90.5	7.2	2.6	108.2	70.6
	Tegel HiSex	89.0	8.7	2.4	113.9	72.1
Enzyme 4	Isa Brown	89.3	8.4	3.0	109.3	72.4
	Hy-Line CB	89.7	3.9	3.2	103.2	70.5
	Tegel SB2	90.5	4.6	1.1	106.4	70.1
	Tegel HiSex	83.7	6.2	2.6	104.1	71.7
Probability Values						
Diet		0.488	0.006	0.854	0.001	0.003
Breed		0.385	0.053	0.830	0.014	0.009
Diet x Breed		0.611	0.012	0.101	0.125	0.002

^{ab} Means within a column for diet or breed with the same superscript do not differ at $P<0.05$.

Table 3.6. Responses in total, broken and dirty egg production, feed intake (g/bird/d) and excreta moisture (EM) levels of four strains of birds fed a wheat-based diet with four commercial enzyme products (44-49 weeks of lay)

		Total Lay %	Broken %	Dirty %	Intake	EM%
Diet						
	Control	80.7	7.4^{b}	2.3^{b}	112.0^{b}	69.6^{ab}
	Enzyme 1	84.3	7.4^{b}	2.6^{b}	109.8^{b}	69.1^{b}
	Enzyme 2	81.6	11.2^{a}	4.0^{a}	116.7^{a}	70.3^{a}
	Enzyme 3	82.5	7.7^{b}	2.9^{ab}	110.8^{b}	68.8^{b}
	Enzyme 4	79.7	7.9^{b}	2.6^{b}	112.9^{ab}	69.5^{ab}
Breed						
	Isa Brown	82.0	7.9^{bc}	2.8	110.9^{b}	69.8^{a}
	Hy-Line CB	80.1	6.5^{c}	2.4	111.6^{ab}	68.7^{b}
	Tegel SB2	80.4	10.2^{a}	3.3	115.4^{a}	69.0^{b}
	Tegel HiSex	84.0	8.6^{ab}	3.1	111.8^{ab}	70.3^{a}
Diet x Breed						
Control	Isa Brown	83.6	9.2	2.3	115.1	70.0
	Hy-Line CB	83.0	4.4	1.7	109.9	69.3
	Tegel SB2	84.5	8.6	2.3	114.2	69.6
	Tegel HiSex	88.4	7.2	2.9	108.7	69.7
Enzyme 1	Isa Brown	83.3	5.0	2.0	106.4	68.3
	Hy-Line CB	82.9	8.1	1.9	109.5	68.4
	Tegel SB2	81.7	9.7	3.6	114.4	68.9
	Tegel HiSex	89.1	6.8	3.1	108.9	70.6
Enzyme 2	Isa Brown	84.3	9.0	2.6	110.8	70.6
	Hy-Line CB	76.0	12.9	4.6	122.9	68.2
	Tegel SB2	82.9	13.0	4.8	118.0	70.9
	Tegel HiSex	83.2	10.0	3.9	115.0	71.5
Enzyme 3	Isa Brown	86.3	8.6	3.9	110.6	69.8
	Hy-Line CB	80.3	2.9	1.3	106.5	68.4
	Tegel SB2	79.4	8.5	3.9	111.8	67.2
	Tegel HiSex	83.8	10.7	2.7	114.1	69.9
Enzyme 4	Isa Brown	76.5	7.8	3.4	111.9	70.5
	Hy-Line CB	82.3	4.3	2.5	109.2	68.9
	Tegel SB2	79.8	11.2	1.7	118.3	68.7
	Tegel HiSex	80.1	8.4	3.0	112.4	69.9
Probability Values						
Diet		0.120	0.004	0.025	0.092	0.001
Breed		0.067	0.005	0.268	0.018	0.006
Diet x Breed		0.427	0.037	0.150	0.152	0.020

^{ab} Means within a column for diet or breed with the same superscript do not differ at $P<0.05$

Table 3.7. Responses in total, broken and dirty egg production, feed intake (g/bird/d) and excreta moisture (EM) levels of four strains of birds fed a triticale diet with four commercial enzyme products (51-56 weeks of lay)

		Total Lay %	Broken %	Dirty %	Intake	EM%
Diet						
	Control	80.2	9.8^{b}	3.1	110.1	71.8^{b}
	Enzyme 1	81.6	8.6^{b}	4.0	110.7	72.8^{a}
	Enzyme 2	81.0	15.5^{a}	4.2	109.5	72.1^{ab}
	Enzyme 3	80.4	10.2^{b}	3.3	106.9	71.7^{b}
	Enzyme 4	79.7	9.7^{b}	2.9	107.1	72.4^{ab}
Breed						
	Isa Brown	81.6^{ab}	10.8^{ab}	3.7^{a}	109.2	72.5^{b}
	Hy-Line CB	77.8^{b}	9.3^{b}	2.3^{b}	108.1	71.1^{c}
	Tegel SB2	79.5^{ab}	12.5^{a}	3.6^{a}	109.2	71.9^{b}
	Tegel HiSex	83.2^{a}	10.4^{ab}	4.3^{a}	108.9	73.3^{a}
Diet x Breed						
Control	Isa Brown	82.6	13.1	3.1	111.7	72.3
	Hy-Line CB	79.4	7.7	1.6	107.7	71.6
	Tegel SB2	75.6	10.6	2.8	112.2	71.3
	Tegel HiSex	83.1	7.8	4.8	108.7	72.0
Enzyme 1	Isa Brown	76.6	6.6	3.7	109.6	72.1
	Hy-Line CB	78.2	9.5	2.3	112.8	71.0
	Tegel SB2	81.8	9.5	5.0	109.8	73.4
	Tegel HiSex	89.6	8.8	5.0	110.7	74.8
Enzyme 2	Isa Brown	81.6	13.0	2.7	106.3	70.4
	Hy-Line CB	74.4	15.8	4.6	111.2	71.1
	Tegel SB2	85.4	18.1	4.7	110.0	73.0
	Tegel HiSex	82.6	15.0	4.8	110.3	73.9
Enzyme 3	Isa Brown	86.4	11.4	5.0	107.9	73.2
	Hy-Line CB	76.1	6.2	1.2	103.0	70.7
	Tegel SB2	76.6	11.6	4.2	108.8	70.2
	Tegel HiSex	82.4	11.8	2.7	108.0	72.8
Enzyme 4	Isa Brown	81.0	10.1	4.1	110.3	74.4
	Hy-Line CB	81.0	7.1	2.1	105.9	71.1
	Tegel SB2	78.3	12.7	1.2	105.2	71.3
	Tegel HiSex	78.5	8.9	4.0	106.8	72.8
Probability Values						
Diet		0.210	0.001	0.145	0.356	0.019
Breed		0.027	0.034	0.009	0.949	0.001
Diet x Breed		0.049	0.165	0.052	0.895	0.001

[ab] Means within a column for diet or breed with the same superscript do not differ at $P<0.05$

4. Enzymes

Diets based on barley, wheat or triticale supported production levels comparable to or better than commercial production standards. None of the four enzymes used in the current trial had an effect on the total egg production. This was perhaps expected because firstly, the experiments were designed to examine excreta moisture contents, and therefore the duration of the trials was not long enough to demonstrate a difference in total egg production, and secondly, the production levels were high for the control birds throughout the study. However, the number of broken eggs differed widely ($P<0.01$) due to diet and breed of birds. It also increased as the flock aged (6.5% to 9.8% over a 14-week period). Whilst some enzymes reduced the overall non-saleable egg production, others markedly increased it. For example, Enzyme 2 increased broken egg percentage from 6.5% to 8.4%, from 7.4% to 11.2% and from 9.8% to 15.5% in birds fed barley-, wheat- and triticale-based diets, respectively. Since there were no apparent problems with egg shell quality in birds fed this diet (see below), the mechanisms by which this occurred may be due to an excess level of enzyme activity leading to damage to the digestive tract. There is anecdotal evidence that enzymes may influence the behaviour of birds (Phil Glatz, unpublished data). The current trials used low temperature pelleting ($<75^{o}C$), which would have allowed a high level of enzyme activity to escape undamaged during the feed manufacturing. Further studies are required to verify this finding in a large-scale, long term experiment. The Enzyme x Strain interactions are difficult to interpret, although these have previously been reported (Bedford, 1997). Although the experiment period (five weeks) for the current trial was not long compared to many production studies conducted for laying hens, the experimental design was robust with sixty birds per treatment so the observed effect cannot be discounted.

Feed represents 65-70% of production cost for laying hens and any saving in feed intake can bring economic benefits to the producer. In the current study, the feed intakes of the birds were not high and the enzymes markedly ($P<0.01$) reduced the daily feed intake of birds fed the barley diets from 110.8g per day to an average of 106.6 g per day.

The moisture level of the excreta from birds given the barley diets was significantly ($P<0.01$) reduced by enzymes. However, enzymes had an inconsistent effect on excreta moisture levels in birds fed the wheat and triticale diets. The droppings from Isa Brown and HiSex birds tended to be wetter than the other strains in all three experiments. The interactions between enzymes and bird strains are highly complex and difficult to draw a clear conclusion as to their practical significance from the current study.

5. Egg and egg shell quality

The effects of the different commercial enzymes on egg and egg shell quality are summarised in Tables 3.8-3.10. Egg weight was not significantly affected by the inclusion of feed enzymes for any of the diets. However, the colour of the shells was significantly lighter (higher reflectivity) when enzymes were added to both the barley-based and wheat-based diets. The addition of all four enzymes to the barley-based diet resulted in significant improvements in egg shell quality, as indicated by increased egg shell breaking strength, shell weight and percentage shell (ratio of shell weight to egg weight). For the wheat-based diet, improvements in shell breaking strength and shell weight were observed for Enzymes 1, 3 and 4 but not for Enzyme 2. In addition, the percentage shell was improved for Enzymes 1 and 3 but not for Enzymes 2 and 4. The internal quality of the eggs, as indicated by Haugh Units was reduced when enzymes were added to both the barley-based and wheat-based diets. Yolk colour was significantly reduced by the presence of Enzymes 3 and 4 for the barley-based and wheat-based diets and by Enzyme 3 for the triticale-based diet. The incidence of cracked and broken eggs was generally lower when enzymes were added. Significant differences were observed among strains of bird for all of the dietary treatments. As has been described previously (Roberts *et al.,* 1997), egg weight was greater in the two imported strains (Isa Brown and Tegel HiSex) than for the Australian strains (Hy-Line CB and Tegel SB2) and the imported strains had darker coloured egg shells (as indicated by lower shell reflectivity). Shell weight was consistently higher for the imported strains, with percentage shell generally higher also. However, the strength of the egg shells, as measured by egg shell breaking strength, was not consistently related to whether the strain was imported or Australian-bred. For the wheat-based and triticale-based diets, there were no significant differences among strains. For the barley-based diet, shell breaking strength was highest in the HiSex and Tegel SB2 birds and lowest in the Hy-Line CB, with the Isa birds intermediate. There were significant differences among strains for internal egg quality (Haugh Units and yolk colour) although this was not related to whether the strain was Australian or imported. There were significant differences in egg and egg shell quality among the three diets. However, because the trial using barley-based diets was conducted in April-May, 1998, the trial with wheat-based diets was in August-September, and the triticale trial was September-October, comparisons among the trials must take into account the different times of year and the different ages of the birds. Most of the differences among the three trials could be accounted for by the different ages of the birds at the times the trials were conducted. Benefits arising from the use of enzyme preparations in layer diets must be offset against any negative effects that the enzymes may have on the eggs produced. While concern has been expressed about negative effects on egg shell quality (Richards, 1998), studies have reported improvements in production (van der Klis *et al.,* 1997) and generally no effect on egg shell quality (Carlos and Edwards, 1998; Gordon and Roland, 1997). The present study demonstrated improvements in egg shell quality as the result of adding commercial enzyme preparations to barley-based and wheat-based layer diets. However, for these diets, the enzymes caused a small reduction in the colour of the egg shells and a reduction in albumen quality. Minor effects on yolk colour were also observed for some enzymes. Adding feed enzymes to the triticale-based diet had no beneficial effects on egg shell quality.

Table 3.8. Effect of different commercial enzymes on egg and egg shell quality in layers receiving a barley-based diet. C=control; E=enzyme; S=strain

Egg Quality Measurement	Strain	Treatment Group					Statistical Analysis P Values		
		C	E1	E2	E3	E4	E	S	E*S
Egg Weight (g)	**ALL**	**64.07**	**63.55**	**63.78**	**63.00**	**63.59**	NS	<.0001	NS
	Isa	66.64	65.66	65.47	63.78	66.75			
	CB	60.25	59.95	59.02	59.38	59.02			
	SB2	62.71	61.26	62.63	61.03	62.08			
	HiSex	66.66	67.30	67.97	67.79	66.49			
Shell Colour Lightness (Percentage Reflectivity)	**ALL**	**42.86**	**44.36**	**45.23**	**44.73**	**45.23**	.0014	<.0001	.0201
	Isa	37.37	38.37	41.22	39.77	37.75			
	CB	51.17	52.62	54.80	52.77	54.85			
	SB2	46.25	46.55	48.17	48.62	49.75			
	HiSex	36.62	39.87	36.70	37.72	38.55			
Breaking Strength (Newtons)	**ALL**	**33.18**	**36.68**	**36.06**	**37.14**	**37.56**	<.0001	.0103	NS
	Isa	33.48	36.75	35.53	35.78	37.91			
	CB	32.77	34.79	34.29	35.57	36.81			
	SB2	31.32	37.76	37.86	38.25	38.28			
	HiSex	35.27	37.40	36.50	38.93	37.25			
Shell Weight (g)	**ALL**	**5.55**	**5.76**	**5.83**	**5.72**	**5.82**	<.0001	<.0001	.0135
	Isa	5.75	6.10	6.07	5.73	6.15			
	CB	5.20	5.20	5.21	5.27	5.30			
	SB2	5.40	5.68	5.79	5.65	5.72			
	HiSex	5.83	6.05	6.25	6.22	6.08			
Percentage Shell (%)	**ALL**	**8.67**	**8.96**	**9.15**	**9.08**	**9.16**	<.0001	<.0001	NS
	Isa	8.64	9.31	9.29	8.98	9.23			
	CB	8.65	8.65	8.84	8.89	8.99			
	SB2	8.61	8.85	9.24	9.26	9.22			
	HiSex	8.75	9.00	9.22	9.20	9.16			
Haugh Units	**ALL**	**91.03**	**90.23**	**88.98**	**86.18**	**85.24**	<.0001	<.0001	.0053
	Isa	91.97	88.80	86.30	88.00	82.82			
	CB	95.20	93.40	92.05	86.72	86.40			
	SB2	87.77	90.50	90.05	84.67	86.05			
	HiSex	89.15	88.40	87.52	85.30	85.70			
Yolk Colour Score	**ALL**	**10.04**	**10.29**	**10.54**	**9.78**	**9.35**	<.0001	<.0001	<.0001
	Isa	9.90	10.45	10.72	9.37	9.82			
	CB	10.15	10.45	10.27	10.15	9.52			
	SB2	9.77	10.07	10.12	9.55	8.62			
	HiSex	10.35	10.17	11.05	10.02	9.42			

Table 3.9. Effect of different commercial enzymes on egg and egg shell quality in layers receiving a wheat-based diet. C=control; E=enzyme; S=strain

Egg Quality Measurement	Strain	Treatment Group					Statistical Analysis P Values		
		C	E1	E2	E3	E4	E	S	E*S
Egg Weight (g)	**ALL**	**65.57**	**65.73**	**65.75**	**65.33**	**66.21**	NS	<.0001	.0027
	Isa	68.32	66.63	67.07	67.29	68.73			
	CB	62.02	62.03	60.19	61.04	62.18			
	SB2	64.43	64.52	66.94	63.01	65.03			
	HiSex	67.47	69.75	68.65	69.95	68.87			
Shell Colour Lightness (Percentage Reflectivity)	**ALL**	**41.69**	**41.17**	**42.65**	**43.05**	**43.81**	.0003	<.0001	NS
	Isa	36.15	34.80	37.77	37.32	38.55			
	CB	48.35	47.50	49.10	51.25	52.60			
	SB2	45.97	44.72	47.05	46.10	47.53			
	HiSex	36.27	37.65	36.82	37.52	36.62			
Breaking Strength (Newtons)	**ALL**	**32.59**	**34.71**	**31.86**	**35.08**	**33.91**	.0050	NS	NS
	Isa	33.30	32.66	33.90	31.05	33.05			
	CB	32.66	33.90	31.05	33.05	35.31			
	SB2	32.62	35.73	31.52	34.92	33.80			
	HiSex	31.77	37.19	32.56	35.38	35.75			
Shell Weight (g)	**ALL**	**5.90**	**6.02**	**5.80**	**5.93**	**5.93**	NS	<.0001	NS
	Isa	6.23	6.24	6.03	6.15	6.15			
	CB	5.38	5.45	5.21	5.33	5.41			
	SB2	5.90	5.96	5.83	5.82	5.85			
	HiSex	6.07	6.40	6.09	6.41	6.29			
Percentage Shell (%)	**ALL**	**9.00**	**9.16**	**8.82**	**9.09**	**8.96**	.0007	<.0001	NS
	Isa	9.12	9.37	8.99	9.15	8.95			
	CB	8.68	8.79	8.66	8.72	8.72			
	SB2	9.16	9.26	8.73	9.27	9.05			
	HiSex	9.01	9.19	8.87	9.19	9.16			
Haugh Units	**ALL**	**85.86**	**82.87**	**82.53**	**79.71**	**83.28**	<.0001	<.0001	.0002
	Isa	85.32	84.02	80.25	80.65	81.10			
	CB	89.52	87.3)	82.77	83.21	84.02			
	SB2	82.35	82.52	81.50	77.55	82.48			
	HiSex	86.25	77.55	85.57	77.42	85.50			
Yolk Colour Score	**ALL**	**11.07**	**11.04**	**10.93**	**10.71**	**10.50**	<.0001	.0004	.1500
	Isa	11.10	11.07	10.82	10.50	10.32			
	CB	11.22	11.17	11.12	11.07	10.47			
	SB2	11.05	11.07	11.00	10.60	10.61			
	HiSex	10.90	10.85	10.75	10.65	10.57			

Table 3.10. Effect of different commercial enzymes on egg and egg shell quality in layers receiving a triticale-based diet. C=control; E=enzyme; S=strain

Egg Quality Measure-ment	Strain	Treatment Group					Statistical Analysis P Values		
		C	E1	E2	E3	E4	E	S	E*S
Egg Weight (g)	**ALL**	**65.51**	**65.57**	**65.06**	**64.90**	**65.98**	NS	<.0001	.0183
	Isa	67.97	65.49	67.16	67.00	69.55			
	CB	61.67	61.86	61.82	60.50	62.14			
	SB2	65.15	64.97	63.75	65.07	63.55			
	HiSex	67.26	69.96	67.48	67.02	68.55			
Shell Colour Lightness (Percentage Reflectivity)	**ALL**	**45.06**	**44.52**	**45.26**	**44.79**	**44.50**	NS	<.0001	NS
	Isa	39.00	39.17	38.97	39.12	38.02			
	CB	52.72	51.57	53.60	52.55	52.92			
	SB2	50.10	47.92	49.40	48.17	48.82			
	HiSex	38.42	39.40	39.75	39.32	38.48			
Breaking Strength (Newtons)	**ALL**	**33.98**	**33.97**	**32.91**	**35.15**	**34.75**	NS	NS	NS
	Isa	36.85	33.67	32.37	35.59	34.25			
	CB	33.47	32.49	31.56	32.79	31.90			
	SB2	33.91	32.79	35.03	35.54	36.16			
	HiSex	33.93	36.84	32.66	36.65	36.65			
Shell Weight (g)	**ALL**	**5.86**	**5.78**	**5.82**	**5.85**	**5.87**	NS	<.0001	.0052
	Isa	6.29	5.99	6.01	6.07	6.22			
	CB	5.32	5.32	5.19	5.23	5.26			
	SB2	5.80	5.54	5.98	5.88	5.67			
	HiSex	6.00	6.24	6.10	6.18	6.32			
% Shell	**ALL**	**8.94**	**8.84**	**8.97**	**9.03**	**8.91**	NS	<.0001	.0085
	Isa	9.26	9.18	8.99	9.08	8.97			
	CB	8.63	8.62	8.42	8.69	8.46			
	SB2	8.91	8.56	9.41	9.07	8.94			
	HiSex	8.94	8.96	9.05	9.27	9.23			
Haugh Units	**ALL**	**82.80**	**83.24**	**84.09**	**81.41**	**82.33**	NS	.0009	.0012
	Isa	82.27	80.97	82.85	86.87	83.27			
	CB	86.35	85.45	87.92	81.72	83.3			
	SB2	79.27	82.52	83.15	81.72	80.74			
	HiSex	83.30	84.02	82.45	75.30	81.87			
Yolk Colour	**ALL**	**10.73**	**10.94**	**10.91**	**10.38**	**10.80**	<.0001	NS	NS
	Isa	10.82	10.90	10.82	10.40	10.80			
	CB	11.02	10.97	10.97	10.47	10.82			
	SB2	10.37	10.97	10.95	10.32	10.92			
	HiSex	10.67	10.90	10.87	10.30	10.65			

IMPLICATIONS AND RECOMMENDATIONS

1. Enzyme supplementation of layer diets based on barley can alleviate the problem of wet droppings and also reduce feed intake without affecting production.
2. The significant Enzyme x Strain interactions demonstrated in all three experiments indicates clearly that enzymes that reduce excreta moisture in one strain may not work in a different strain. It is recommended that enzyme data obtained using one strain of birds be used with caution when applying them to another strain.
3. The number of broken and cracked eggs increases as the flock ages; some enzymes can alleviate this problem whilst others worsen it. Appropriate dosage rates could be important when using enzymes in layer diets. The effect of different doses of enzymes on bird behaviour should be examined.

SECTION FOUR.

RELATIONSHIP BETWEEN INTESTINAL SPIROCHAETES AND WET LITTER PROBLEMS

INTRODUCTION

Colonisation of adult birds with intestinal spirochaetes has been associated with a number of clinical signs and production problems, including diarrhoea, increased fat content of the faeces, faecal staining of eggshells, delayed onset of egg laying, reduced egg weights, reduced growth rates, increased feed consumption and poor digestion of feed (see Stephens and Hampson, A Final Report to RIRDC on Spirochaetes in Chickens).

This is part of a project funded by RIRDC to examine the occurrence of spirochaetes in the Australian commercial flocks of poultry. We collaborated with Ms Carol Stephens and Dr David Hampson of Murdoch University on the project to investigate whether there was a link between intestinal colonisation with spirochaetes and wet droppings in poultry. This report is an excerpt of a paper submitted to Avian Pathology by Stephens and Hampson (1999).

RESULTS AND DISCUSSION

Information on the occurrence of wet litter or production problems was only available for 54 of the 69 flocks tested. Of these, 34 reported no disease signs and spirochaetes were isolated from five (14.7%). Twenty flocks reported disease signs, including wet litter, production drop or both. Fourteen of these flocks (70%) were colonised with spirochaetes. These differences were highly statistically significant in the chi-square test with Yates adjustment ($P < 0.0001$). Spirochaetes were not isolated from six flocks that reported problems of wet litter. Four of these were broiler flocks from one company, located in the same area, and the wet litter was suspected to be associated with the poor quality of their water supply. The other two flocks with diarrhoea but no spirochaetes were unrelated broiler breeder flocks.

Spirochaetes were obtained from 11 layer flocks for which adequate disease information was available. Of these, nine (81.8%) reported wet litter and/or production drop, while two flocks were healthy. Adequate disease information was only available for seven of the eight broiler breeder flocks that were positive for spirochaetes. Of these seven, five (71.4%) reported problems, with three having wet litter and two wet litter associated with reduced production. The other two flocks reported no disease signs. Average faecal moisture was higher for both broiler breeder and layer flocks which were colonised with intestinal spirochaetes than for non-colonised flocks by 14%, which was highly significant ($p<0.001$).

It is concluded that colonisation with spirochaetes can lead to wet litter problems in poultry, without any associated with nutrition.

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PUBLICATIONS ARISING FROM THE PROJECT UNTIL SUBMISSION OF THE FINAL REPORT

Roberts, J.R., Ball, W. and Leary, A. (1998). Effects of different cereal grains on egg and egg shell quality in laying hens. Australian Poultry Science Symposium, 10: 199.

Roberts, J.R., Choct, M. and Ball, W. (1999). Effect of different commercial enzymes on egg and egg shell quality in four strains of laying hens. Australian Poultry Science Symposium, 11: 139-143.

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Roberts, J.R., Choct, M. and Ball, W. (1999). The effect of adding commercial enzyme preparations to feed on egg and egg shell quality in laying hens. Proceedings of the Queensland Poultry Science Symposium (in press).

Roberts, J.R. and Choct, M. (1999). The use of commercial enzymes and egg and egg shell quality in four strains of laying hens. Proceedings of the Italian Poultry Conference (in press).

Compendium Summary

Project Title

The Significance of Wet Droppings in Laying Hens.

Objectives

To investigate the genetic and nutritional basis for watery and sticky droppings in layers and to develop strategies minimising it.

Background

Dirty eggs represent approximately 4% of total egg production, which accounts for an estimated loss in revenue of $10 million per annum. In addition, sticky and watery excreta can make cage and shed cleaning difficult and time-consuming. There are also concerns that wet droppings may lead to increased gas production in the shed, hence an elevated odour problem for the surrounding environment.

Research

A total of six experiments were conducted. The first experiment examined strain differences in excreta moisture. For the other five experiments, excreta moisture as well as saleable and non-saleable egg production and egg and egg shell quality were measured to examine: (a) the effect of different cereal bases in commercial layer diets; (b) the influence of high levels of chloride and magnesium levels; (c) the efficacy of 4 different enzyme products in 4 strains of birds fed diets based on three different cereals (barley, wheat and triticale). Information was also collected through a collaboration with researchers from another RIRDC project (UMU-23E) which investigated the relationship between colonisation of poultry with intestinal spirochaete bacteria and incidence of wet droppings.

Outcomes

1. There were clear genetic differences in the excreta moisture content of laying hens. Isa Brown and Tegel HiSex strains had wetter excreta ($P<0.01$) compared with Hy-Line CB.
2. Barley, wheat and triticale diets produced markedly different excreta moisture contents with barley causing the wettest excreta. Total egg production was similar regardless of the cereal base, but egg shell quality was poorer and the number of non-saleable was higher with barley, wheat and triticale than sorghum and standard commercial diets.
3. High chloride or magnesium levels did not affect excreta moisture, total egg production and egg and egg shell quality although the number of non-saleable eggs tended to be elevated.
4. In barley diets, enzymes reduced the problems with wet droppings and also reduced feed intake without affecting production. Different enzyme products worked differently depending on the strain of birds. The number of broken and cracked eggs increased as the flock aged; some enzymes alleviated this problem whilst others worsened it.
5. Birds with intestinal spirochaetes generally had wetter ($P<0.01$) excreta.

Implications

1. Wet dropping problems can, to an extent, be alleviated by choosing appropriate strains of birds.
2. Although a similar level of total egg production may be achieved using sorghum, wheat, barley or triticale, the saleable egg percentage and egg shell quality can differ widely due to the type of grain is used as the energy source in the diet. The use of barley-based diets can lead to significantly wetter excreta.
3. High levels of chloride or magnesium in the diet have no effect on excreta moisture, but may adversely affect saleable egg production.
4. Enzymes are generally beneficial in reducing excreta moisture and improving egg and egg shell quality, especially in birds fed barley, wheat or triticale diets. However, there is a significant enzyme x strain interaction. Thus, an enzyme that reduces excreta moisture in one strain, may not work in a different strain. It is recommended that enzyme data obtained using one strain of birds be used with caution when applying them to another strain.
5. The number of broken and cracked eggs increases as the flock ages; some enzymes can alleviate this problem whilst others worsen it. Appropriate dosage rates could be important when using enzymes in layer diets. The effect of different doses of enzymes on bird behaviour should be examined.
6. Colonisation with spirochaetes may cause wet litter problems, perhaps independent of nutrition.

Publications

Roberts, J.R., Ball, W. and Leary, A. (1998). Effects of different cereal grains on egg and egg shell quality in laying hens. Australian Poultry Science Symposium, 10: 199.

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Project Details

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