RURAL INDUSTRIES RESEARCH
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Egg Program

Nutritive Value of Lupins for Laying Hens

A report for the Rural Industries Research and Development Corporation

By R J Hughes

October 1997

ISBN *(RIRDC to allocate)*
ISSN 1440-6845

"Nutritive Value of Lupins for Laying Hens"
Publication no …….
Project no. DAS-44A

Researcher Contact Details

Name	Mr R. J. Hughes
Address	Pig and Poultry Production Institute University of Adelaide Roseworthy SA 5371
Phone:	08 8303 7788
Fax:	08 8303 7977
Email:	Hughes.bob@pi.sa.gov.au
Website:	

RIRDC Contact Details
Rural Industries Research and Development Corporation
Level 1, AMA House
42 Macquarie Street
BARTON ACT 2600
PO Box 4776
KINGSTON ACT 2604

Phone: 02 6272 4539
Fax: 02 6272 5877
Email: rirdc@netinfo.com.au
Website: http://www.rirdc.gov.au

Published in December 1997
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FINAL REPORT ON RIRDC PROJECT DAS 44A

EGG INDUSTRY RESEARCH AND DEVELOPMENT COMMITTEE

NUTRITIVE VALUE OF LUPINS FOR LAYING HENS

prepared by

R J HUGHES

Pig and Poultry Productions Institute

Nutrition Research Laboratory

University of Adelaide, Roseworthy Campus

Roseworthy 5371

South Australia

October 1997

EGG INDUSTRY RESEARCH AND DEVELOPMENT COMMITTEE

Project Number:	DAS 44A
Project Title:	NUTRITIVE VALUE OF LUPINS FOR LAYING HENS
Organisation:	South Australian Research & Development Institute (SARDI)
Principal Investigator	Mr R J Hughes
Research Staff	Dr P.C. Glatz, Senior Research Scientist, SARDI Dr R.J. van Barneveld, Senior Research Scientist, SARDI Mr A. Kocher, Research Officer, SARDI
Address:	SARDI Nutrition Research Laboratory Roseworthy Campus University of Adelaide Roseworthy SA 5371
Telephone:	(08) 8303 7788
Facsimile:	(08) 8303 7977
E-mail:	hughes.bob@pi.sa.gov.au
Commencement:	1/1/96
Completion:	30/9/97
Funds Provided Through RIRDC:	$15,450 1995-96 $17,360 1996-97 $32,810 Total

Funds Provided From Other Sources

SARDI provided about $35,000 per annum for salary costs of professional and technical staff, purchase of feed ingredients and costs associated with steam pelleting and transport of experimental diets to and from a commercial feed mill. Additional funds were provided for purchase of commercial cages ($18,000), and a further $3,000 for manufacture of feed hoppers since the feed troughs and partitions supplied with the cages proved to be unsuitable for experimental work.

The Grain Pool of WA and Finnfeeds International Ltd each contributed $5,000 towards the costs of these studies. In addition, the Grain Pool covered the costs of supply and transport of lupin material from WA to SA. Finnfeeds International provided enzyme product at no charge and paid the consultant's fee for assistance with the formulation of experimental diets.

CONTENTS

A. SUMMARY

Nutritive values of Australian sweet lupin *Lupinus angustifolius* cultivar Gungurru and white lupin *Lupinus albus* cultivar Kiev mutant were assessed in a series of four experiments each of 7 - 8-week duration which were conducted on the same flock of 960 Tegel Tint and Tegel SB2 hens.

Experiment #1 examined the effects of lupin species (*L. angustifolius* cv Gungurru and *L. albus* cv Kiev mutant), removal of seed-coat, and dietary addition of a proprietary enzyme product (Avizyme 2300 at 1kg/tonne) in wheat-based diets on the performance of laying hens in the period 36 - 44 weeks of age. Inclusion rates of lupin were Gungurru wholeseed 27.9%, Gungurru kernel 18.9%, Kiev wholeseed 18.2%, and Kiev kernel 15.0%. Steam-pelleted diets contained ME 11.3 MJ/kg, protein 17%, lysine 0.77%, methionine 0.36%, Ca 3.75% and available P 0.38.

Wheat-based layer diets containing 28% wholeseed Gungurru, 19% de-hulled Gungurru, 18% wholeseed Kiev or 15% de-hulled Kiev produced comparable results in terms of rate of lay, egg size, excreta condition and egg quality. The seed coat of both species was deemed to be low in energy but had no obvious anti-nutritive effects in diets for laying hens. Commercial enzyme product reduced feed intake and incidence of soiled eggs.

Experiment #2 examined the effects of lupin species (Gungurru in wholeseed and kernel forms, and Kiev mutant wholeseed) in corn-based diets, and dietary addition of enzyme product (Avizyme 2300 at 1kg/tonne) on the performance of laying hens in the period 46 - 53 weeks of age. Inclusion rates of lupin were Gungurru wholeseed 25.3%, Gungurru kernel 121.7%, and Kiev wholeseed 21.2%. Steam-pelleted diets contained ME 11.5 MJ/kg, protein 16.5%, lysine 0.77%, methionine 0.38%, Ca 3.7% and available P 0.36%.

Excreta moisture, incidence of soiled eggs and egg weight were not affected by dietary inclusion of lupin in corn-based diets. Enzyme reduced excreta moisture in Tegel SB2 hens given diets with wholeseed Gungurru or Kiev lupin, but had no effect on Tegel Tint hens. On the other hand, enzyme improved yolk colour by 0.3 Roche fan units in Tint hens given wholeseed Gungurru or Kiev lupin, but not Tegel SB2 hens.

Experiment #3 examined the effects of dietary inclusion rate (0, 5, 10 and 15%) of a commercial isolate of NSP from Gungurru, and addition of enzyme product (Avizyme 2300 at 1kg/tonne) on the performance of laying hens in the period 59 - 67 weeks of age. Steam-pelleted diets contained ME 11.3 MJ/kg, protein 15.5%, lysine 0.70%, methionine 0.35%, Ca 4.0% and available P 0.35%.

Lupin kernel isolate and enzyme had no effects on rate of lay, incidence of soiled eggs, egg weight, or shell thickness. However, lupin kernel isolate reduced feed intake and yolk colour, and increased excreta moisture content, although there was no indication of a dose response effect. Enzyme did not ameliorate the effects of lupin kernel isolate on excreta condition.

Experiment #4 examined the effects of dietary inclusion rate (0, 7.5, 15 and 22.5%) of wholeseed Gungurru in wheat or sorghum-based diets on the performance of laying hens in the period 81 - 89 weeks of age. Mash diets contained ME 11.3 MJ/kg, protein 15.5%, lysine 0.70%, methionine 0.35%, Ca 4.0% and available P 0.35%.

Dietary inclusion of 22.5% wholeseed Gungurru in wheat or sorghum-based diets had no deleterious effects on feed intake, rate of lay, excreta moisture or egg quality in comparison with control diets containing no lupin. Yolk colour was improved by at least 0.2 Roche fan units at higher levels of inclusion of lupin in both wheat and corn diets.

In conclusion, Australian sweet lupin (*L. angustifolius* cv. Gungurru) and white lupin (*L. albus* cv Kiev mutant) are valuable alternative sources of protein and energy for inclusion in layer diets. Removal of seed coat is an unnecessary added cost but care needs to be taken when assigning energy values to wholeseed and de-hulled lupin for formulation purposes. There is potential for wet droppings and increased soiling of eggs as a result of high dietary levels of NSP from Gungurru lupin. Further development of enzymes is required for cost-effective removal of anti-nutritive effects of lupin NSP.

B. IMPLICATIONS AND RECOMMENDATIONS

The results of this project clearly indicate that modern cultivars of Australian sweet lupin (*L. angustifolius* cv. Gungurru) and white lupin (*L. albus* cv Kiev mutant) with low concentrations of alkaloids (bitter components) are valuable alternative sources of protein and energy for inclusion in layer diets, and that relatively high dietary levels of these lupins (22.5%) are not detrimental to production performance of hens. However, there remains a concern that high levels of non-starch polysaccharides and oligosaccharides in lupin (particularly sweet lupin *L. angustifolius*) have potential to promote wet excreta and hence, increased incidence of soiled eggs.

1. Scope for more efficient use of lupins in layer feeds

Both wholeseed lupin and lupin kernel can be included in layer feeds at relatively high levels. Removal of seed coat is an unnecessary added cost which achieves little benefit apart from increasing the nutrient density of the lupin material by 10 - 15%.

Cost-effective use of lupins in layer feeds will be determined by a number of highly variable factors. These include purchase prices for lupins as well as other feed ingredients which in turn will depend on energy values assigned to lupin material. This proved to be a difficulty encountered in the current project as values assigned to wholeseed and kernel from Gungurru and Kiev were subsequently found to be inaccurate. It was concluded that use of values derived from studies with broiler chickens can be misleading due to large differences in the ability of young and older birds to handle feed ingredients with high levels of NSP.

Accuracy and precision of feed formulation could be improved if more reliable information was available on nutritive value of the different forms and species of lupin (as, indeed, would be the case for other feed ingredients).

It is recommended that support be given to the ongoing development of suitable databases such as GRAILE and ALFI (see page 22 for further details). Recent results from DAS236 "Assessment of the potential of NIRS to predict the digestible energy content of cereals for growing pigs" (R.J. van Barneveld, personal communication) provides hope that near infrared spectroscopy (NIRS) can be adapted for determination of metabolisable energy values of feed ingredients for poultry. To date, use of NIRS for prediction of energy values for use in formulation of poultry diets has had mixed success. Intuitively, prediction methods such as NIRS should prove to be more useful for layers than broilers given that hens have more mature digestive tracts than chickens which appear to be less susceptible to anti-nutritive factors such as NSP and oligosaccharides, judging by the results discussed in this report and similar studies using the same lupin samples in broiler studies (DAS-10CM).

2. Scope for improvement by development of enzyme technology

Further developments in feed enzyme technology could eventually provide cost-effective treatment of anti-nutritive factors in lupins. It is highly unlikely that companies supplying feed enzymes to the Australian poultry industry will undertake research and development of enzyme products specifically targeted at anti-nutritive factors in lupins *per se* because the international market for such products is very small in comparison with the overall market.

The Australian poultry industry (both eggs and chicken meat) should evaluate carefully some recent claims made about successful development of enzyme products for improving the nutritive value of other legume grains, e.g., soybean meal. It is possible that enzyme products eventually proven to be suitable for soybean meal could also improve the nutritive value of lupin by depolymerisation of NSP and oligosaccharides. Comparative studies of the structure and composition of NSP and oligosaccharides in lupin and soybean meal ought to be done in order to gauge the likely effectiveness of treatment of lupins with enzyme products initially designed for soybean meal.

C. BACKGROUND TO THE PROJECT

1. Current industry practice

Early cultivars of lupin were high in alkaloids and bitter components, and regarded as unsuitable as feedstuffs for monogastric animals. Genetic selection of varieties low in these anti-nutritive factors has led to the use of lupins as a protein source for the intensive livestock industries.

High protein, amino acid and energy levels combined with cost-competitiveness with a wide range of cereals, legumes and animal proteins give lupins excellent potential for use in Australian pig and poultry diets. *L. angustifolius* cv. Gungurru, in particular, is widely used as a monogastric protein source (van Barneveld and Hughes 1994).

Previous studies indicate that both *L. angustifolius* and *L. albus* can support acceptable levels of production in layers. Hughes and Orange (1976) offered laying hens *L. angustifolius* cv Uniwhite at levels of 10 and 20% in the diet with no subsequent loss in performance provided methionine was added. Prinsloo *et al.* (1992) offered up to 30% *L. albus* cv Buttercup to Hisex laying hens without a significant effect on egg production, egg mass, food conversion efficiency, egg shell thickness, Haugh units or yolk colour.

However, uncertainty surrounds the effects of high levels of non-starch polysaccharides (NSP) and oligosaccharides, the value of additional processing such as de-hulling, and the cost-effectiveness of commercial enzyme products. Clarification of these points is considered a high priority by the Australian pig and chicken meat industries. A better knowledge of the factors effecting the nutritive value of lupins will also pave the way for increased usage of lupins in layer feeds.

The effects of high levels of NSP and oligosaccharides on performance of laying hens and incidence of wet droppings and soiled eggs are specific points to be resolved. Producers and feed formulators require clear guidelines on the economics of using whole and de-hulled lupins in layer diets and when to include enzymes to overcome inconsistent responses of hens to these diets.

2. Chemical composition of lupins

The chemical composition of lupin species used in monogastric production (*L. angustifolius, L. albus, L. luteus,* and *L. mutabilis*) has been widely reviewed (Hill 1986; Cheung 1991; Petterson and Mackintosh 1994). A number of aspects of the chemical composition of lupins have an influence on lupin use and monogastric production.

Typical composition of *L. angustifolius* (from Cheung 1991)

Component	Composition (%)
Protein	39.5 - 44.4
Lipid	8.4 - 8.7
Starch	0.56 - 0.66
Ash	2.6 - 3.3
Insoluble NSP	33.8 - 34.2
Soluble NSP	3.45 - 4.18
Oligosaccharides (raffinose and stachyose)	7.6 - 8.0

3. Potential anti-nutritive factors in lupins

The relatively high levels of NSP in lupins (compared with cereals) is of concern as it has previously been demonstrated that the soluble NSP of wheat, barley and rye have anti-nutritive activity in broilers as a result of reduced digestibility of major nutrients (Choct and Annison 1992). These NSP have not been characterised in detail but are known to have a very high galactose content (83%).

The negative effects of high levels of lupin NSP on broiler production has been clearly demonstrated by Brenes *et al.* (1993). The addition of a combination of enzymes (protease, carbohydrase and a-galactosidase) to a diet containing 70% raw lupins improved the weight gain and feed to gain ratio of broiler chicks by 18 and 10%, respectively. Although the factor(s) that were effected by enzyme treatment were not identified, it is likely that these were associated with the hydrolysis of the different complex carbohydrates.
A high level of the oligosaccharides raffinose and stachyose may also cause nutritive problems in poultry. These a-galactosides are not broken down by endogenous digestive enzymes. In other animals they are known to cause an osmotic diarrhoea when present at high levels. The materials are highly fermentable and may cause distress through excessive gas production in the hind gut. In laying hens, watery droppings could result in soiling of eggs and environmental problems from flies, odours and manure disposal.

The presence of oligosaccharides has been suggested as the cause of variable production responses to lupins in pigs (Wigan *et al.* 1994). However, oligosaccharide levels in lupins are not dissimilar to levels in soybean meal. Hence, variable responses to lupins are likely to be due to complex interactions between a combination of lupin components and other dietary ingredients, particularly cereals.

Other anti-nutritive factors are present which may be limiting the value of lupins in poultry diets. The levels of alkaloids in current varieties are low (<0.02%) but can occur at higher levels. In addition, haemagglutinins have been associated with some legumes.

4. De-hulling of lupins

Further processing of lupins may be highly beneficial for poultry. Brenes *et al.* (1993) demonstrated the nutritive value of alkaloid-free lupins can be significantly increased by de-hulling or autoclaving. Chicks fed diets containing high concentrations of autoclaved or de-hulled lupins (47.5%) were able to support weight gains and feed to gain ratios that were similar to those obtained when corn-soybean meal diets were offered. Brenes *et al.* (1993) suggested that additional research is required to identify the nature of the anti-nutritional factors in alkaloid-free seeds. Little is known about the effects of further processing of lupins on nutrition of layers.

5. Industry significance

Although lupins (*L. angustifolius* cv Gungurru, in particular) are widely used as a monogastric protein source, uncertainty surrounds the effects of high dietary levels of oligosaccharides and non-starch polysaccharides (NSP), the value of additional processing such as de-hulling, and the cost-effectiveness of enzyme products. Strategies to overcome these problems are needed in order that greater use can be made of lupins in layer diets with anticipated reductions in feed costs.

D. OBJECTIVES OF THE PROJECT

The overall aim was to provide producers and feed formulators with clear guidelines on the economics of using whole and de-hulled lupins and the need for inclusion of enzymes in layer diets containing lupins. Specific aims were to:-

1. Obtain different cultivars of sweet lupin *(L. angustifolius*) and white lupin (*L. albus*) known to contain high and low levels of components which are likely to have anti-nutritive properties when included in layer diets.

2. Examine the nutritive effects of hulls, non-starch polysaccharides (NSP) and oligosaccharides in lupins on egg production, egg quality, excreta condition and incidence of soiled eggs.

3. Assess the economic benefits for the egg industry of different cultivars of lupins, hull removal and the use of commercial feed enzymes which target the anti-nutritive factors in lupins.

E. RESEARCH METHODOLOGY

1. Compositional analysis

Wherever possible, experimental work in this project was done with lupin material of known composition as determined by analyses for protein, apparent metabolisable energy (AME), amino acids, soluble and insoluble NSP, and oligosaccharides in associated projects supported by CMRDC (DAS-10CM), PRDC (DAS-29P and DAS-33P) and GRDC (DAW-440B). In addition, all lupin material was screened to avoid individual samples with high levels of alkaloids.

2. Assessment of nutritive value

Nutritive effects of different species of lupins, seed-coat removal, dietary inclusion rate and commercial enzyme product were determined in a series of four short-term laying experiments (7 - 8 weeks) separated by at least 2-week periods of feeding of a high quality control layer diet to the same flock of commercial laying hens. Each new experiment was re-randomised over different cages to avoid carry-over effects from previous experiments. Records were kept on egg production and mortality, and feed intake throughout each experiment. Measurements of egg weight, shell quality, yolk colour, fresh excreta moisture and incidence of soiled eggs were made at the end of each experimental period. All diets within an experiment were formulated to contain the same levels of nutrients such as metabolisable energy, protein, lysine, methionine tryptophan, linoleic acid, Ca, available P, Na, and Cl. All diets met minimum nutritional requirements according to current commercial standards.

3. Modes of action of anti-nutritive factors

Effects of anti-nutritive factors in lupins were examined by the addition of graded levels of lupin material known to contain high and low levels of the components in question. Potential interactions between lupin components and cereals were examined using diets based on wheat, corn or sorghum. In addition, commercial enzyme product were included in diets as part of the development of strategies to enable lupins to be used to a greater extent in commercial layer feeds.

F. PERSONNEL

The following people were involved in the planning of the experimental work and analysis of results described in this report:-

Mr R.J. Hughes
Senior Research Scientist
SARDI/PPPI

Mr A. Kocher
Research Officer
SARDI/PPPI

Dr R.J. van Barneveld
Senior Research Scientist
SARDI/PPPI

Dr P.C. Glatz
Senior Research Scientist
SARDI/PPPI

Dr D. Creswell
Creswell Livestock Consultants
Mosman, NSW 2088

Mr M. Tucek
The Grain Pool
Perth, WA 6000

We gratefully acknowledge the dedicated efforts of the following members of staff of SARDI and Rural Services Department, University of Adelaide:-

Mrs C. Adley
Ms M. Brennan
Ms T. Brennan
Mrs E. Daniels
Ms T. Grech
Mr P. Keatley
Mr. A. Mezgec
Mr A. Richardson
Mr D. Schultz
Ms K. Swanson
Mr S.Turner

G. DETAILED RESULTS -- EXPERIMENT #1

Effects of lupin species, seed-coat removal and dietary enzyme on laying performance of hens given wheat-based diets

Introduction

Results from classical AME experiments with commercial broiler chickens to determine the nutritive value of Australian sweet lupin *L. angustifolius* cv Gungurru and white lupin *L. albus* cv Kiev mutant (R.J. Hughes *et al.*, unpublished data) suggest that wholeseed and kernel forms of these two lupin species should support good laying performance provided energy differences between species and form of lupin were taken into account when diets were formulated. Furthermore, glycanase enzyme products can improve the AME of Gungurru lupin (Annison *et al.* 1996) in broilers. However, addition of Gungurru lupins to broiler diets usually raises excreta moisture content (R.J. Hughes *et al.*, unpublished data). Comparable information is not available for laying hens.

This experiment examined laying performance, egg quality, excreta condition and incidence of soiled eggs of hens given practical diets containing relatively high levels of wholeseed and kernel forms of Gungurru and Kiev lupin. The glycanase enzyme product examined in this study is known to have a range of enzymic activities and could be regarded as a typical example of currently available feed enzymes.

Objectives

Determine the effects on the performance of laying hens, egg quality, excreta condition and incidence of soiled eggs of:-

a. Lupin species *L. angustifolius* cv Gungurru and *L. albus* cv Kiev mutant.
b. Removal of seed-coat.
c. Proprietary enzyme product (Avizyme 2300).

Study period

Experimental feeds were given for 8-weeks commencing when hens reached 34 weeks of age in June, 1996

Experimental methods

a. <u>Birds, housing and management</u>

A total of 960 laying hens (Tegel Tint and Tegel SB2) were housed five per cage in 192 Harrison "Welfare" back-to-back, single-tier cages (each 500 mm wide by 545 mm deep; 545 cm^2/bird) in a layer shed equipped with a thermostatically controlled evaporative cooling system set to operate when shed temperature at bird level reaches 25°C. A 16-hour light program was provided by incandescent globes on at 0400 h and off at 2000 h (Central Standard Time). Birds had access to feed and water from nipple drinkers at all times. From 17 to 34 weeks of age birds received a high nutrient density commercial layer mash formulated for these strains.

b. Experimental feeds

Eight dietary treatments (12 replicates; 10 birds in two adjacent cages for each replicate) were examined in a 2^3 factorial experiment involving two species of lupin (*L. albus* cv Kiev mutant and *L. angustifolius* cv Gungurru), with and without seed-coat removal, and with and without dietary addition of the proprietary enzyme product Avizyme 2300 (1g/kg inclusion rate). Composition of experimental basal diets is shown in Table 1. Each diet provided ME 11.3 MJ/kg, protein 17%, Ca 3.75%, available P 0.38%, methionine 0.37%, lysine 0.77%, tryptophan 0.18%, Na 0.16% and Cl 0.19%.

The experimental diets were mixed at PPPI then transported to a commercial feed mill for steam-pelleting at low temperature (< 80°C). The original intention was to offer the feed in mash form but since the lupin material was ground very finely by the supplier in WA, it was decided to pellet the diets to avoid selective feeding by hens.

c. Data recording

Data were recorded on each experimental replicate of 10 birds in two adjacent cages. Egg production and mortality were recorded daily. Weighed amounts of feed were given at least once each week. Uneaten feed in hoppers was measured at 4-week intervals. Birds were weighed at 4-week intervals commencing at 34 weeks of age. When birds reach 42 weeks of age, egg weight of all eggs laid over a three-day period were recorded. Incidence of dirty eggs was assessed visually. During this period, fresh excreta was collected for 24 hours for moisture determination.

Results

Results of analysis of variance are shown in Table 2 - 5. Effects of species of lupin, seed-coat removal, and enzyme addition are summarised in Tables 6 - 10.

Discussion

Egg production, excreta moisture, and shell quality were unaffected by lupin species, form of lupin or enzyme addition. Tegel Tint hens ate more feed (5.6 g/bird/day) and laid more eggs (4.5/100 hen-days) although egg size was smaller (0.7 g) in comparison with SB2 hens.

Gungurru lupin increased feed intake by 5.4 g/bird/day compared with Kiev lupin, whereas de-hulling of both species reduced feed intake by 1.9 g/bird/day. These results suggest that energy values for Kiev lupin were underestimated relative to Gungurru, as were the energy values for lupin kernel relative to whole seed of both species, possibly because AME values obtained in chick bioassays are not directly applicable for formulation of layer diets. Seed coat of both lupin species appeared not to contain anti-nutritive factors but did have an energy dilution effect in this study.

Enzyme addition reduced feed intake by 4.4 g/bird/day, egg size by 0.7 g and incidence of soiled eggs by 2.7%. Incidence of soiled eggs was affected by a significant interaction between breed of hen and dietary enzyme (Table 4). Addition of enzyme significantly reduced incidence of soiled eggs laid by Tegel Tint but had no effect in SB2 (Figure 1). Enzyme degradation of NSP in ingredients other than lupin could have contributed to these benefits.

Yolk colour was significantly reduced by de-hulling (0.3 Roche fan units). Yolk colour of eggs was affected by a significant interaction between species of lupin and dietary enzyme (Table 5). Addition of enzyme to diets containing *L. angustifolius* cv Gungurru significantly improved yolk colour by 0.3 Roche fan units but there was no significant effect of enzyme in diets containing *L. albus* cv Kiev mutant (Figure 2).

Conclusions

- Egg production, excreta moisture, and shell quality were unaffected by lupin species, form of lupin or enzyme addition.
- Gungurru increased feed intake by 5.4 g/bird/day.
- Enzyme reduced feed intake by 4.4 g/bird/day, egg size by 0.7 g, and incidence of soiled eggs by 2.7%.
- Enzyme improved yolk colour on Gungurru diet by 0.3 Roche fan units.
- Tegel Tint hens ate more feed (5.6 g/bird/day) and laid more eggs (4.5/100 hen-days) which were smaller (0.7 g) in comparison with Tegel SB2 hens

H. DETAILED RESULTS -- EXPERIMENT #2

Effects of lupin species, seed-coat removal and dietary enzyme on laying performance of hens given corn-based diets

Introduction

Results of Experiment #1 indicated that benefits of enzyme addition were more likely to be related to degradation of NSP in wheat rather than removal of any anti-nutritive effects of lupin material in the feed. In addition, there was no indication that seed-coat of either species of lupin had any deleterious effects other than to act as an energy diluent. However, It is possible that deleterious effects of NSP in wheat masked any subtle effects of anti-nutritive factors in lupin kernel or seed-coat.

Experiment #2 was conducted with corn as the cereal base in order that background levels of NSP would be as low as practical. A control diet with no lupin was included to quantify any effects of the enzyme product on dietary ingredients other than lupin.

Objectives

Determine the effects on the performance of laying hens, egg quality, excreta condition and incidence of soiled eggs of:-

a. Lupin species *L. angustifolius* cv Gungurru and *L. albus* cv Kiev mutant.

b. Removal of seed-coat from *L. angustifolius* cv Gungurru.

c. Proprietary enzyme product (Avizyme 2300).

Study period

Experimental feeds were given for 7-weeks commencing when hens reached 46 weeks of age in August, 1996

Experimental methods

a. <u>Birds, housing and management</u>

Same as for Experiment #1. Birds received a high nutrient density commercial layer mash between experiments.

b. <u>Experimental feeds</u>

Eight dietary treatments (12 replicates; 10 birds in two adjacent cages for each replicate) were examined in a randomised block design. Composition of experimental basal diets is shown in Table 11. Each diet provided ME 11.5 MJ/kg, protein 16.5%, Ca 3.7%, available P 0.36%, methionine 0.38%, lysine 0.77%, tryptophan 0.18%, Na 0.16% and Cl 0.15%. The experimental diets were mixed at PPPI then transported to a commercial feed mill for steam-pelleting at low temperature (< 80°C).

c. Data recording

Data were recorded on each experimental replicate of 10 birds in two adjacent cages. Egg production and mortality were recorded daily. Weighed amounts of feed were given at least once each week. Uneaten feed in hoppers was measured at four and at seven weeks. Birds were weighed at the beginning and end of the experiment and after one and four weeks on experimental diets. When birds reach 53 weeks of age, egg weight of all eggs laid over a three-day period were recorded. Incidence of dirty eggs was assessed visually. During this period, fresh excreta was collected for 24 hours for moisture determination.

Results

Results of analysis of variance are shown in Table 12 - 15. Effects of species of lupin, seed-coat removal, and enzyme addition are summarised in Tables 16 - 20.

Discussion

Tegel Tint hens laid more eggs (7.6/100 hen-days) than Tegel SB2 hens over the course of the experiment (Table 16). Egg shells from SB2 hens were thicker (8 μm), and egg weight (0.4 g) and incidence of soiled eggs (2.5%) tended to be higher (Tables 19 and 20).

A significant interaction between breed and diet was observed in rate of lay (Table 12). This was due to poor performance of hens given diets with Gungurru wholeseed supplemented with enzyme. The effect was most noticeable in SB2 hens throughout the experiment, whereas egg production by Tint hens was depressed in the first four weeks only, then hens tended to recover (Table 16).

A similar pattern of results was observed in feed intake in SB2 hens. In the first four weeks, hens given wholeseed Gungurru with enzyme ate significantly less feed (11.5 g/bird/day) than hens given wholeseed Gungurru without enzyme, whereas feed intake was lower (10.3 g/bird/day) over seven weeks (Table 17). Also of interest was the significant reduction in feed intake (8.1 g/bird/day) in the first four weeks due to addition of enzyme to the corn control diet.

A likely explanation for the poor performance of SB2 hens given wholeseed Gungurru with enzyme is that these hens commenced the experiment well below average liveweight of hens on other dietary treatments (Table 18). By the end of the experimental period, these hens had gained sufficient weight that they were no longer significantly lighter than SB2 hens on other diets. However, it is not obvious why these hens were lower in liveweight at the start of the experiment, nor why Tint hens performed poorly in the first four weeks.

The interaction between breed and diet approached significance (P = 0.07) in regard to excreta moisture content (Table 14). Addition of enzyme to the Gungurru diets significantly reduced excreta moisture content by 3.2% in SB2 hens given Gungurru kernel and the difference of 3.5% approached significance in the case of Gungurru wholeseed (Table 19). There was no indication that enzyme affected excreta moisture content in Tint hens.

Addition of enzyme to the diets affected some aspects of egg quality. In SB2 hens, egg weight was reduced by 2.4 g by enzyme addition to the corn control diet (Table 20), and shell thickness was reduced by 13 μm in the Kiev wholeseed diet (Table 20). Yolk colour was significantly improved by 0.3 Roche fan units by enzyme addition to Gungurru or Kiev wholeseed diets given to Tint hens, but not in SB2 hens (Table 20). It is possible that enzyme product influences fat metabolism in hens given lupin diets. Although not statistically significant, there appears to be a pattern of increased yolk colour in hens given lupin diets compared with hens given corn control diet with or without enzyme.

Conclusions

- Tint hens laid more eggs (7.6/100 hen-days) which were smaller (0.4 g) then SB2 hens.
- Excreta moisture, incidence of soiled eggs and egg weight were not affected by lupin.
- Enzyme reduced excreta moisture 3.2% in SB2 hens given diets with Gungurru lupin.
- Enzyme improved yolk colour by 0.3 Roche fan units in Tint hens given wholeseed Gungurru or Kiev lupin.

I. DETAILED RESULTS -- EXPERIMENT #3

Effects of lupin kernel NSP and dietary enzyme on performance of hens

Introduction

Experiment #2 examined the effects of dietary inclusion rate (0, 5, 10 and 15%) of a commercial isolate of NSP from de-hulled *L. angustifolius* in a sorghum-based diet, and addition of enzyme product (Avizyme 2300 at 1kg/tonne) on the performance of laying hens in the period 59 - 67 weeks of age. The total NSP content of the isolate was 56% which was mainly galactose (75%). The soluble NSP content of the isolate was 6%.

Objectives

Determine the effects on the performance of laying hens, egg quality, excreta condition and incidence of soiled eggs of:-

a. Dietary inclusion of a commercial extract of NSP from lupin kernel
b. Use of a proprietary feed enzyme product (Avizyme 2300)

Study period

Experimental feeds were given for 8-weeks commencing when hens reached 59 weeks of age in November, 1996

Experimental methods

a. <u>Birds, housing and management</u>

Same as for Experiment #1. Birds received a high nutrient density commercial layer mash between experiments.

b. <u>Experimental feeds</u>

Eight dietary treatments (12 replicates; 10 birds in two adjacent cages for each replicate) were examined in a randomised block design. Composition of experimental basal diets is shown in Table 21. Each diet provided ME 11.3 MJ/kg, protein 15.5%, Ca 4.0%, available P 0.35%, methionine 0.35%, lysine 0.70%, tryptophan 0.16%, Na 0.16% and Cl 0.21%. The experimental diets were mixed at PPPI then transported to a commercial feed mill for steam-pelleting at low temperature (< 80^{o}C).

c. <u>Data recording</u>

Data were recorded on each experimental replicate of 10 birds in two adjacent cages. Egg production and mortality were recorded daily. Weighed amounts of feed were given at least once each week. Uneaten feed in hoppers was measured at 4-week intervals. Birds were weighed at the beginning and end of the experiment and after two and four weeks on experimental diets. When birds reach 67 weeks of age, egg weight of all eggs laid over a three-day period were recorded. Incidence of dirty eggs was assessed visually. During this period, fresh excreta was collected for 24 hours for moisture determination.

Results

Results of analysis of variance are shown in Table 22 - 25. Effects of species of lupin, seed-coat removal, and enzyme addition are summarised in Tables 26 - 30.

Discussion

Egg production, liveweight, incidence of soiled eggs, egg weight and shell thickness were not affected by dietary inclusion of lupin kernel isolate or enzyme.

There were highly significant differences between breeds. Tint hens were lighter (160 g/bird) than SB2 hens and superior in terms of rate of lay (3.6 eggs/100 hen-days) and feed intake (5.6 g/bird/day). Tint hens had higher excreta moisture (1.8%) but a lower incidence of soiled eggs (7.1%). SB2 hens were superior to Tint hens in terms of egg weight (0.6 g), shell thickness (7 μm) and yolk colour (0.3 Roche fan units.

Dietary inclusion of lupin NSP reduced feed intake (Table 27) and yolk colour (Table 30), and increased excreta moisture content (Table 29). However, there was no evidence of a dose response effect of lupin NSP on feed intake or excreta moisture. Yolk colour was significantly affected by an interaction between breed and lupin NSP (Table 25), with higher levels of lupin NSP depressing yolk colour in Tint but not in SB2 hens (Figure 3).

Conclusions

- Lupin kernel NSP and enzyme had no effects on rate of lay, incidence of soiled eggs, egg weight, or shell thickness.
- Lupin kernel NSP reduced feed intake and yolk colour, but there was no indication of a dose response effect.
- Tint hens were superior to SB2 hens in rate of lay (3.6 eggs/100 hen-days) and feed intake (5.6 g/bird/day), on the other hand, SB2 hens laid bigger eggs (0.6 g) with thicker shells (7 μm) and better yolk colour (0.3 Roche fan units).
- Tint hens had higher excreta moisture (1.8%) but laid fewer soiled eggs (7.1%) than SB2 hens.

J. DETAILED RESULTS -- EXPERIMENT #4

Interaction between lupin inclusion rate and type of cereal in layer diets for hens

Introduction

The presence of oligosaccharides has been suggested as the cause of variable production responses to lupins in pigs (Wigan *et al.* 1994). However, oligosaccharide levels in lupins are not dissimilar to levels in soybean meal. Hence, the variable responses to lupins are likely to be due to far more complex interactions between a combination of lupin components and other dietary ingredients, particularly cereal grains.

Results from Experiments #1 and #2 suggest that background levels of NSP from dietary ingredients, particularly the cereal base, have a bearing on the way that lupin NSP effect laying performance, egg quality and excreta condition.

Experiment #4 examined the possibility that laying hens would exhibit variable production responses as observed in other animal species as a result of interactions between lupin and other dietary ingredients containing NSP.

Objectives

Determine the effects on the performance of laying hens, egg quality, excreta condition and incidence of soiled eggs of:-

a. Dietary inclusion rate of milled lupin seed *L. angustifolius* cv Gungurru.
b. Type of cereal (wheat or sorghum) used in the diet.
c. Interaction between lupin inclusion rate and type of cereal

Study period

Experimental feeds were given for 8-weeks commencing when hens reached 81 weeks of age in April, 1997

Experimental methods

a. Birds, housing and management

Same as for Experiment #1. Birds received a high nutrient density commercial layer mash between experiments.

b. Experimental feeds

Eight dietary treatments (12 replicates; 10 birds in two adjacent cages for each replicate) were examined in a 4 x 3 factorial experiment involving four dietary levels of milled lupin seed (0, 7.5, 15, and 22.5%) and two types of cereal grain (wheat or sorghum) known to contain relatively high and low levels of NSP, respectively. Composition of basal diets is shown in Table 31. Each diet provided ME 11.5 MJ/kg, protein 17.0%, Ca 3.8%, available P 0.4%, methionine 0.36%, lysine 0.77%, tryptophan 0.17%, Na 0.16% and Cl 0.20%. The experimental diets were mixed at PPPI and given in mash form.

c. Data recording

Data were recorded on each experimental replicate of 10 birds in two adjacent cages. Egg production and mortality were recorded daily. Weighed amounts of feed were given at least once each week. Uneaten feed in hoppers was measured at 4-week intervals. Birds were weighed at the beginning and end of the experiment. When birds reach 89 weeks of age, egg weight of all eggs laid over a three-day period were recorded. Incidence of dirty eggs was assessed visually. During this period, fresh excreta was collected for 24 hours for moisture determination.

Results

Results of analysis of variance are shown in Table 32 - 35. Effects of species of lupin, seed-coat removal, and enzyme addition are summarised in Tables 36 - 40.

Discussion

Tegel SB2 hens ate more feed (13.7 g/bird/day, Table 37) than Tint hens and laid eggs with thicker shells (9 μm, Table 40). Tint hens tended (P = 0.07) to have higher excreta moisture (0.9%) than SB2 hens (Table 39). Both breeds tended to have lower feed intake on the wheat diets compared with sorghum (Table 37), and there were more soiled eggs (3.5%) produced on the sorghum diets (Table 39). These results were unexpected. However, this might be a characteristic of this particular sample of sorghum which had lower than usual AME and promoted wetter than usual droppings in broiler chickens in AME bioassays (Hughes, unpublished data).

Inclusion of up to 22.5% Gungurru lupin in wheat or sorghum-based diets had no deleterious effects on laying performance, excreta condition, or egg quality (Tables 36, 39 and 40). Yolk colour was improved by at least 0.2 Roche fan units at higher levels of inclusion of lupin in both wheat and sorghum diets (Table 40).

Conclusions

- Inclusion of up to 22.5% Gungurru wholeseed in wheat or sorghum-based diets had no deleterious effects on laying performance, excreta condition or egg quality.
- Yolk colour was improved by at least 0.2 Roche fan units at higher levels of inclusion of lupin in both wheat and sorghum diets.
- SB2 hens ate more feed (13.7 g/bird/day) and laid eggs with thicker shells (9 μm) than Tint hens.
- Tint hens tended to have higher excreta moisture (0.9%) than SB2 hens but there was no difference in incidence of soiled eggs.

K. DISSEMINATION OF INFORMATION

1. Scientific papers

A paper titled “nutritive value of lupins for layers” by R.J. Hughes and A. Kocher has been submitted for presentation at the Australian Poultry Science Symposium to be held at the University of Sydney in February, 1998. See Appendix 3 for details of this paper.

2. Industry seminars

Preliminary results from this project have been presented in three industry seminars:-

- EIRDC Nutrition Workshop, University of Sydney, December 13, 1996.
- SA Farmers Federation, Poultry Section, Roseworthy Campus, University of Adelaide, February 27, 1997.
- SA Pig and Poultry Fair, Roseworthy Campus, University of Adelaide, October 8, 1997.

3. Other communications

Specific information about nutritive value of lupins has been distributed through personal communications with commercial nutritionists employed by feed mills and feed enzyme companies, and with private consultants providing feed formulation services to egg producers in South Australia, and nationally. In addition, detailed information and advice on the nutritive value of lupins has been provided to:-

Dr D. Petterson (Department of Agriculture, WA)
for inclusion in GRAILE database

Mr P. Burridge (SARDI)
Project Officer
GRDC Project DAW-440B

Dr Y. Ru (SARDI)
for inclusion in the ALFI database as part of a joint PRDC/GRDC project.

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TABLE 1. -- Composition of diets used in Experiment #1

Hens 36 - 44 weeks of age

Ingredient (%)	Gungurru Whole	Gungurru Kernel	Kiev Whole	Kiev Kernel
Wheat †	57.4	69.1	69.2	73.5
Lupin ‡	27.9	18.9	18.2	15.0
Tallow	3.9	1.1	1.7	0.6
Marble	8.1	8.3	8.2	8.2
Palfos	1.63	1.53	1.55	1.53
Salt	0.16	0.15	0.14	0.14
Na bicarbonate	0.25	0.25	0.25	0.25
Choline	0.05	0.05	0.05	0.05
Lysine	0.18	0.23	0.31	0.33
Methionine	0.18	0.16	0.16	0.16
Premix	0.25	0.25	0.25	0.25

† Measured and assumed values were 14.0 MJ/kg dry matter basis (by broiler bioassay) and 14.5% crude protein (Nx6.25) air-dry basis.

‡ Measured and assumed values used in diet formulation are shown in Appendix 1.

TABLE 2. -- Experiment #1 -- Hens 36 - 44 weeks of age

Summary of analysis of variance

Egg production and feed intake

EFFECT	HDEP1_4	HDEP5_8	HDEP1_8	FBD0_28	FBD0_56	FBD28_56
BLOCK	NS	NS	NS	NS	NS	NS
BREED (B)	0.004	0.0001	0.0001	0.02	0.0001	0.0001
LUPIN (L)	NS	NS	NS	0.0001	0.0001	0.0001
FORM (F)	NS	NS	NS	0.02	0.06	NS
ENZYME (E)	NS	NS	NS	0.0002	0.0001	0.001
B * L	NS	NS	NS	NS	NS	NS
B * F	NS	NS	NS	NS	NS	NS
B * E	NS	NS	NS	NS	NS	NS
L * F	NS	NS	NS	NS	NS	NS
L * E	NS	NS	NS	NS	NS	NS
F * E	NS	NS	NS	NS	NS	NS
B * L * F	0.05	NS	0.07	NS	NS	NS
B * L * E	NS	NS	NS	NS	NS	NS
B * F * E	NS	NS	NS	NS	NS	NS
L * F * E	0.015	0.002	0.002	0.06	0.03	0.054
B * L * F * E	NS	NS	NS	NS	NS	NS
Mean	84.6	84.1	84.3	114.0	113.8	113.5
Error MS	18.95	31.05	21.23	27.25	21.54	33.52
CV	5.1	6.6	5.5	4.6	4.1	5.1

HDEP1_4 = Hen-day egg production weeks 1 - 4 (eggs/100 hen-days)
HDEP5_8 = Hen-day egg production weeks 5 - 8 (eggs/100 hen-days)
HDEP1_4 = Hen-day egg production weeks 1 - 8 (eggs/100 hen-days)

FBD0_28 = Feed intake weeks 1 - 4 (g/bird/day)
FBD0_56 = Feed intake weeks 1 - 8 (g/bird/day)
FBD28_28 = Feed intake weeks 5 - 6 (g/bird/day)

TABLE 3. -- Experiment #1 -- Hens 36 - 44 weeks of age

Summary of analysis of variance

Live weight of hens

EFFECT	WT0	WT1	WT4	WT8
BLOCK	NS	NS	NS	0.03
BREED (B)	0.000	0.0001	0.0001	0.0002
LUPIN (L)	NS	NS	NS	NS
FORM (F)	NS	NS	NS	NS
ENZYME (E)	NS	NS	NS	NS
B * L	NS	NS	NS	NS
B * F	NS	NS	NS	NS
B * E	NS	0.07	0.055	NS
L * F	NS	NS	NS	NS
L * E	NS	NS	NS	NS
F * E	NS	NS	NS	NS
B * L * F	0.05	NS	NS	NS
B * L * E	NS	NS	NS	NS
B * F * E	NS	NS	NS	NS
L * F * E	NS	NS	NS	NS
B * L * F * E	0.06	0.09	0.04	0.02
Mean	2.033	2.066	2.020	2.027
Error MS	0.046	0.047	0.055	0.054
CV	10.6	10.5	11.6	11.8

WT0 = Live weight (kg) at start of experiment
WT1 = Live weight (kg) after one week
WT4 = Live weight (kg) after four weeks
WT8 = Live weight (kg) after eight weeks

TABLE 4. -- Experiment #1 -- Hens 44 weeks of age

Summary of analysis of variance

Excreta moisture and incidence of soiled eggs

EFFECT	EXCRETA	SOILPC	SOILED
BLOCK	NS	NS	NS
BREED (B)	NS	NS	NS
LUPIN (L)	NS	NS	NS
FORM (F)	NS	NS	NS
ENZYME (E)	NS	0.055	0.02
B * L	NS	NS	NS
B * F	NS	NS	NS
B * E	NS	0.04	0.04
L * F	NS	NS	NS
L * E	NS	NS	NS
F * E	NS	NS	NS
B * L * F	NS	NS	NS
B * L * E	NS	0.04	0.06
B * F * E	NS	NS	NS
L * F * E	NS	NS	0.09
B * L * F * E	NS	NS	NS
Mean	76.6	8.6	2.8
Error MS	9.44	42.89	1.39
CV	4.0	75.8	42.7

EXCRETA = Excreta moisture content (%)
SOILPC = Incidence of soiled eggs (%)
SOILED = Incidence of soiled eggs (square root transformation)

TABLE 5. -- Experiment #1 -- Hens 44 weeks of age

Summary of analysis of variance

Egg weight and quality

EFFECT	AEWT	EWT	SHELLPC	THICK	YOLKOL
BLOCK	NS	NS	NS	NS	NS
BREED (B)	0.053	NS	0.009	NS	NS
LUPIN (L)	NS	NS	NS	0.08	0.09
FORM (F)	NS	0.03	NS	NS	0.0008
ENZYME (E)	0.03	NS	NS	NS	NS
B * L	NS	NS	NS	NS	NS
B * F	NS	NS	NS	NS	0.09
B * E	NS	NS	NS	NS	NS
L * F	NS	NS	NS	NS	NS
L * E	NS	NS	NS	NS	0.001
F * E	NS	NS	NS	NS	NS
B * L * F	NS	NS	NS	NS	NS
B * L * E	NS	NS	NS	NS	NS
B * F * E	NS	NS	NS	NS	NS
L * F * E	NS	NS	0.08	0.07	NS
B * L * F * E	0.06	NS	NS	NS	NS
Mean	60.0	59.1	9.4	371	9.0
Error MS	2.162	16.71	0.558	591.9	0.353
CV	2.45	6.9	7.9	6.6	6.6

AEWT = Average weight (g) of all eggs laid over three days
EWT = Egg weight (g) of eggs used for quality measurements
SHELLWT = Shell weight (g)
SHELLPC = Shell as % of egg weight
THICK = Shell thickness (μm) at equator
YOLKOL = Yolk colour (Roche fan)

TABLE 6. -- Experiment #1 -- Hens 36 - 44 weeks of age

Hen-day egg production

(Least squares means)

				Experimental phase		
Breed	Lupin	Form	Enzyme	Weeks 1 - 4	Weeks 5 - 8	Weeks 1 - 8
					Eggs per 100 hen-days	
B	G	K	-	86.0	80.4	83.3
B	G	K	+	83.2	79.6	81.4
B	G	S	-	78.9	77.5	78.2
B	G	S	+	83.2	83.3	83.3
B	K	K	-	81.1	78.1	79.6
B	K	K	+	82.9	81.9	82.4
B	K	S	-	84.2	83.4	83.7
B	K	S	+	85.3	82.8	84.1
W	G	K	-	88.0	88.3	88.1
W	G	K	+	82.7	84.5	83.5
W	G	S	-	84.2	86.0	84.8
W	G	S	+	86.5	91.5	88.9
W	K	K	-	85.2	85.9	85.6
W	K	K	+	89.2	90.4	89.8
W	K	S	-	85.4	88.7	87.0
W	K	S	+	85.9	82.6	84.3
B				83.1	80.9	82.0
W				85.9	87.2	86.5
	G			84.1	83.9	83.9
	K			84.9	84.2	84.6
		K		84.8	83.6	84.2
		S		84.2	84.5	84.3
			-	84.1	83.5	83.8
			+	84.9	84.6	84.7
		Overall mean		84.6	84.1	84.3

Breed (W = White, B = Black)
Lupin (G = Gungurru, K = Kiev)
Form (K = Kernel, S = Seed)
Enzyme (- = Without, + = With)

TABLE 7. -- Experiment #1 -- Hens 36 - 44 weeks of age

Feed intake

(least squares means)

				Experimental phase		
Breed	Lupin	Form	Enzyme	Weeks 1 - 4	Weeks 5 - 8	Weeks 1 - 8
				Feed intake (g/bird/day)		
B	G	K	-	116.9	115.0	116.0
B	G	K	+	111.3	107.2	109.3
B	G	S	-	116.4	114.9	115.7
B	G	S	+	117.5	112.7	115.1
B	K	K	-	111.6	106.4	109.0
B	K	K	+	105.9	104.2	105.0
B	K	S	-	114.5	111.3	112.9
B	K	S	+	106.8	103.9	105.4
W	G	K	-	117.9	122.0	119.9
W	G	K	+	111.5	118.6	114.8
W	G	S	-	120.8	121.7	121.3
W	G	S	+	118.2	122.3	120.2
W	K	K	-	114.0	118.0	115.9
W	K	K	+	111.8	114.4	113.0
W	K	S	-	117.1	117.9	117.5
W	K	S	+	110.5	109.5	110.0
B				112.6	109.4	111.0
W				115.2	118.0	116.6
	G			116.3	116.8	116.5
	K			111.5	110.7	111.1
		K		112.6	113.2	112.9
		S		115.3	114.3	114.8
			-	116.2	115.9	116.0
			+	111.7	111.6	111.6
			Overall mean	114.0	113.5	113.8

Breed (W = White, B = Black)
Lupin (G = Gungurru, K = Kiev)
Form (K = Kernel, S = Seed)
Enzyme (- = Without, + = With)

TABLE 8. -- Experiment #1 -- Hens 36 - 44 weeks of age

Live weight

(least squares means)

				Live weight (kg)			
Breed	Lupin	Form	Enzyme	Week 0	Week 1	Week 4	Week 8
B	G	K	-	2.13	2.19	2.13	2.15
B	G	K	+	2.06	2.13	2.09	2.07
B	G	S	-	2.09	2.10	2.03	2.06
B	G	S	+	2.27	2.30	2.28	2.28
B	K	K	-	2.09	2.08	2.04	2.02
B	K	K	+	2.11	2.14	2.07	2.05
B	K	S	-	2.10	2.11	2.07	2.09
B	K	S	+	2.08	2.13	2.07	2.02
W	G	K	-	1.90	1.95	1.90	1.92
W	G	K	+	1.95	1.96	1.91	1.93
W	G	S	-	1.97	2.05	2.01	2.05
W	G	S	+	1.90	1.91	1.78	1.86
W	K	K	-	2.03	2.02	2.00	2.03
W	K	K	+	1.86	1.88	1.86	1.88
W	K	S	-	1.98	2.04	2.01	2.01
W	K	S	+	1.98	1.97	1.97	1.99
B				2.12	2.15	2.10	2.09
W				1.95	1.97	1.93	1.96
	G			2.03	2.07	2.02	2.04
	K			2.03	2.05	2.01	2.01
		K		2.02	2.04	2.00	2.01
		S		2.05	2.08	2.03	2.04
			-	2.04	2.07	2.03	2.04
			+	2.03	2.05	2.00	2.01
		Overall mean		2.03	2.07	2.02	2.03

Breed (W = White, B = Black)
Lupin (G = Gungurru, K = Kiev)
Form (K = Kernel, S = Seed)
Enzyme (- = Without, + = With)

TABLE 9. -- Experiment #1 -- Hens 44 weeks of age

Excreta moisture and incidence of soiled eggs

(least squares means)

Breed	Lupin	Form	Enzyme	Excreta moisture (%)	Soiled eggs (%)	Soiled eggs (% transformed)
B	G	K	-	76.6	6.3	2.5
B	G	K	+	78.1	14.3	3.7
B	G	S	-	75.4	7.3	2.7
B	G	S	+	75.3	11.1	3.1
B	K	K	-	78.6	13.6	3.7
B	K	K	+	76.1	5.4	2.4
B	K	S	-	77.4	6.4	2.5
B	K	S	+	77.0	5.2	2.1
W	G	K	-	77.2	13.9	3.7
W	G	K	+	77.1	5.7	2.2
W	G	S	-	77.8	10.3	3.2
W	G	S	+	74.6	4.7	1.8
W	K	K	-	75.9	10.3	3.2
W	K	K	+	75.2	1.9	1.3
W	K	S	-	77.2	8.8	2.6
W	K	S	+	75.3	6.8	2.6
B				76.8	8.7	2.8
W				76.3	7.8	2.6
	G			76.5	9.2	2.8
	K			76.6	7.3	2.5
		K		76.8	8.9	2.8
		S		76.2	7.6	2.6
			-	77.0	9.6	3.0
			+	76.1	6.9	2.4
		Overall mean		76.6	8.6	2.8

Breed (W = White, B = Black)
Lupin (G = Gungurru, K = Kiev)
Form (K = Kernel, S = Seed)
Enzyme (- = Without, + = With)

TABLE 10. -- Experiment #1 -- Hens 44 weeks of age

Egg weight and quality

(least squares means)

Breed	Lupin	Form	Enzyme	Egg weight (g)	Shell proportion (%)	Shell thickness (μm)	Yolk colour (Roche)
B	G	K	-	61.0	9.4	378	8.7
B	G	K	+	59.5	9.4	376	8.9
B	G	S	-	61.0	9.3	373	9.1
B	G	S	+	60.4	9.5	379	9.4
B	K	K	-	59.8	9.2	365	8.9
B	K	K	+	59.9	9.4	370	8.8
B	K	S	-	61.3	9.1	368	9.2
B	K	S	+	60.0	9.0	368	9.1
W	G	K	-	59.4	9.6	380	9.0
W	G	K	+	59.5	9.4	365	9.4
W	G	S	-	60.5	9.5	369	9.0
W	G	S	+	59.0	9.7	372	9.4
W	K	K	-	60.5	9.4	368	8.9
W	K	K	+	59.2	9.7	374	8.8
W	K	S	-	59.8	9.6	372	9.2
W	K	S	+	60.8	9.3	367	9.0
B				60.4	9.3	372	9.0
W				59.7	9.5	371	9.1
	G			60.0	9.5	374	9.1
	K			60.1	9.3	369	9.0
		K		59.9	9.5	372	8.9
		S		60.3	9.4	371	9.2
			-	60.4	9.4	372	9.0
			+	59.7	9.4	371	9.1
		Overall mean		60.0	9.4	371	9.0

Breed (W = White, B = Black)
Lupin (G = Gungurru, K = Kiev)
Form (K = Kernel, S = Seed)
Enzyme (- = Without, + = With)

TABLE 11. -- Composition of diets used in Experiment #2

Hens 46 - 53 weeks of age

Ingredient (%)	Corn	Gungurru Seed	Gungurru Kernel	Kiev seed
Corn †	58.95	58.35	51.59	53.82
Lupin ‡	-	25.30	21.70	21.20
Millrun	12.00	-	12.00	10.00
Fishmeal	3.00	3.00	3.00	3.00
Soybean	14.80	2.00	-	-
Tallow	1.00	1.20	1.50	1.70
Marble	8.40	7.80	8.20	8.10
Palfos	1.08	1.43	1.13	1.20
Salt	0.13	0.14	0.12	0.11
Na bicarbonate	0.25	0.25	0.25	0.25
Choline	0.05	0.05	0.05	0.05
Tryptophan	-	0.03	0.02	0.02
Lysine	-	0.03	0.02	0.12
Methionine	0.09	0.17	0.17	0.18
Premix	0.25	0.25	0.25	0.25

† Measured value for crude protein (Nx6.25) air-dry basis was 9.7%.

‡ Measured and assumed values used in diet formulation are shown in Appendix 1.

TABLE 12. -- Experiment #2 -- Hens 46 - 53 weeks of age

Summary of analysis of variance

Egg production and feed intake

EFFECT	HDEP1_4	HDEP5_7	HDEP1_7	FBD0_28	FBD28_47	FBD0_47
BLOCK	0.003	0.04	0.006	0.02	0.0001	0.002
BREED (B)	0.0001	0.0001	0.0001	NS	NS	NS
DIET (D)	0.003	0.01	0.004	0.02	NS	NS
B * D	0.06	0.006	0.02	0.02	NS	NS
Mean	79.4	76.5	78.2	121.7	132.1	125.8
Error MS	34.31	47.16	34.91	26.46	47.87	26.62
CV	7.4	9.0	7.6	4.2	5.2	4.1

HDEP1_4 = Hen-day egg production weeks 1 - 4 (eggs/100 hen-days)
HDEP5_7 = Hen-day egg production weeks 5 - 7 (eggs/100 hen-days)
HDEP1_7 = Hen-day egg production weeks 1 - 7 (eggs/100 hen-days)

FBD0_28 = Feed intake weeks 1 - 4 (g/bird/day)
FBD28_47 = Feed intake weeks 5 - 7 (g/bird/day)
FBD0_47 = Feed intake weeks 1 - 7 (g/bird/day)

TABLE 13. -- Experiment #2 -- Hens 46 - 53 weeks of age

Summary of analysis of variance

Live weight of hens

EFFECT	WT0	WT1	WT4	WT8
BLOCK	NS	NS	NS	NS
BREED (B)	0.002	0.004	0.0001	0.0004
DIET (D)	NS	NS	NS	NS
B*D	NS	NS	NS	NS
Mean	2.06	2.04	2.18	2.09
Error MS	0.061	0.057	0.068	0.066
CV	12.0	11.7	11.9	12.4

WT0 = Live weight (kg) at start of experiment
WT1 = Live weight (kg) after one week
WT4 = Live weight (kg) after four weeks
WT7 = Live weight (kg) after seven weeks

TABLE 14. -- Experiment #2 -- Hens 53 weeks of age

Summary of analysis of variance

Excreta moisture and incidence of soiled eggs

EFFECT	EXCRETA	SOILPC	SOILED
BLOCK	0.04	NS	NS
BREED (B)	NS	0.09	0.11
DIET (D)	NS	NS	NS
B*D	0.07	NS	NS
Mean	74.2	6.7	2.3
Error MS	5.62	50.5	1.86
CV	3.2	106	59

EXCRETA = Excreta moisture content (%)
SOILPC = Incidence of soiled eggs (%)
SOILED = Incidence of soiled eggs (square root transformation)

TABLE 15. -- Experiment #2 -- Hens 53 weeks of age

Summary of analysis of variance

Egg weight and quality

EFFECT	AEWT	EWT	SHELLPC	THICK	YOLKOL
BLOCK	NS	NS	NS	0.09	0.004
BREED (B)	0.09	NS	NS	0.002	NS
DIET (D)	NS	0.05	NS	NS	0.0001
B*D	NS	0.01	NS	NS	NS
Mean	62.0	62.9	9.1	369	9.8
Error MS	2.61	18.42	0.510	698	0.337
CV	2.6	6.8	7.8	7.2	5.9

AEWT = Average weight (g) of all eggs laid over three days
EWT = Egg weight (g) of eggs used for quality measurements
SHELLPC = Shell as % of egg weight
THICK = Shell thickness (μm) at equator
YOLKOL = Yolk colour (Roche fan)

TABLE 16. -- Experiment #2 -- Hens 46 - 53 weeks of age

Hen-day egg production

(least squares means)

			Experimental phase		
Breed	Diet	Enzyme	Weeks 1 - 4	Weeks 5 - 7	Weeks 1 - 7
			Eggs per 100 hen-days		
B	Corn control	-	78.7	77.7	78.2
B	Corn control	+	74.9	72.9	74.0
B	Gungurru seed	-	77.6	77.4	77.5
B	Gungurru seed	+	62.1 †	55.3 †	59.2 †
B	Gungurru kernel	-	78.7	77.3	78.1
B	Gungurru kernel	+	73.1	73.1	73.1
B	Kiev seed	-	78.0	74.2	76.4
B	Kiev seed	+	78.2	69.9	74.6
W	Corn control	-	79.9	75.1	77.8
W	Corn control	+	85.4	83.3	84.5
W	Gungurru seed	-	86.3	80.4	83.8
W	Gungurru seed	+	79.2 †	79.3	79.2
W	Gungurru kernel	-	83.2	78.2	81.1
W	Gungurru kernel	+	84.4	82.7	83.7
W	Kiev seed	-	85.6	79.3	82.9
W	Kiev seed	+	79.5	78.2	79.0
B	Over all diets		75.2	72.2	73.9
W	Over all diets		82.9	79.6	81.5
		Overall mean	79.4	76.5	78.2

Breed (W = White, B = Black)
Enzyme (- = Without, + = With)

† Pair-wise *t* test indicates a significant difference ($P < 0.05$) between diets with and without enzyme addition.

TABLE 17. -- Experiment #2 -- Hens 46 - 53 weeks of age

Feed intake

(least squares means)

Breed	Diet	Enzyme	Weeks 1 - 4	Weeks 5 - 7	Weeks 1 - 7
			Experimental phase		
			Feed intake (g/bird/day)		
B	Corn control	-	126.2	131.0	128.1
B	Corn control	+	118.1 †	132.1	123.7
B	Gungurru seed	-	124.1	134.1	128.1
B	Gungurru seed	+	112.6 †	125.7	117.8 †
B	Gungurru kernel	-	123.4	135.1	128.2
B	Gungurru kernel	+	118.3	135.6	125.3
B	Kiev seed	-	124.6	131.0	127.1
B	Kiev seed	+	125.7	130.7	127.7
W	Corn control	-	116.4	129.5	121.5
W	Corn control	+	120.0	131.8	124.8
W	Gungurru seed	-	121.1	128.7	124.2
W	Gungurru seed	+	119.0	133.2	124.5
W	Gungurru kernel	-	123.4	133.8	127.4
W	Gungurru kernel	+	124.3	135.8	128.8
W	Kiev seed	-	123.8	132.0	127.1
W	Kiev seed	+	120.8	130.2	124.5
B	Over all diets		122.1	132.3	126.2
W	Over all diets		121.2	131.8	125.4
		Overall mean	121.7	132.1	125.8

Breed (W = White, B = Black)
Enzyme (- = Without, + = With)

† Pair-wise *t* test indicates a significant difference ($P < 0.05$) between diets with and without enzyme addition.

TABLE 18. -- Experiment #2 -- Hens 46 - 53 weeks of age

Live weight

(least squares means)

			Live weight (kg)			
Breed	Diet	Enzyme	Week 0	Week 1	Week 4	Week 7
B	Corn control	-	2.16	2.15	2.29	2.22
B	Corn control	+	2.02	2.02	2.16	2.08
B	Gungurru seed	-	2.15	2.07	2.27	2.14
B	Gungurru seed	+	1.89 †	1.87	2.03	1.96
B	Gungurru kernel	-	2.18	2.15	2.30	2.17
B	Gungurru kernel	+	2.11	2.07	2.30	2.21
B	Kiev seed	-	2.16	2.14	2.34	2.16
B	Kiev seed	+	2.22	2.23	2.38	2.30
W	Corn control	-	2.00	1.98	2.07	2.01
W	Corn control	+	1.99	1.96	2.07	1.98
W	Gungurru seed	-	1.91	1.89	2.01	1.92
W	Gungurru seed	+	2.04	2.00	2.16	2.10
W	Gungurru kernel	-	2.04	2.06	2.19	2.11
W	Gungurru kernel	+	1.99	1.96	2.11	2.03
W	Kiev seed	-	2.01	1.99	2.06	1.98
W	Kiev seed	+	1.99	2.00	2.13	1.96
B	Over all diets		2.11	2.09	2.26	2.16
W	Over all diets		2.00	1.98	2.10	2.01
		Overall mean	2.06	2.04	2.18	2.09

Breed (W = White, B = Black)
Enzyme (- = Without, + = With)

† Pair-wise *t* test indicates a pre-existing significant difference ($P < 0.05$) between diets with and without enzyme addition.

TABLE 19. -- Experiment #2 -- Hens 53 weeks of age

Excreta moisture and incidence of soiled eggs

(least squares means)

Breed	Diet	Enzyme	Excreta moisture (%)	Soiled eggs (%)	Soiled eggs (% transformed)
B	Corn control	-	72.9	5.7	2.2
B	Corn control	+	73.7	5.6	2.2
B	Gungurru seed	-	74.9 †	10.4	2.9
B	Gungurru seed	+	71.4	8.6	2.9
B	Gungurru kernel	-	75.3	11.7	2.9
B	Gungurru kernel	+	72.1 ‡	14.4	3.7
B	Kiev seed	-	75.1	5.7	2.3
B	Kiev seed	+	74.1	2.3	1.2
W	Corn control	-	75.2	4.7	2.0
W	Corn control	+	74.0	4.5	1.8
W	Gungurru seed	-	74.7	4.6	2.0
W	Gungurru seed	+	76.3	8.9	2.9
W	Gungurru kernel	-	74.5	9.4	2.6
W	Gungurru kernel	+	74.2	2.7	1.5
W	Kiev seed	-	72.9	4.5	1.8
W	Kiev seed	+	74.3	4.4	1.9
B	Over all diets		73.7	8.0	2.5
W	Over all diets		74.5	5.5	2.1
		Overall mean	74.2	6.7	2.3

Breed (W = White, B = Black)
Enzyme (- = Without, + = With)

† Pair-wise *t* test indicates that the difference between diets with and without enzyme addition approached significance (P = 0.07).

‡ Pair-wise *t* test indicates a significant difference (P < 0.05) between diets with and without enzyme addition.

TABLE 20. -- Experiment #2 -- Hens 53 weeks of age

Egg weight and quality

(Least squares means)

Breed	Diet	Enzyme	Egg weight (g)	Shell proportion (%)	Shell thickness (μm)	Yolk colour (Roche)
B	Corn control	-	64.4	8.9	369	9.4
B	Corn control	+	62.0 †	9.1	373	9.3
B	Gungurru seed	-	62.0	9.2	375	10.1
B	Gungurru seed	+	63.7	8.9	366	10.1
B	Gungurru kernel	-	62.7	9.2	373	10.2
B	Gungurru kernel	+	62.9	9.4	384	10.1
B	Kiev seed	-	64.2	9.2	376	9.8
B	Kiev seed	+	62.6	9.0	363 ‡	10.0
W	Corn control	-	63.9	8.9	360	9.4
W	Corn control	+	63.2	9.2	368	9.2
W	Gungurru seed	-	63.1	9.1	364	9.7
W	Gungurru seed	+	64.4	9.2	373	10.0 †
W	Gungurru kernel	-	63.7	9.1	366	10.0
W	Gungurru kernel	+	62.4	9.2	367	10.2
W	Kiev seed	-	59.6	9.0	357	9.8
W	Kiev seed	+	61.5	9.1	361	10.1 ‡
B	Over all diets		63.1	9.1	372	9.9
W	Over all diets		62.7	9.1	364	9.8
		Overall mean	62.9	9.1	369	9.8

Breed (W = White, B = Black)
Enzyme (- = Without, + = With)

† Pair-wise *t* test indicates a significant difference ($P < 0.05$) between diets with and without enzyme addition.

‡ Pair-wise *t* test indicates that the difference between diets with and without enzyme addition approached significance ($P < 0.07$).

TABLE 21. -- Composition of diets used in Experiment #3

Hens 59 - 67 weeks of age

Ingredient	Lupin kernel isolate			
%	0%	5%	10%	15%
Sorghum †	59.14	58.54	57.80	52.31
Millrun	10.12	5.10	0.10	0.10
Meat and bone	7.50	8.00	8.20	8.00
Soybean	12.50	12.10	12.00	11.20
Lupin kernel isolate †	-	5.00	10.00	15.00
Tallow	1.20	1.80	2.40	4.00
Marble	8.80	8.70	8.70	8.50
Salt	0.14	0.14	0.15	0.14
Na bicarbonate	0.13	0.13	0.13	0.15
Choline	0.05	0.05	0.05	0.05
Lysine	-	-	-	0.05
Methionine	0.12	0.14	0.17	0.19
Tryptophan	-	-	-	0.01
Premix	0.25	0.25	0.25	0.25

† Measured values for crude protein (Nx6.25) air-dry basis were 7.3% for sorghum and 15.5% for lupin kernel isolate. Detailed information on the chemical composition and nutritive value for pigs can be found in the Final Report on PRDC Project DAS-29P.

TABLE 22. -- Experiment #3 -- Hens 59 - 67 weeks of age

Summary of analysis of variance

Egg production and feed intake

EFFECT	HDEP1_4	HDEP5_8	HDEP1_8	FBD0_28	FBD0_56	FBD28_56
BLOCK	NS	NS	NS	0.03	0.006	0.008
BREED (B)	0.02	0.09	0.04	0.0001	0.0001	0.0006
NSP (N)	NS	NS	NS	0.001	0.002	0.02
ENZYME (E)	NS	NS	NS	0.047	NS	NS
B * N	0.09	NS	NS	0.02	0.01	0.03
B * E	NS	NS	NS	NS	NS	NS
N * E	NS	NS	NS	NS	NS	NS
B * N * E	NS	NS	NS	NS	NS	NS
Mean	71.9	69.7	70.8	114.3	117.0	119.8
Error MS	52.7	76.5	58.9	34.1	30.3	43.3
CV	10.1	12.6	10.8	5.1	4.7	5.5

HDEP1_4 = Hen-day egg production weeks 1 - 4 (eggs/100 hen-days)
HDEP5_8 = Hen-day egg production weeks 5 - 8 (eggs/100 hen-days)
HDEP1_4 = Hen-day egg production weeks 1 - 8 (eggs/100 hen-days)

FBD0_28 = Feed intake weeks 1 - 4 (g/bird/day)
FBD0_56 = Feed intake weeks 1 - 8 (g/bird/day)
FBD28_28 = Feed intake weeks 5 - 6 (g/bird/day)

TABLE 23. -- Experiment #3 -- Hens 59 - 67 weeks of age

Summary of analysis of variance

Live weight of hens

EFFECT	WT0	WT2	WT4	WT8
BLOCK	NS	NS	NS	NS
BREED (B)	0.0003	0.003	0.001	0.01
NSP (N)	NS	NS	NS	NS
ENZYME (E)	NS	NS	0.053	NS
B * N	NS	NS	NS	NS
B * E	NS	NS	NS	NS
N * E	0.08	NS	0.096	NS
B * N * E	NS	NS	NS	NS
Mean	2.132	2.121	2.149	2.176
Error MS	0.073	0.075	0.074	0.084
CV	12.7	12.9	12.7	13.3

WT0 = Live weight (kg) at start of experiment
WT2 = Live weight (kg) after two week
WT4 = Live weight (kg) after four weeks
WT8 = Live weight (kg) after eight weeks

TABLE 24. -- Experiment #3 -- Hens 67 weeks of age

Summary of analysis of variance

Excreta moisture and incidence of soiled eggs

EFFECT	EXCRETA	SOILPC	SOILED
BLOCK	0.002	NS	NS
BREED (B)	0.0007	0.0009	0.0004
NSP (N)	0.0001	NS	NS
ENZYME (E)	0.06	NS	NS
B * N	NS	NS	NS
B * E	NS	NS	NS
N * E	NS	NS	NS
B *N * E	NS	NS	NS
Mean	79.5	12.6	3.3
Error MS	4.74	82.2	2.10
CV	2.7	72.0	44.1

EXCRETA = Excreta moisture content (%)
SOILPC = Incidence of soiled eggs (%)
SOILED = Incidence of soiled eggs (square root transformation)

TABLE 25. -- Experiment #3 -- Hens 67 weeks of age

Summary of analysis of variance

Egg weight and quality

EFFECT	AEWT	EWT	SHELLPC	THICK	YOLKOL
BLOCK	NS	0.02	NS	NS	0.0001
BREED (B)	0.03	NS	NS	0.04	0.004
NSP (N)	NS	0.01	0.06	NS	0.0001
ENZYME (E)	NS	NS	NS	NS	0.07
B * N	NS	NS	0.02	0.06	NS
B * E	NS	0.0001	NS	NS	NS
N * E	NS	NS	0.08	NS	0.0001
B *N * E	NS	NS	NS	NS	0.03
Mean	65.6	64.9	9.0	361	8.9
Error MS	4.79	26.2	0.567	895	0.802
CV	3.3	7.9	8.4	8.3	10.0

AEWT = Average weight (g) of all eggs laid over three days
EWT = Egg weight (g) of eggs used for quality measurements
SHELLWT = Shell weight (g)
SHELLPC = Shell as % of egg weight
THICK = Shell thickness (μm) at equator
YOLKOL = Yolk colour (Roche fan)

TABLE 26. -- Experiment #3 -- Hens 59 - 67 weeks of age

Hen-day egg production

(least squares means)

			Experimental phase		
Breed	NSP	Enzyme	Weeks 1 - 4	Weeks 5 - 8	Weeks 1 - 8
			Eggs per 100 hen-days		
B	0	-	70.6	69.7	70.2
B	0	+	67.9	69.4	68.6
B	5	-	72.2	69.7	70.9
B	5	+	77.2	71.5	74.4
B	10	-	70.5	66.0	68.3
B	10	+	69.2	67.2	68.2
B	15	-	68.4	68.2	68.3
B	15	+	68.3	66.3	67.3
W	0	-	82.6	78.9	80.8
W	0	+	71.3	68.8	70.1
W	5	-	74.2	70.3	72.3
W	5	+	72.4	70.7	71.5
W	10	-	70.8	65.3	68.1
W	10	+	68.6	67.0	67.8
W	15	-	76.2	75.8	76.0
W	15	+	77.9	77.9	77.9
B			70.5	68.5	69.5
W			74.1	71.8	73.1
	0		73.1	71.7	72.4
	5		74.0	70.5	72.3
	10		69.8	66.4	68.1
	15		72.7	72.1	72.4
		-	73.2	70.5	71.9
		+	71.6	69.9	70.7
	Overall mean		71.9	69.7	70.8

Breed (W = White, B = Black)
NSP (0, 5, 10, 15%)
Enzyme (- = Without, + = With)

TABLE 27. -- Experiment #3 -- Hens 59 - 67 weeks of age

Feed intake

(Least squares means)

			Experimental phase		
Breed	NSP	Enzyme	Weeks 1 - 4	Weeks 5 - 8	Weeks 1 - 8
			Feed intake (g/bird/day)		
B	0	-	119.3	125.6	122.4
B	0	+	122.7	122.6	122.6
B	5	-	117.2	125.6	121.4
B	5	+	119.8	123.2	121.4
B	10	-	117.6	125.5	121.4
B	10	+	117.1	120.6	118.8
B	15	-	113.6	120.4	117.0
B	15	+	113.6	121.4	117.5
W	0	-	116.0	129.5	122.6
W	0	+	119.5	119.4	119.5
W	5	-	107.9	115.0	111.5
W	5	+	110.1	114.5	112.6
W	10	-	105.5	111.2	108.3
W	10	+	108.3	113.7	110.9
W	15	-	110.7	118.8	114.7
W	15	+	118.0	120.8	119.4
B			117.6	123.1	120.3
W			112.0	117.9	114.9
	0		119.4	124.3	121.8
	5		113.8	119.6	116.7
	10		112.1	117.7	114.9
	15		114.0	120.3	117.2
		-	113.5	121.4	117.4
		+	116.1	119.5	117.9
	Overall mean		114.3	119.8	117.0

Breed (W = White, B = Black)
NSP (0, 5, 10, 15%)
Enzyme (- = Without, + = With)

TABLE 28. -- Experiment #3 -- Hens 59 - 67 weeks of age

Live weight

(Least squares means)

			Live weight)kg)			
Breed	NSP	Enzyme	Week 0	Week 2	Week 4	Week 8
B	0	-	2.22	2.24	2.25	2.28
B	0	+	2.19	2.17	2.22	2.22
B	5	-	2.23	2.19	2.26	2.30
B	5	+	2.15	2.15	2.20	2.17
B	10	-	2.11	2.11	2.08	2.17
B	10	+	2.31	2.27	2.34	2.36
B	15	-	2.14	2.14	2.13	2.18
B	15	+	2.30	2.21	2.24	2.19
W	0	-	1.98	1.97	2.00	2.09
W	0	+	2.04	2.07	2.08	2.14
W	5	-	2.03	2.04	2.02	2.11
W	5	+	1.92	1.93	1.97	2.04
W	10	-	2.08	2.06	2.08	2.10
W	10	+	2.28	2.29	2.32	2.28
W	15	-	1.98	1.97	1.99	2.02
W	15	+	2.08	2.10	2.14	2.15
B			2.21	2.18	2.21	2.23
W			2.05	2.05	2.07	2.12
	0		2.11	2.11	2.14	2.18
	5		2.08	2.08	2.11	2.16
	10		2.19	2.18	2.20	2.23
	15		2.12	2.10	2.12	2.14
		-	2.10	2.09	2.10	2.16
		+	2.16	2.15	2.19	2.20
		Overall mean	2.13	2.12	2.15	2.18

Breed (W = White, B = Black)
NSP (0, 5, 10, 15%)
Enzyme (- = Without, + = With)

TABLE 29. -- Experiment #3 -- Hens 67 weeks of age

Excreta moisture and incidence of soiled eggs

(Least squares means)

Breed	NSP	Enzyme	Excreta moisture (%)	Soiled eggs (%)	Soiled eggs (% transformed)
B	0	-	76.2	17.3	4.1
B	0	+	77.1	15.9	4.0
B	5	-	78.5	13.5	3.7
B	5	+	78.1	16.3	3.8
B	10	-	80.0	21.4	4.3
B	10	+	79.7	11.7	3.4
B	15	-	80.1	13.5	3.3
B	15	+	80.1	18.1	4.2
W	0	-	77.1	9.1	2.5
W	0	+	79.5	7.4	2.5
W	5	-	80.4	3.2	1.7
W	5	+	82.1	11.8	3.3
W	10	-	79.5	10.7	2.8
W	10	+	81.1	9.4	2.6
W	15	-	81.3	16.6	3.9
W	15	+	82.7	3.3	1.2
B			78.7	16.0	3.8
W			80.5	8.9	2.6
	0		77.4	12.4	3.3
	5		79.8	11.2	3.1
	10		80.1	13.3	3.3
	15		81.0	12.9	3.3
		-	79.1	13.2	3.3
		+	80.1	11.7	3.2
		Overall mean	79.5	12.6	3.3

Breed (W = White, B = Black)
NSP (0, 5, 10, 15%)
Enzyme (- = Without, + = With)

TABLE 30. -- Experiment #3 -- Hens 67 weeks of age

Egg weight and quality

(Least squares means)

Breed	NSP	Enzyme	AEWT	SHELLPC	THICK	YOLKOL
B	0	-	66.6	8.9	363	8.7
B	0	+	66.4	9.0	367	9.4
B	5	-	66.0	8.9	366	9.8
B	5	+	65.1	9.2	367	9.0
B	10	-	65.8	9.0	368	8.5
B	10	+	66.9	9.1	372	8.9
B	15	-	66.6	9.1	367	8.9
B	15	+	66.0	8.8	359	8.6
W	0	-	65.4	9.6	377	8.0
W	0	+	64.9	8.8	357	9.6
W	5	-	64.4	8.6	351	9.0
W	5	+	64.6	8.6	345	9.1
W	10	-	64.6	8.9	356	8.7
W	10	+	66.5	9.1	360	8.5
W	15	-	64.5	9.2	361	8.5
W	15	+	66.0	9.1	369	8.3
B			66.2	9.0	366	9.0
W			65.1	9.0	359	8.7
	0		65.8	9.1	366	8.9
	5		65.0	8.8	357	9.2
	10		65.9	9.0	364	8.7
	15		65.8	9.1	364	8.6
		-	65.5	9.0	364	8.8
		+	65.8	9.0	362	8.9
	Overall	mean	65.6	9.0	361	8.9

Breed (W = White, B = Black)
NSP (0, 5, 10, 15%)
Enzyme (- = Without, + = With)

TABLE 31. -- Composition of diets used in Experiment #4

Hens 81 - 89 weeks of age

Ingredient	Wheat-base				Sorghum-base			
%	0%	7.5%	15%	22.5%	0%	7.5%	15%	22.5%
Wheat †	58.53	59.66	60.21	59.78	-	-	-	-
Sorghum †	-	-	-	-	52.15	52.70	51.24	50.47
Millrun	15.00	9.00	5.00	-	17.50	12.50	10.00	5.00
Meat and bone	8.00	5.90	6.40	3.90	9.00	8.00	8.00	5.10
Soybean	6.00	5.00	0.50	-	10.30	8.00	4.00	4.00
Lupin seed ‡	-	7.50	15.00	22.50	-	7.50	15.00	22.50
Tallow	3.50	3.50	3.50	3.80	2.40	2.40	2.80	3.20
Marble	8.2	8.6	8.5	8.4	7.9	8.1	8.1	8.2
Palfos	-	-	-	0.65	-	-	-	0.58
Salt	0.07	0.12	0.11	0.16	0.09	0.12	0.12	0.18
Na bicarbonate	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Choline	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Lysine	0.08	0.09	0.13	0.14	-	-	0.03	0.04
Methionine	0.12	0.13	0.15	0.17	0.16	0.18	0.20	0.22
Tryptophan	-	-	-	-	-	-	0.01	0.01
Yolk colorant	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Premix	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

† Measured values for crude protein (Nx6.25) air-dry basis were 13.0% for wheat and 9.4% for sorghum.

‡ Measured and assumed values used in diet formulation are shown in Appendix 2.

TABLE 32. -- Experiment #4 -- Hens 81 - 89 weeks of age

Summary of analysis of variance

Egg production and feed intake

EFFECT	HDEP1_4	HDEP5_8	HDEP1_8	FBD0_28	FBD0_56	FBD28_56
BLOCK	NS	NS	NS	0.003	0.02	NS
BREED (B)	NS	NS	NS	0.0001	0.0001	0.0001
GRAIN (G)	NS	NS	NS	0.03	0.01	0.03
LUPIN (L)	NS	NS	NS	NS	NS	NS
B * G	NS	NS	NS	NS	NS	NS
B * L	NS	NS	NS	NS	NS	NS
G * L	**	NS	0.06	NS	NS	NS
B * G * L	NS	NS	NS	0.02	0.02	0.08
Mean	52.2	51.8	52.0	113.2	114.8	116.5
Error MS	92.49	72.70	66.48	46.33	40.74	54.11
CV	18.4	16.4	15.7	6.0	5.6	6.3

HDEP1_4 = Hen-day egg production weeks 1 - 4 (eggs/100 hen-days)
HDEP5_8 = Hen-day egg production weeks 5 - 8 (eggs/100 hen-days)
HDEP1_4 = Hen-day egg production weeks 1 - 8 (eggs/100 hen-days)

FBD0_28 = Feed intake weeks 1 - 4 (g/bird/day)
FBD0_56 = Feed intake weeks 1 - 8 (g/bird/day)
FBD28_28 = Feed intake weeks 5 - 8 (g/bird/day)

TABLE 33. -- Experiment #4 -- Hens 81 - 89 weeks of age

Summary of analysis of variance

Live weight of hens

EFFECT	WT0	WT8
BLOCK	NS	NS
BREED (B)	0.003	0.005
GRAIN (G)	NS	NS
LUPIN (L)	NS	NS
B * G	NS	NS
B * L	NS	NS
G * L	NS	NS
B * G * L	NS	NS
Mean	2.296	2.304
Error MS	0.141	0.128
CV	16.4	15.5

WT0 = Live weight (kg) at start of experiment
WT8 = Live weight (kg) after eight weeks

TABLE 34. -- Experiment #4 -- Hens 89 weeks of age

Summary of analysis of variance

Excreta moisture and incidence of soiled eggs

EFFECT	EXCRETA	SOILED
BLOCK	NS	NS
BREED (B)	0.07	NS
GRAIN (G)	NS	0.04
LUPIN (L)	NS	NS
B * G	NS	NS
B * L	NS	NS
G * L	NS	NS
B * G * L	NS	NS
Mean	70.6	2.84
Error MS	8.38	2.60
CV	4.1	56.8

EXCRETA = Excreta moisture content (%)
SOILED = Incidence of soiled eggs (square root transformation)
(actual incidence was 10.1% prior to transformation)

TABLE 35. -- Experiment #4 -- Hens 89 weeks of age

Summary of analysis of variance

Egg weight and quality

EFFECT	AEWT	EWT	SHELLPC	THICK	YOLKOL
BLOCK	NS	0.03	NS	0.047	NS
BREED (B)	NS	NS	NS	0.02	NS
GRAIN (G)	NS	NS	NS	NS	NS
LUPIN (L)	NS	NS	NS	0.055	0.001
B * G	NS	NS	0.054	0.03	NS
B * L	NS	NS	NS	NS	NS
G * L	NS	0.053	NS	NS	NS
B * G * L	NS	NS	NS	NS	NS
Mean	65.5	67.3	8.4	342	11.8
Error MS	13.5	35.9	0.781	976	0.372
CV	5.6	8.9	10.5	9.1	5.2

AEWT = Average weight (g) of all eggs laid over three days
EWT = Egg weight (g) of eggs used for quality measurements
SHELLPC = Shell as % of egg weight
THICK = Shell thickness (μm) at equator
YOLKOL = Yolk colour (Roche fan)

TABLE 36. -- Experiment #4 -- Hens 81 - 89 weeks of age

Hen-day egg production

(Least squares means)

			Experimental phase		
Breed	Grain	Lupin	Weeks 1 - 4	Weeks 5 - 8	Weeks 1 - 8
			Eggs per 100 hen-days		
B	S	0	47.6	52.7	50.2
B	S	7.5	52.2	49.8	51.0
B	S	15.0	51.7	49.4	50.5
B	S	22.5	55.8	53.2	54.5
B	W	0	55.7	55.8	55.8
B	W	7.5	46.8	46.6	46.7
B	W	15.0	53.0	54.3	53.6
B	W	22.5	46.5	51.6	49.0
W	S	0	46.2	52.7	49.5
W	S	7.5	60.4	57.6	59.0
W	S	15.0	48.5	47.4	47.9
W	S	22.5	57.3	53.3	55.3
W	W	0	55.5	48.4	52.0
W	W	7.5	52.2	53.2	52.8
W	W	15.0	54.5	52.4	53.4
W	W	22.5	51.9	51.2	51.5
B			51.2	51.7	51.4
W			53.3	52.0	52.7
	S		52.5	52.0	52.2
	W		52.0	51.7	51.8
		0	51.3	52.4	51.8
		7.5	52.9	51.8	52.4
		15.0	51.9	50.9	51.4
		22.5	52.9	52.3	52.6
	Overall mean		52.3	51.8	52.0

Breed (W = White, B = Black)
Grain (W = Wheat, S = Sorghum)
Lupin (0, 7.5, 15.0, 22.5%)

TABLE 37. -- Experiment #4 -- Hens 81 - 89 weeks of age

Feed intake

(Least squares means)

			Experimental phase		
Breed	Grain	Lupin	Weeks 1 - 4	Weeks 5 - 8	Weeks 1 - 8
			Feed intake (g/bird/day)		
B	S	0	119.5	124.6	122.1
B	S	7.5	121.8	127.1	124.5
B	S	15.0	125.8	128.3	127.1
B	S	22.5	124.0	128.1	126.1
B	W	0	119.7	120.7	120.2
B	W	7.5	118.2	122.5	120.3
B	W	15.0	113.2	115.3	114.3
B	W	22.5	120.1	127.2	123.6
W	S	0	100.1	108.7	104.4
W	S	7.5	110.3	110.5	110.3
W	S	15.0	125.8	108.9	107.4
W	S	22.5	105.8	109.2	109.7
W	W	0	104.2	105.7	104.9
W	W	7.5	105.8	109.8	107.8
W	W	15.0	111.2	113.2	112.2
W	W	22.5	100.5	103.9	102.0
B			120.3	124.2	122.2
W			106.0	108.7	107.3
	S		114.7	118.2	116.4
	W		111.6	114.8	113.1
		0	110.9	114.9	112.9
		7.5	114.0	117.4	115.7
		15.0	114.0	116.4	115.2
		22.5	113.7	117.1	115.3
	Overall mean		113.2	116.5	114.8

Breed (W = White, B = Black)
Grain (W = Wheat, S = Sorghum)
Lupin (0, 7.5, 15.0, 22.5%)

TABLE 38. -- Experiment #4 -- Hens 81 - 89 weeks of age

Live weight

(Least squares means)

			Live weight (kg)	
Breed	Grain	Lupin	Week 0	Week 8
B	S	0	2.38	2.39
B	S	7.5	2.45	2.49
B	S	15.0	2.34	2.36
B	S	22.5	2.38	2.42
B	W	0	2.40	2.45
B	W	7.5	2.31	2.26
B	W	15.0	2.42	2.32
B	W	22.5	2.36	2.33
W	S	0	2.41	2.45
W	S	7.5	2.21	2.23
W	S	15.0	2.25	2.23
W	S	22.5	2.17	2.15
W	W	0	2.17	2.24
W	W	7.5	2.15	2.22
W	W	15.0	2.08	2.17
W	W	22.5	2.27	2.15
B			2.38	2.38
W			2.21	2.23
	S		2.32	2.34
	W		2.27	2.27
		0	2.34	2.38
		7.5	2.28	2.30
		15.0	2.27	2.27
		22.5	2.29	2.26
		Overall mean	2.30	2.30

Breed (W = White, B = Black)
Grain (W = Wheat, S = Sorghum)
Lupin (0, 7.5, 15.0, 22.5%)

TABLE 39. -- Experiment #4 -- Hens 89 weeks of age

Excreta moisture and incidence of soiled eggs

(Least squares means)

Breed	Grain	Lupin	Excreta moisture (%)	Soiled eggs (%)	Soiled eggs (% transformed)
B	S	0	69.5	10.1	2.82
B	S	7.5	71.0	8.3	2.59
B	S	15.0	69.9	18.4	3.84
B	S	22.5	70.7	10.9	3.32
B	W	0	71.1	5.2	1.99
B	W	7.5	70.7	4.8	1.75
B	W	15.0	68.9	11.3	3.21
B	W	22.5	69.1	10.7	2.93
W	S	0	70.4	9.4	2.77
W	S	7.5	70.5	15.4	3.88
W	S	15.0	71.4	11.5	3.25
W	S	22.5	72.0	10.9	2.94
W	W	0	71.2	2.7	1.45
W	W	7.5	70.5	13.8	3.16
W	W	15.0	71.8	5.5	2.04
W	W	22.5	71.8	13.4	3.44
B			70.1	10.0	2.81
W			71.2	10.3	2.87
	S		70.7	11.9	3.18
	W		70.6	8.4	2.50
		0	70.6	6.9	2.26
		7.5	70.7	10.6	2.84
		15.0	70.5	11.7	3.08
		22.5	70.9	11.5	3.16
		Overall mean	70.6	10.1	2.84

Breed (W = White, B = Black)
Grain (W = Wheat, S = Sorghum)
Lupin (0, 7.5, 15.0, 22.5%)

TABLE 40. -- Experiment #4 -- Hens 89 weeks of age

Egg weight and quality

(Least squares means)

Breed	Grain	Lupin	AEWT	SHELLPC	THICK	YOLKOL
B	S	0	64.4	8.2	338	11.6
B	S	7.5	67.3	8.4	345	11.6
B	S	15.0	65.5	8.4	344	12.1
B	S	22.5	66.3	8.2	336	11.8
B	W	0	65.9	8.9	366	11.6
B	W	7.5	66.3	8.3	343	11.7
B	W	15.0	65.3	8.5	350	12.0
B	W	22.5	62.7	8.2	340	12.0
W	S	0	65.7	8.8	349	11.7
W	S	7.5	67.0	8.2	329	11.7
W	S	15.0	64.9	8.7	350	11.7
W	S	22.5	66.6	8.4	334	11.6
W	W	0	63.5	8.5	340	11.5
W	W	7.5	66.3	8.2	323	11.7
W	W	15.0	67.7	8.1	331	12.1
W	W	22.5	63.2	8.4	337	11.9
B			65.4	8.4	345	11.8
W			65.6	8.4	336	11.7
	S		66.0	8.4	341	11.7
	W		65.1	8.4	340	11.8
		0	64.9	8.6	348	11.6
		7.5	66.7	8.3	336	11.6
		15.0	65.8	8.4	344	12.0
		22.5	64.7	8.2	335	11.8
	Overall	mean	65.5	8.4	342	11.8

Breed (W = White, B = Black)
Grain (W = Wheat, S = Sorghum)
Lupin (0, 7.5, 15.0, 22.5%)

FIGURE 1. -- Effect of a breed by enzyme interaction on incidence of soiled eggs in Experiment #1 (Hens 44 weeks of age)

*** denotes significant effect of enzyme ($P < 0.05$)**

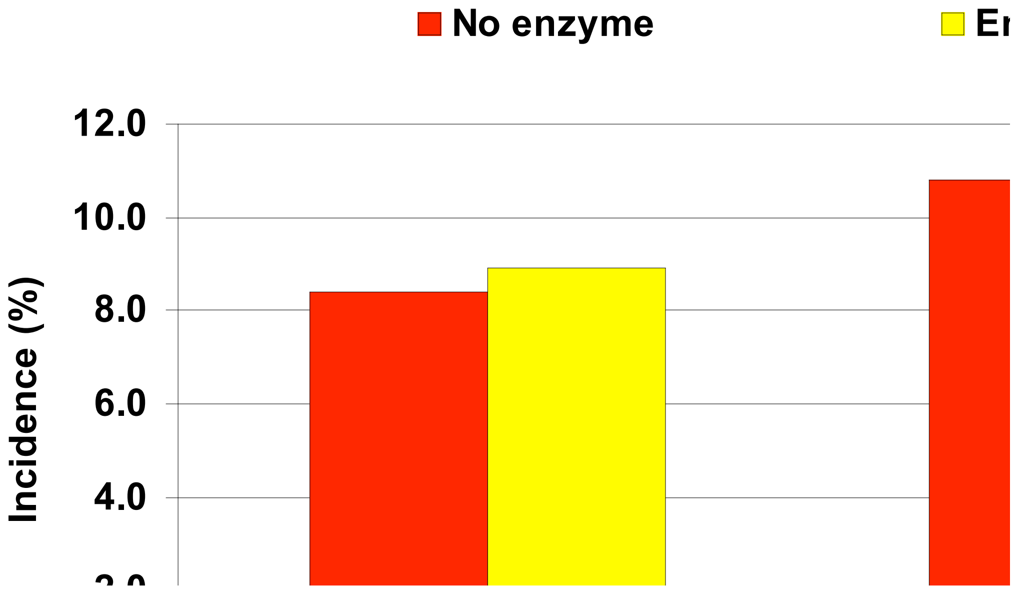


FIGURE 2. -- Effect of a lupin by enzyme interaction on egg yolk colour in Experiment #1 (Hens 44 weeks of age)

*** denotes significant effect of enzyme (P < 0.05)**

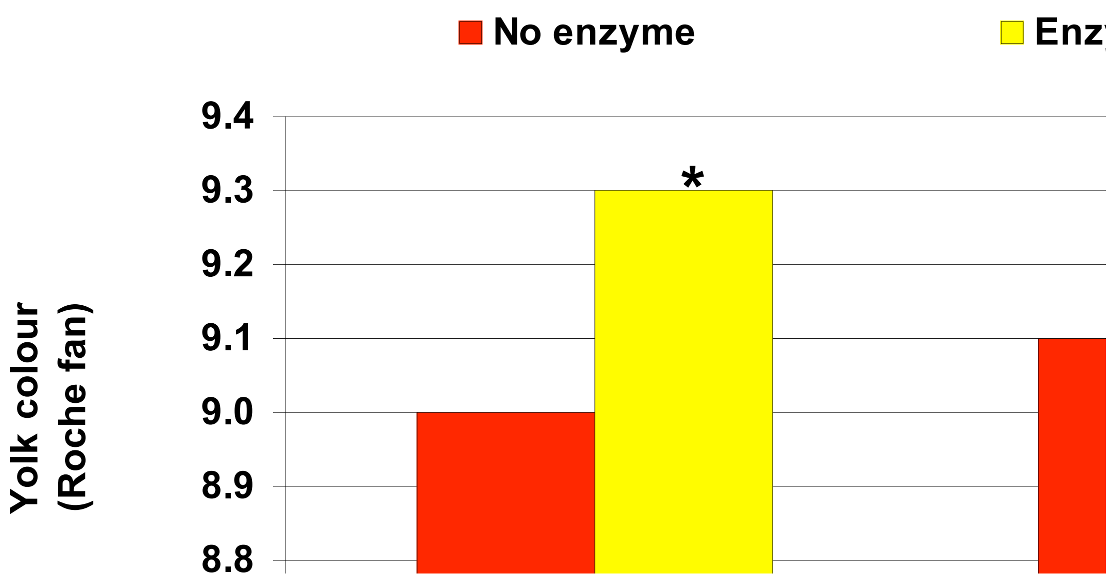
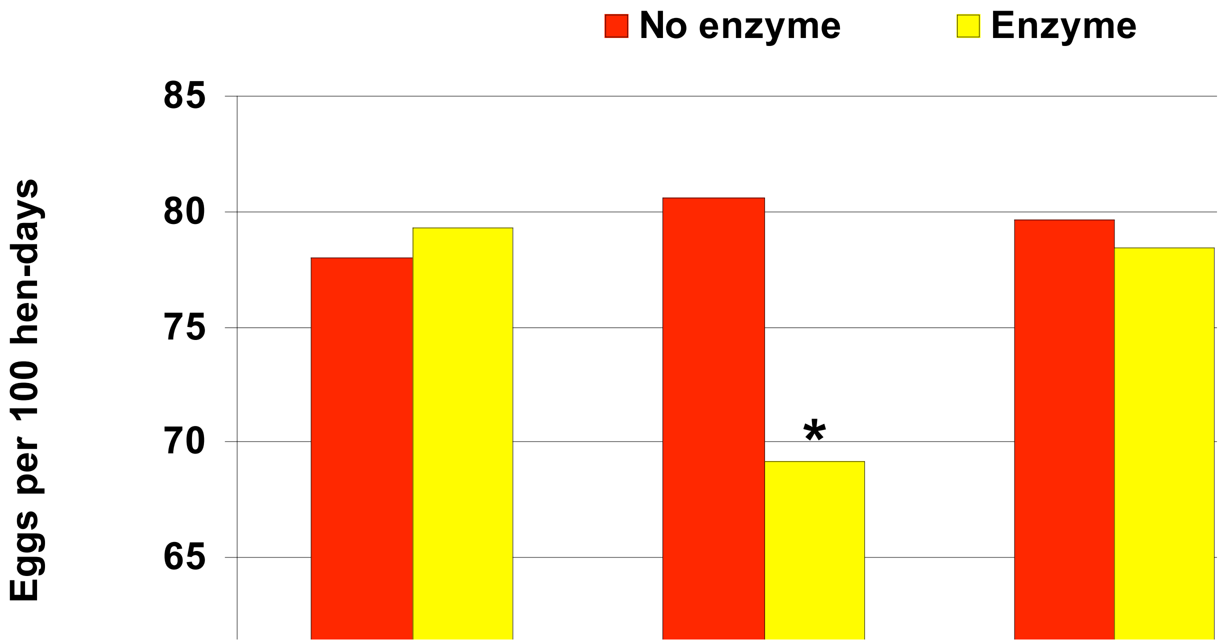


FIGURE 3. -- Effect of a breed by diet interaction on rate of lay in Experiment #2 (Hens 46 - 53 weeks of age)
*** denotes significant effect of enzyme (P < 0.05)**



NUTRITIVE VALUE OF LUPINS FOR LAYERS

R.J. Hughes and A. Kocher *

Summary

Nutritive values of Australian sweet lupin *Lupinus angustifolius* cv. Gungurru, and white lupin *Lupinus albus* cv Kiev mutant, were assessed in a series of three experiments each of 8-week duration which were conducted on the same flock of 960 Tegel Tint and SB2 hens.

Layer diets containing wholeseed Gungurru 280 g/kg, de-hulled Gungurru 190 g/kg, wholeseed Kiev 180 g/kg or de-hulled Kiev 150 g/kg produced comparable results in terms of rate of lay, egg weight, excreta condition and egg quality. The seed coat of both species was deemed to be low in energy but had no obvious anti-nutritive effects in diets for laying hens. A commercial enzyme product reduced feed intake and incidence of soiled eggs. In another experiment, dietary inclusion of 225 g/kg wholeseed Gungurru in wheat- or sorghum-based diets had no deleterious effects on feed intake, rate of lay, excreta moisture or egg quality in comparison with control diets containing no lupin. However, an experiment with a commercial isolate of non-starch polysaccharide (NSP) from de-hulled *L. angustifolius* showed that there was potential for wet droppings and increased soiling of eggs as a result of NSP in lupin.

In conclusion, Australian sweet lupin and white lupin are valuable alternative sources of protein for laying hens. Removal of seed coat is an unnecessary added cost but care needs to be taken when assigning energy values to lupin for formulation purposes. Further development of enzymes is required for the removal of anti-nutritive effects of NSP in lupin.

I. INTRODUCTION

High protein, amino acid and energy levels, combined with cost-competitiveness with a wide range of cereals, legumes and animal proteins, give Australian lupins excellent potential for use in poultry diets. *Lupinus angustifolius* cv. Gungurru, in particular, is widely used as a protein source for monogastrics (van Barneveld and Hughes, 1994).

However, some uncertainty surrounds the effects of high levels of oligosaccharides and non-starch polysaccharides (NSP), the value of additional processing such as de-hulling, and the cost-effectiveness of commercial enzyme products. Do high levels of oligosaccharides and NSP increase the incidence of wet droppings and soiled eggs? Does the seed coat of lupins contain anti-nutritive factors and will de-hulling lead to improvements? Can addition of feed enzymes to diets containing wholeseed or de-hulled lupins improve laying performance?

Answers to these questions were sought in a series of experiments conducted on the same flock of hens. Summarised results of three experiments are discussed in this report.

II. MATERIALS AND METHODS

A total of 960 laying hens (480 Tegel Tint and 480 Tegel SB2) were housed five per cage in 192 Harrison "Welfare" back-to-back, single-tier cages (each 500 mm wide by 545 mm deep; 545 cm^2/bird) in a controlled environment layer shed. A 16 h light program was provided. Hens had access to feed and water at all times. From 18 to 36 weeks of age, and in periods between experiments, birds received a high nutrient density layer mash.

In each experiment, 8 dietary treatments (12 replicates; 10 birds in two adjacent cages for each replicate) were examined over an 8-week period. Dietary treatments were re-randomised for each experiment. Major feed ingredients were analysed for metabolisable energy (ME, by broiler bioassay) and protein. Diets within an experiment had similar levels of ME, protein, essential amino acids, calcium (Ca), available phosphorus (aP), sodium and chlorine. Hens were weighed at the start and end

* SARDI, Pig and Poultry Production Institute, Nutrition Research laboratory, University of Adelaide, Roseworthy, SA 5371.

of each experiment. Egg production and mortality were recorded daily. Feed intake was measured at 4-week intervals. Egg weight, excreta moisture, incidence of soiled eggs, shell thickness and yolk colour were measured at the end of each experiment.

Experiment 1 examined the effects of lupin species (*L. angustifolius* cv Gungurru and *L albus* cv Kiev mutant), removal of seed-coat, and dietary addition of enzyme product (Avizyme 2300 at 1kg/tonne) in wheat-based diets on the performance of laying hens in the period 36 - 44 weeks of age. Inclusion rates of lupin (g/kg) were Gungurru wholeseed 279, Gungurru kernel 189, Kiev wholeseed 182, and Kiev kernel 150. Steam-pelleted diets contained per kg ME 11.3 MJ, protein 170 g, lysine 7.7 g, methionine 3.6 g, Ca 37.5 g and aP 3.8 g.

Experiment 2 examined the effects of dietary inclusion rate (0, 50, 100 and 150 g/kg) of a commercial isolate of NSP from de-hulled *L. angustifolius* in a sorghum-based diet, and addition of enzyme product (Avizyme 2300 at 1kg/tonne) on the performance of laying hens in the period 59 - 67 weeks of age. The total NSP content of the isolate was 560 g/kg which was mainly galactose (420 g/kg). The soluble NSP content of the isolate was 60 g/kg. Steam-pelleted diets contained per kg ME 11.3 MJ, protein 155 g, lysine 7.0 g, methionine 3.5 g, Ca 40 g and aP 3.5 g.

Experiment 3 examined the effects of dietary inclusion rate (0, 75, 150 and 225 g/kg) of *L. angustifolius* cv Gungurru in wheat or sorghum-based diets on the performance of laying hens in the period 81 - 89 weeks of age. Mash diets contained per kg ME 11.5 MJ, protein 170 g, lysine 7.7 g, methionine 3.6 g, Ca 38 g and aP 4 g.

III. RESULTS AND DISCUSSION

Results from Experiment 1 (Table 1) show that egg production, excreta moisture, and shell quality were unaffected by lupin species, form of lupin or enzyme addition. Gungurru lupin increased feed intake by 4.3% compared with Kiev lupin, whereas de-hulling of both species reduced feed intake by 1.7%. Enzyme addition reduced feed intake by 3.9%, egg weight by 1.2% and incidence of soiled eggs by 28%. Enzyme degradation of NSP in ingredients other than lupin could have contributed to these benefits. Yolk colour was significantly reduced by de-hulling (3.3%). On the other hand, yolk colour was improved by 3.3% by addition of enzyme to the Gungurru diets. Tint hens ate more feed (4.2%) and laid more eggs (5.2%) although egg weight was smaller (1.2%) in comparison with Tegel SB2 hens.

These results suggest that energy values for Kiev lupin were underestimated relative to Gungurru, as were the energy values for lupin kernel relative to whole seed of both species, possibly because AME values obtained in chick bioassays are not directly applicable for formulation of layer diets. Seed coat of both lupin species appear not to contain anti-nutritive factors but did have an energy dilution effect in this study.

In experiment 2, dietary inclusion of lupin kernel isolate reduced feed intake and increased excreta moisture content. However, there was no evidence of a dose response effect of lupin NSP on feed intake or excreta moisture. On the other hand, yolk colour was significantly affected by an interaction between breed and lupin NSP, with higher levels of lupin NSP depressing yolk colour in Tint but not in SB2 hens. Addition of enzyme had no significant effects on performance, excreta condition or egg quality.

Table 1. Effects of breed (SB2 and Tint), lupin species (Gungurru and Kiev), lupin form (wholeseed and de-hulled) and enzyme product on feed intake (FI), egg production (EP), excreta moisture (EM), soiled eggs (SE), egg weight (EW), shell thickness (ST) and yolk colour (YC). Non-significant effects (P>0.05) are shown as ns.

Effect	FI (g/bird/d)	EP (%)	EM (g/kg)	SE (%)	EW (g)	ST (μm)	YC (Roche)
	Probability of greater F value in analysis of variance						
Breed	<0.001	ns	ns	ns	0.06	ns	ns
Lupin	<0.001	ns	ns	ns	ns	0.08	0.09

Form	0.06	ns	ns	ns	ns		<0.001
Enzyme	<0.001	ns	ns	0.06	<0.05	ns	ns
			Least squares means				
SB2	110.0	82.0	768	8.7	60.4	372	9.0
Tint	116.6	86.5	763	7.8	59.7	371	9.1
Gungurru	116.5	83.9	765	9.2	60.0	374	9.1
Kiev	111.1	84.6	766	7.3	60.1	369	9.0
De-hulled	112.9	84.2	768	8.9	59.9	372	8.9
Wholeseed	114.8	84.3	762	7.6	60.3	371	9.2
No enzyme	116.0	83.8	770	9.6	60.4	372	9.0
Enzyme	111.6	84.7	761	6.9	59.7	371	9.1
Mean	113.8	84.3	766	8.6	60.0	371	9.0

Table 2. Effects of breed (SB2 and Tint), dietary inclusion rate (0, 50, 100 and 150 g/kg) of a commercial isolate of NSP from *L. angustifolius*, and enzyme product on feed intake (FI), egg production (EP), excreta moisture (EM), soiled eggs (SE), egg weight (EW), shell thickness (ST) and yolk colour (YC). Non-significant effects (P>0.05) are shown as ns. Lupin NSP mean values having a common superscript are not significantly different (P<0.05).

Effect	FI (g/bird/d)	EP (%)	EM (g/kg)	SE (%)	EW (g)	ST (µm)	YC (Roche)
			Probability of greater F value in analysis of variance				
Breed	<0.001	<0.05	<0.001	<0.001	<0.05	<0.05	<0.01
Lupin NSP	<0.05	ns	<0.001	ns	ns	ns	<0.001
Enzyme	ns	ns	0.06	ns	ns	ns	0.07
			Least squares means				
SB2	120.3	69.5	787	16.0	66.2	366	9.0
Tint	114.9	73.1	805	8.9	65.1	359	8.7
Lupin NSP 0 g/kg	121.8 ^{a}	72.4	774 ^{a}	12.4	65.8	366	8.9 ^{b}
Lupin NSP 50 g/kg	116.7 ^{b}	72.3	798 ^{b}	11.2	65.0	357	9.2 ^{a}
Lupin NSP 100 g/kg	114.9 ^{b}	68.1	801 ^{b}	13.3	65.9	364	8.7 ^{ab}
Lupin NSP 150 g/kg	117.2 ^{b}	72.4	810 ^{b}	12.9	65.8	364	8.6 ^{c}
No enzyme	117.4	71.9	791	13.2	65.5	364	8.8
Enzyme	117.9	70.7	801	11.7	65.8	362	8.9
Mean	117.08	70.8	759	12.6	65.6	363	8.9

In Experiment 3, inclusion of up to 225 g/kg Gungurru lupin in wheat- or sorghum-based diets had no deleterious effects on laying performance, excreta condition, or egg quality (Table 3). Yolk colour was improved by at least 0.2 Roche fan units at higher levels of inclusion. Significant increases in feed intake (2.8%) and incidence of soiled eggs (29%) by hens given sorghum-based diets was unexpected. However, this might be a characteristic of this particular sample of sorghum which had lower than usual AME and promoted wetter than usual droppings in broiler chickens in AME bioassays (Hughes, unpublished data).

Table 3. Effects of breed (SB2 and Tint) and dietary level (0, 75, 150 and 225 g/kg) of wholeseed Gungurru lupin in wheat- or sorghum-based diets on feed intake (FI), egg production (EP), excreta moisture (EM), soiled eggs (SE), egg weight (EW), shell thickness (ST) and yolk colour (YC). Non-significant effects (P>0.05) are shown as ns. Lupin mean values having a common superscript are not significantly different (P<0.05).

Effect	FI (g/bird/d)	EP (%)	EM (g/kg)	SE (%)	EW (g)	ST (μm)	YC (Roche)
	Probability of greater F value in analysis of variance						
Breed	<0.001	ns	0.07	ns	ns	<0.05	ns
Lupin level	ns	ns	ns	ns	ns	0.06	<0.001
Grain base	<0.05	ns	ns	<0.05	ns	ns	ns
	Least squares means						
SB2	122.2	51.4	701	10.0	65.4	345	11.8
Tint	107.3	52.7	712	10.3	65.6	336	11.7
Lupin 0 g/kg	112.9	51.8	706	6.9	64.9	348	11.6 [c]
Lupin 75 g/kg	115.7	52.4	707	10.6	66.7	336	11.6 [bc]
Lupin 150 g/kg	115.2	51.4	705	11.7	65.8	344	12.0 [a]
Lupin 225 g/kg	115.3	52.6	709	11.5	64.7	335	11.8 [ab]
Sorghum	116.4	52.2	707	11.9	66.0	341	11.7
Wheat	113.1	51.8	706	8.4	65.1	340	11.8
Mean	114.8	52.0	706	10.1	65.5	342	11.8

IV. CONCLUSIONS

Australian sweet and white lupins are valuable alternative sources of protein for laying hens. The seed coat of neither species contained anti-nutritive factors but did have an energy dilution effect. It is possible that beneficial effects from the enzyme product used in these studies came from degradation of NSP from other ingredients as well as lupin.

V. ACKNOWLEDGMENTS

Financial support was provided by SARDI, Egg Industry Research & Development Council, The Grain Pool of WA, and Finnfeeds International (UK) Ltd. We gratefully acknowledge the dedicated efforts of the poultry research staff at PPPI.

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