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– CRUSADER –

A production system for Australian farmed rabbits

A report for the Rural Industries Research and Development Corporation

by Dr Sandra J Eady

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Foreword

The primary aim of this project was to provide research and development operations to support profitable and sustainable Australian meat rabbit production. The focus of the project was to identify and implement methods to improve key profit drivers. Individual areas of work that have been identified by industry as high priority are management of disease, improved survival of kittens and growers, provision of optimum nutrition and benchmarking performance. The project has delivered a system for benchmarking performance, improved genotypes for disease resistance and management recommendations to optimise productivity and profit.

This project also brought the Crusader breeding program to the stage where it could be commercialised and run by industry. At the completion of the project both the rabbits and accompanying database and breeding program technologies were successfully transferred to a commercial meat rabbit enterprise.

This collaborative project was funded by CSIRO Livestock Industries and RIRDC.

This report, a new addition to RIRDC's diverse range of over 1200 research publications, forms part of our New Animal Products R&D program, which aims to accelerate the development of viable new animal industries.

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Peter O'Brien
Managing Director
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The Crusader team is grateful to rabbit farmers who assisted in this project in a number of ways - by providing data in farmer surveys, participating in field days, providing feedback on project outcomes such as software design and organising regional workshops, at which Crusader results were presented. Special acknowledgement goes to the Crusader Advisory Group Members – Kathleen Bowerman, Daniel Brown, Glenn McNeill and Margaret James.

We also wish to thank Dr Peter McInnes, RIRDC, for his continuing encouragment over the two years of the project. His support and guidance played an important part in the successful commercialisation of the Crusader breeding program.

The Crusader project has been a CSIRO team effort with contributions from John Smith, Jim Flack, Sue Belson, Andrew Eichorn, Robyn Malcolm, Kerri Schmaucher and Bud Holland.

This work was financially supported by CSIRO Livestock Industries and the Rural Industries Research and Development Corporation. We are appreciative of the significant resources both organisations provided to assist the emerging meat rabbit industry in Australia.

The component of work on breeding for disease resistance was undertaken as part of an INRA Visiting Scientist Research Fellowship for Dr Eady and was financially supported by Rural Industries Research and Development Corporation and CSIRO in Australia, and INRA in France.

Dr Sandra J Eady
Project Leader
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Executive Summary

The meat rabbit industry has consolidated and grown over the last three years despite the severe drought conditions during 2002/2003 contributing to almost a doubling in feed prices. Meat processors report that the number of rabbit suppliers has grown slowly but the volume being supplied by individuals has increased significantly. Well established small businesses are now emerging and vertical integration of production, processing and wholesaling is a common business model for the most successful farmers. The industry continues to experience high domestic demand for farmed rabbit. The Centre for International Economics (CIE 2004) predicts that consolidation will continue as the average size of rabbit farms increases (currently 100 does compared with 57 in 1999) and smaller farmers leave the industry due to lack of economy of scale.

In 1998/99 production of farmed rabbit meat was 106 tonnes (Foster 1999), compared to 72 tonnes for wild harvested rabbit. This represented a farm gate gross value of $0.62 million which rose to $0.9 million in 1999/2000 (RIRDC 2001). In 2003 an estimate of production by farmers was in the order of 270 tonnes/annum ($2.5 million farm gate value) (Farmed Rabbit Industries of Australia Meeting, February 2004). The CIE (2004) prediction is that production levels will continue to grow steadily at around 14 per cent a year to 2005, slowing to 10 per cent to 2008, and 8 per cent to 2015. Anecdotal evidence from rabbit processors (Crusader Field Day, September 2001) is that the market could accommodate 300,000 to 400,000 rabbits per annum, or 380 to 510 tonnes of meat without additional market development and promotion.

Crusader® is Australia’s first research and development project to support the emerging farmed rabbit meat industry in this country. The project was conducted by CSIRO Livestock Industries with financial support from Rural Industries Research and Development Corporation for a two year period from August 2002 to June 2004. Project staff and facilities were located at the FD McMaster Laboratory at Armidale in New South Wales. It followed the original Crusader project funded from 1999 to 2002.

In a benefit:cost study undertaken by the CIE (CIE 2004) the benefits flowing from the initial Crusader project (1999-2002) were largely from animal husbandry and management information and delivered a return of 15 per cent on the R&D investment. The breeding program results had not translated through to industry at that time, most likely due to the small yearly incremental nature of the improvements and the genetic lag between breeding nucleus and industry. CIE predicts that when they are achieved on-farm they will be of similar value. The prime activity of the next project (reported here) was to provide animal husbandry and management information, supported by the continuing genetic improvement of breeding stock for industry use. The focus of the project was to identify and implement methods to improve key profit drivers. Individual areas of work identified by industry as high priority are management of disease, improved survival of kittens and growers, providing optimum nutrition and benchmarking performance.

The original project contract was for five years but alternate funding arrangements were negotiated after two years with the decision to commercialise the Crusader breeding program. This report covers those objectives met during the first two years.

Over the two-year life of the project the goals were to:

i. **Develop a disease identification/control package and select Crusader rabbits for disease resistance.**

Project Output: Digital images and accompanying disease identification and control information were organised into a web-based and hard copy publication with the assistance of local veterinary expertise. Candidate traits for selection for disease resistance were assessed, and those found to be heritable have been added to the Crusader breeding objective. Genetic merit for resistance to bacterial infection has improved by 11% in grower rabbits with an accompanying 5% phenotypic reduction in mortality. The project has delivered to industry a management guide to reduce disease and breeding stock with improved genetic resistance to disease.

ii. Investigate environmental and genetic means of reducing pre-weaning mortality.

Project Output: A range of cage design issues were investigated as to their effect on doe health. Methods for reducing hocksore by the use of suitable pressure mats were identified. The Crusader breeding program continued to select for increased litter size at weaning, achieving a 9% improvement in this trait since the breeding program commenced. The project delivered sound management advice to improve the welfare of breeding does and supplied the industry with superior breeding stock capable of lifting the litter size of industry rabbits.

iii. Investigate the role of stocking density in pens in optimising productivity and welfare of grower rabbits.

Project Output: Methods of improving the productivity of grower rabbits were evaluated including reduction in stocking density in group pens and continued selection for improved liveweight gain. Stocking density did not have a direct effect on growth or incidence of disease symptoms but lower stocking densities did result in improvements in survival rate. There has been a 17% improvement in rate of liveweight gain since the breeding program commenced. This activity delivered to the industry recommendations on stocking density in grower accommodation and rabbits with the genetic potential to grow faster.

iv. Establish benchmark parameters for levels of production, enterprise costs (including labour) and income.

Project Output: An Enterprise Model was built to estimate gross margin from meat rabbit production. It used information from the Crusader project, farmer surveys and a small group (3-4) of farmers who maintain good production and expenditure records. The Crusader Enterprise Model was posted on the project web site (www.csiro.au/crusader) in August 2003 and has been downloaded more than 1000 times since then. It has been used by potential farmers, existing farmers and groups undertaking feasibility studies on the meat rabbit industry. This activity delivered to industry an enterprise model against which farmers can benchmark their performance and investigate parameters in their own enterprise that are having major impact on profitability.

v. Establish an industry alliance group to facilitate involvement and consultation in setting research goals and evaluating outputs.

Project Output: After a public call for expressions of interest, the Crusader Advisory Group was formed in May 2003 and met on 3 June 2003 and 12 December 2003. Contributions by members have been important to the project in defining areas of immediate interest (feed costs and formulation, ability to benchmark performance), providing avenues for dissemination of project results through regional workshops, and direct contributions to Crusader Field Day in July 2003. The Advisory Group also played an important role in the commercialisation of the breeding program. Establishment of the Advisory Group delivered a mechanism by which industry priorities can be incorporated into R&D efforts and regional technology transfer activities can be coordinated.

Overall, the meat rabbit industry is gaining coordination, with a meeting held in February 2004 to plan the formation of a national association - Farmed Rabbit Industries of Australia Pty (FRIA). A number of farmers have developed their expertise and enterprises to the stage of being able to manage large breeding herds (200 does plus). In December 2003 a call was made for expressions of interest in managing the Crusader breeding program. Four of the five respondents were in the position of being able to incorporate the Crusader program into their enterprise at 2 month's notice. The enterprise selected was Snowy Mountains Gourmet Rabbit Company (SMGRC) at Bredbo in NSW. R&D support for the breeding program will continue over the next three years with a focus on introducing new and innovative traits to improve profit, such as additional disease resistance traits and doe longevity.

In summary, the meat rabbit industry in Australia has grown considerably over the life of the Crusader project, from production of 106 tonnes of meat in 1999 to an estimated 270 tonnes in 2003. Use of Crusader stock has significantly lifted the income of farmers and provided them with a reliable source of improved rabbits. The Crusader Enterprise Model has allowed potential industry entrants to objectively evaluate returns from the industry and has contributed to the ability of industry members to base decisions on sound economic evaluation. This has reduced financial risk and strengthened the viability of existing enterprises. The project has provided an impetus for the emerging industry to form a national association which will assist in promoting industry growth and will represent its members. An independent assessment of the Crusader project has shown a significant return on investment in R&D - 15% for husbandry and management outputs and 15% for genetic improvements, once they are realised throughout the industry. Commercialisation of the Crusader breeding program means that the industry can now independently run an advanced genetic improvement scheme on a sustainable basis.

1. Introduction to the Crusader® Project

Crusader® is Australia's first research and development program to support the emerging farmed rabbit meat industry in this country. The current project was conducted by CSIRO Livestock Industries with financial support from Rural Industries Research and Development Corporation for a two year period from August 2002 to June 2004, continuing on from three years of initial research largely focused on establishing a breeding program for meat rabbits. Project staff and facilities were located at the FD McMaster Laboratory at Armidale in New South Wales.

1.1 Industry background

The renewal of rabbit farming for meat production commenced in 1987, when Western Australia changed its legislation to allow farming of rabbits in that state. New South Wales and Victoria followed suit in 1995 and 1997, respectively, and now farming for meat is allowed in all states with the exception of Queensland. Despite periodic bans on farming, Australia has had an established rabbit meat industry for many years, based on harvesting wild rabbits. In the early 1990s, over 2.7 million wild rabbits per annum were sold for meat (Foster 1999). With the release, in 1996, of rabbit haemorrhagic disease as a biological control agent, the population of wild rabbits was dramatically reduced (Bowen and Read 1998), with only 100,000 being harvested per annum in the late 1990s (Foster 1999).

The meat rabbit industry has consolidated and grown over the last three years despite the severe drought conditions during 2002/2003, resulting in an almost doubling in feed prices. Processors report that the number of suppliers of rabbits has grown slowly but the volume being supplied by individuals has increased significantly. Well established small businesses are now emerging and vertical integration of production, processing and wholesaling is a common business model for the most successful farmers. The industry continues to experience high demand for farmed rabbit. The Centre for International Economics (CIE 2004) predict that consolidation will continue as the average size of rabbit farms increases (currently 100 does compared with 57 in 1999) and smaller farmers leave the industry due to lack of economy of scale.

In 1998/99 production of farmed rabbit meat was 106 tonnes (Foster 1999), compared to 72 tonnes for wild harvested rabbit. This represented a farm gate gross value of $0.62 million which rose to $0.9 million in 1999/2000 (RIRDC 2001). In 2003 an estimate of production by farmers was in the order of 270 tonnes/annum ($2.5 million farm gate value) (FRIA Meeting, February 2004). The CIE prediction (CIE 2004) is that production levels will continue to grow steadily at around 14 per cent a year to 2005, slowing to 10 per cent by 2008, and to 8 per cent by 2015. Anecdotal evidence from rabbit processors (Crusader Field Day, September 2001) is that the market could accommodate 300,000 to 400,000 rabbits per annum, or 380 to 510 tonnes of meat without additional market development and promotion.

The industry is gaining coordination with a meeting held in February 2004 to plan the formation of a national association - Farmed Rabbit Industries of Australia Pty (FRIA). A number of farmers have developed their expertise and enterprises to the stage of being able to manage large breeding herds (200 does plus). In December 2003 a call was made for expressions of interest in managing the Crusader rabbit breeding program. Four of the five respondents were in the position of being able to incorporate the Crusader program into their enterprise at 2 month notice.

1.2 Project goals

In a benefit:cost study undertaken by the CIE (CIE 2004) the benefits flowing from the initial Crusader project (1999-2002) were largely from animal husbandry and management information and delivered a return of 15 per cent on the R&D investment. The breeding program results had not translated through to industry at that time, most likely due to the small yearly incremental nature of the improvements and the genetic lag between breeding nucleus and industry. When they are achieved on farm they will be of similar value. The primary activity of the next project (reported here) was to provide animal husbandry and management information, supported by the continuing genetic improvement of breeding stock for industry use. The focus of the project was to identify and implement methods to improve key profit drivers. Individual areas of work identified by industry as high priority are management of disease, improved survival of kittens and growers, providing optimum nutrition and benchmarking performance.

The original project contract was for five years but a new contract was negotiated after two years with the decision to commercialise the Crusader breeding program. This report covers those objectives met during the first two years.

Over the two year life of the project the goals and planned outputs were to:

i. Develop a disease identification/control package and select Crusader rabbits for disease resistance. Digital images and accompanying disease identification and control information will be organised into a web-based and hard copy publication with the assistance of local veterinary expertise. Candidate traits for selection for disease resistance will be assessed, and if found to be heritable, will be added to the breeding objective. These activities will deliver to industry a management guide to reduce disease and will provide resistant breeding stock.

ii. Investigate environmental and genetic means of reducing pre-weaning mortality. A range of cage design issues will be investigated as to their effect on doe health and pre-weaning mortality. The Crusader breeding program will continue to select for litter size at weaning. These activities will deliver a management guide to maximise kitten survival and provide genotypes with improved maternal ability.

iii. Investigate the role of stocking density in pens in optimising productivity and welfare of grower rabbits. This activity will deliver to the industry sound designs of pens for grower accommodation.

iv. Establish benchmark parameters for levels of production, enterprise costs (including labour) and income. Information to build an enterprise model will be gathered from the Crusader project, from farmer surveys and from a smaller group (3-4) of farmers who are maintaining production and expenditure records. This sub-project will deliver to industry an enterprise model against which farmers can benchmark their performance and investigate parameters in their own enterprise that are having major impact on profitability.

v. Establish an industry alliance group to facilitate involvement and consultation in setting research goals and evaluating outputs. The group will have a membership of 3-4, initially 2 representatives from NSW (northern and southern regions) and 1 from Victoria. Membership will be by invitation after a public call for expressions of interest. This activity will deliver a mechanism by which industry priorities can be incorporated into R&D efforts and regional technology transfer activities can be coordinated.

2. Strategies for Improving Rabbit Health

2.1 Introduction

Profit for meat rabbit enterprises is highly sensitive to the number of rabbits turned off as growers. Turn-off is a function of number of rabbits born alive and subsequent survival as kittens and growers. Assuming levels of production in the order of 7 kittens per litter born alive, Table 2.1.1 gives gross margin (net of variable costs but not labour) at a range of survival rates for kittens and growers. In the first two sections of the table kitten mortality and grower mortality are varied independently, the third section of the table gives the combined effect of improvements in both.

Table 2.1.1 Effect of kitten and grower survival on gross margin for meat rabbit production.

Kitten survival with grower survival set at 85%	65%	70%	75%	80%	85%*
Gross Margin ($/doe/year)	157.68	170.36	184.03	197.70	211.37
Grower survival with kitten survival set at 70%	80%	85%	90%	95%	97%*
Gross Margin ($/doe/year)	155.44	170.36	182.27	200.18	206.15
Combined kitten and grower survival	65% + 80%	70% + 85%	75% + 90%	80% + 95%	85% + 97%*
Gross Margin ($/doe/year)	142.84	170.36	200.01	231.79	254.84

* Approximate upper biological limit for survival.

One would anticipate that as management and disease control improved there would be concomitant improvement in both kitten and grower survival. These figures demonstrate the significant impact on profit of even a small improvement in survival. With approximate industry figures of 70% survival of kittens and 85% of growers, a lift to 75% and 90%, respectively, would increase gross margin by $30.35 per doe per year or 18%.

The current project studied diseases contributing to grower mortality, to determine if disease resistance could be improved through a genetic approach or though housing improvements.

2.2 Disease resistance and Crusader

2.2.1 Introduction

As a developing industry, rabbit meat production faces a number of challenges, one of which is disease control. Diseases are largely caused by *Pasteurella multocida* and *Staphylococcus aureus*. In Europe where rabbit farming is well established, approaches to disease control have relied on environmental hygiene, requiring large capital investment in housing and routine inclusion of antibiotics in rabbit feed. Management systems with a reliance on the use or antibiotics are under challenge with increasing public health concerns regarding the feeding of antibiotics to livestock. Even with these controls *Pasteurella multocida* infection still occurs, albeit at low incidence and severity.

Crusader - RIRDC and CSIRO's meat rabbit research project, seeks to improve rabbit health and survival by taking a more sustainable approach by breeding for disease resistance. Table 2.1.1 demonstrates the impact that improved survival of growers has on returns to Australian farmers. However, to undertake such a breeding program to improve disease resistance, both practical means of measuring resistance and statistical methods for estimating a rabbit's breeding merit for disease resistance, need to be developed.

During 2002, Dr Hervé Garreau from the INRA rabbit breeding program (the world's largest rabbit genetics research group) spent 3 months at the FD McMaster Laboratory, CSIRO Livestock Industries, Armidale. During this time, significant progress was made in the area of statistical analysis of disease data to allow breeding values to be estimated for one particular group of diseases (*Pasteurella* infection in growers). Since then, this disease trait has been included in the Crusader breeding program and now, rabbits sold to industry are above average, in the Crusader herd, for resistance to this particular disease.

However, this was the first step as statistical techniques for analysing the current disease resistance trait need to be optimised; the genetic relationship between *Pasteurella* infection and other diseases in grower rabbits investigated; and the relationship between production and disease resistance determined. Association between disease resistance in growers and health of breeding does also needs to be established.

During the life of this project two of the issues above have been investigated – statistical techniques for analysing disease data and relationships between disease and production.

2.2.2 Methodology

i. Animals

The Crusader meat rabbit facility was established at the FD McMaster Laboratory, Armidale, by CSIRO in 1999. After an initial evaluation of the three main meat breeds (Prayaga and Eady 2002, Prayaga and Eady 2003) in Australia (New Zealand White, Californian and Flemish Giant) a selection program began in July 2001. A composite strain of rabbits was established and selection of breeding stock has been based on an index of economic return combining estimated breeding values for litter size at weaning and average daily live weight gain from weeks 5 to 10 of age. As disease incidence and mortality have a significant impact on profit, these traits were also identified as important in the breeding objective but could not be included until there were estimates of genetic parameters. Initial estimates were obtained in 2002 from analyses undertaken by Hervé Garreau, INRA, during a 3 month Fellowship at CSIRO. The analyses undertaken in the current study advanced this area of work using a larger dataset and investigating alternate statistical models.

This study focused on estimating parameters for disease resistance in grower rabbits from weaning age to turn-off age. Young rabbits were weaned at 5 weeks of age with individuals from litters randomly allocated to pens for growing (litters were not kept together after weaning). During the growing phase rabbits were weighed weekly and scored for the incidence of disease. The last measurement was made at 10 weeks of age and rabbits were turned off for slaughter at 12-13 weeks of age.

ii. Disease trait description

Disease scores were categorised into 3 classes – infection, scouring and other. These are described in Table 2.2.1.

The weekly recording of disease incidence gave a 0 or 1 score for each rabbit. These scores were added across weeks to give an index of disease incidence. For rabbits that died from disease, an additional 3 points was added to the animal's index score for that disease, and for rabbits that were euthanased, an additional 2 points were added. Each disease was treated independently, that is, if a rabbit had both snuffles and was scouring it received a score of 1 for both the infection and scouring trait for that week. When analysing data for a particular disease trait, rabbits that died from a different class of disease were excluded from the analysis.

Table 2.2.1 Description of disease classes and proportion of deaths, natural or from euthanasia, attributed to each class.

Group	% of total deaths	Disease Description/Symptoms Observed
Infection i.e. *Pasteurella spp.* and *Staphylococcus spp.*	51.6% - comprising 23.4% dead and 28.2% euthanased.	Abscesses usually located in region of lymph nodes, snuffles (nasal discharge), skin infection, eye infection, infected injuries, infection around ear tag, genital infection, urinary track infection, lung infection, middle-ear infection, toe-nail infection.
Scouring	30.5% - comprising 28.3% dead and 2.2% euthanased.	Diarrhoea
Other common causes of death/euthanasia	18.2%	Hock sore, maloccluded teeth, calici virus, poor condition/under weight, congenital defects (e.g. splayed legs)

Each disease trait was defined for analysis in three different ways:

i. **Index Score** (sum of incidence at each measurement time plus death adjustment).
ii. **Weekly Incidence** (0,1) at a given age from week 5 to week 10 giving 6 traits.
iii. **Overall Incidence** (0,1) over the whole measurement period (i.e. resulting in two classes of rabbits, those with index score of 0 and those with an index score of >0)

iii. Live weight traits

Live weight traits analysed for grower rabbits were weaning weight at 5 weeks of age (5 Week Wt, kg), weight at 10 weeks of age (10 Week Wt, kg) and average daily live weight gain (ADG, g/head/day) between 5 and 10 weeks of age.

iv. Statistical analysis

Liveweight traits (5 Week Wt, 10 Week Wt and ADG) and disease traits related to Infection (Index Score, Weekly Incidence, and Overall Incidence) were analysed using a linear model for the observed data. In addition a threshold model was used to analyse 0,1 data for Weekly Incidence and Overall Incidence. The statistical package used for all analyses was ASReml (Gilmour *et al.* 2002).

Given the mixed breed origin of the composite strain of rabbits, a genetic groups model was used. The significance of the fixed effects and their first order interactions (where possible to estimate) were estimated for each trait. Where significant, the fixed effects of sex, month:year of birth, parity of the doe, number weaned per litter, and level of individual heterosis were included in the model, which also included the random effects of animal and litter. As none of the first order interactions of fixed effects were significant, the interaction terms were omitted from the final model.

Based on the solutions for individual classes of parity and number weaned, groupings were made of classes with similar effects. The range in values for parity was from 1 to 18. For both disease and live weight traits these were reduced to six classes - parity 1, 2, 3, 4-6, 7-10, and greater than 10. The range in values for number weaned was 1 to 13. For both disease and live weight traits these were reduced to three classes – 1-5, 6-9 and greater than 9. For both groups of traits, animals were divided into 4 classes for level of heterosis – 0 to 0.25, 0.26 to 0.50, 0.51 to 0.75 and 0.75 to 1.

Once significant fixed effects were determined, the model was expanded to include the additional random effect of a maternal genetic component. The following animal model was used to estimate direct and maternal genetic components of variance for the disease and live weight traits:

$$Y_{hijklmnop} = \mu + A_i + M_j + L_k + r_l + s_m + t_n + u_o + v_p + e_{ijklmnop}$$

where Y is the trait; μ is the common mean; A_i is the random effect of the *i*th animal; M_j is the random effect of the *j*th dam; L_k is the random effect of the *k*th litter; r_l is the effect of the *l*th month+year; s_m is the effect of the *m*th sex (female or male); t_n is the effect of *n*th parity class; u_o is the effect of the *o*th number weaned class; v_p is the effect of the *p*th heterosis class and $e_{ijklmnop}$ is the random error.

When a threshold model was used for (0,1) disease traits, a sire rather than animal model was fitted and a logit transformation was used for the data. It is not statistically valid to use an animal model with a threshold trait (A.R. Gilmour, pers. comm.).

Variance components were estimated by the restricted maximum likelihood procedure. From the ratio of appropriate variance components, heritability of each trait was estimated. Correlations were estimated from bivariate analyses, fitting significant fixed effects for each trait independently. Approximate standard errors for heritabilities and correlations came from the ASReml analysis.

2.2.3 Results

The distribution of index scores for disease caused by Infection is given in Figure 2.2.1. The majority of animals (72%) showed a zero score.

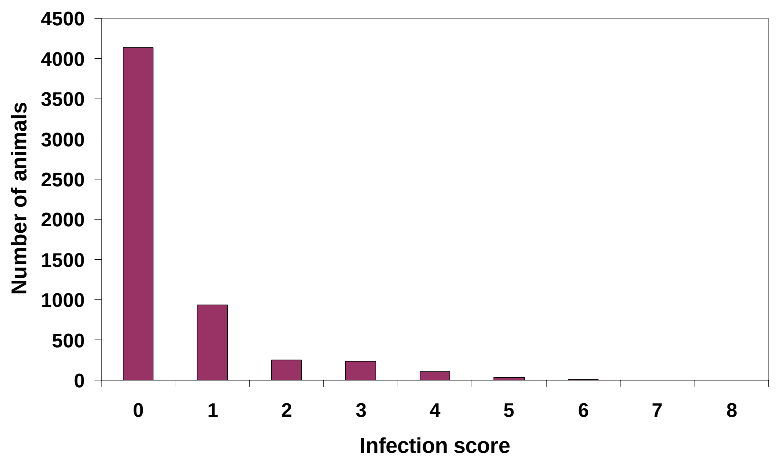


Figure 2.2.1 Frequency of Infection score (0-6) for grower rabbits from 5 to 10 weeks of age.

Disease incidence at each measurement time is given in Table 2.2.2. Incidence of Infection increased steadily with age from a minimum of 2.2% at 5 weeks of age to maximum of 12.0% at 10 weeks of age. The incidence of Scouring was lower and peaked at 2.8% at 7 weeks of age. No further analyses of the Scouring data was undertaken in this study.

Table 2.2.2 Proportion of animals exhibiting disease symptoms at weekly measurement intervals from 5 to 10 weeks of age.

Trait	Age (weeks)					
	5	**6**	**7**	**8**	**9**	**10**
Infection (%)	2.2	4.2	6.5	8.2	10.7	12.0
Scouring (%)	0.5	1.4	2.8	2.3	1.4	0.9

The significance of fixed effects is shown in Table 2.2.3. Sex was generally non-significant for the disease traits, with only the Week 7 measurement showing it to be significant. All traits varied significantly according to month and year. Parity of the dam had no effect on the disease traits but was significant for live weight traits. Size of litter at weaning had a significant effect on 4 of the 9 disease traits, with no apparent pattern to the result. Level of heterosis had no effect on any of the traits. When only records from rabbits exhibiting snuffles were analysed, the mean Index Score was greater than that observed for all "infection" symptoms (1.528 v's 0.495), indicating that snuffles was a more persistent symptom than the others.

Table 2.2.3 Mean and phenotypic variance (Pvar) for disease and liveweight traits and significance levels for fixed effects.

Trait	Mean	Pvar	Sex	Month + Year	Parity	Number Weaned	Level of Heterosis
Disease Traits							
Index Score	0.495	0.906	ns	**	ns	**	ns
Week 5	0.021	0.020	ns	**	ns	ns	ns
Week 6	0.039	0.037	ns	**	ns	**	ns
Week 7	0.061	0.049	**	**	ns	ns	ns
Week 8	0.075	0.067	ns	**	ns	ns	ns
Week 9	0.098	0.083	ns	**	ns	ns	ns
Week 10	0.110	0.094	ns	**	ns	**	ns
Overall Incidence	0.279	0.186	ns	**	ns	**	ns
Only Snuffles Index Score	1.528	0.036	ns	**	ns	ns	ns
Liveweight Traits							
5 Week Wt (kg)	0.85	0.03	ns	**	**	**	ns
10 Week Wt (kg)	2.04	0.09	**	**	**	**	ns
ADG (g/hd/d)	34	38	**	**	**	ns	ns

ns – not significantly contributing to variation (P>0.05).

The heritability estimate (Table 2.2.4) for Index Score was 0.07±04 when maternal genetic effect was fitted, and 0.09±0.03 without. Maternal genetic effect was negligible, 0.01±0.02, but the common litter environment was significant (0.10±0.02). Heritability estimates (Table 2.2.4) for the live weight traits varied with age, with weight at 5 weeks of age having a low heritability (0.07±0.06) increasing to 0.20±0.06 at 10 weeks of age. Heritability for ADG was moderate at 0.29±0.07. From 5 to 10 weeks of age the common litter effect on live weight decreased from 0.46±0.03 to 0.22±0.02. Maternal genetic effects were apparent for the two liveweight measurements (0.06±0.04 at 5 weeks and 0.09±0.04 at 10 weeks) but was lower for ADG (0.04±0.03). Estimates of heritability and common litter effects for ADG and Index Score, without fitting a maternal genetic effect, are also given in Table 2.2.4. Subsequent analyses of ADG and the Infection traits did not include a maternal genetic effect.

Table 2.2.4 Variance components and standard error for direct genetic (heritability, h^2), maternal genetic (m^2) and common litter effects (c^2) for Index Score (Infection), live weight at 5 weeks of age (5 Week Wt), live weight at 10 weeks of age (10 Week Wt) and average daily gain (ADG) between 5 and 10 weeks of age.

Traits	Heritability (h^2)	Maternal Genetic (m^2)	Common Litter (c^2)
Index Score			
with m^2	0.07±0.04	0.01±0.02	0.10±0.02
without m^2	0.09±0.03		0.10±0.01
5 Week Wt (kg)	0.07±0.06	0.06±0.04	0.46±0.03
10 Week Wt (kg)	0.20±0.06	0.09±0.04	0.22±0.02
ADG (g/hd/d)			
with m^2	0.29±0.07	0.04±0.03	0.16±0.02
without m^2	0.31±0.05		0.17±0.02

Heritability of Weekly Incidence increased from close to zero at 5 and 6 weeks of age up to a maximum of 0.08±0.02 at 8 weeks of age (Table 2.2.5) . There was a decrease in heritability at 10 weeks, down to 0.04 ±0.02.

A threshold model was also used to estimate heritability at those times when it was significantly different from zero using a linear model. As it was necessary to use a sire model for the threshold analyses, a linear sire model was first fitted to check if the data structure was adequate to separate sire and litter effects. This was done by comparing the estimates of variance components for the animal and sire models. There was a reasonably consistent result from the two approaches with the Overall Incidence showing the largest difference in heritability estimates between an animal and sire model (0.08 versus 0.03, Table 2.2.5).

As predicted, the estimates for variance components (and error of measurement) were higher when a threshold model was used (Falconer 1981). Heritability for Weekly Incidence at Week 8, 9 and 10 increased by a factor of 5 while the estimate for Overall Incidence by a factor of 3, compared to estimates from linear sire model (Table 2.2.5).

A sub-set of the animals with symptoms of snuffles only (upper respiratory track infection with nasal discharge) was analysed to check if a tighter definition of a particular infection might yield a higher heritability estimate. However, heritability for a snuffles only index was lower (0.05±0.06) than that for the combined Infection Index Score.

The genetic and phenotypic correlations between individual disease traits and between disease traits and live weight traits are given in Table 2.2.6. The genetic correlation between Index Score and incidence at Week 5 and Week 6 were poorly estimated, probably due to the low incidence of disease at these measurement times. From Week 7 to 10 the genetic relationship appeared to be very high (>0.9), which in turn introduced difficulty estimating correlations at some measurement times. Care should be taken in interpreting the basis of this correlation as the two traits are not mathematically independent, measurement at any one week being a component of the Index Score. The phenotypic correlations show how incidence at a later age, when incidence was also higher, was more strongly related to the Index Score, reaching a maximum of 0.52±0.01 at Week 9. Genetic correlations between individual measurement at Week 7, 8, 9 and 10 were also high (Table 2.2.6).

Table 2.2.5 Variance components and standard error for direct genetic (heritability) and common litter effects for Weekly Incidence and Overall Incidence using a linear model with observed data and using a threshold model with an assumed underlying normal distribution of liability.

Trait	**Heritability**	**Common Litter**	**Heritability**	**Commoon Litter**	**Heritability**	**Commoon Litter**
	Animal Linear Model		*Sire Linear Model*		*Threshold Model*	
Week 5	0.01±0.02	0.18±0.02				
Week 6	0.00 (data too sparse)	0.08±0.01				
Week 7	0.03±0.02	0.03±0.01				
Week 8	0.08±0.02	0.05±0.01	0.06±0.03	0.07±0.01	0.29±0.23	0.29±0.07
Week 9	0.07±0.02	0.08±0.01	0.08±0.04	0.09±0.01	0.38±0.20	0.33±0.06
Week 10	0.04±0.02	0.08±0.01	0.05±0.03	0.09±0.01	0.27±0.18	0.33±0.06
Overall Incidence	0.08±0.02	0.07±0.01	0.03±0.03	0.10±0.01	0.10±0.10	0.30±0.04
Only snuffles index	0.05±0.06	0.12±0.04				

Because of the number of records per sire, the genetic correlations between ADG and Infection traits had large standard deviations and although they were positive, it is not possible to draw conclusions as to the real relationship from this dataset (Table 2.2.6).

Table 2.2.6 Phenotypic and genetic correlations between Infection disease traits and between ADG and Infection traits.

Trait	**Correlations between Index Score and other Infection traits**	
	Genetic	**Phenotypic**
Week 5	-0.26±0.70	0.28±0.01
Week 6	No estimate – data too sparse	0.39±0.01
Week 7	0.92±0.12	0.49±0.01
Week 8	1.01±0.07 (no convergence)	0.49±0.01
Week 9	0.88±0.09	0.52±0.01
Week 10	1.06±0.13 (no convergence)	0.50±0.01
Overall Incidence	1.01±0.03	0.79±0.01
	Correlations between Week 8 and Week 7-10	
Week 7	0.72±0.21	0.16±0.02
Week 9	0.85±0.11	0.21±0.01
Week 10	1.23±0.20 (no convergence)	0.15±0.01
	Correlation between ADG and Infection traits	
Index Score	0.19±0.17	-0.13±0.02
Week 8	0.11±0.17	-0.05±0.02
Week 9	0.00±0.18	-0.08±0.02
Week 10	0.24±0.21	-0.07±0.08
Overall Incidence	-0.01±0.17	-0.11±0.02

2.2.4 Points for discussion

Analysing traits that are recorded as an incidence (0 or 1) causes statistical challenges because the variance of the trait will be dependent on the incidence. For analysis of variance, the assumption is that mean and variance are independent. The closer the incidence is to 50% the less of a problem is created by this relationship but where incidences are low, a non-linear approach using a threshold model may be preferable.

The Infection data collected in Crusader can be expressed in a number of formats – Index Score (0-8), Weekly Incidence (0,1) or Overall Incidence (0,1). For estimating breeding values for disease resistance, Index Score is the most appealing for a number of reasons. It reduces the number of zero scores to about 70% (from 88 to 98% for single weekly recording) and creates up to 8 categories of scores thus making it similar to a continuously varying character. It also captures the extra biological information of knowing how long the rabbit was sick; a rabbit that repeatedly has snuffles for a number of weeks has a higher score than one which recovers from one occurrence of the disease.

However, measuring disease incidence every week is a very time consuming task and would not be feasible in most industry improvement programs. This led to the investigation of each weekly measurement as a potential replacement for the Index Score. The results suggest that a single measurement at Week 7, 8, 9 or 10 could replace the Index Score as the heritability is similar and the genetic correlation with Index Score is high. However, further investigation is required as the heritability estimates were not entirely consistent, with Week 10 estimate being lower than for the other weeks. More data is also required to clarify the relationship between ADG and disease resistance.

But overall, the strong relationship between Index Score and Weekly Incidence is encouraging as it suggests that selection for disease resistance, based on one observation later in the growing period, may be almost as effective as multiple measures. The use of a threshold model for the single weekly traits may offer statistical advantages over a linear model when incidence is low (< 10%) but there is the practical disadvantage that individual animal solutions (EBVs) cannot be readily estimated.

Currently the Crusader breeding program includes Index Score as a selection trait. Breeding values are estimated from observed data using a univariate linear animal model. The assumed heritability is 0.09. The results from this study confirm this approach; the heritability estimate for Index Score is also 0.09 and the Index rather than a single measure or overall incidence is the preferred trait, as long as weekly recording of disease incidence can be carried out within the research herd. As the genetic correlation between disease and ADG is unclear, the practice of estimating breeding values separately for each trait using a univariate analysis should continue.

2.2.5 Recommendations for future research

- Better define the usefulness of one disease measurement late in the growing period as a substitute for the index of disease collected over 6 weekly measurements.
- Re-examine the genetic correlation between disease incidence and growth rate as more data become available.
- Extend the use of the threshold model to estimate genetic correlations between single measures of disease incidence and growth rate.
- Investigate the correlation between disease incidence during the growing stage and disease incidence during the breeding life of does, as data becomes available on does.

2.3 International collaboration on disease resistance

2.3.1 Introduction

Genetic variation for bacterial infection has been reported for a range of livestock species (Raadsma 1995; Heringstad *et al.* 2000) including footrot and fleece rot in sheep, and mastitis in dairy species. There are reports of genetic variation for more general disease expression in pigs (Henryon *et al.* 2001). In rabbits there are reports of genetic resistance to *Pasteurella*, Baselga *et al.* (1988) estimating heritability of lung damage, caused by infection, to be 0.12 to 0.28. The international collaboration undertaken was to determine if routine observational comments made on live commercial rabbits, including disease incidence, could be used to identify genetic variation for bacterial infection in commercial breeding programs in France.

2.3.2 Methodology

i. Animals and data

The study was undertaken in two populations of meat rabbits, housed separately and selected independently for live weight at slaughter age. Population 1 (Pop. 1) had 281 sires with an average of 62 progeny. Population 2 (Pop. 2) had 1186 sires with an average of 40 progeny. At 10 and 9 weeks of age, respectively, for the two populations, each rabbit was weighed and inspected for general health and well-being. If a problem was noted for a rabbit, the major cause was recorded. The recording was not specifically to score rabbits for the absence or presence of disease. In Pop. 1, 6.9% of animals had a comment related to bacterial infection and in Pop. 2 the incidence was 3.9%.

Comments that were classified as related to bacterial infection were – respiratory problems, snuffles, eye infection, wry neck, abscesses and any other form of infection (nail, injury, genital). Rabbits with no comment or a comment unrelated to infection were given a score of 0. Rabbits with a comment indicating the presence of an infection were given a score of 1. Rabbits that died prior to the weighing date were omitted from the analysis regardless of cause of death. Numbers that died from infection were small (16 and 13 rabbits in Pop. 1 and 2, respectively), and their omission would not unduly bias the results. Sex was determined at time of weighing.

Fixed effects were sex, week+year of birth, parity of dam and number weaned per litter. Sub-classes of each effect were formed to give similar numbers per class. In Pop. 1 the range in values for parity (number of litters a doe has produced) was from 1 to 12 and for number weaned was from 1 to 10. In Pop. 2 the range in values for parity was 1 to 12 and for number weaned was 1 to 14. In both populations parity sub-classes of 1, 2, 3, 4, 5, 6, 7, 8 and 9-12 were formed. In Pop. 1 number weaned sub-classes of 1-5, 6, 7, 8 and 9-10 were formed, and in Pop. 2 the number weaned sub-classes were 1-3, 4, 5, 6, 7, 8, 9 and 10-14.

ii. Statistical analysis

Disease incidence and live weight were analysed using a linear model for the observed data. The statistical package used for all analyses was ASReml (Gilmour *et al.* 2002). A separate analysis was undertaken for each population. The significance of fixed effects and their first order interactions were estimated, where possible, for each trait. Significant fixed effects were retained in the final models. First order interactions of fixed effects were not significant and were omitted from the final models. The model to determine the significance of fixed effects also included random effects of animal and litter. Once significant fixed effects were determined, the model was expanded to include the additional random effect of a maternal genetic component. The following animal model was used to estimate direct and maternal genetic components of variance for the disease and liveweight traits:

$$Y_{hijklmno} = \mu + A_i + M_j + L_k + r_l + s_m + t_n + u_o + e_{ijklmno}$$

where Y is the trait; μ is the common mean; A_i is the random effect of the *i*th animal; M_j is the random effect of the *j*th dam; L_k is the random effect of the *k*th litter; r_l is the effect of the *l*th week+year; s_m is the effect of the *m*th sex (female or male); t_n is the effect of *n*th parity class; u_o is the effect of the *o*th number weaned class and $e_{ijklmno}$ is the normally distributed random error.

Variance components were estimated by the restricted maximum likelihood procedure. From the ratio of appropriate variance components, heritability of each trait was estimated. Correlations were estimated from bivariate analyses, fitting significant fixed effects for each trait independently. Approximate standard errors for heritabilities came from the ASReml analysis. In addition to the linear model, which assumes the trait to be a continuous variable, two threshold models (logit and probit) were used to analyse disease incidence. The three approaches were compared using a sire model with random litter effect and the same fixed effects as in the animal model.

2.3.3 Results and discussion

Heritability for the infection trait, when treated as a continuous variable, was low but significantly different from zero (0.044±0.010 for Pop. 1 and 0.034±0.006 for Pop. 2). There appeared to be no significant maternal genetic component for the disease trait. Live weight was heritable, 0.180±0.034 and 0.159±0.020 for Pop. 1 and 2, respectively. In contrast to the disease trait, there was a significant maternal genetic effect of approximately 0.1. If an animal model is to be used, the correct model for analysing live weight must include this additional random genetic effect, as omitting it will result in inflated heritability estimates, as observed with these data (Table 2.3.1).

For the disease trait, the fixed effects of sex and parity of dam were significant in both populations ($P<0.01$) but number weaned was not. Males consistently showed a higher incidence of infection than females. The pattern of infection for parity classes was not consistent across the two populations, showing a steady decrease with increasing parity in Pop. 1 but a bi-modal pattern in Pop. 2 (Figure 2.3.1). For live weight males were heavier than females by 16 g and 11 g for Pop. 1 and 2, respectively.

Table 2.3.1 Fixed effects and direct genetic effect (heritability, h^2), common litter effect (c^2) and maternal genetic effect (m^2) for infection and live weight.

	Week +Year	Sex	Dam parity	Litter size	H^2	c^2	m^2
Infection (0 or 1 score treated as continuous variable)							
Pop. 1	**	**	**	ns	0.044±0.010	0.047±0.006	
Pop. 2	**	**	**	ns	0.034±0.006	0.063±0.004	
Infection with maternal genetic effect (0 or 1 score treated as continuous variable)							
Pop. 1	**	**	**	ns	0.041±0.013	0.046±0.006	0.006±0.006
Pop. 2	**	**	**	ns	0.023±0.007	0.062±0.004	0.011±0.005
Live weight (grams)							
Pop. 1	**	**	**	**	0.375±0.028	0.097±0.007	
Pop. 2	**	**	**	**	0.364±0.020	0.161±0.006	
Live weight with maternal genetic effect (grams)							
Pop. 1	**	**	**	**	0.183±0.034	0.085±0.007	0.101±0.022
Pop. 2	**	**	**	**	0.159±0.020	0.130±0.006	0.091±0.014

** P<0.01.

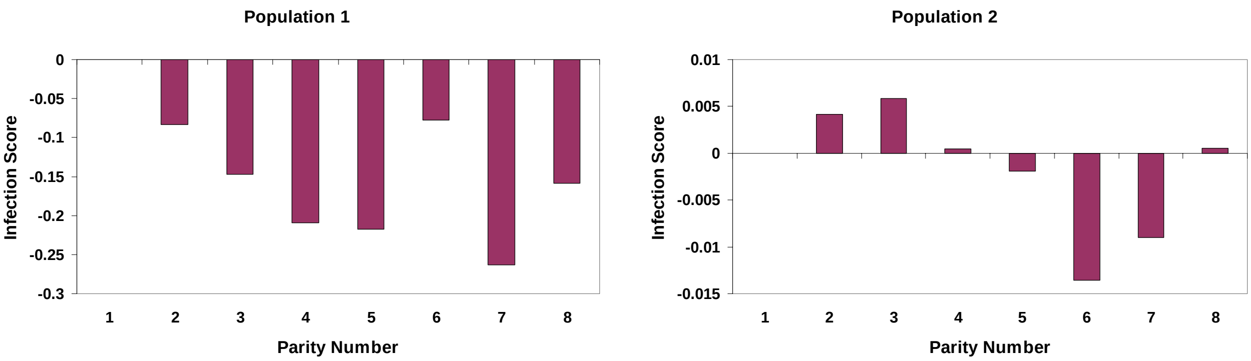


Figure 2.3.1 Pattern of infection score with increasing dam parity.

The genetic correlation between disease incidence and live weight was low in Pop. 1 (-0.13) and not significantly different from zero. In Pop. 2 it could not be estimated, most likely due to non-positive definite variance structure.

Heritability estimates for the infection trait varied from low to moderate depending on the statistical model used (Table 2.3.2). The use of a threshold model gave higher heritability as expected, as the transformation to the underlying liability scale reduces the variance of measurement error (Falconer 1981). However, the estimates of >0.35 seem improbably high, as the expected magnitude of increase in heritability when going from a continuous to a threshold model would be in the order of 3-fold, for the incidence levels reported here. The use of simulation to investigate the optimum model is warranted, followed by confirmation of realised heritability via selection experiments.

Table 2.3.2 Direct genetic effect (heritability, h^2) and common litter effect (c^2) for incidence of bacterial infection using a continuous variable model and logit and probit threshold models, with random effects of sire and litter.

	h^2	c^2
Continuous variable model		
Pop. 1	0.042±0.012	0.056±0.006
Pop. 2	0.035±0.008	0.070±0.004
Logit threshold model		
Pop. 1	0.379±0.106	0.276±0.035
Pop. 2	0.351±0.090	0.356±0.029
Probit threshold model		
Pop. 1	0.133±0.037	0.088±0.015
Pop. 2	Non-estimable	

The value of future data may be improved; in this study the purpose of its collection was not specifically to score for the presence or absence of disease and the predominant symptom was recorded, rather than all symptoms. In research populations (See Section 2.2), where incidence of bacterial infection (approximately 10% of animals) has been scored systematically in growing rabbits, heritability estimates are in the range of 0.08 to 0.1, when analysed as a continuous variable.

The incidence of infection will also influence heritability, with low incidence tending to reduce heritability estimates. In practical terms, the usefulness of a routine scoring system may be dependant on the incidence at time of observation. However, with a systematic assessment of rabbits, incidence is likely to be in excess of 5-6% and may also increase with age (See Section 2.2), suggesting assessment at 10 weeks rather than 9 weeks may be better. Further information is required for the commercial enterprise in this study to introduce selection for disease resistance, and there are plans to collect more data across a range of ages (8-10 weeks of age).

The single estimate of the genetic relationship between infection incidence and live weight is slightly favourable but not significantly different from zero. The lack of a significant effect of number of kits weaned on the disease trait suggests it is not strongly correlated with litter size. If it is the case that disease resistance is not strongly genetically linked with other production traits, then it will need to be included as an additional selection trait in its own right to make improvement. Further investigation of the relationship between disease resistance in growers and disease resistance in breeding does is warranted. There may be a stronger case for a relationship between doe longevity and disease resistance.

2.3.4 Conclusions

Routine observational data on disease incidence in growing rabbits may be a useful indicator of genetic resistance to bacterial infection, the trait appearing to have a significant genetic component. The magnitude of heritability estimates (0.03 to 0.37) varied with statistical model, higher values resulting from the use of threshold models. Overall, heritability may be improved if rabbits are scored systematically for disease incidence. From initial estimates the genetic correlation of disease with growth rate is slightly favourable, but not statistically different from zero, and there appears to be no strong relationship with litter size. Further research investigating different statistical approaches are warranted and further work is required to refine the scoring system used and define the optimum age of measurement.

2.4 Disease reference material

The Crusader Meat Rabbit Disease Tool Kit currently contains 8 of the most common diseases affecting farmed rabbits in Australia. A listing of symptoms, causes, treatment and prevention is accompanied by photographs. It is recommended that farmers use this material in consultation with a qualified veterinarian who can advise on the use of specific drugs and treatments.

The Disease Tool Kit is available on the Crusader web site (www.csiro.au/crusader) and in hard copy form (see Appendix 8.1). It will be distributed at field days, workshops and industry meetings.

3. Rabbit Management and Housing

3.1 Evaluation of cage floors and pressure mats for breeding does

3.1.1 Introduction

Rabbits housed in wire cages or pens are prone to pressure sores on their hocks from sitting on the wire. This condition can be alleviated by providing a mat on which the rabbits can rest. In European rabbit farms it is common for plastic moulded mats with space for waste to drop through to form part of the cage floor. The most common cage used in Australia does not have this design feature and mats need to be provided as a separate installation. The gauge of wire used in floor mesh can also influence the level of hocksore and Australian code of housing for rabbits specifies a gauge of not less than 2.5 mm.

In the Crusader facility the cages have floors of 2.5 mm mesh. The incidence of hocks sore commonly ranges from 5-8% of rabbits in the shed at any one time. The majority of does recover from hocksore but reoccurrence is high. The first type of mats provided for does were Animat®, a specifically designed animal mat of extruded rubber. However, the rubber was soft enough for the rabbits to chew and the mats quickly disintegrated into small pieces. The next style of mat used was cement board, which provided a smooth surface for resting that was hard enough to resist chewing. However, the level of hocksore was not significantly improved, and alternatives needed to be investigated.

3.1.2 Methodology

A trial was conducted at the Crusader facility to assess the effectiveness of mats of different design on the incidence of hocksore. In addition to mats, the standard gauge of wire (2.5 mm) for floors was increased to 3 mm to see if this change alone could reduce incidence of hocksore.

The treatments investigated were:

1. Cement board mats (300 x 300 mm) on 2.5 mm gauge wire floors
2. Coreflute plastic mats (300 x 375 mm with 12 mm holes) with drainage holes on 2.5 mm gauge floors
3. Cement mats on 3 mm gauge wire floors
4. No mat and 3 mm gauge wire floors
5. Moulded plastic mats (300 x 375 mm) produced in Europe by Extrona® on 2.5 mm gauge wire floor
6. Door mats made from strips of tyre rubber (330 x 590 mm) on 2.5 mm gauge wire floor

Due to animal welfare concerns the 2.5 mm floor with no mat was not included as a treatment. Each of the mats are pictured in Photograph 3.1.

The trial commenced in April 2003 and continued until March 2004. Health of the does in each treatment was monitored weekly and incidence of hocksore was recorded. Data from the initial 3 weeks of the trial period were omitted from analysis so as to remove the effect of does with existing hocksore at the commencement of the trial.

The assessment period varied for treatments. Within 3 months it was clear that the incidence of hocksore was not improved by the use of Coreflute mats and, as the mats were easily chewed and were light enough for the does to move around the cage, they were replaced with two more alternatives - the Extrona® and Rubber Tyre mats. This confounds treatment effect with time but the assumption was made that incidence of hocksore was unlikely to change over time as the shed environment remained stable, there was no active selection for improved reduced hocksore and the level of the disease remained stable in the treatments that spanned the full experimental period.
Details of the number of cages allocated to each treatment, the period of the treatment and the number of does populating the cages are given in Table 3.1.

Table 3.1 Number of cages allocated to each treatment, measurement period, number of rabbits and number of observations made during the experiment.

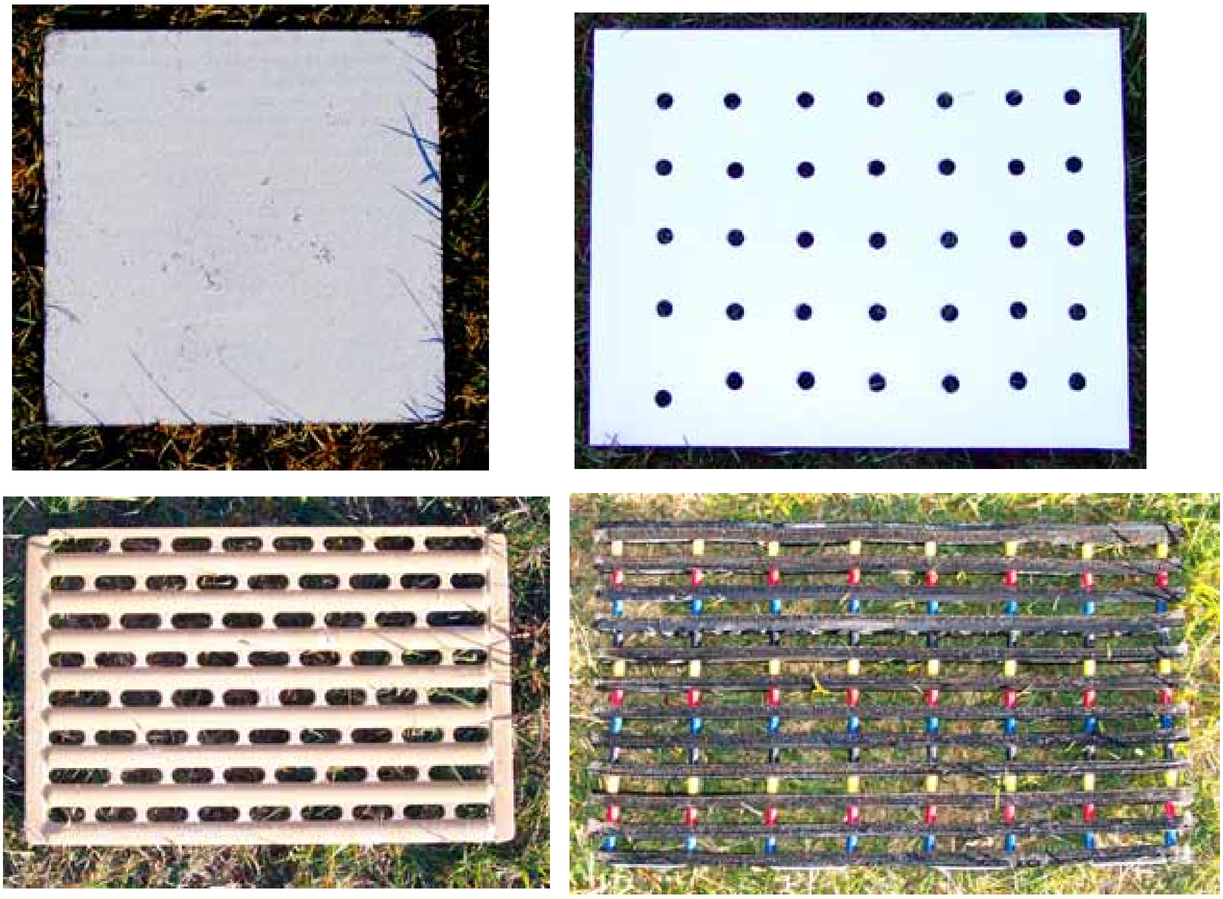
	Cement mat + 2.5 mm wire floor	Coreflute mat + 2.5 mm wire floor	Cement mat + 3mm wire floor	No mat + 3mm wire floor	Extrona mat + 2.5 mm wire floor	Rubber Tyre mat + 2.5 mm wire floor
Number of cages	48	48	12	12	24	24
Measurement period (excluding 1st 3 weeks of data)	15/05/03 to 13/03/04	15/05/03 to 14/08/03 for 24 cages and 17/09/03 for 24 cages	15/05/03 to 13/03/04	15/05/03 to 13/03/04	04/09/03 to 13/03/04	08/10/03 for 12 cages and 24/10/03 for 12 cages to 13/03/04
Total observations	2005	744	485	508	505	494
Number of does resident in cages	120	68	34	26	37	34
Number of hocksore observations	62	35	23	6	5	1
Number of does affected by hocksore	25	11	7	3	2	1

3.1.3 Results and discussion

Results were expressed in two ways; the first being the number of times hocksore was observed as a symptom over the trial period (**incidence)** which combines the number of does and the period for which they were affected; and the second being the number of individual does affected by hocksore over the trial period (**does affected**). The base level of incidence in the two weeks pre-experiment was 5.8%.

Chi squared statistics and significance of treatment effects were calculated, contrasting the frequency of hocksore in each treatment. Results are presented graphically in Figure 3.1. The incidence of hocksore was similar for Cement (3.1%), Coreflute (4.7%) and Cement+3mm floor (4.7%) treatments. The incidence of hocksore was significantly ($P<0.05$) lower in the treatments with No mat+3mm floor (1.2%), Extrona® (1.0%) and Rubber Tyre (0.2%). The proportion of does affected by hocksore followed a similar pattern, with the highest proportion in the Cement, Coreflute, Cement+3mm groups, a reduced proportion in the No mat+3mm group and the lowest proportion in the Extrona® and Rubber Tyre groups (Figure 3.1).

The results show that hocksore can be reduced in breeding does by the provision of suitable pressure mats. The Extrona® and Rubber Tyre mats showed the greatest improvement over Cement or Coreflute mats. The Extrona® mats are imported from Spain and retail for between $12 and $16. The Rubber Tyre mats are readily available from hardware stores for around $10. The use of 3 mm gauge wire for floor construction showed some advantage in reducing hocksore but not when combined with the cement mats. Based on this evidence the recommendation is for mats, similar to the Extrona® and Rubber Tyre mats, to be used to alleviate problems of hocksore in breeders.



Photograph 3.1 Pressure mats assessed for effectiveness in reducing incidence of hocksore in breeding does – Cement mat (top L), Coreflute mat (top R), Extrona® mat (bottom L) and Rubber Tyre mat (bottom R).

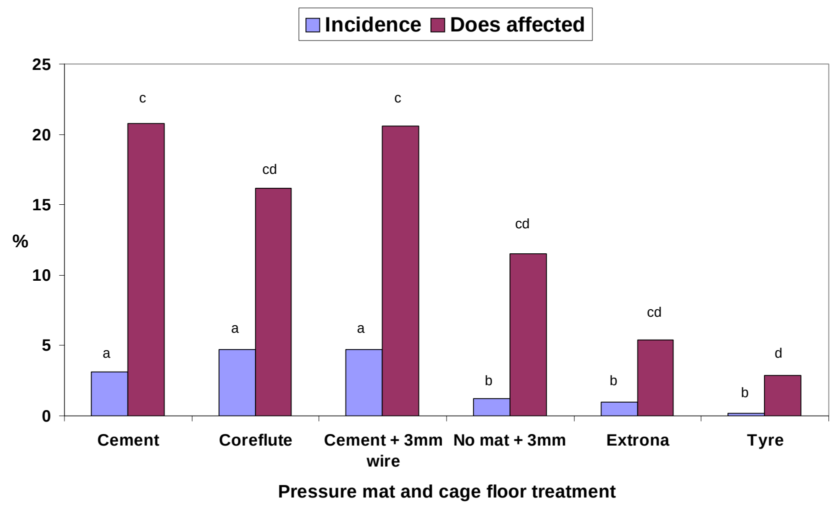


Figure 3.1 Incidence of hocksore observations and proportion of does showing hocksore symptoms when housed in cages with differing pressure mats and gauge of wire in the floor. Within measurement trait different data labels denote significant differences (P<0.05).

3.2 Effect of stocking rate of grower rabbits on growth and survival

3.2.1 Introduction

The Australian Model Code of Practice for Intensive Husbandry of Rabbits (SCARM 1998) specifies the floor area to be provided for each class of rabbit. For grower rabbits the area is 0.07 m^2 per rabbit. The most common rabbit pens in Australia are manufactured by HJN International, Wetherill Park NSW 2164. The floor base made by HJN is 1.2 m x 3 m giving a total area of 3.6 m^2. This is commonly dived into 4 or 6 individual pens for grower rabbits (Photograph 3.2.1). In the Crusader facility at Armidale the floor base is dived into 4 pens each of 0.9 m^2 which can accommodate 12 grower rabbits (5-12 weeks of age). This experiment was undertaken to test if reducing the stocking density of rabbits (to 6 per pen) would improve the growth rate and health of the rabbits.

3.2.2 Methodology

The experiment was conducted in 2002 and 2003, with approximately 500 rabbits per year included in the study. There were 2 treatment groups (Photograph 3.2.1):

Normal Density - with 12 rabbits per pen
Low Density - with 6 rabbits per pen

The rabbits were allocated to each treatment at random when they were weaned at 5 weeks of age. Alternate cages were allocated to each treatment. The rabbits were weighed weekly and scored for incidence of disease from 5 to 10 weeks of age. Average daily gain (**ADG, g/head/day**) between 5 and 10 weeks of age was calculated for each rabbit. If a rabbit showed signs of disease, it received a score of 1 at each measurement time. **Disease Index** was calculated as the sum of scores from 5 to 10 weeks of age and ranged from 0 (never sick) to 6 (sick every time the rabbit was weighed). All mortalities were recorded and cause of death determined. Dead rabbits were not replaced so the stocking density varied during the measurement period when there were deaths.

Analysis of variance was used to compare means for ADG, Disease Score and 10 Week Weight (kg). The model fitted treatment group, year and number weaned (number of litter mates for an individual rabbit) as fixed effects. Chi-square analysis was used to compare incidence of disease and mortality rate for the different treatments.

3.2.3 Results and discussion

The stocking density of grower rabbits had no significant effect on their growth rate or 10 week weight. Rabbits grew at approximately 38-39 g/day and 10 week weight averaged 2.26 kg. Disease Index was not significantly different between treatment groups (Table 3.2.1).

The 3 traits were also significantly affected by year and number weaned. The year effect reflects a combination of changes in shed environment and management along with genetic improvements in ADG and 10 Week Weight. Larger litter size results in lighter rabbits which tend to have lower growth rates.

Table 3.2.1 Means for Average Daily Gain (ADG, g/head/day), 10 Week Weight (kg) and Disease Index (0-6 scale) for grower rabbits housed at different stocking densities from 5 to 10 weeks of age.

Treatment Group	ADG	10 Week Weight	Disease Index
Normal stocking density (0.07 m2/rabbit)	38.1 (0.28)	2.25 (0.01)	0.71 (0.04)
Low stocking density (0.14m2/rabbit)	38.9 (0.04)	2.27 (0.02)	0.69 (0.06)

All data on mortalities across the two years was pooled for a chi-square analysis of mortality rates. There was a significantly higher (P=0.012) rate of mortality for rabbits stocked at the normal density (15.9%) compared to rabbits at half the normal stocking density (10.2%). Examination of the cause of mortality (Table 3.2.2) suggests that rabbits stocked at the normal density are more susceptible to lung infections leading to death than rabbits at a lower stocking density. However, numbers are small and differences are not statistically significant. The difference in mortality does not show up as a difference in Disease Index, which is consistent with the most common cause of death being lung infection where external symptoms are often not present.

Table 3.2.2 Number of deaths and cause of death for grower rabbits housed at different stocking densities from 5 to 10 weeks of age.

Treatment Group	Number of rabbits and cause of death						
	Total dead	Unknow n	Absces s	Injury	Lung infectio n	Wry neck	Scourin g
Normal density (0.07 m^2/rabbit)	120	6 5%	25 20.8%	7 5.8%	38 31.7%	1 0.8%	37 30.8%
Low density (0.14 m^2/rabbit)	35	0 0%	9 25.7%	5 14.3%	7 20.0%	0 0%	13 37.0%

The difference in mortality is highly significant, resulting in a difference of gross margin of $17.35/doe/year. If one assumes a 150 doe unit requires an additional $15,000 capital investment to enlarge the space for growers to allow lower stocking density, then the extra return would be $2603 per annum. With 8% interest and a 3% depreciation allowance for the additional building investment, the additional cost would be $1650 per annum, suggesting that it would be profitable for farmers to reduce stocking densities if such a change yielded similar improvements in survival as demonstrated in this instance.

Photograph 3.2.1 Grower cages showing rabbits at two stocking densities. Rabbits tend to naturally congregate at one end of the cage rather than spreading out.

3.3 Environmental monitoring of rabbit sheds

3.3.1 Description of the Crusader facility and testing

The Crusader facility consists of two conventional steel frame farm sheds clad with galvanised sheet (Photograph 3.3.1 and 3.3.2). The breeder shed has silver foil insulation in the roof and around some of the walls. It has a sprinkler system on the roof which operates in hot weather (>26 ^{o}C) and heat lamps over the kit boxes that operate when shed minimum temperature falls below 8 ^{o}C. The grower shed has 1.5R rated insulation blanket in the roof and foil lining all the walls. Each shed has a large fan which blows air into a long plastic tube running under the pitch of the roof. The tube has holes in the sides to allow air to enter the shed, blowing along the roof line rather than down onto the rabbits. There is a gap between the ground and the bottom of the walls to allow air to escape from the shed. All openings are screened to reduce access by insects. The floors of both sheds are dirt with worm beds under the cages to compost the waste. The worms are very active in the breeder shed but there is little activity in the grower shed where the amount of waste is much higher.

On the Northern Tablelands at Armidale, NSW, summer temperatures are not extreme and the breeder shed operates satisfactorily with the sprinkler system keeping inside temperatures to below 31 ^{o}C. Winter minimums of 0 ^{o}C have been recorded and the heat lamps are essential for kitten survival. The grower shed gets to 35 ^{o}C on extremely hot days and would benefit from a sprinkler system on the roof or forced evaporative cooling for a short period in summer. Minimum temperatures in the grower shed are buffered by the insulation and greater density of rabbits and rarely drop below 5 ^{o}C. While these temperature ranges are not optimal for rabbits (18-22 ^{o}C) they have not caused undue stress to animals and losses from heat stress are rare. New born kittens are susceptible to cold and if not born in the nest box may die before staff arrive in the morning. However, this is not common.

As well as making sure the rabbit shed environment is suitable for rabbits, owners must also ensure that it is safe for themselves and employees. To check the operating environment, in October 2003, an Occupational Hygiene Assessment was undertaken at the Crusader facility. The assessment covered levels of ammonia in the sheds on commencement of work when they were first opened and later in the day; presence of air contaminants such as carbon monoxide, hydrogen sulphide and sulphur dioxide which can be produced when burning hair off the cages; the level of dust and contaminants generated during the normal work routine and when applying lime to the worm beds; and level of air turnover provided by the ventilation system.

Photograph 3.3.1 External view of grower shed (L) showing air intake with louvres and flyscreen, and internal view of grower shed (R) showing ventilation tube, insulation in walls and roof, and grower pens.

Photograph 3.3.2 Internal view of breeder shed (L) showing ventilation tube, heat lamps, doe cages and worm beds and close up of heating lamps (R) installed over kit boxes fixed in floor of the cage.

3.3.2 Results of the assessment and changes to management and facilities

Respirable dust was insignificant (<0.1 mg/m^3) compared to the recommended guideline of 5 mg/m^3. Staff who had the task of spreading lime on the worm beds and cleaning the shed showed a level of 3.5 mg/m^3 of inspirable dust, where the occupational standard for general nuisance dust is 10 mg/m^3. Although well within the recommended level of exposure to dust, the work practices were modified to eliminate the use of lime and ensure protective masks were worn when undertaking jobs that created dust, e.g. raking the aisles.

Ammonia levels in both sheds were well below the long term (25 ppm) and short term (35 ppm) exposure limits recommended for workers. The level in the breeder shed was 2.5 to 3 ppm and did not vary during the day and after liming of the worm beds. In the grower shed the initial level on opening the shed was 6 ppm which dropped to 2.5 to 3 ppm for the rest of the day. The threshold level for detection of ammonia odour is 0.04 ppm so although the level of ammonia was well within the safety limits, it was still detectable.

As there was no evidence that liming the worm beds reduced ammonia levels in the sheds and it contributed to inspirable dust, this process was eliminated in favour of a vinegar spray to assist in neutralising the pH of the beds.

Breathing zone test for carbon monoxide, hydrogen sulphide and sulphur dioxide as possible by-products from burning of hair off the cages gave non-detectable results when this task was being undertaken.

The ventilation assessment estimated the air change per hour to be 5 for the breeder shed and 4 for the grower shed. Levels of carbon dioxide were normal indicating adequate fresh air was being introduced to the sheds. Carbon monoxide levels were also normal indicating that the quality of the air coming into the sheds was good, e.g. not contaminated by vehicle fumes.

Given the higher ammonia levels in the grower shed and the lower air change per hour, modifications were made to increase air turn-over. The number of vent holes in the plastic tube were increased to reduce resistance to air flow and additional vents in the bottom of the walls were installed.

4. Commercialisation of the Crusader® Breeding Program

4.1 Progress to date in the breeding program

The Crusader breeding program commenced in May 2001 with the first progeny of selected rabbits being born in July 2001. From May 2001 to April 2003 the rabbits were selected on an index combining estimated breeding value (EBV) for average daily liveweight gain (ADG, g/head/day) from 5 to 10 week of age and litter size at weaning or number weaned (NW). The relative economic weight for each trait was a function of the extra profit derived from one standard phenotypic deviation improvement in that trait.

Index ($/doe/year) = (Number Weaned EBV x $33.71) + (Average Daily Gain EBV x $10.61)

In May 2003 a disease resistance trait was introduced to the index and the first offspring of rabbits selected with the expanded index were born in August 2003. The trait was incidence of bacterial infection in grower rabbits from 5 to 10 weeks of age. The economic weight for the disease EBV was calculated using the Crusader Enterprise Model to predict increased returns from one phenotypic standard deviation change in the trait and the predicted flow-on effect on survival and improved growth rate.

Index ($/doe/year) = (Number Weaned EBV x $33.71) + (Average Daily Gain EBV x $10.61) + (Disease Resistance EBV x -$28.81)

Genetic parameters used to estimate breeding values are based on values from literature for ADG and NW and on estimates from Crusder data (Section 2.2) and are given in Table 4.1

Table 4.1 Heritability estimates for traits in the Crusader Index drawn from published literature and Crusader data.

Trait	No. of estimates	Range	Heritablity used for Crusader EBVs
Number born alive (NBA)	11	0.05-0.33	0.1
Number weaned (NW)	10	0.02-0.14	0.05
Average daily gain (ADG)	9	0.17-0.48	0.3
Disease resistance	1	na	0.1

Genetic, phenotypic and environmental trends for each trait in the index are given in Figures 4.1.1 (litter size at weaning), Figure 4.1.2 (average daily liveweight gain) and Figure 4.1.3 (disease resistance).

To aid in interpretation the following definitions apply for each trend:

i. **Genetic trend** is the change in estimated breeding values over time, reflecting the underlying change in genes for each trait and the genetic merit of the animal for improving that trait in their offspring.
ii. **Phenotypic trend** is the observed performance of the animals, reflecting the combination of genetic and environmental effects on the expression of the trait.
iii. **Environmental trend** is the way in which the environment has changed over time to effect the trait, reflecting changes in management, housing, nutrition and exposure to such things as disease or stress.

Given mean starting values of 4 kittens weaned per litter, 34 g/head/day for growth rate and average infection score of 0.50, genetic improvement has been 9% for kittens weaned, 17% for growth rate and 11% for disease resistance since the breeding program commenced in July 2001.

Phenotypic trends have shown the same pattern for litter size and growth rate, improving by 69% and 33%, respectively, but disease resistance has not improved at the phenotypic level. For litter size the improvement is a clear combination of genetic and environmental effects, as both show significant improvement over time (Figure 4.1.1). Environmental factors that have contributed to kitten survival have been changes to kit box design, heating during cold weather and improvements to hygiene. The phenotypic trend for growth rate is positive even though the environmental trend is unfavourable (Figure 4.1.2). The unfavourable environmental trend may be due to the severe drought conditions during 2003 when the quality of feed changed.

Although the genetic trend for disease resistance shows improvement (the disease score decreasing), the phenotypic trend is unfavourable (increasing score denoting higher incidence of disease). This is explained by the environmental trend for disease, which indicates a marked adverse change in conditions impacting on disease incidence. The commencement of the breeding program coincided with the commissioning of a new shed for growers. The environmental trend in Figure 4.1.3 initially shows a low disease environment, deteriorating over time as dust, waste and bacteria levels build up. This is a common phenomenon observed with new sheds.

Although the incidence of infection has not improved phenotypically over the period of selection, overall mortality rates have decreased from 15% to 10% (Figure 4.1.4). If losses from the calici virus outbreak in Jan-Feb 2004 are excluded, the improvement is even greater. This improvement is likely to be attributed to the genetic improvement in resistance to bacterial infection in addition to management changes.

Overall progress in the breeding program has been substantial with a combination of genetic and management improvements lifting gross margins from an estimated $174 to $242 per doe per annum. The average index value of animals has improved to +$40 per doe per annum (Figure 4.1.5), indicating that a significant proportion of the improvement has been from the selection program.

Figure 4.1.1 Genetic, phenotypic and environmental trends for rabbits selected for improved litter size at weaning (number of kittens/litter). Base data point represents the base population prior to selection and y-axis scale varies for each trend.

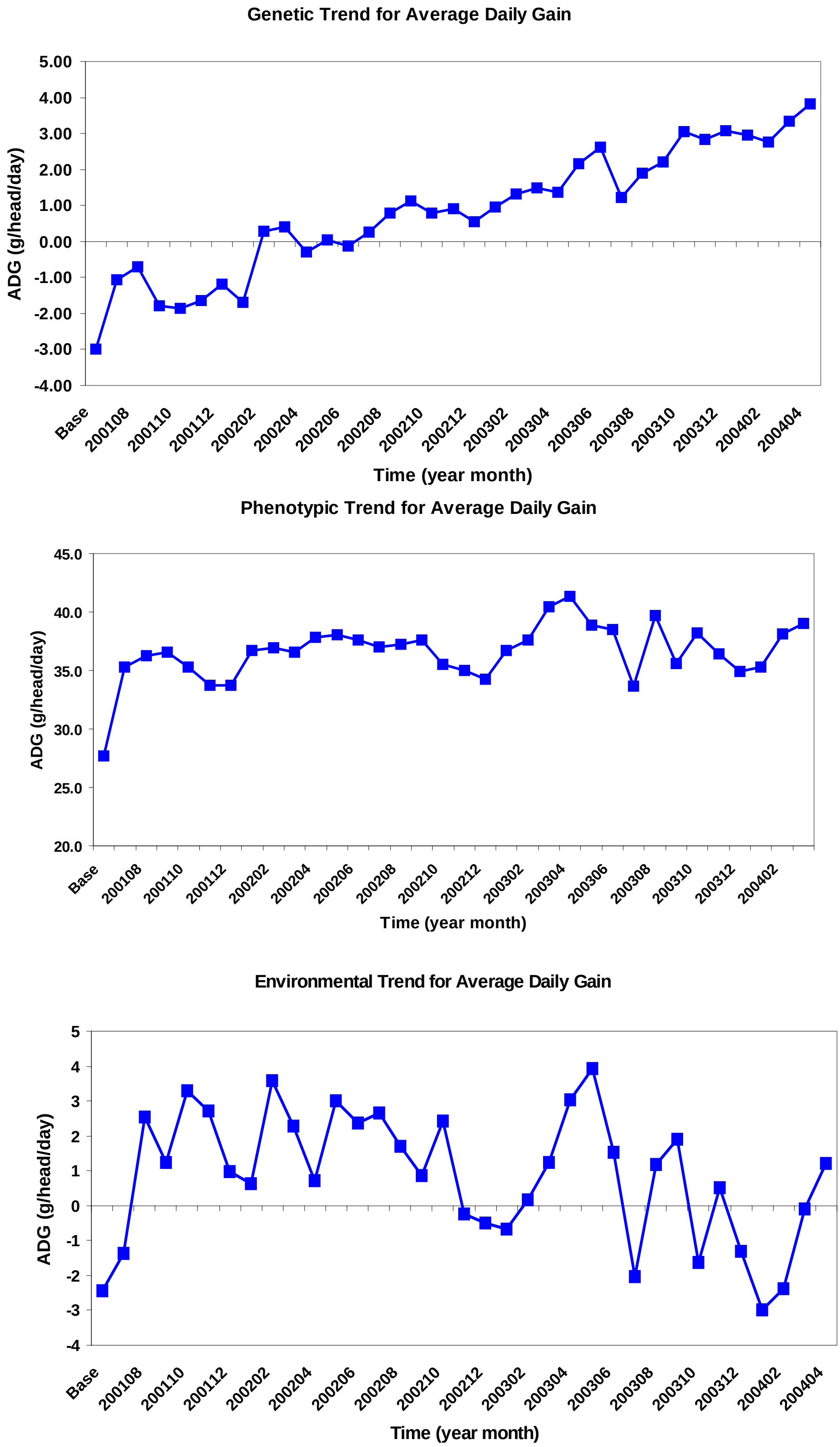
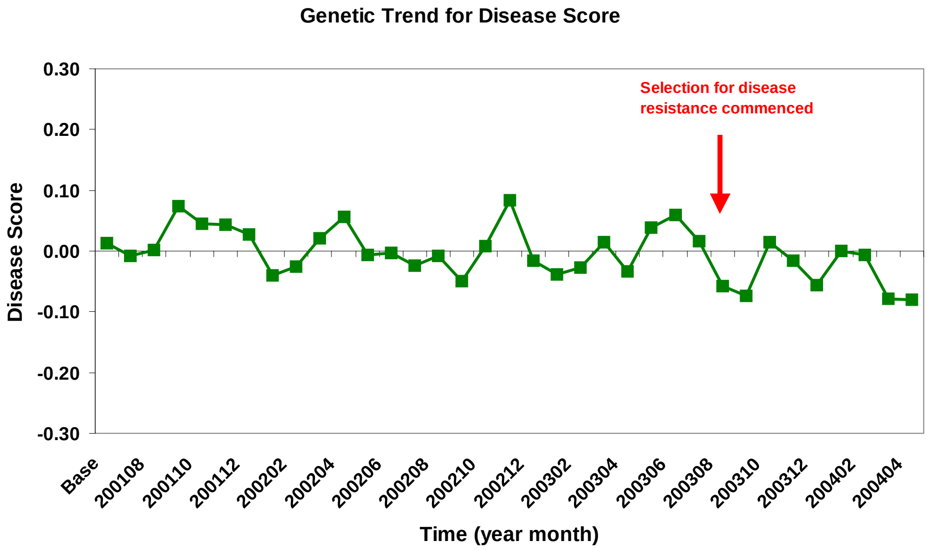
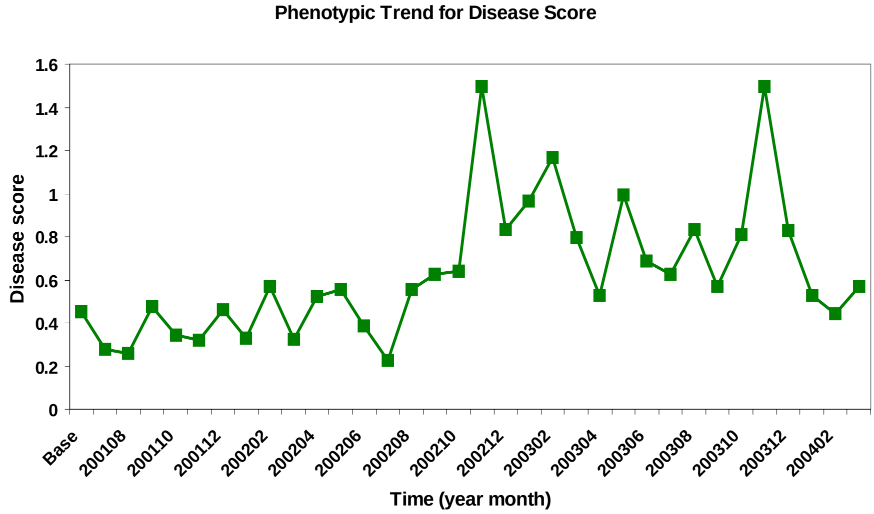


Figure 4.1.2 Genetic, phenotypic and environmental trends for rabbits selected for average daily liveweight gain (ADG, g/head/day) . Base data point represents the base population prior to selection and y-axis scale varies for each trend..





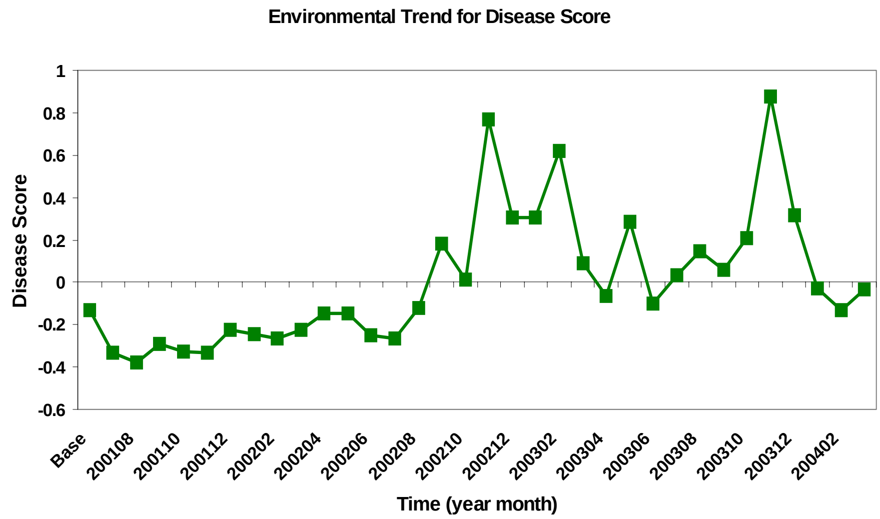


Figure 4.1.3 Genetic, phenotypic and environmental trends for rabbits selected for disease resistance (Disease Score, 0-6) . Base data point represents the base population prior to selection and y-axis scale varies for each trend.

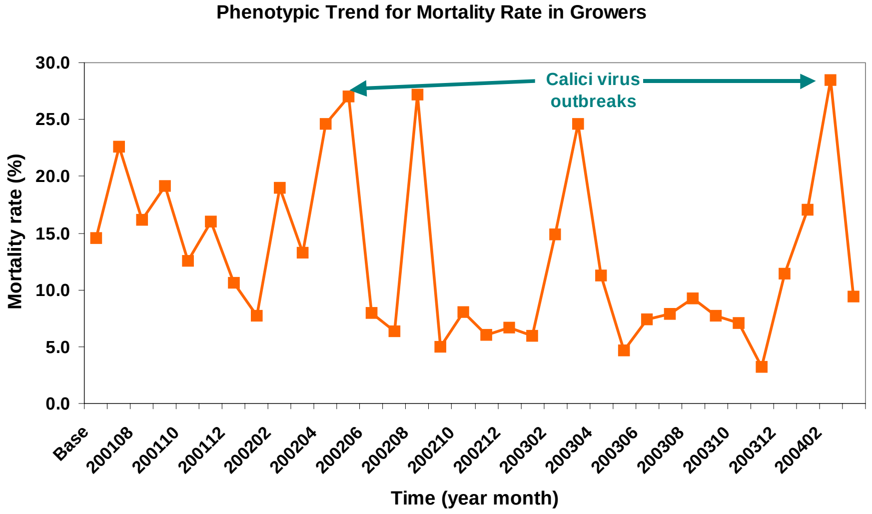


Figure 4.1.4 Phenotypic trend for mortality rate (%) in grower rabbits. Base data point represents the base population prior to selection.

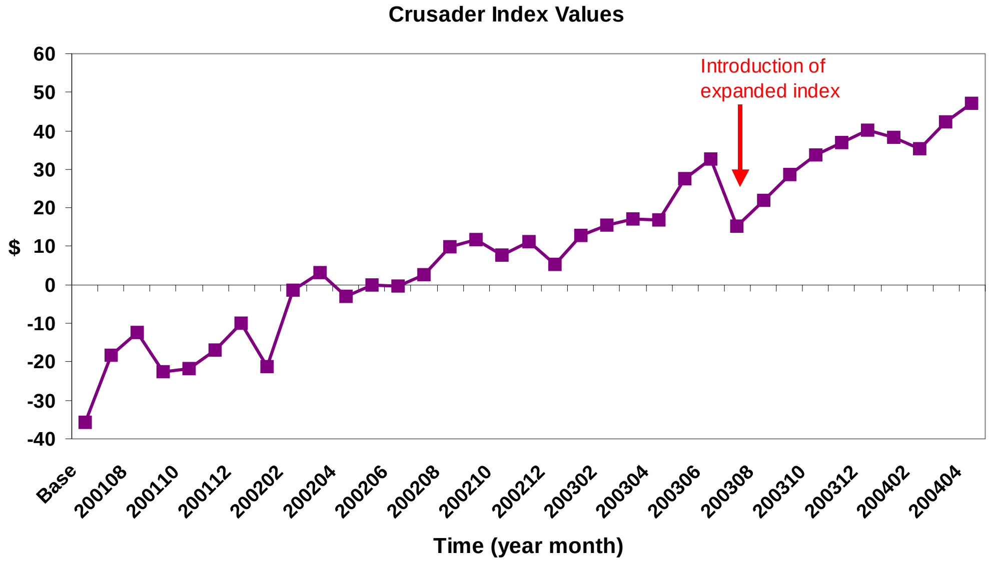


Figure 4.1.5 Crusader Index for base population and selected rabbits over time.

4.2 Call for expressions of interest and tender outcome

An objective of the current project was to transfer the Crusader breeding program, including the rabbits, to an experienced industry enterprise under appropriate and agreed commercial arrangements. Initially it was anticipated that this would occur toward the end of the project in 2006-2007 but circumstances arose which favoured an earlier commercialisation.

In November 2003 negotiations commenced between CSIRO and RIRDC to commercialise the breeding program. This discussion was initiated for two reasons. The first was that the breeding program had reached the stage where its management was largely routine. Research was continuing with the introduction of novel traits such as disease resistance but the day-to-day operation of the program was procedural and well documented, and the database maintenance and estimation of breeding values largely automated. This coincided with the industry reaching a stage of development where there were a number of commercial farmers capable of managing the breeding program.

Therefore, the decision was made to proceed, and in December 2003 expressions of interest (Appendix 8.2.1) were invited from members of the industry with established enterprises who potentially could manage Crusader. On-farm visits were made by RIRDC and CSIRO staff to gather further information (Appendix 8.2.2) from the respondents who were able to address the initial selection criteria. Snowy Mountains Gourmet Rabbit Company (SMGRC), run by Michael and Kathleen Bowerman, Bredbo NSW, were selected to contract manage the Crusader breeding program.

4.3 Transfer of rabbits, database and breeding program

In April 2004, Kathleen Bowerman spent a week training with the Crusader staff on-site at Armidale. The first shipment of 120 rabbits were delivered to Bredbo on 22 April 2004 and the final transfer was on the 30 June 2004. In all approximately 350 rabbits, primarily young breeding stock, were transferred. The movement of rabbits was planned such that there would be minimum impact on the breeding program, with a break of only 3 weeks from matings. From late August 2004, Crusader rabbits will be available for sale from SMGRC. At the same time that the rabbits moved so was the large database of pedigree information and performance records. All day to day operations associated with the breeding program, including data entry and estimation of breeding values, will move to SMGRC.

Photograph 4.1 Kathleen Bowerman (R), SMGRC, and Sandra Eady, CSIRO, going through procedures to score rabbits for disease incidence in the Crusader facility prior to the transfer of rabbits to Bredbo.

4.4 Ongoing management and research and development support

CSIRO will continue its involvement with Crusader, providing research and development for the ongoing breeding program. The initial focus will be on improving the disease resistance of the Crusader rabbits, a trait that is vital to efficient production and an area of work in which Australia is leading. Collaborative research will continue with the French rabbit breeding group at INRA, which will keep the Australian breeding program up to date with new and innovative traits for selection and advances in gene technology.

In addition to the breeding research, SMGRC will undertake some applied research in conjunction with CSIRO, the initial study being an evaluation of different nest box designs for kitten survival. The Crusader Advisory Group, which consists of four rabbit industry members, will continue to provide industry comment, input and direction to the project.

5. Application in Industry

Industry liaison and application of project outcomes had been an important component of the Crusader Project. The breeding program was designed to provide seed stock directly to industry and each phase of the project included field days and workshops to deliver research outcomes, management and husbandry information and technology in a timely manner.

5.1 Information services for the general public

As Crusader is the only production research unit for meat rabbits in Australia, there has been a high level of demand for information from prospective and current farmers, the general media and agricultural science related groups. On average the project has dealt with 6-8 enquiries per week, and at times 6-8 enquiries per day after media releases and field days. The breeding facility was visited regularly by educational groups such as schools, TAFE and University of New England.

Crusader has a high industry profile and has responded to numerous media requests (>15 per annum) for radio and print material. The Crusader website (www.csiro.au/crusader) has become the prime means of distributing general information on rabbit farming and in 2002/03 was recording >400 hits per month which grew to 600 hits per month in 2003/04.

An Enterprise Model was built to estimate gross margin from meat rabbit production. It used information from the Crusader project, farmer surveys and a small group (3-4) of farmers who maintained production and enterprise expenditure records. The Crusader Enterprise Model was posted on the project web site (www.csiro.au/crusader) in August 2003 and has been downloaded more than 1000 times since then. It has been used by potential farmers, existing farmers and groups undertaking feasibility studies on the meat rabbit industry.

5.2 Farmer-focused services

5.2.1 Field days and workshops

The Crusader project provided information to farmers throughout 2002/03 and 2003/04 at the following workshops and field days:

i. Meat Rabbit Field Day held by the Country Gourmet Rabbits Co-operative Ltd, 29 June 2002 at Boorowa, NSW.
ii. Victorian Gourmet Rabbit Producers Association Workshop, 21 July 2002 at Hallam, Victoria
iii. SA Rabbit Breeders Association Workshop, 27 September 2002 at Millicent, SA
iv. Specialist rabbit workshop on genetic improvement held at Geelong, VIC on 28 September, 2002
v. Meat Rabbit Field Day held by the Country Gourmet Rabbits Co-operative Ltd, May 2003 at Cootamundra, NSW
vi. Armidale Business Enterprise Centre Workshop at Inverell, NSW in November 2003
vii. Port Macquarie Business Enterprise Centre Workshop at Kempsey, NSW in November 2003
viii. Crusader Meat Rabbit Field Day at CSIRO Armidale, NSW in July 2003 with focus on economic modelling and improving farmer returns.

Each workshop/field day was attended by 70-100 people and the Crusader Field Day in July 2003 was attended by 170 people.

Photograph 5.1 Farmers at Crusader Field Day at CSIRO, Armidale in July 2003.

5.2.2 Sale of breeding stock

During the period of the project sales of Crusader breeding stock continued strongly with 351 animals sold to 50 farmers between 1 July 2002 and 31 May 2004. The average merit of breeding stock sold to farmers is shown in Figure 5.1. It is estimated that since breeding stock sales commenced, approximately 25% of the industry have directly used Crusader breeding stock.

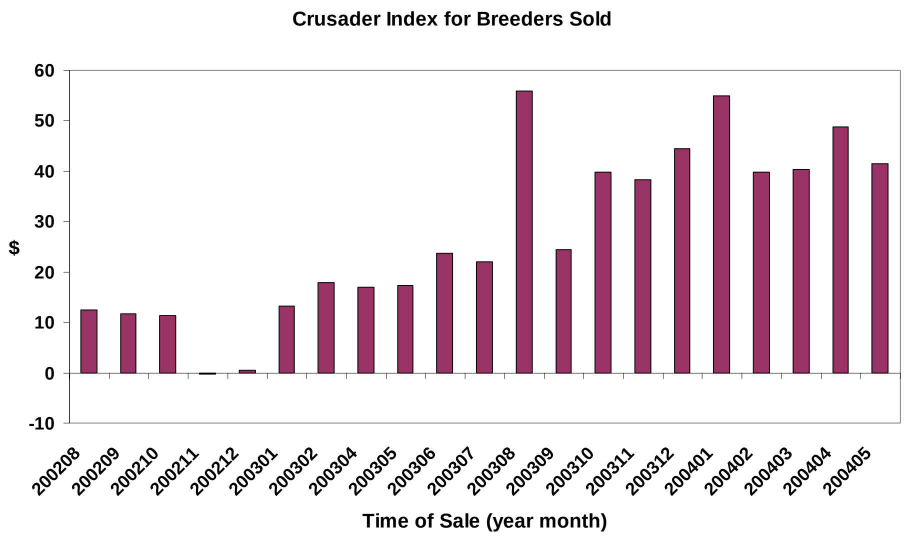


Figure 5.1 Average Crusader Index value ($) for breeders sold into industry between July 2002 and May 2004.

5.2.3 Crusader Advisory Group

During the planning phase for this project, stakeholder input was sought from industry members as to issues of priority for R&D and the role that the Crusader project should take in meeting these needs. One issue that came out of these discussions was the desirability of formally involving industry members in the planning and implementation of the Crusader project. As part of the project's undertaking to do this, an Advisory Group was established.

In March 2003 an advertisement was placed in the rural press requesting expressions of interest from people in the meat rabbit industry (farmers, processors, wholesalers) to serve on the Crusader Advisory Group. This notice was also circulated to industry members. Applicants were asked to describe their involvement with industry, their vision for the industry, how they have contributed to industry development and how they would contribute to the Crusader project. The responses were assessed by the project leader and two independent people and 4 applicants were invited to form the

Advisory Group. The inaugural members were Kathleen Bowerman (Bredbo, NSW), Daniel Brown (Guyra, NSW), Margaret James (Kempsey, NSW) and Glenn McNeill (Lara, Vic).

The Advisory Group met on 3 June 2003 and 12 December 2003. Contributions by members have been important to the project in defining areas of immediate interest (feed costs and formulation, ability to benchmark performance), providing avenues for dissemination of project results through regional workshops, and direct contributions to the Crusader Field Day in July 2003. The Advisory Group also played an important role in the commercialisation of the breeding program.

Photograph 5.2 Advisory Group members with Crusader staff at field day in July 2003. L to R John Smith (Crusader Facility Manager), Margaret James (Macleay Valley Rabbits, Kempsey), Sandra Eady (Crusader Project Leader) and Glenn McNeill (QAFR, Lara).

5.3 Industry focused activities

5.3.1 Farmed Rabbit Industries of Australia Pty Ltd

The call for expressions of interest to serve on the Crusader Advisory Group resulted in 30 industry members applying for the 4 positions. This response demonstrated the willingness of many industry members to contribute at the industry level. The decision was made by Crusader and RIRDC to harness this enthusiasm to further the development of a national association. The industry members who had expressed an interest in contributing to the Crusader Advisory Group were invited to attend a meeting in Sydney in February 2004 to discuss the formation of a national association. Additional industry participants were also nominated by industry to attend. The meeting resulted in the formation of FRIA with the first annual general meeting scheduled for 30 July 2004. The formation of a national association will have many benefits for industry development and is a positive outcome, to which Crusader was able to provide some impetus and contribution.

5.3.2 Rabbit farming – an evaluation of the Crusader R&D program

In June 2003 the Centre for International Economics (CIE) was commissioned to undertake a study of the return on R&D investment for the initial Crusader project that ran from 1999 to 2002. In conjunction with Crusader staff, a questionnaire was developed and circulated to a cross-section of industry participants. The benefits flowing to industry from the initial Crusader project were largely from animal husbandry and management information and delivered a return of 15 per cent on the R&D investment (CIE 2004). The breeding program results had not translated through to industry at that time. This is likely to be due to the small incremental nature of the improvements each year and the genetic lag between breeding nucleus and industry. When they are achieved on-farm, CIE predict they will be of similar value.

6. Ongoing Research Support for Industry

The meat rabbit industry in Australia has continued to grow over the life of this project, from a production of an estimated 159 tonnes in 2001 to 270 tonnes in 2003 and Crusader has contributed significantly to this performance. An independent assessment of the initial Crusader project (1999-2002) has shown a return on investment in R&D of 15% for husbandry and management outputs and potentially another 15% for genetic improvements, once they are realised throughout the industry (CIE 2004).

There are still many areas of R&D requiring attention - disease control, doe reproductive performance, survival of kittens, growth rate, shed and cage design and nutrition. Figure 6.1 reiterates the ranking of issues of importance for research identified by farmer survey in 2001. The industry is now at the stage where a component of research can be undertaken on-farm. These resources should be utilised to expand the range of work supporting the industry. Areas of applied research conducive to on-farm investigation include feeding trials for growers and breeders, and evaluation of equipment such as nest boxes. With the establishment of specialist rabbit processors there is also the opportunity to involve industry members in research on product development and specification. More structured on-farm experiments could be undertaken with the Crusader stock at SMGRC and this possibility is included in the commercial agreement to manage the rabbits.

In the area of genetic improvement, activities of highest return to the industry at this stage are the introduction of disease resistance, for both growers and breeders, into the selection program and the establishment of a national program for genetic evaluation. Disease control is an ongoing challenge for the industry and harnessing genetic resistance will be a valuable tool for farmers. The establishment of a national genetic evaluation program will expand the number of breeders who are able to provide objectively measured rabbits with estimated breeding values. It will also enable the industry to independently run a genetic improvement program without reliance on external funding from CSIRO or RIRDC.

With the support of RIRDC and CSIRO, the industry has initiated the formation of a national association – Farmed Rabbit Industries of Australia Pty Ltd (FRIA). In the future this organisation will play a valuable role in determining priorities for research and development. To assist this process, the Crusader Enterprise Model will be a valuable tool that can be used to identify those parameters having the largest impact on profit.

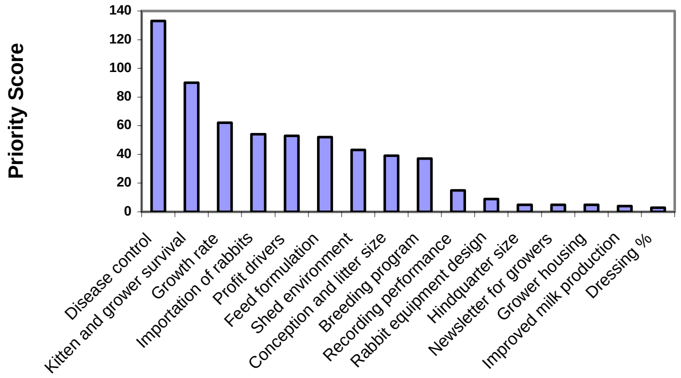


Figure 6.1 Priority score given to research issues by meat rabbit farmers in 2001.

7. List of scientific publications from Crusader (2002 – 2004)

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9. Appendices

9.1 Crusader Disease Toolkit

Crusader Meat Rabbit Disease Tool Kit

The most common diseases affecting farmed rabbits in Australian are summarised listing their symptoms, causes, treatment and prevention. It is recommended that you use this material in consultation with a qualified veterinarian who can advise on the use of specific drugs and treatments.

Additional information on rabbit diseases and production can be gained from references such as "Rabbit Production" by McNitt, Patton, Lukefahr and Cheeke (1996, published by Interstate Publishers, Inc, Danville, Illinois).

SNUFFLES

Symptoms: Initial signs are repeated sneezing with a clear mucous discharge from the nose. This may become creamy in appearance and in severe cases cause crusting on the nose (see opposite). A useful way of detecting snuffles is to look for wet or matted fur on the inside of front legs caused by continual nose wiping. Snuffles can develop into pneumonia if the infection spreads to the lower respiratory tract and lungs. It is a common disease of rabbits and is endemic in most rabbit sheds.

Cause: Most often bacteria called *Pasteurella multocida* but can also be caused by *Staphylococcus spp.* These bacteria spread in the air and by contact with contaminated hands, cages, equipment or other rabbits. There is often a specific strain of Pasteurella on each farm to which newly introduced rabbits will be more susceptible. These bacteria are endemic in the environment and stressed rabbits are more likely to succumb to infection.

Figure 1 Rabbit showing signs of fur matting on front paws from wiping its nose.

Figure 2 Rabbit with severe snuffles showing creamy exudate around the nose

Treatment: Not all infections respond to antibiotic treatment but it is possible to reduce the incidence by the use of an effective antibiotic. In commercial meat rabbits it is often not economically viable to treat rabbits and animals with severe snuffles are culled.

Prevention: Sheds and cages should be kept as clean as possible. Good ventilation is required to maintain air quality and reduce ammonia, however, care needs to be taken to avoid direct drafts over the rabbits. Temperature range should be kept at a minimum (between 18-24°C) as changes in temperature can trigger stress and out breaks of snuffles.

PNEUMONIA

Symptoms: Laboured breathing, often with mouth open and head thrown back at late stages. Skin around eyes and mouth appears blue from lack of oxygen. Pneumonia is most easily diagnosed after death by checking the lung tissue – the normally bright pink tissue is purplish and less spongy. There may be fluid in the chest cavity.

Cause: Most often a bacteria called *Pasteurella multocida* but can also be caused by *Staphylococcus spp*. These bacteria spread in the air and by contact with contaminated hands, cages, equipment or other rabbits. There is often a specific strain of *Pasteurella* on each farm to which newly introduced rabbits will be more susceptible. These bacteria are endemic in the environment and stressed rabbits are more likely to succumb to infection.

Figure 3 Pneumonia infected lung showing dark reddish discolouration. Normal lung tissue is bright pink and spongy

Treatment: Pneumonia is difficult to treat with antibiotics as by the time symptoms are observed the infection is likely to be well advanced.

Prevention: Avoid stress in the rabbits by ensuring good air quality, no direct drafts on the rabbits and temperature fluctuation is small (18 to 24°C). Sheds and cages should be kept as clean as possible. Good nutrition and fresh clean water is essential.

ABSCESS

Symptoms: Abscess form a large pustular lump under the skin or in the internal body cavities. If close to the skin they may rupture discharging a thick pus. Abscesses can also occur internally causing septicaemia (blood poisoning), normally there are no external signs with internal abscess with death of animal the first symptom.

Cause: Most often a bacteria called *Pasteurella multocida* but can also be caused by *Staphylococcus spp*. These bacteria spread in the air and by contact with contaminated hands, cages, equipment or other rabbits. Broken skin and injury wounds are common sites for infection. There is often a specific strain of Pasteurella on each farm to which newly introduced rabbits will be more susceptible. These bacteria are endemic in the environment and stressed rabbits are more likely to succumb to infection.

Figure 4 Rabbit with abscess in jaw area

Figure 5 Abscess opened up to show creamy pus filled sac

Treatment: Wounds detected early can be treated with success with daily irrigation of antiseptic solution until healed. As is difficult and time consuming to treat abscesses these rabbits are best culled immediately. Abscesses can be lanced and puss drained with a large incision wound but must be allowed to heal from inside to outside to prevent reoccurrence. The healing process may be assisted by antibiotic treatment.

Care should be taken when undertaking the treatment of abscesses because the pus material will contain high numbers of organisms that can be easily spread onto pen surfaces and via hands to other animals.

Prevention: Sheds and cages should be kept as clean as possible. Good hygiene in the kit box is essential as bacteria can enter the rabbit's bloodstream at birth via the umbilical cord. Affected rabbits should be isolated or culled immediately to prevent further contamination.

COCCIDIOSIS

Symptoms: Diarrhoea or scouring with matted dirty fur around the anus. In the early stages the rabbit may show signs of ill thrift. Rabbits appear lethargic, go off their feed, scour, become dehydrated and can die within 48 hours if left untreated. On post mortem the liver may show signs of damage in the form of white spots. While the liver form of the disease can be the most spectacular, the intestinal form is more common and likely to be significant on most properties. Diagnosis will need autopsy findings of inflamed intestines and demonstration of coccidial oocysts in faeces or gut smears.

Cause: A protozoan parasite that invades the bile duct or intestine. The most common form is intestinal coccidiosis which causes scouring. The less common liver form damages the bile duct which causes the liver to develop characteristic white spots.

Figure 6 Rabbit showing signs of scouring.

Figure 7 Liver showing white spots characteristic of coccidia infection

Treatment: There are coccidiostats that can be used to treat affected rabbits. These can be administered through the water or feed under veterinary advice.

Prevention: Coccidiostats can be added to feed at the pelleting stage at low levels to suppressive coccidia infection. This practice requires a veterinary prescription. Re-infection with coccidiosis occurs through contact with faeces. Good cage hygiene can interrupt this cycle. Rabbits housed on the ground are particularly susceptible to this parasite unless all faecal material is removed daily.

HOCK SORE

Symptoms: Hair loss on the foot pad and hock area is followed by ulcerated sores that often become infected. Affected rabbits look like they are "walking on eggs" and gingerly shift their weight from foot to foot. Rabbits may lose body condition and can die from septicaemia (blood poisoning). Most often the rear hocks become sore but all feet can be affected in severe cases.

Cause: This condition is common with rabbits on wire floors. Type of wire, cleanliness and the condition of the cage floor are important factors associated with hock sore.

Figure 8 Broken skin from pressure sores on hind legs

Figure 9 Pressure sores with thick scabs and signs of infection

Treatment: Hock sore can be treated by soaking off surface crust and irrigating with a topical solution but the healing process is slow and the condition often reoccurs. Affected rabbits should be provided with a mat to allow them to get off the wire floor. Rabbits with reoccurring hocksore should be culled.

Prevention: Mats on wire floors assist in prevention but may pose sanitation problems. Mats which allow the passage of faeces and urine are the best but care should be taken to ensure they are kept clean. Nail trimming is also advisable so that nails do not catch on cage floors causing animals to put more weight onto hocks.

CALICI VIRUS

Symptoms: Calici virus is hard to detect because often there are no external signs. A dead rabbit found in the cage might be all that is seen. Animals, if noticed, will appear to be lethargic and have difficulty breathing. Convulsing sometimes occurs for a few moments before death. There may be blood around the nose. Post mortem generally shows internal bleeding in a range of organs. The liver is brownish red and swollen with a characteristic "orange peel" appearance. Heart and kidneys are normally blood filled with signs of blood sometimes around the intestines, the spleen is enlarged. It is difficult for most non-trained people to calici. However, there is invariably blood in the windpipe (trachea) which appears as bands of reddening in the tracheal wall. Together with the appearance of the liver this sign is probably the most reliable.

Positive diagnosis can be obtained by submitting fresh tissue samples, via a veterinarian, for laboratory testing.

Figure 10 Signs of haemorrhaging

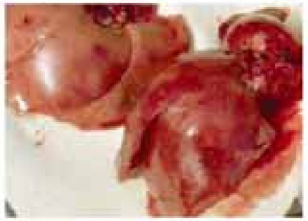

Figure 11 Mottled orange-peel appearance of liver

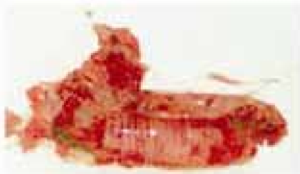

Figure 12 Characteristic banding in windpipe from haemorrhaging

Cause: A virus that causes severe internal haemorrhaging, resulting in rapid death of the rabbit. Rabbits older than 6-7 weeks of age seem to be the most commonly affected by calici virus. The virus is present in saliva and nasal secretions of infected rabbits. It can be spread via insects, birds, rodents, people and their clothing and contaminated feed and water equipment.

Treatment: There is no practical treatment for infected rabbits.

Prevention: A vaccine is available for rabbits and its administration should be followed by regular booster vaccinations as directed. The most common rabbits vaccinated are the breeding does and bucks. The major preventative measure is to exclude insects, birds and rodents from the rabbit shed. Prevention is also helped by good sanitary practices in the rabbit shed such washing hands, cleaning cages and equipment and wearing clean clothing.

MASTITIS

Symptoms: Infected mammary gland usually swells up and there is a hard lump generally around the nipple, progressively enlarging if untreated. The region can become reddish inflamed and painful, sometimes in more severe cases the affected area turns blue. Does with mastitis often have increased temperature. If untreated the infection will become abscessed and hard. Often kittens will grow poorly or die as milk supply is restricted and suckling is painful.

Cause: Mastitis is an infection of the mammary gland often caused by *Staphylococcus aureus* but can also be caused from *Pasteurella multocida* plus other bacteria. Bacteria can enter the mammary gland via the teat canal, through injury to the teats or via the blood stream (septicaemia).

Figure 13 Mammary gland of rabbit swollen and red from infection

Figure 14 Mammary gland turning blue from severe mastitis

Treatment: Treatment with an effective antibiotic at the early stage of infection can assist the doe to overcome the infection. Mastitis often reoccurs with subsequent lactations and affected rabbits should be culled.

Prevention: Good hygiene is essential for the control of mastitis. Cages and equipment should be cleaned prior to kindling. Particular attention should be paid to keeping cages and nest boxes clean during lactation. Topical treatment of nipple injuries can reduce the chance of infection through this route. Infection is readily spread though human contact and hands should be disinfected before handling each lactating doe. Kittens from infected does are also a source of infection and should not be fostered onto healthy does.

MUCOID ENTEROPATHY AND/OR ENTEROTOXEMIA

Symptoms: Soft jelly like faeces or diarrhoea that soils the fur around the anus. Rabbits can die very quickly, often before symptoms of scouring are observed. It is usually grower rabbits from 6-8 weeks of age that are affected.

Causes: These two diseases are associated with a disruption of gut function that may be caused by bacteria such as *Escherichia coli* or by a lack of fibre in the diet of the rabbit. Stress, overcrowding and poor sanitation can increase susceptibility of rabbits to these diseases.

(Coccidiosis can also cause scouring and should be considered as a possible cause. See previous section)

Figure 15 Rabbit showing signs of scouring

Treatment: The most effective treatment is to increase the level of fibre being fed to the animals. This can be given in the form of lucerne or grass hay.

Prevention: Feed grower rabbits a diet with adequate fibre levels (>12% - 14%). Monitor rabbit health and adjust stocking rate if necessary. Good sanitation in the grower shed with cages and equipment regularly cleaned. Free access to fresh clean drinking water.

9.2 Commercialisation of the Crusader breeding program

9.2.1 Expression of interest

Background

The Crusader Meat Rabbit Project has been jointly funded by Rural Industries R&D Corporation (RIRDC) and CSIRO since 1999. One outcome of the project has been the development of an improved rabbit strain selected for increased growth rate, reproductive performance and disease resistance.

An objective of the current research is the transfer of the Crusader breeding program including the rabbits, to an experienced industry enterprise under appropriate and agreed commercial arrangements. That enterprise would continue the present program as a contractor for RIRDC which would retain the ownership of the rabbits. CSIRO's role will be to continue research and development input into the project.

Future Action

RIRDC and CSIRO have agreed that the transfer should occur before or by June 30, 2004.

An expression of interest is being sought from some leading breeding establishments particularly those that have a record in performance recording and an interest in genetic improvement.

Expression of Interest

The successful applicant would continue in their enterprise the breeding program currently being undertaken by CSIRO at Armidale. There would be a need to manage the program as has occurred at CSIRO. As such there will be a need to:

(i) record measurements not normally recorded in detail in commercial operations including those related to mating, kindling, weaning and disease incidence in breeders/growers and body condition scoring.

(ii) using an Assess database prepare weekly forms and enter data.

(iii) verify data, update the master database, and undertake routine estimation of breeding values

RIRDC will negotiate with the successful operator a financial annual commitment from RIRDC, until 31 July 2007, at a level that will compensate the commercial breeder for the additional cost of running the breeding program and their management. An amount of up to $60,000/annum from RIRDC could be negotiated. In addition CSIRO and RIRDC will provide the services of a genetic consultant, Dr Sandra Eady, equivalent to 40% of her present research time with CSIRO.

The proceeds from the sale of rabbits will be returned to the operator. The sale policy and price of rabbits will be agreed annually by the operator, CSIRO and RIRDC. A portion of those sold would be as breeders to other rabbit enterprises at competitive prices. Crusader would retain its function as a national breeding program supplying improved rabbits to industry and would receive promotion and support from RIRDC and CSIRO for this role.

Invitation

You are invited to forward by Email an expression of interest by 6 January 2004 to June Murphy at RIRDC, Canberra, Email: june.murphy@rirdc.gov.au.

The expression should address the following criteria in no more than two pages:

(i) Experience in commercial rabbit breeding on a scale commensurate with the 120 doe Crusader unit

(ii) Experience in production recording, using computer software systems to record information, produce work plans and track production

(iii) A track record of a viable business unit in the rabbit industry and a commitment to future industry development

(iv) Placement of the Crusader breeding program in the enterprise in the strategic benefit of the industry as a whole, and to the development of a national genetic evaluation program

(v) Acceptance for negotiation of the general conditions outlined above

(vi) An ability to commence the above breeding operation before or by June 30, 2004 and how this would be phased into current operations

The Expression of Interest is not binding on any parties, but is the basis for future negotiations.

Further details on the scope of activities can be obtained by Emailing Sandra Eady – Sandra.Eady@csiro.au.

9.2.2 List of extra issues explored with potential contract breeders

Name: **Date:**

Criteria 1: Experience in commercial rabbit breeding on a scale commensurate with the 120 doe Crusader unit (Can you look after rabbits?)	
Describe breeding shed routines.	
How is disease monitored, recorded and treated.	
What are the vital statistics for the production unit. Number born alive per litter Number weaned per litter Weight and age at slaughter Kindling interval Are these figures generated by a report on your database?	
What is normal mortality between birth and weaning, weaning and sale age.	
How are health treatments recorded.	
What are the hygiene routines in the shed.	
What is the system for cage cleaning.	
What do rabbits die from, how is this recorded.	
Describe equipment used – mats, nest boxes, feeders etc	
What is the feeding system – source of feed, storage, delivery to sheds.	

How are rabbit euthanased and on what basis is a decision on euthanasia made.	
In what instances are antibiotics used in the production system. How is this recorded.	
Criteria 2: Experience in production recording, using computer software systems to record information, produce work plans and track production	
Demonstrate systems being used.	
Examples of shed worksheets.	
Are shed routines documented.	
What type of filing system is used.	
Day to day knowledge of what is happening with the rabbits.	
Ability and capacity to learn new systems.	
Regularity of database updates. Is database current.	
Performance records kept on both cages and computer simultaneously.	
Criteria 3: Track record of a viable business unit in the rabbit industry and a commitment to future industry development	
Are rabbits a major source of income in the enterprise. What % of the total income. What contributes to the remaining income.	
Stable business structure, who has an interest – partners, other family members.	
Significant turnover, what are the key financial indicators in the enterprise.	
Program of insurance, work cover, OH&S program, quality control programs, good business records, systems for paying staff, staff training programs.	
What type of accounting system is being used. Who is doing the BAS – farmer or accountant.	
Is there a business plan. What is the future investment plan.	
Potential and actual throughput of abattoir	
Who will look after the rabbits on a day to day basis. What commitments does the principal have elsewhere.	
What is the present day value of the capital invested in rabbits.	
What is the total labour input.	
Criteria 4: Placement of the Crusader breeding program in the enterprise is in the strategic benefit of the industry as a whole, and to the development of a national genetic evaluation program	
Are there other vested interests/alliances.	
Good networks in the industry	
Good communication style.	
Happy and able to deal with the “crap” side of the business.	
Ability and willingness to take direction. Likelihood of being creative and doing things independently.	
Rabbits distributed quickly and cheaply from enterprise.	
Will building the strength of this breeding program add to industry strength.	
Can the breeder work with and take direction from an outside person.	

Criteria 6: An ability to commence the above breeding program before or by June 30, 2004 and how this would be phased into current operations	
Stage of new sheds, when will they be operational.	
Where will the rabbits go in April 2004.	
Extra equipment or staff required.	
Time availability to commit to learning the system – at Chiswick and at own location. Flexibility to spend a week at Chiswick, two days on a training course.	
Would the Crusader rabbits add or subtract on the current production system.	
How will the Crusader rabbits fit in to the current breeding program.	

Other issues	