# Breeding Focus 2016 – Improving Welfare

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# Preface

The inaugural ‘Breeding Focus’ workshop was held in 2014 to outline and discuss avenues for genetic improvement of resilience. The Breeding Focus workshop was developed to provide a forum for exchange between industry and research across livestock and aquaculture industries. The objective of Breeding Focus is to cross-foster ideas and to encourage discussion between representatives from different industries because the challenges faced by individual breeding organisations are similar across species. This book accompanies the Breeding Focus 2016 workshop. The topic of this workshop is ‘Breeding Focus 2016 - Improving welfare’.

> *“Animal welfare means how an animal is coping with the conditions in which it lives. An animal is in a good state of welfare if (as indicated by scientific evidence) it is healthy, comfortable, well nourished, safe, able to express innate behaviour, and if it is not suffering from unpleasant states such as pain, fear, and distress. Good animal welfare requires disease prevention and veterinary treatment, appropriate shelter, management, nutrition, humane handling and humane slaughter/killing. Animal welfare refers to the state of the animal; the treatment that an animal receives is covered by other terms such as animal care, animal husbandry, and humane treatment.”* (World Organisation for Animal Health 2008).

Animal breeding offers opportunities to improve the state of animals. Existing methodologies and technologies used in animal breeding can be used to improve welfare of animals on farm while maintaining productivity. Welfare and productivity are not necessarily in opposition because several welfare measures are genetically independent from productivity traits. Further, it is often economically beneficial to improve welfare traits. These aspects provide ample opportunities to improve both welfare and productivity through selective breeding.

The chapters of this book describe existing frameworks to define welfare of animals and outline examples of genetic improvement of welfare of farm animals. A reflection on ethical issues of animal breeding and welfare is presented and further avenues for genetic improvement of welfare are discussed.

We thank all authors for their contributions to this book and their presentations at the Breeding Focus 2016 workshop in Armidale. Each manuscript was subject to peer review by two referees. We thank all reviewers who generously gave their time to referee each book chapter. A special thank you goes to Kathy Dobos for looking after all details of organising this workshop and for her meticulous work on putting this book together.

Susanne Hermesch and Sonja Dominik

Armidale, September 2016.

# Selection for immune competence in beef breeding programs modelled on potential reductions in the incidence of bovine respiratory disease

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## Abstract

Livestock industries are expected to intensify as land resources for agricultural production decline and global demand for animal protein increases. As a consequence, strategies aimed at sustainably improving the health and welfare of livestock will be critical to the future of our livestock industries. This study has made a first attempt at modelling the potential benefits of incorporating measures of immune competence in beef cattle breeding programs with the aim of improving general disease resistance, and as a consequence animal welfare. This study explores a variety of selection strategies and estimates their potential economic benefits based on data stemming from the dairy industry. Results demonstrated that the estimated heritability and predicted relationship between immune competence and growth traits strongly affect the potential gains which can be expected in immune competence and also overall response to selection. The economic values used in this study were conservative, suggesting that higher selection genetic responses and dollar returns are possible. For more accurate predictions, it will be crucial to obtain genetic and phenotype parameters for immune competence and correlations with other traits specifically for beef cattle. Research is currently underway to determine such parameters for beef cattle. The study also emphasises the need for robust economic values for traits, such as immune competence, where potential economic benefits of the traits are not just purely driven by the cost versus profit of the product, but also strongly influenced through public perception of the industry.

## Introduction

Bovine respiratory disease (BRD) is the most common disease encountered in Australian feedlots, causing significant economic losses and animal welfare issues. It has been estimated that BRD costs the Australian feedlot sector in excess of $40 million annually, with losses estimated at up to $20 per head (MLA Project AHW.087). Bovine respiratory disease is a complex, multi-factorial disease caused by a variety of infectious agents and is most prevalent in cattle during periods of heightened stress such as the initial six weeks spent acclimatising to the feedlot environment. Commercial vaccines have been developed to protect cattle against particular agents contributing to the BRD disease complex, however providing protection against the full complement of potential BRD causing agents and achieving protective responses in all vaccinated animals is difficult to achieve. Strategies, aimed at reducing the incidence of BRD in Australian feedlots, are required to complement BRD vaccination programs.

The establishment of a protocol to assess immune competence in dairy cattle has enabled genetic selection strategies, aimed at breeding animals with enhanced 'general' disease resistance, to be developed and implemented in industry (Wilkie and Mallard 1999). This approach combines measures of both antibody-mediated immune responses (AMIR) and cell-mediated immune responses (CMIR) to assess 'general' immune competence. Extra- and intra-cellular pathogens are most effectively controlled by AMIR and CMIR, respectively, therefore individuals identified as having a balanced ability to mount both types of responses are expected to exhibit broad-based disease resistance. A similar testing protocol, based on differing antigens, to assess 'general' immune competence in beef calves during yard weaning is being developed as part of a joint Meat & Livestock Australia and CSIRO funded project (Hine *et al.* 2014). Currently, the potential for genetic selection, aimed at improving 'general' immune competence to reduce the incidence of disease in Australian beef cattle with a particular focus on reducing BRD incidence in the feedlot environment, is being investigated.

The beef industry is actively working towards improving the health and welfare of animals in their production systems. Including immune competence in beef breeding objectives is expected to promote improved health and welfare through improving general disease resistance. It is hypothesized that combining selection for important production and reproduction traits with selection for health and fitness traits, such as enhanced 'general' immune competence in a selection index will enable beef cattle producers to breed highly productive animals with an enhanced ability to resist disease challenges encountered in their production environment. Such strategies are expected to result in significant long-term economic gains for producers through reduced disease treatment costs, reduced reliance on the use of antibiotics to treat disease, decreased production losses, reduced processing penalties, improved health and welfare outcomes for animals, lower mortality in the herd and improved consumer confidence in products of the beef industry.

In an effort to predict the potential benefits of incorporating selection for 'general' immune competence in breeding programs, hypothetical selection index scenarios have been modelled drawing on available information from the dairy sector.

## Material and Methods

### *Breeding objective traits and selection criteria*

A selection index can be used to investigate the effect of including novel traits in breeding programs. It consists of two main components. The first component is called "breeding objective", includes traits that drive profit and targeted to be improved through genetic selection. The second component is called the selection criteria and includes traits that can be routinely measured ("selection criteria") to inform the breeding objective traits. In some cases if the breeding objective trait is easy and cheap to measure, it also acts as the selection criteria for that trait. An example of such a trait is live weight. However, for breeding objective traits that are difficult to measure, correlated traits can be used as selection criteria to inform the breeding objective trait. For example, marble score can only be obtained at slaughter. To inform marbling score as a breeding objective trait, intra muscular fat content as assessed at scanning of live animals is used as a correlated selection criteria trait.

For this study a simplified breeding objective for a beef cattle stud operation that is selling bulls to commercial producers of feeder cattle (seed-stock producer) was defined based on three breeding objective traits which characterise growth, reproduction and carcase quality. Growth is represented by sale weight (SW), which relates to live sale-weight at 17 months of age. Reproduction is represented by cow weaning rate (CWR), which relates to percent of cows that wean a calf from the total number of cows mated. This is calculated as annual percent pregnant x (1 – reproductive waste) (Fordyce *et al*. 2014). Carcase quality is represented by marbling score (MS). Marbling score is a visual beef quality grading system, scored from 0 (low marbling) to 9 (highly marbled), referring to the visible fat between muscle fibres in the rib eye muscle (AUS-MEAT Limited 2010). Immune competence (Immuno) was included in the breeding objective and represents a combined measure of an animal's ability to mount both antibody-mediated and cell-mediated immune responses (Hine *et al*. 2011).

Immuno was also measured as selection criteria. Other selection criteria traits included live weight measured 200 and 400 days of age (WT200 and WT400) and intra muscular fat (IMF) assessed on live animals using ultrasound scanning of the rib-eye between the $12^{th}$ and 13th rib. Traits and their phenotypic and genetic parameters, including economic values for the breeding objective traits are summarised in Tables 1 and 2. Weight at 200 days and WT400, IMF and Immuno were recorded on the selection candidates themselves, their sires, their dams and their half-sibs. Number of records from the different information sources are shown in Table 1. It was assumed that each sire was mated to 50 females and 40 of these half-sibs would be measured for selection criteria. Marbling score is not recorded, but informed through IMF.

The economic values for the breeding objective traits, heritabilities and genetic and phenotypic parameters for SW, CWR, MS, WT 200 and 400 and IMF were adopted from Archer *et al.* (2004). Parameters for Immuno and its relationships with other production traits were estimated based on studies in dairy cattle which have estimated genetic parameters of general immune competence (Thompson-Crispi 2012 and Thompson-Crispi *et al*. 2012). Some of the traits used in this study were not represented amongst the published information, and therefore assumptions had to be made. For example, genetic correlations between general immune competence and four reported reproductive traits (gestation length in heifers and cows, calf survival and calf size) were low and positive (ranging between 0.12 and 0.17) with one value low and negative correlation at -0.13 (Thompson-Crispi 2012). Consequently, it was assumed that Immuno and CWR have a low and positive correlation as was reflected in the majority of the dairy cattle estimates. Similar assumptions were made for other traits where published information was not available. The economic value for Immuno was based on information from the Canadian Dairy industry, where estimated breeding values for general immune competence are available for sires whose semen is marketed by Semex Pty. Ltd. (Mallard *et al*. 2014). It has been demonstrated that progeny from high immunity sires (being one standard deviation or more above the mean for antibody and cell-mediated immune responsiveness) had 25% fewer incidences of calf pneumonia (Mallard *et al*. 2014).

*Table 1. Breeding objective traits (BO) and selection criteria (SC), their abbreviations and units, and the number of records collected on the selection candidate, its dam, sire and half sibs*

| Trait | Abbreviation | Unit | BO | SC | Information sources* | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Own | Dam | Sire | Half sibs |
| Sale-weight | SW | Kg | Yes | No | 0 | 0 | 0 | 0 |
| Cow weaning rate | CWR | % | Yes | No | 0 | 0 | 0 | 0 |
| Marbling score | MS | Score | Yes | No | 0 | 0 | 0 | 0 |
| 200 day weight | WT200 | Kg | No | Yes | 1 | 1 | 1 | 40 |
| 400 day weight | WT400 | Kg | No | Yes | 1 | 1 | 1 | 40 |
| Intramuscular fat | IMF | % | No | Yes | 1 | 1 | 1 | 40 |
| Immune competence | Immuno | stddev | Yes/No | Yes/No | 1 | 1 | 1 | 40 |

*Information sources are in relation to the selection candidate

For the purposes of this project it has been assumed that a similar reduction in BRD could be achieved in beef cattle in the feedlot environment which are progeny of high immunity beef sires. The economic value for Immuno used is this study is flexible and can be tailored to different feed lot systems based on their annual turn-over of occupancy to account for the increased incidence of BRD expected to be associated with increased turn-over.

Economic value ($/per year) = Cost of BRD per head x % reduction in BRD incidence expected in high immune competence animals x annual turn-over (1)

The annual cost associated with BRD has been estimated to be $20 per head (MLA Project AHW.087) and a 25% reduction in BRD incidence was assumed as outlined above. In this study, the economic value was derived for a feed lot operation with an annual turn-over of three times capacity. Based on these assumptions a 25% improvement per phenotypic standard deviation would be valued at $5 per feedlot occupancy. This results in an economic value of $15 per year for a feedlot system where occupancy is turned over 3 times per annum. The economic value of $15 served as the most realistic estimate for immune competence in the selection index scenarios outlined below. However, because of the uncertainty of what the real economic values is, a sensitivity analysis explored economic values that were 25% higher ($18.75) and lower ($11.25) than what was assumed to be the most realistic value.

## *Selection index scenarios*

Six different scenarios were modelled to explore the effect of including immune competence in beef breeding programs on selection response. The selection index scenarios and the abbreviations used to describe them throughout the text are detailed in Table 3. All indexes include the three major breeding objective traits SW, CWR and MS. For the first selection index, immune competence was included as a breeding objective trait, but not measured as a selection criteria, with Immuno informed by other correlated trait responses (Index1). The second index included Immuno as a breeding objective trait as well as a selection criterion (Index2). The inclusion of Immuno as a selection criterion adds another source of information, which increases index accuracy, and as Immuno in the breeding objective and selection criteria are genetically highly correlated is expected to increase the opportunity to drive genetic gains in this trait.

Different variations of Index1 and Index2 used a range of genetic parameters and economic values to explore various scenarios which either favour progress in immune competence or provide little opportunity to progress this trait. The sensitivity of selection responses were tested for Indexes 1 and 2. Index scenarios with genetic parameters that do not favour progress in Immuno used a low heritability of $h^2 = 0.1$ for Immuno and unfavourable genetic correlations between Immuno and liveweight traits (SW, 200WT and 400WT). These scenarios are labelled with a “↓” to depict unfavourable parameters. Scenarios that use a heritability of $h^2=0.3$ for Immuno and favourable genetic correlations between Immuno with liveweight traits are labelled with a “↑” to indicate favourable parameters. To test the sensitivity of responses to the economic value for Immuno, it was varied between $11.25 ($), $15 ($$) and $18.75 ($$$) and labelled with the dollar signs as shown.

*Table 2. Genetic standard deviation ($\sigma_G$), economic values for breeding objective traits (EV in $) heritability ($h^2$ in bold) and genetic (above the diagonal) and phenotypic correlations (below the diagonal) for breeding objective traits and selection criteria*

| Trait | $\sigma_G$ | EV ($) | EV*$\sigma_G$ ($) | SW | CWR | MS | WT200 | WT400 | IMF | Immuno |
|---|---|---|---|---|---|---|---|---|---|---|
| SW | 19.29 | 0.81 | 15.60 | **0.31** | -- | -- | -- | -- | -- | -- |
| CWR | 7.27 | 0.93 | 6.76 | 0 | **0.05** | -- | -- | -- | -- | -- |
| MS | 0.44 | 0.01 | 0.00 | 0 | 0 | **0.38** | -- | -- | -- | -- |
| WT200 | 9.49 | -- | -- | 0.68 | 0 | 0 | **0.18** | 0.75 | -0.60 | -0.20, +0.20 |
| WT400 | 15.45 | -- | -- | 0.90 | 0 | 0 | 0.75 | **0.25** | 0 | -0.20, +0.20 |
| IMF | 0.34 | -- | -- | -0.02 | 0.09 | 0.72 | 0 | -0.01 | **0.12** | 0.12 |
| Immuno $h^2$=0.1 | 0.32 | 11.25, 15, 18.75 | 3.60, 4.80, 6.00 | -0.20, +0.20 | -0.12 | 0.12 | -0.20, +0.20 | -0.20, +0.20 | 0.12 | **0.10** |
| Immuno $h^2$=0.3 | 0.55 | 11.25, 15, 18.75 | 6.19, 8.25, 10.31 | -0.20, +0.20 | -0.12 | 0.12 | -0.20, +0.20 | -0.20, +0.20 | 0.12 | **0.30** |

Abbreviations: SW: Sale weight, CWR: Cow weaning rate, MS: Marble score, WT200: 200-day weight, WT400: 400-day weight, IMF: Intramuscular fat, Immuno: Immune competence.

*Table 3. Description of selection index scenarios*

| | Immuno Index1 | | Immuno Index2 | | | |
|---|---|---|---|---|---|---|
| **Abbreviation** | $$↓ | $$↑ | $↑ | $↓ | $$↑ | $$$↑ |
| **Immuno included in*** | BO | BO | BO/SC | BO/SC | BO/SC | BO/SC |
| **Heritability** | | | | | | |
| $h^2$=0.1 (↓) | ✓ | | | ✓ | | |
| $h^2$=0.3 (↑) | | ✓ | ✓ | | ✓ | ✓ |
| **Correlations (WT/Immuno)** | | | | | | |
| negative (↓) | ✓ | | | ✓ | | |
| positive (↑) | | ✓ | ✓ | | ✓ | ✓ |
| **Economic value** | | | | | | |
| $11.25 ($) | | | ✓ | ✓ | | |
| $15 ($$) | ✓ | ✓ | | | ✓ | |
| $18.75 ($$$) | | | | | | ✓ |

*BO=Breeding objective trait, SC=Selection criteria

Two variations of Index1 were modelled, both assuming an economic value of $15 for a unit of improvement in Immuno. The first variation assumed favourable genetic parameters for progress in Immuno (Index 1 $$↑) i.e. positive correlations with weight traits and moderate heritability. The second variation of the index assumed unfavourable parameters for progress in Immuno (Index 1 $$↓) with negative correlations with weight traits and low heritability.

Four variations of Index 2 were modelled. The correlations between Immuno and liveweight traits were either positive or negative and economic values varied between low, medium and high. The variations included Index 2 $↑, Index 2 $↓, Index 2 $$↑ and Index 2 $$$↑ (Table 3).

## *Herd parameters*

For the purpose of this study a hypothetical Angus stud herd with 450 breeding cows ($n_s$) was used. The male and female generation interval ($L_m$ and $L_f$), which is the age of sires and dams at birth of their selected progeny was 2 years of age. Each bull is mated each year to 50 cows, which determines the number of half-sibs that are available for measurement. The calving and survival rates were estimated at 90%. Each year 23 males and 90 females were used as replacements giving a selection intensity (i) for males of 1.69 ($i_m$) and for females of 0.88 ($i_f$). Seventy two bulls are sold commercially and used by those purchasers for three years with each bull producing 150 progeny. Therefore, each year bulls produced from this stud have an estimated total number of 10,800 commercial progeny ($n_c$).

### *Response to selection*

The response to selection, per head per round of selection, for the multiple trait selection index was calculated for each of the selection index scenarios. Results reported include the standard deviation of the breeding objective ($SD_{BO}$), the genetic gain as trait and dollar responses per round of selection, the standard deviation of the index ($SD_{Index}$) which describes the total dollar response per head per round of selection, as well as the index accuracy (Acc) which is the ratio of $SD_{index}$ and $SD_{BO}$ and illustrates how well the breeding objective traits are described by the selection criteria. To calculate the genetic gain per year (R), the response per round of selection was multiplied by the selection intensities for males and females and divided by the generation interval. The genetic gain per year per head was used in further calculations for discounted profit.

### *Discounted profit and net profit value*

The discounted profit and net profit values were calculated to describe the long term value of the genetic gains made at the commercial herd level. The annual returns in year y were based on the genetic gain in dollars per year, starting in year 2 when commercial progeny of a sire are being born. Annual costs included health treatments at $30 per head and $10 per head to measure immune competence where applicable. It was assumed that for immune competence testing all animals in the herd are measured once. A discount rate of 7% per year was applied to returns and cost to calculate the discounted return in year y. The annual discounted profit per year was calculated by subtracting discounted annual cost from discounted returns per year. The annual discounted profit for each of the selection index scenarios was summed over an 11 year period to obtain the net profit value (NPV), providing a measure of profitability.

Discounted $returns_y = [(R_y + R_{y-1})*n_c]/(1+\text{discount rate})^y\text{-}1$, with $R_y$= genetic gain in year y, $n_c$ = number of commercial progeny (2)

Discounted $cost_y$ = ((health cost + measurement cost)* $n_s$)/ $(1+\text{disount rate})^{y-1}$, with $n_s$ = head of cattle in stud herd, y = year (3)

Annual discounted $profit_y$ = discounted $returns_y$ – discounted $cost_y$ (4)

Net profit value (NPV) = $\sum_{y=0}^{11} discounted\ profit_y$ (5)

## Results

The results from calculations using the different selection index scenarios described above are summarised in Table 4. The standard deviation of the selection index ($SD_{index}$, representing the total dollar response per head per round of selection) was generally higher for variations of Index 2 compared to Index 1, as a result of including Immuno as a selection criterion in addition to being a breeding objective trait. The standard deviation of the selection index increased with increasing economic values for Immuno. As expected, overall responses for Immuno were higher when favourable relationships with liveweight and higher heritability values were modelled. The lowest total dollar response, was found for Index1 $$↓ with the maximum difference to the most profitable scenario (Index2 $$$↑) being $5.08 per head per round of selection. Increases in total dollar response were realised when the additional selection response in Immuno was higher than losses in the other breeding objective traits, i.e. sale weight and cow weaning rate.

For Index 1 with favourable relationships between Immuno and liveweight (Index1 $$↑) a positive response for Immuno could still be achieved, despite the fact that Immuno was not included as a selection criterion. This was a result of correlated responses, which was a consequence of the responses achieved in in live weight traits. Consequently, if the relationships with live weight traits were unfavourable (Index1 $$↓) response in Immuno was unfavourable.

*Table 4. Standard deviation of the breeding objective ($SD_{BO}$), of the index ($SD_{Index}$), Index Accuracy (Acc) and trait responses per round of selection (in $) for the breeding objective traits sale weight (SW), cow weaning rate (CWR), marbling score (MS) and immune competence (Immuno) used in selection index scenarios*

| | $SD_{BO}$ | $SD_{Index}$ | Acc | SW | CWR | MS | Immuno |
|---|---|---|---|---|---|---|---|
| Index1 $$↓ | 16.64 | 6.24 | 0.37 | 6.82 | 0.00 | 0.00 | -0.58 |
| Index1 $$↑ | 19.94 | 7.93 | 0.40 | 6.80 | 0.00 | 0.00 | 1.12 |
| Index2 $↑ | 18.94 | 9.18 | 0.48 | 6.54 | -0.30 | 0.00 | 2.95 |
| Index2 $↓ | 16.63 | 6.40 | 0.39 | 6.77 | -0.02 | 0.00 | -0.38 |
| Index2 $$↑ | 19.48 | 9.73 | 0.50 | 6.02 | -0.32 | 0.00 | 4.03 |
| Index2 $$$↑ | 21.01 | 11.32 | 0.54 | 5.99 | -0.38 | 0.00 | 5.71 |

The results in Table 4 demonstrate that when relationships between Immuno and liveweight traits are unfavourable (Index 1 $$↓ and Index2 $↓), it is easier to achieve higher profit by putting more emphasis on sale weight as is reflected in the trait response for sale weight. However, with favourable relationships, the emphasis on Immuno increases and therefore responses, accompanied by little decreased response for sale weight. The annual net profit value (NPV, Figure 1) emphasises the same trends that were observed in the index responses per round of selection over an 11-year time frame. Index1 $$↓ and Index2 $$↓ had the lowest NPV and the positive effect of higher economic values for Immuno is highlighted in the increase in NVP (Index2 $↑, $$↑ and $$$↑) (Figures 1 and 2).

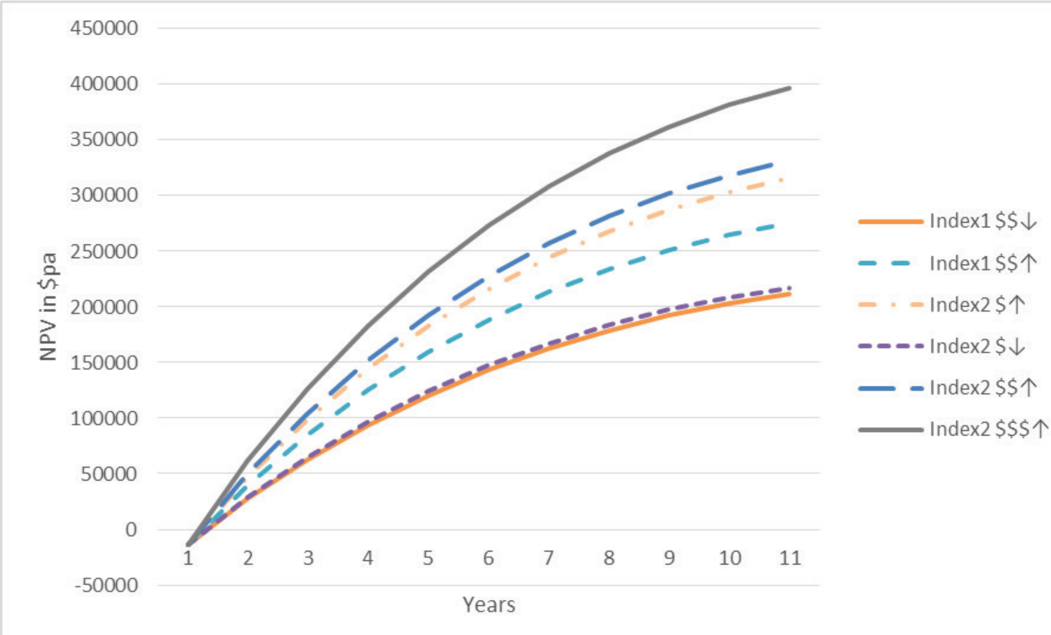


*Figure 1. Annual net profit value (NPV) over 11 years for various selection index scenarios for a herd of 450 Angus breeding females*

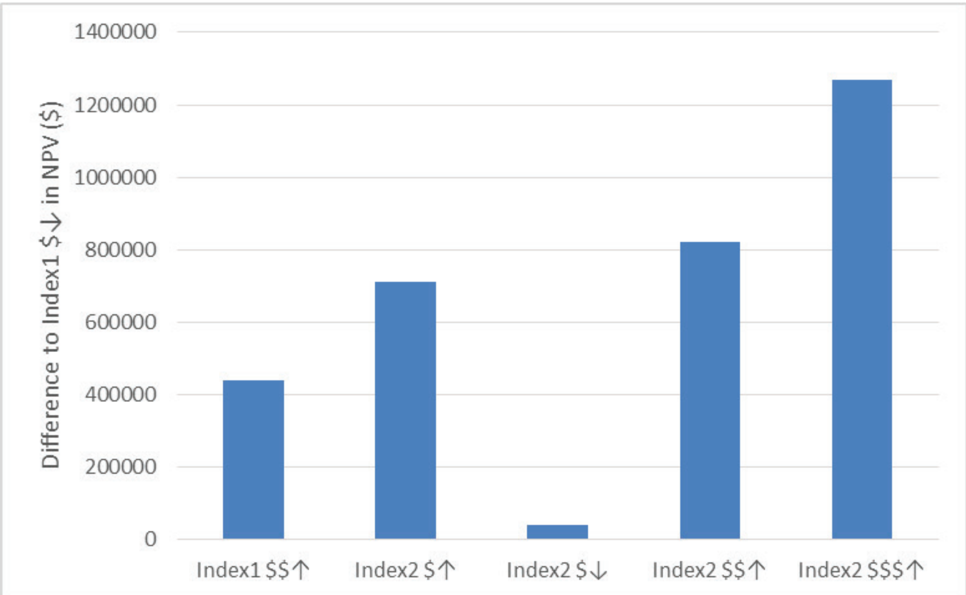


*Figure 2. Difference in net profit value (total NPV in $) between Index1 $$↓ and other selection index scenarios*

The total NPV over an 11 year time frame were compared to Index1 $$↓, which yielded the lowest total NPV (Figure 2). Index2 $↓ had only a slightly higher NPV compared to Index1 $$↓, highlighting that a small increase in profit can be gained by including Immuno as selection criterion even if the relationships with liveweight are unfavourable and Immuno has a low heritability. For Index2 $$↑, the results demonstrate that by including Immuno as selection criterion, the NPV can be increased substantially if relationships between liveweight and Immuno are favourable.

## Discussion

Unfavourable genetic correlations exist between production traits and the incidence of many common diseases in livestock (Rauw *et al*., 1998). For example, the genetic correlation between milk production and the incidence of mastitis in dairy cattle has been estimated at between 0.15 to 0.37 (Lyons *et al*., 1991; Uribe *et al*., 1995; Van Dorp *et al*., 1998). Such findings suggest that selection for production traits in livestock with little or no emphasis on health and fitness traits has the potential to increase the incidence of disease in livestock production systems. One of the drives would have been the exponential increase in dairy cow milk production internationally over the last 50 years and a linear increase in the number of dairy cows (FAOstats, 2016). Based on this knowledge the Australian Beef industry is actively investing in research programs aimed at developing breeding strategies to improve the health, and as a consequence the welfare, of animals in their industry.

Animal health can be improved through both targeted management practices and the implementation of genetic selection strategies aimed at breeding animals with improved disease resistance. In combination, these approaches have the potential to dramatically improve animal health. Health and welfare are intimately linked and therefore improving animal health is expected to result in improved welfare outcomes for livestock. The concept of breeding for 'general' disease resistance was first proposed by Wilkie and Mallard (1999) and has been used successfully to reduce the incidence of disease in intensively farmed pigs and dairy cattle (Mallard and Wilkie 2007, Mallard *et al.* 2014). Following extensive research to validate the benefits of breeding for improved 'general' disease resistance in dairy cattle, the global breeding company Semex Pty. Ltd. are now marketing semen from sires with estimated breeding values for immune competence (Mallard *et al*. 2014). Such advances have allowed dairy producers to place direct selection emphasis on traits aimed at improving the health and welfare of animals in their herds. In the current study, the potential reduction in BRD incidence in feedlot cattle that could be expected as a result of incorporating measures of immune competence in selection indexes for beef cattle was predicted based on disease incidence data from dairy farms using sires with known EBVs for immune competence.

In the absence of known parameters, this study made a first attempt at modelling potential benefits of selection for immune competence in beef breeding programs. Although a lot of assumptions had to be made, this study explores potential benefits of breeding for improved immune competence by modelling extremes of high and low opportunity to improve the trait.

The key outcome of the study was that response in Immuno can be driven more strongly, if it is used a selection criterion in addition to being included in the breeding objective. Adding Immuno to a selection index results in selection response in the trait at the cost of the responses in the other breeding objective traits due to competition for selection pressure. If relationships with other breeding objective traits are unfavourable and the heritability for Immuno is low, gains in Immuno were of insufficient value to compensate for the losses in the other traits. However, favourable genetic parameters for Immuno still compromised responses in other traits due to reduced selection pressure consequently being applied to those traits, but was offset through the gain in Immuno and the overall increase in the total dollar response. Accurate estimates of heritabilities for Immuno and correlations with other traits for beef cattle are necessary to make more informed predictions and are currently being generated. However the results of the current study provide first information on the expected trends.

The economic benefits of placing selection emphasis on a particular trait drives uptake by industry. Even though substantial responses could be achieved in Immuno in this study, it is safe to assume that the economic values for Immuno were conservative estimates, since they were only derived from the economic benefit in the feedlot sector and did not take into account reduced health associated costs in the stud operation. In addition increased consumer confidence in the beef industry as a result of improved animal welfare and reduced use of antibiotics is expected to significantly increase the economic value of improving general disease resistance of beef cattle.

Changing consumer confidence can have a significant effect on the profitability of livestock industries. Consumers are increasingly conscious of the health and welfare of the animals producing their food and are demanding the highest possible standards of animal welfare through purchasing choices. For example, the number of consumers opting to purchase eggs from free-range hens in preference to eggs from caged hens, based on welfare concerns, is increasing. This change in consumer preference has been the catalyst for dramatic changes throughout the egg industry and is evidence of the influence consumers can exert on farming practices. Consumers are also increasingly concerned with the use of antibiotics in food-producing animals. As a consequence, the practice of supplementing animal feed with antibiotics to prevent disease and promote growth is under increasing scrutiny and is unlikely to continue into the future. Therefore, breeding strategies aimed at improving the health and welfare of animals and reducing reliance on antibiotics to treat disease can be expected to also improve consumer confidence.

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