Feeding the Genes

Interactions between feeding system and APR and ABVs in dairy cows

FINAL REPORT

Dairy Australia
Your Levy at Work

Australian Dairy Herd Improvement Scheme

Feeding the Genes

Interactions between feeding system and APR and ABVs in dairy cows

Final Report

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Harris Park Group

CONTENTS

Previous reports

This Report consists of two previous reports with some minor editing, and results of addtional analyses.

The two previous reports are:

Feeding the Genes: Interactions between feeding system and APR and ABVs in dairy cows, Final Report, John Morton, Pauline Brightling, and Steve Little. 27th May 2013

Feeding the Genes: Further analyses, John Morton, Jock Macmillan and Jennie Pryce.14th March 2014

EXECUTIVE SUMMARY

BACKGROUND

The Australian Profit Ranking was introduced by ADHIS in 2001 as a national selection index for dairy sires and cows. It estimates the relative genetic profitability of different animals and enables the ranking of bulls and cows based on a combination of economically important traits; breeding values for each of these traits are estimated using Australian Breeding Values.

From April 2010, the Australian Profit Ranking was calculated with an updated formula that reflected current economics while placing more emphasis on daughter fertility, survival and mastitis resistance than the derived economic values. Coinciding with this, a significant extension initiative was implemented by ADHIS to increase the use of Australian Breeding Values (and the Australian Profit Ranking) through publishing the Good Bulls Guide. The Guide lists bulls by common breeding objectives, such as profit, production, fertility, mastitis resistance etc.

Following an extensive review of economics and farmer preferences in 2014, the Australian Profit Ranking was replaced with a new economic breeding index in April 2015, the Balanced Performance Index. At the same time, two additional breeding indices were also introduced: the Health Weighted Index and the Type Weighted Index. As the key economic drivers behind these indices and the Australian Profit Ranking are reasonably consistent, these three new breeding indices are very closely correlated with the Australian Profit Ranking. In Feeding the Genes, effects of the Australian Profit Ranking were studied. Given these very close correlations, effects of the new breeding indices would be very similar to those reported for the Australian Profit Ranking.

A diverse range of feeding systems is used across the Australian dairy industry. Dairy Australia has identified five broadly defined feeding systems ranging from predominantly pasture and conserved fodder with low concentrate use, through to total mixed ration systems. The Australian Breeding Values used to calculate Australian Profit Rankings are based on animal performance using pooled data from Australian herds using a diverse range of feeding systems. However advisors and farmers work with individual farms, and some question the validity of the Australian Profit Ranking in their situation. In other words, advisors and farmers have asked whether there is important genotype by environment interaction (G*E). Several trials assessing genetic merit by feeding interactions have been conducted in research herds, and numerous large scale cohort studies have compared cows of varying genetic merit in commercial herds with various environments. However, few of these large scale cohort studies have compared cows of varying genetic merit between feeding systems, and no such studies have been conducted in Australia. This study addressed the need for a scientifically rigorous assessment of the effects of increased Australian Profit Ranking within commercial Australian dairy herds using different feeding systems.

Australian Profit Rankings were calculated using Australian Breeding Values. Thus, assessing G*E for Australian Breeding Values for both the associated trait and other traits may improve understanding of G*E with Australian Profit Ranking. In addition to Australian Profit Ranking, the Australian Selection Index is also used, so G*E for this index is also of interest.

Herd managers desire cows that both produce well and 'last', so both milk production and cow longevity are important. To describe 'lasting', recalving by 20 months can be used to collectively describe short to medium term reproductive performance, culling and death. Disease can reduce longevity through effects on reproductive performance, and risk of culling or death. In the absence of accurate disease records, the occurrence of short lactations (lactations of less than 120 days duration) is a useful surrogate for serious disease, as a substantial proportion of cows with short lactations are likely to have had post partum disease(s) that seriously affected milk production. Thus, G*E effects on recalving by 20 months and occurrence of short lactations are of interest.

Milk production per cow is generally lower where the feeding system consists of pasture and conserved fodder with low concentrate use, and is much higher in herds using the total mixed ration feeding system. Herd average milk yield is readily calculated with routinely collected milk recording data whereas feeding system data are not routinely collected. When studying G*E or assessing sires in different environments, it would be simpler into define environment as herd average milk yield than feeding system. Accordingly, it was also important to assess whether feeding system is a surrogate 'environment' for herd average milk yield when assessing G*E. This could also inform the nature of any interactions detected.

When assessing effects of G*E on slopes (ie effects on rates of change in traits per unit increase in genetic merit), slopes can be described on an absolute scale. For example, the increase in milk volume (kg) per unit increase in the cow's sire's Australian Profit Ranking may be estimated. However, as mean milk yield varies between environments, even where G*E is present on an absolute scale, the responses to increased genetic merit may be similar proportionally, so no G*E would be present on that scale. For example, increases in milk yield per 50 unit increase in the cow’s sire’s Australian Profit Ranking were greater in higher input feeding systems. On average, herd milk yield per cow is higher in these higher input feeding systems, and there was interest in understanding whether the increases in milk yield per 50 unit increase in the cow’s sire’s Australian Profit Ranking are similiar proportionally (ie when expressed as ratios of means) across feeding systems.

Finally, sire usage in commercial dairy herds is of interest. Of particular interest are sire usage by feeding system and by herd average milk yield per cow. This could provide information about farmers' perceptions of bulls that they consider should suit their system. For example, farmers operating high production systems may think that bulls tested in high production environments (e.g. North America) may be more suitable for their herds. These choices may determine, and may be partly determined by, semen price. So comparison ofsemen prices for high and low Australian Profit Ranking sires would also be informative.

The Feeding the Genes project consisted of a literature review and a detailed research study.

LITERATURE REVIEW

The literature review objectives were to define G*E, to briefly discuss the importance of this interaction, and to summarise key design features and results from studies that compare the effects of genetic merit in dairy cows on milk yield, reproductive performance and/or survival between environments with high versus lower energy intake within the same study.

Relevant studies that compare the effects of genetic merit in dairy cows on milk yield, reproductive performance and/or survival between environments were identified by searching bibliographic databases, by reviewing lists of references in selected papers and from papers nominated by members of the Feeding the Genes Project Reference Group.

Findings from cohort studies using controlled environments suggested that genetic merit by energy intake interactions are occurring, with effects of genetic merit larger when cows have higher energy intakes and that adverse effects of genetic merit and/or % Holstein genes on reproductive performance are partly ameliorated by increased energy intake.

Environment was defined in many ways in large scale cohort studies in commercial herds but environments are rarely based on feeding system. Herd mean milk production variables are used much more commonly. There is evidence that nutritional factors are important causes of genotype by environment interaction in dairy cow populations. Results of these studies indicate that genotype by environment interaction for milk production is generally low to modest, but important reranking may be occurring in some circumstances. Genotype by environment interaction may be most important between feeding systems, and across pasture-fed herds with different feed intakes.

Evidence about genotype by environment interactions for reproductive traits is limited, but these results suggest that important reranking may be occurring in some circumstances. Intervals from calving are very poor phenotypic descriptors of reproductive performance in seasonal and split calving herds. The impact of using these intervals in seasonal and split calving herds requires investigation.

Environment has also been defined based solely on country of location of the cows and herds. Interbull (the International Bull Evaluation Service) routinely assesses genetic correlations between participating countries for numerous traits. For Holstein cows, in 2014, genetic correlations for protein yield between Australian and North American sires were 0.75, between Australian and and European sires 0.75 to 0.79, between Australian and New Zealand sires 0.85, and between various European countries, USA and Canada 0.85 to 0.92. These results are further evidence that interactions between genotype by environment (country in this case) are greatest when environments are more different. Interbull also assesses genetic correlations between participating countries for numerous reproductive traits. Genetic correlations between Australian sires and those from other countries vary widely, from 0.26 to 0.88, with most between 0.65 and 0.80. For calving interval, the genetic correlation between Australian and USA sires was 0.85. Reproductive traits were not assessed in the same way in all countries; reduced genetic correlations would be expected where measurement methods are markedly different.

The research objectives were as follows:

- to estimate the effects of Australian Profit Ranking on milk production, recalving by 20 months and occurrence of short lactations in Holstein and Jersey cows in commercial Australian dairy herds using various feeding systems, and to ascertain whether these effects differ substantially between herds with different feeding systems
- to investigate the effects of various Australian Breeding Values on the associated milk production trait or on recalving by 20 months in Holstein and Jersey cows, and to ascertain whether these effects differ substantially between herds with different feeding systems
- to assess whether feeding system is a surrogate environment for herd average milk yield when assessing G*E
- to assess effects of Australian Selection Index and Australian Breeding Values within various feeding systems and herd average milk solids yields on the associated and other milk production traits, and on recalving by 20 months and occurrence of short lactations
- to assess whether Australian Profit Ranking increases milk yield by the same percentage in each feeding system and over a range of herd average milk yields per cow
- to describe sire usage by feeding system and herd average milk yield per cow
- to describe semen prices for low and high Australian Profit Ranking sires.

The purpose for investigating these interactions was not to assess effects of these interactions on sire reranking for Australian Profit Ranking, Australian Breeding Values and Australian Selection Index. These have been addressed using the Feeding the Genes dataset in additional projects using models that account for familial relationships between animals conducted by Natasja Boots in 2013, and Rob Woolaston in 2014. Rather, these analyses of interactions were performed to assess the effects of these interactions on direction and magnitude of responses to increases in genetic merit in different environments, and to add to understanding of biological determinants of these interactions. The results are also likely to be useful for extension purposes. All models were performed at the phenotypic level ie familial relationships between animals were not specifically accounted for. The dataset was more than adequate for fitting these statistical 'phenotypic' models to assess interactions for milk yield and recalving variables, with several exceptions noted in the text.

A retrospective cohort study was conducted, with effects of Australian Profit Ranking, Australian Breeding Values and Australian Selecton Index on milk production of dairy cows and recalving by 20 months and short lactations compared between five herd feeding systems using data from 505 commercial Australian herds.

Eligible herds were identified from the ADHIS database. In mid 2012, letters were sent to herd managers asking them to complete a herd data questionnaire, to ascertain their herd’s feeding system in each of 2008, 2009, 2010 and 2011.

Dairy Australia’s five feeding system categories were used: low bail feeding, moderate to high bail feeding, partial mixed ration, hybrid, and total mixed ration.

Of the 2016 herds approached, 505 were enrolled in the study. All Australian dairying regions were represented. Cow, lactation, and sire data for cows in the enrolled herds were obtained from ADHIS.

KEY FINDINGS AND CONCLUSIONS

General

- Comparisons of data from the InCalf Fertility Data Project 2011 and the Feeding the Genes project identified, on average, 107 more calvings per herd annually in the InCalf Fertility Data Project 2011. This was presumably due to unrecorded and unidentifiable sires, and possibly failure of data processing centres to submit all calvings to ADHIS. Given possible selection biases due to missing data, this highlights the importance of reviewing strategies to maximise completeness of data in the ADHIS database.
- Most Australian herds use low bail (up to 1t of grain, grain mixes or grain-based concentrates fed per cow annually) and moderate to high bail (> 1t but feed pad and mixer wagon not used) feeding systems. However, a modest proportion of herds use partial mixed rations, hybrid and total mixed rations feeding systems.
- For all milk yield variables, variation was greater between lactations within herds than between herds.
- For Holstein cows, mean sire Australian Profit Rankings were lower in the PMR, hybrid and TMR feeding systems. For both breeds, there was greater variability in sire Australian Profit Rankings within herds than between herds.

Effects on milk yield

- For Holstein cows, effects of sire Australian Profit Ranking on milk yield variables differed by feeding system. Effects were positive in all feeding systems. They were approximately twice as large in total mixed ration feeding system herds compared with low bail feeding herds. However, effects were more similar for the most popular feeding systems (low bail, moderate to high bail, and partial mixed ration feeding systems).
- Effects of sire Australian Profit Ranking on milk volume and protein yield also differed by herd average solids per cow. Effects were positive at all herd average solids per cow levels. However, no such interaction was evident for fat yield.
- For milk volume and protein yield, adjustment for interaction between Australian Profit Ranking and herd average solids per cow removed the interaction between Australian Profit Ranking and feeding system. Thus, for milk volume and protein yield, the interaction between Australian Profit Ranking and feeding system is largely accounted for by interaction between Australian Profit Ranking and herd average solids per cow.
- In contrast, the interaction between Australian Profit Ranking and feeding system for fat yield is not accounted for by interaction between Australian Profit Ranking and herd average solids per cow.
- These results indicate that the biological determinants of G*E for fat yield differ from those for milk volume and protein yield. Features of feeding systems determine Australian Profit Ranking effects on fat yield. In contrast, determinants associated with herd average milk yield determine Australian Profit Ranking effects on milk volume and protein yield. Reasons for this are not known.
- Implications of these relationships for calculating sire Australian Breeding Values depend, in part, on the extent of sire re-ranking due to these interactions, and the relative economic values of milk volume, fat and protein yields.

- For Jersey cows in herds using low and moderate to high bail feeding systems and partial mixed ration feeding, increases in both Australian Profit Ranking increase milk volume, and fat and protein yields. Increases in milk volume, and fat and protein yield are smaller for the low bail feeding system than for the other two feeding systems.
- Proportional effects on milk volume, and fat and protein yields were highest in total mixed ration herds; proportional effects on protein yield were similar in low bail, moderate to high bail, and hybrid feeding systems. Proportional effects on milk volume and protein yield increased slightly with increasing herd average solids per cow, while fat responses declined with increasing herd average solids per cow.
- Australian Selection Index and Australian Profit Ranking were closely correlated, and interactions between Australian Selection Index and environment were similar to those for Australian Profit Ranking.
- Effects of Australian Breeding Value for milk volume, fat or protein in Holstein cows on milk volume, fat and protein yield, and recalved by 20 months were generally as expected based on genetic correlations. Where important G*E was detected, increases in milk volume, fat and protein yield associated with increases in the genetic measure were mostly larger in higher feed input feeding systems and/or at higher herd average solids per cow.

Effects on recalving by 20 months

- Cows with higher Australian Profit Rankings are just as likely (if not more likely) to last in the herd as cows with lower genetic merit.
- Effects of increasing the Australian Profit Ranking on whether a cow recalved by 20 months were weakly positive across all except the total mixed ration feeding system, and across all herd milk yield categories; effects were stronger in herds with higher herd average solids per cow.
- For Holsteins, cows with higher Australian Breeding Values for daughter fertility and survival are more likely to recalve by 20 months in all feeding systems. The effects of Australian Breeding Value for survival are smallest in the low bail feeding system and largest in the total mixed ration feeding system.
- For Jersey cows in herds using low and moderate to high bail feeding systems and partial mixed ration feeding, cows with higher Australian Breeding Values for daughter fertility and survival are just as likely (if not more likely) to recalve by 20 months as cows with lower Australian Breeding Values for these traits.
- Cows with higher Australian Profit Rankings have a similar risk of a short lactation to other cows in the herd.
- Increases in Australian Breeding Values for fat and protein yield resulted in moderately large decreases in odds of recalving by 20 months in the total mixed ration feeding system, and small to moderate reductions in other systems.
- Increases in Australian Breeding Values for survival and daughter fertility resulted in small to modest increases in odds of recalving by 20 months in all systems.

Sire usage and semen price

- Other than in total mixed ration herds, between 52% and 68% of cows were sired by Australian sires. In the total mixed ration herds, 39% of cows were sired by Australian sires. USA and Canadian sires were used more commonly in higher feed input herds.
- Relatively few cows were sired by New Zealand sires in any feeding system.
- Within each feeding system, a large number of sires had been used over the 5 years from mid 2004 to early 2009.
- Similar sires were most popular in herds using low bail, moderate to high bail, PMR, and hybrid feeding systems, but many of these differed from the most popular sires in herds using the TMR system.
- Within each herd average solids per cow category, a large number of sires had been used.
- Sires with a wide range of Australian Profit Rankings had been used (-303 to 430), indicating that rate of increase in Australian Profit Ranking was markedly less than that possible.
- Partial mixed ration and total mixed ration herds and high milk yield herds made less rapid progress in increasing Australian Profit Ranking than other herds. Rates of increase varied from 12-13 units per year in low bail feeding and low-producing herds to 8 units per year in total mixed ration and high-producing herds.
- Mean sire Australian Profit Rankings were lower in herds using higher input feeding systems and with higher average milk yields; the average sire Australian Profit Ranking was 68, ranging from 77 for the herds using low bail feeding to only 47 for total mixed ration herds. The average sire Australian Profit Ranking was also highest in herds averaging around 400 kg MS/cow (77) and lowest in the highest producing herds (55). Sire Australian Breeding Values for milk volume were higher in herds using higher input feeding systems, and herds with higher average milk yields. Mean sire Australian Breeding Values for fat and protein yields were lower in herds using higher input feeding systems, and herds with higher average milk yields. Mean sire Australian Breeding Values for fat and protein concentrations were lowest in total mixed ration herds and high-producing herds.
- These finding indicate that when USA sires were selected, sires with low Australian Profit Rankings were being selected in preference to Australian sires with higher Australian Profit Rankings. The lower mean sire Australian Profit Rankings in partial mixed ration, hybrid and total mixed ration feeding systems were due to both a) selection of lower Australian Profit Rankings Australian sires and b) increased use of USA sires.
- Sires with low reliabilities were commonly used, but these patterns in Australian Profit Rankings were not due to use of lower reliability sires.
- For USA sires, selection priority for TPI was similar across systems.
- Rate of increase in Australian Profit Ranking is substantially reduced if sires are selected based on TPI rather than Australian Profit Ranking.
- There was no important association between Australian Profit Ranking and recommended retail price for semen.

RECOMMENDATIONS

The biological determinants of G*E for fat yield differ from those for milk volume and protein yield. Reasons for this should be investigated, and implications of these G*E relationships for sire proving should be assessed.

Sires chosen for inseminations from mid 2004 to early 2009 were described but sire choices may have changed since then. Further research is required to describe more recent sire choices.

Effects of increases in sire Australian Profit Ranking are about as theoretically expected in most herds, and are larger than expected in TMR and high-producing herds, yet low Australian Profit Ranking sires were commonly used. Ironically, sire Australian Profit Rankings were lowest in those herds where the benefits of increasing Australian Profit Ranking are greatest. We estimate that Australian Profit Rankings of selected sires would have been at least 100 units higher, if only sires from the Good Bulls Guide (or the equivalent sires for the earlier years studied) had been used in the study herds. Reasons for low rates of increase in Australian Profit Ranking should be fully understood. This highlights the need for thorough understanding of herd managers' sire selection processes and their perceptions about appropriate sires for their herds. In particular, reasons for herd owners selecting sires with negative Australian Profit Rankings should be understood.

Perceptions of managers of higher feed input herds about sire choices should also be fully understood, including reasons for the high use of low Australian Profit Ranking USA and Canadian sires.

IN A NUTSHELL

The Feeding the Genes project consisted of a literature review and a detailed research study.

The key findings from the literature review were as follows:

- Genotype by environment interaction for milk production is generally low to modest, but important reranking may be occurring in some circumstances. Genotype by environment interaction may be most important between feeding systems, and across pasture-fed herds with different feed intakes.
- Evidence about genotype by environment interactions for reproductive traits is limited, but important reranking may be occurring in some circumstances. This should be investigated in various Australian environments in future.

The key findings from the research study were as follows:

- Herd managers do not need to be feed high rates of supplements to benefit from selecting high Australian Profit Ranking sires.
- In all feeding systems, the daughters of higher Australian Profit Ranking sires produce more milk and are just as likely (if not more likely) to last in the herd as daughters of lower Australian Profit Ranking sires. This dispels the commonly-held belief that the daughters of high Australian Profit Ranking sires are less likely to last a long time in the herd.

- The benefits of greater genetic merit vary between feeding systems (ie there is an interaction between genetic merit and feeding system). The response from selecting high Australian Profit Ranking sires is greater in herds using more intensive feeding systems (hybrid and total mixed ration) but selecting high Australian Profit Ranking sires has benefits in all feeding systems.
- Given the very close correlations between Australian Profit Ranking and each of the Balanced Performance Index, the Health Weighted Index and the Type Weighted Index, effects of the new breeding indices would be very similar to these effects of the Australian Profit Ranking.
- On average, semen from high Australian Profit Ranking sires cost no more than that from lower Australian Profit Ranking sires.
- Herd managers using artificial breeding should select high Balanced Performance Index, Health Weighted Index or Type Weighted Index sires whose semen price is appropriate and whose Australian Breeding Values are aligned with the breeding objectives for their herd.

KEY MESSAGES

Herd managers using artificial breeding should select high Balanced Performance Index, Health Weighted Index or Type Weighted Index sires whose semen price is appropriate and whose Australian Breeding Values are aligned with the breeding objectives for their herd.

RESEARCH

CHAPTER 1. RESEARCH MATERIALS AND METHODS

1.1 STUDY OVERVIEW

A retrospective cohort study was conducted using data from 505 commercial Australian herds. Lactations were selected, the cow's sires Australian Profit Ranking, Australian Breeding Values and Australian Selection Index obtained, milk production, and occurrences of recalving by 20 months and short lactations determined, and the herd's feeding system and herd averge milk yield defined.

Lactation-level data were selected from the ADHIS database. Feeding system data were obtained directly from managers of selected herds by questionnaire.

1.2 ENROLMENT OF HERDS

All herds in which at least 30 Holstein cows calved in 2011 and/or at least 30 Jersey cows calved in 2011 were selected from the ADHIS database. Herds with less than fifty cows calved in 2011 were excluded. Of these 2018 herds, 2 herds were excluded at the request of the data processing centre that serviced those herds.

Around 25th July 2012, letters were sent to managers of all of the remaining 2016 herds, asking them to complete the herd data questionnaire (either as hard copy or on-line). On 17th August, some of the listed herds that were known to be using the hybrid or TMR feeding systems that had not responded were contacted by email, with the same request. Responses up to 24th September 2012 were used.

Flow of herds is summarised in Figure 1.1. After excluding trial responses by project team members, 525 responses were received. For 490 responses, the herd identifier provided by the respondent exactly matched a national herd ID for an eligible herd. For the remaining 35 responses, the herd identifier provided by the respondent closely matched a national herd ID; differences were due to the respondent using 1 instead of lower case ‘l’ (lower case is allowed in national herd IDs; n=12), 5 instead of S (n=6), 0 instead of O (n=5), O instead of 0 (n=3), 8 instead of B (n=2), one additional or omitted character (n=4), and other transpositions (eg 2 instead of 3; n=3).

These 525 responses were from 513 herds; nine herds responded twice and one herd responded four times. Two of these 10 herds were excluded as some data provided differed between responses. For the remaining 8 herds, one response was more complete than other response, and this was used for analyses.

Of these 511 herds, data were inadequate to define the herd feeding system in 2011/12 in 5 herds; so these herds were excluded, as was one herd whose cow- and lactation-level data were not requested from ADHIS because the herd identifier provided by the respondent was not initially matched to a national herd ID. Accordingly, 505 herds were enrolled.

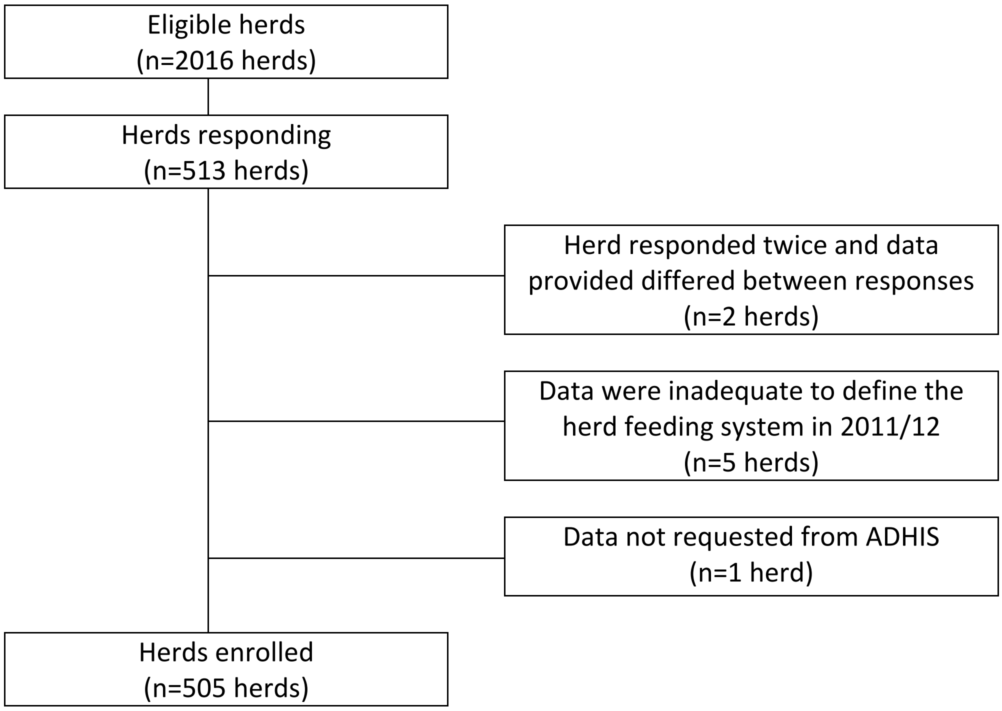


Figure 1.1 Flow of herds enrolled in study.

1.3 IDENTIFICATION OF HERD FEEDING SYSTEMS

Managers of enrolled herds completed a herd data questionnaire either as hard copy (submitted by fax or post) or on-line through a custom-designed survey tool. The questionnaire is reproduced in Appendix 1.

From the responses to the questionnaire, for each of 2008/09, 09/10, 10/11 and 11/12, each herd was categorised as using one of 5 feeding systems:

- Low bail
- Moderate to high bail ('Mod-high bail')
- Partial mixed ration ('PMR')
- Hybrid
- Total mixed ration ('TMR')

Categorisation was based on the scheme developed as part of Dairy Australia’s Feed2Milk program, with some modifications (Table 1.1).

Table 1.1 Scheme for categorising herd feeding system

For each 12 month period:	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
Tonnes of grain, grain mixes or grain-based concentrates fed per cow in 12 month period	0 to 1t	>1t	>1t	>1t	>1t
Times when milking cows did not graze pasture but were fed entirely on conserved fodder, grains, grain-based concentrates or other supplements?		No or yes	No or yes	Yes	Yes
If yes, for how many months:		0 - 12	0 - 3	4 - 10	11 - 12
Used both a feed pad and a mixer wagon to feed conserved fodder, grains, grain-based concentrates and / or other supplements		No	Yes	Yes	Yes

1.4 IDENTIFICATION OF HERD CALVING SYSTEM

The calving system for each herd in each year was determined based on the monthly distribution of calvings using cows of all breeds from 2007 to 2012. The herd was classified as year-round calving if less than 80% of calvings in that year occurred in the 6 months with most calvings. Of remaining herds, months with at least 4 calvings were identified, and the number of 'clusters' in the year identified. A cluster consisted of a sequence of months, each with at least 4 calvings, immediately preceded by at least one month with no or less than 4 calvings. Herds with more than one cluster in the year were classified as split-calving while herds with one cluster were classified as seasonal calving. The calving system for remaining herds was not classified.

1.5 COW-, LACTATION- AND SIRE-LEVEL DATA

Cow, lactation, and sire data were obtained from ADHIS for these 505 herds. Data for all lactations commencing with calvings from 1st January 2006 were requested. Data were extracted from the ADHIS database between 25th September 2012 and 5th October 2012.

1.6 LACTATION SELECTION

Lactations commencing from 2008 to 2011 were enrolled. For each of 2008, 2009, 1010 and 2011, all lactations commencing with calvings in that year were selected where:

- the cow was a Holstein (ie FFFF) or Jersey (ie JJJJ),
- the cow's sire identity was recorded, and
- the cow's sire had an Australian Profit Ranking estimate.

For analyses of milk production variables, standard lactation milk volume must also have been recorded.

For analyses of odds of recalving by 20 months, all lactations commencing with a calving on or before the herd's last eligible calving date were selected.

Some cows were recorded as having the same calving date in two or more herds. These lactations were excluded from analyses. No calvings were duplicated within the same herd.

1.7 AUSTRALIAN PROFIT RANKINGS AND AUSTRALIAN BREEDING VALUES

Australian Profit Rankings and Australian Breeding Values were those calculated on 20th August 2012 other than Australian Breeding Values for daughter fertility. As a major change in the method for calculation of Australian Breeding Values for daughter fertility was made after August 2012 (moving from a single trait model to a multi-trait model), Australian Breeding Values for daughter fertility as calculated on 15th April 2013 were used, other than for Chapter 7, where values calculated on 20th August 2012 were used as described below.

Each cow's sire's Australian Profit Ranking and Australian Breeding Value were used.

For estimates of each cow's Australian Profit Ranking and Australian Breeding Values, a sire pathway approach was used rather than using each cow's own estimates. This approach was used because each cow's estimates are derived, in part, from variables closely related to the dependent variables for the current study (milk production, recalved by 20 months). For this reason, effects of Australian Profit Ranking and Australian Breeding Value would be substantially overestimated if each cow's own estimates were used. In contrast, because any particular cow's contribution to her sire's Australian Profit Ranking and Australian Breeding Values is relatively small, any bias for this reason would probably be small.

Each cow's Australian Profit Ranking was estimated as:

> sire's Australian Profit Ranking*0.5 + maternal grandsire's Australian Profit Ranking*0.25+ 0*0.25

This assumes that the cow's maternal grand dam's Australian Profit Ranking was 0.

Where the maternal grandsire was not recorded, the cow's Australian Profit Ranking was estimated as:

> sire's Australian Profit Ranking*0.5 + 0*0.5

This is valid if the average of the cow's maternal grandsire's and dam's Australian Profit Ranking is 0.

The same approach was used for Australian Breeding Values, except that for non-yield traits (daughter fertility and survival), the value of 100 was used in place of 0.

For Holstein cows, of the 250,857 selected lactations, the maternal grand dam's Australian Profit Ranking and Australian Breeding Values for milk yield traits was available for 81% (203,829/250,857). For Jersey cows, of the 43,941 selected lactations, the maternal grand dam's Australian Profit Ranking and Australian Breeding Value for milk yield traits was available for 84% (36,808/43,941).

1.8 MILK PRODUCTION VARIABLES

Standard lactation yields (ie 305-or 300-day yields) were used. Fat and protein percentages were calculated as fat or protein yield (in kg)*100/milk volume (in litres). These are thus weighted average percentages, weighted by litres.

For Holstein cows, of the 250,857 selected lactations, the standard lactation code was recorded for 97% (243,393/250,857). Of these, the standard lactation was 305 days for 97% (236,835/243,393) and 300 days for the remainder. For Jersey cows, of the 43,941 selected lactations, the standard lactation code was recorded for 99% (43,494/43,941). Of these, the standard lactation was 305 days for 96% (41,784/43,494) and 300 days for the remainder. Standard lactation code was disregarded in statistical analyses because lactations with unrecorded values would then have been excluded from analyses, and given the high proportion that were 305 days, and the small difference between the two options. For simplicity, all lactations are referred to as '305-day' lactations in this Report.

1.9 RECALVED BY 20 MONTHS

Herd managers desire cows that 'last' in their herds. To describe 'lasting', recalved by 20 months was used to collectively describe short to medium term reproductive performance, culling and death for each lactation. In seasonal calving herds, cows not recalved by 20 months have failed to reconceive in the mating period following the cow's calving and/or been culled or died. In split calving herds, these cows are likely to have failed to reconceive in both of the two mating periods following the cow's calving, and/or been culled or died. In year-round calving herds, these cows have failed to reconceive by 11 months after their calving and/or been culled or died.

Each lactation was classified as having been followed by another calving 20 months or less later (ie 608 days or less after the calving that commenced the lactation) or not (subsequent calving more than 608 days later or no subsequent calving recorded).

Lactations commencing with a calving on or before the last eligible calving date for the herd were used for these analyses. The last eligible calving date for the herd was calculated as the last recorded calving date minus 20 months (ie 608 days). Where 'gaps' in calving data were identified for the herd (see below), only lactations commencing 20 or more months before the gap were used.

'Gaps' in calving data were defined within herds as periods of 3 or more consecutive months without calvings when calvings were recorded in each of the corresponding months in the previous calendar year (Table 1.2).

Table 1.2 Example of gaps in calving data in one herd. Numbers of calvings by month are shown. The gap (highlighted blue) commences on 1st June 2009, the first day of a period of 3 or more consecutive months without calvings when calvings were recorded in each of the corresponding months in the previous calendar year.

Year	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2008						2	1	56	37	13	6	2
2009	3											
2010			2		2		4	47	41	14	2	1
2011	1		3	3	1		4	77	22	11	6	2
2012		1	14	1	8		1	3	14			

1.10 SHORT LACTATIONS

Odds of short lactations (lactations of less than 120 days duration) were also assessed, as a substantial proportion of cows with short lactations are likely to have had post partum disease(s) that seriously affected milk production.

1.11 AGE

For each lactation, cow age at calving was calculated as: (calving date minus birth date)/365.25, rounded to the nearest integer. Calculated ages <2 years or >20 years were set as missing values.

1.12 LACTATIONS LOST TO FOLLOW-UP

Details of lactations lost to follow-up are shown in Figures 1.2 and 1.3 (Holstein cows) and Figures 1.4 and 1.5 (Jersey cows).

Further lactations were excluded as follows:

- where the cow's maternal grandsire's Australian Profit Ranking or Australian Breeding Value were fitted as a covariate and this was not available,
- for analyses of fat yield and fat percentage where fat yield was not recorded, and for protein yield and protein percentage where protein yield was not recorded,
- for analyses of effects of Australian Breeding Values for daughter fertility and survival where estimates of these for the cow's sire were not available,
- for analyses of odds of recalving by 20 month, lactations in those age categories where either all cows or no cows recalved by 20 months, and
- for analyses of odds of short lactation, lactations where the termination date was not recorded.

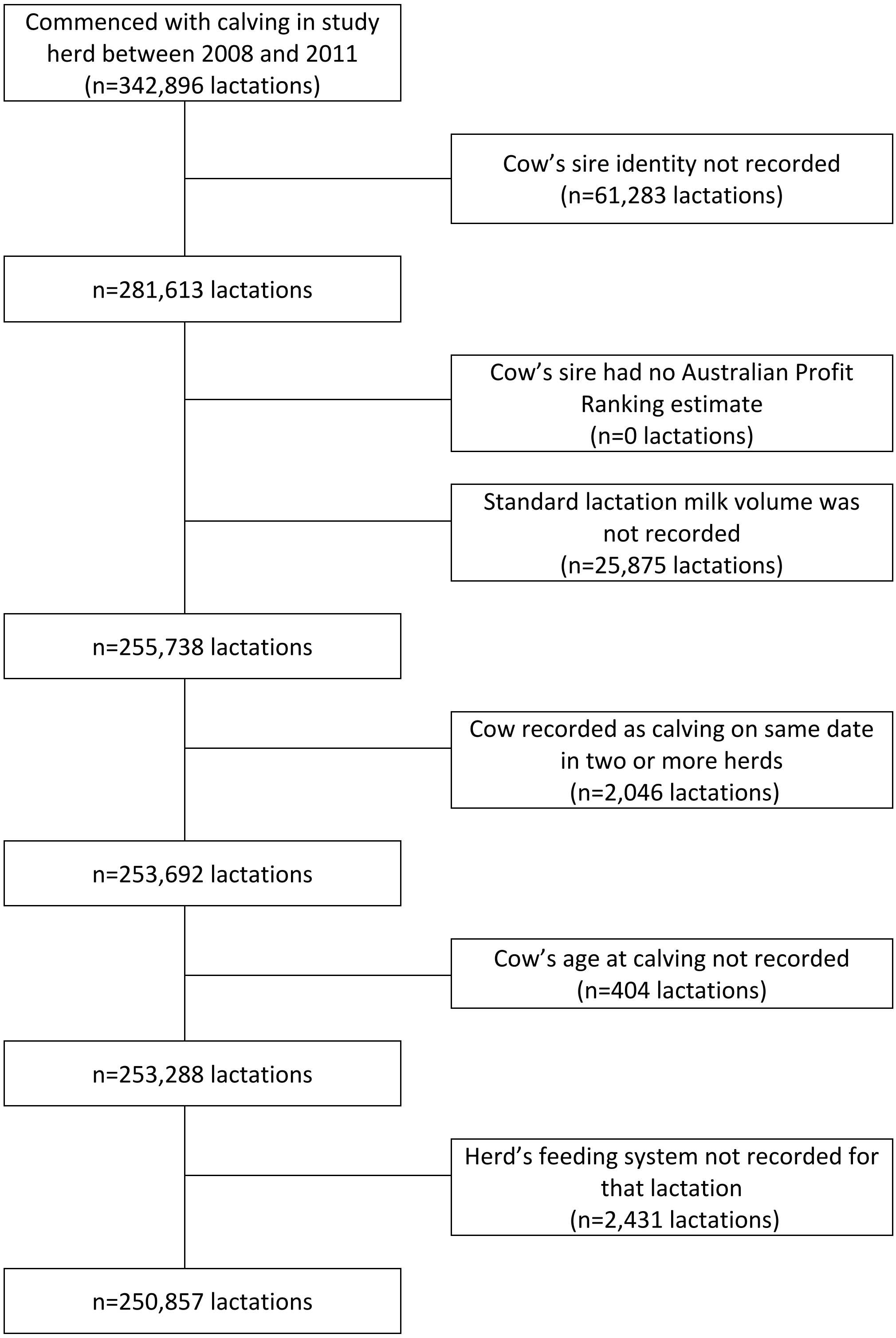


Figure 1.2 Flow of lactations enrolled in study for analyses of milk yield in Holstein cows.

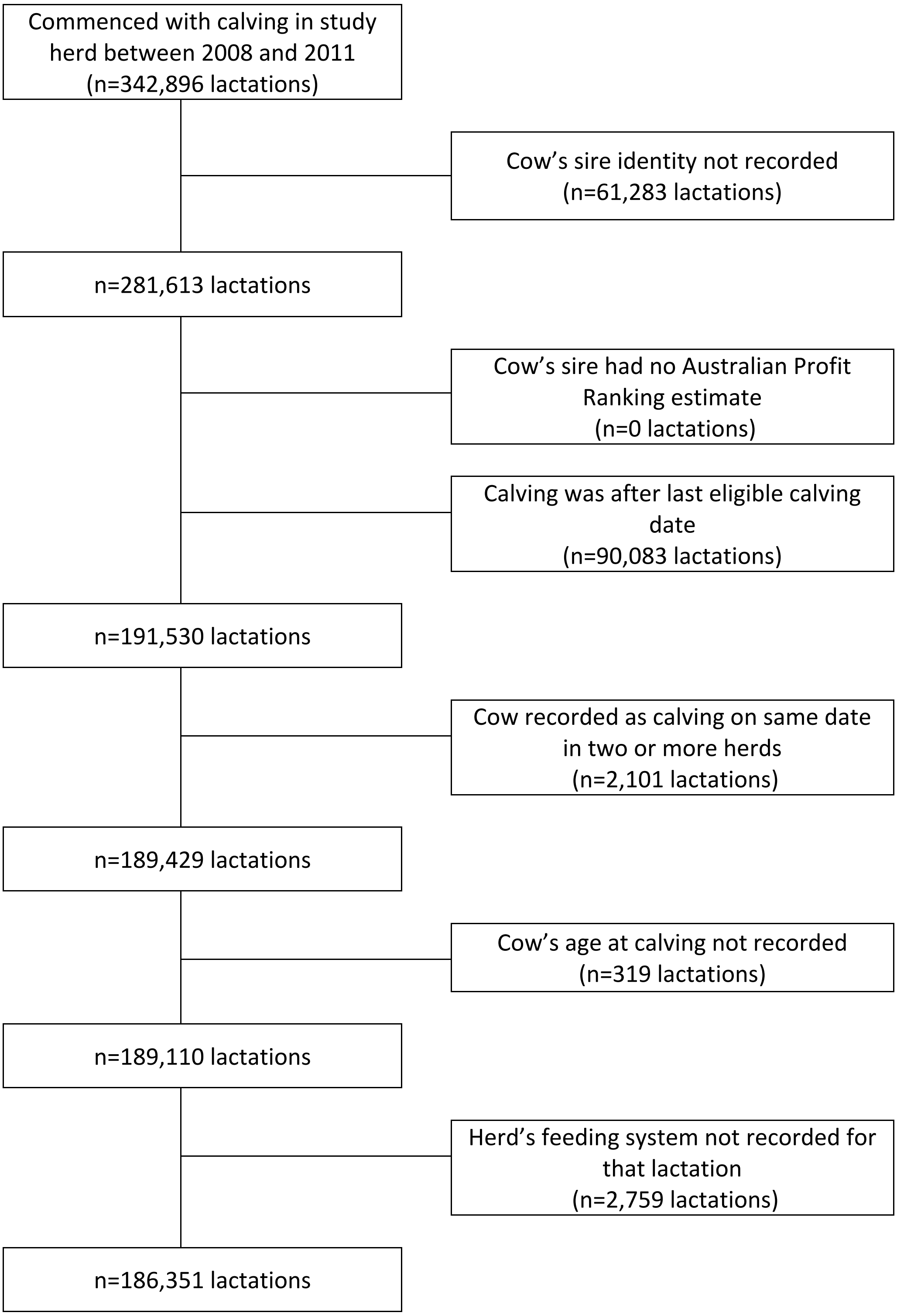


Figure 1.3 Flow of lactations enrolled in study for analyses of odds of recalving by 20 months in Holstein cows.

Of the 186,351 retained lactations, 108,067 were the first eligible lactation for the cow in the study dataset.

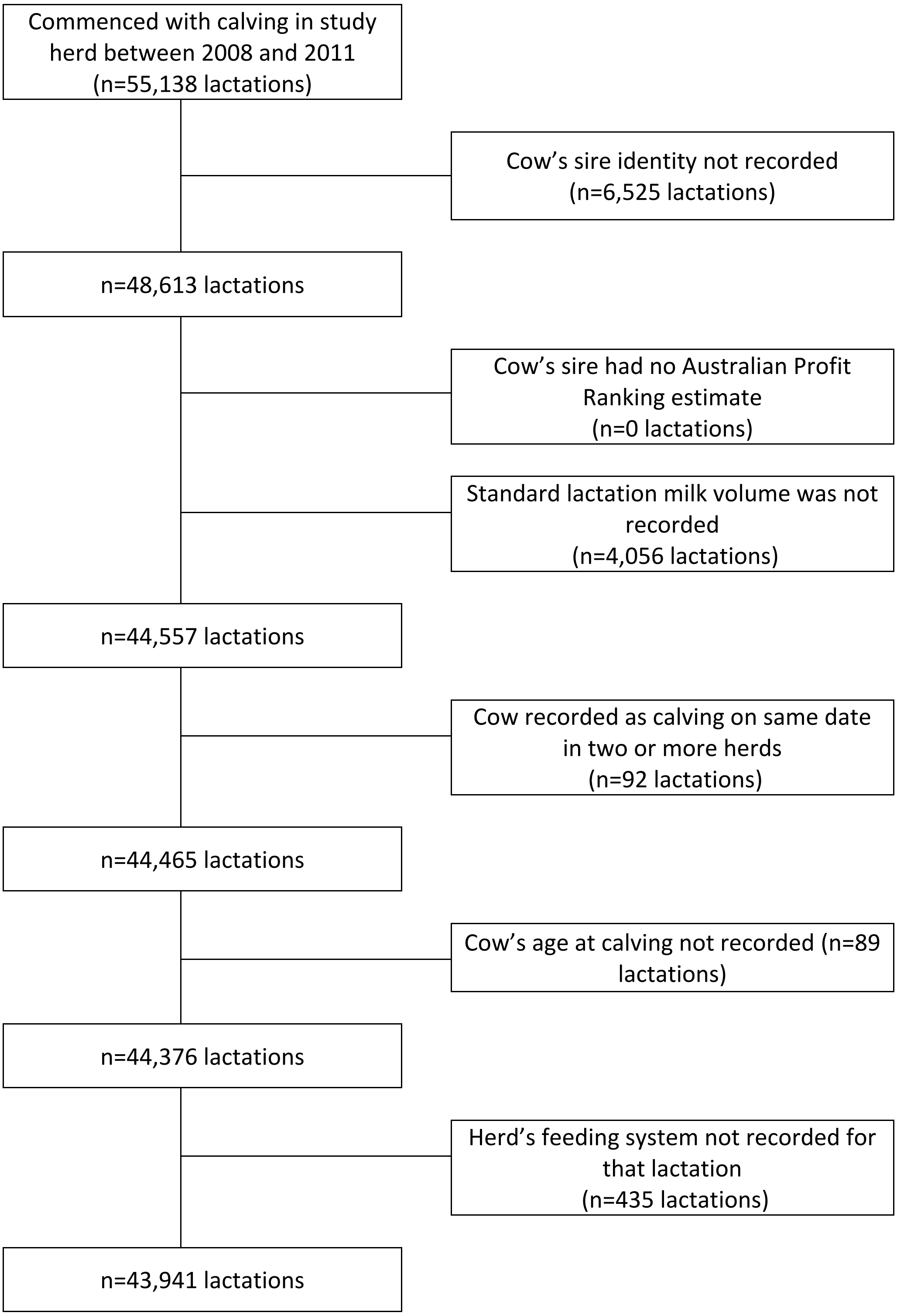


Figure 1.4 Flow of lactations enrolled in study for analyses of milk yield in Jersey cows.

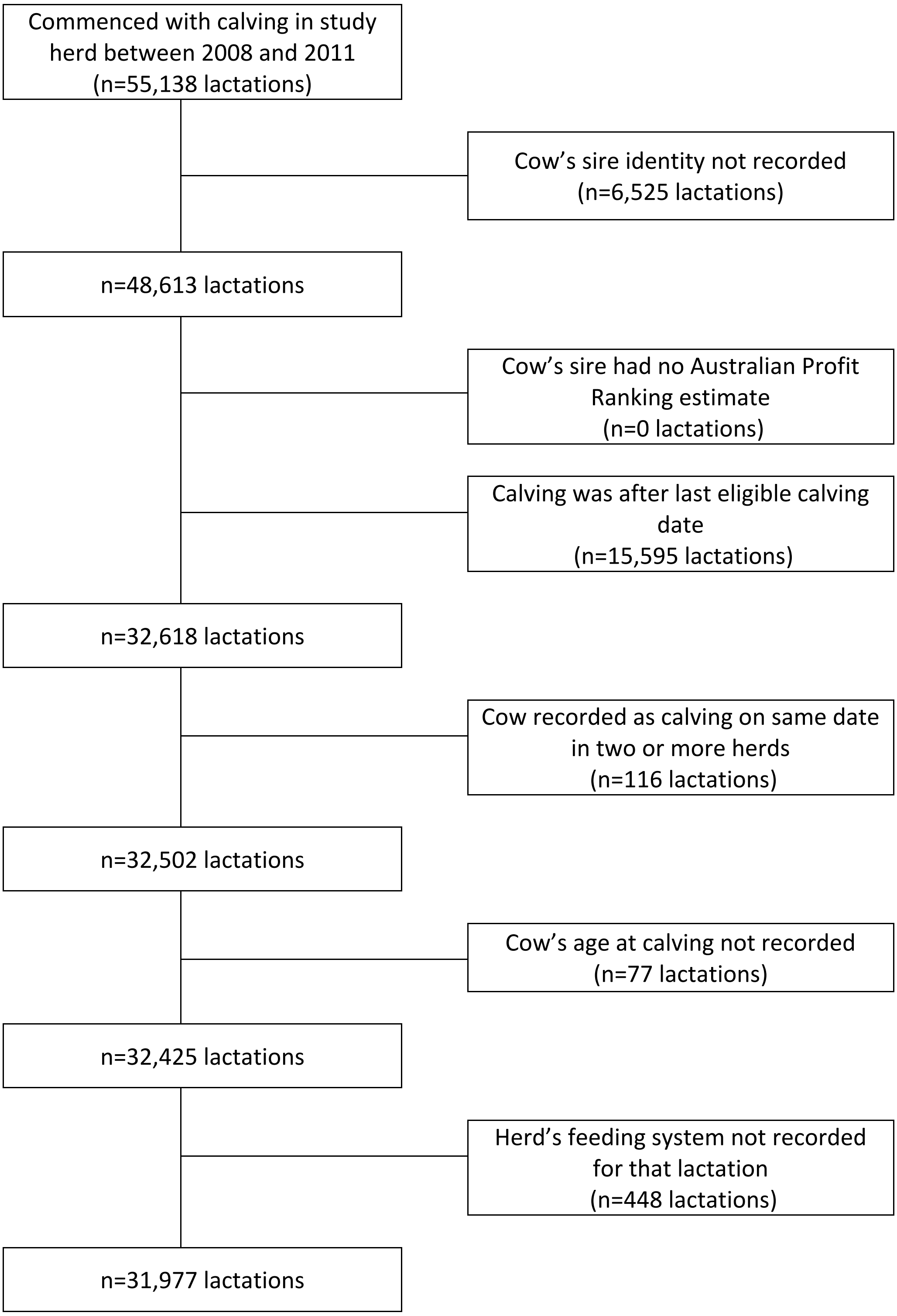


Figure 1.5 Flow of lactations enrolled in study for analyses of odds of recalving by 20 months in Jersey cows.

Of the 31,977 retained lactations, 17,878 were the first eligible lactation for the cow in the study dataset.

1.13 REPRODUCTIVE DATA

Study herds were not selected based on availability of reproductive data (artificial insemination and pregnancy diagnosis data). However it was desirable to assess interactions between Australian Profit Ranking (and Australian Breeding Value) and herd feeding system on reproductive performance. Accordingly, availability of reproductive data in the ADHIS database for study herds was assessed.

The following were identified for each study herd in each year:

- Percentage of lactations where at least one artificial insemination was recorded
- Percentage of lactations where at least one pregnancy diagnosis was recorded
- Of lactations with at least one pregnancy diagnosis recorded, the percentage where at least one pregnancy diagnosis was either between 4 and 17 weeks of gestation or not detectably pregnant.

Pregnancy diagnoses where the stage of gestation was not recorded, or recorded as being between 1 and 27 days or greater than 280 days were disregarded.

Herd-years meeting all of the following criteria were then identified:

- At least 50% of lactations had at least one artificial insemination recorded.
- At least 80% of lactations had at least one pregnancy diagnosis recorded.
- Of lactations with one or more pregnancy diagnoses recorded, at least 80% had at least one pregnancy diagnosis either between 4 and 17 weeks of gestation or not detectably pregnant.

These herd-years were considered to have adequate reproductive data for analyses. These criteria are the same as or similar to those used in the software used for NatScan (the national herd reproductive performance analysis, using the ADHIS dataset).

Across both Holstein and Jersey cows, 31,633 lactations were in herd-years with adequate reproductive data (Table 1.3). These lactations were from between 28 and 44 herds in each of 2008 to 2011.

Table 1.3 Numbers of lactations from Holstein and Jersey cows pooled, and numbers of herds providing these lactations by year in herd-years with adequate reproductive data

	Year				Pooled
	2008	**2009**	**2010**	**2011**	
No. lactations	6,456	7,477	7,697	10,003	31,633
No. herds	28	36	40	44	

For assessment of interaction between Australian Profit Ranking and herd feeding system, separate analyses would be required for Holsteins and Jerseys. Further, within each breed, lactations would be lost to follow-up for the following reasons:

- cow's sire identity not recorded
- cow's age at calving not recorded
- herd's feeding system not recorded for that lactation
- calving system for herd-year not classifiable

- calvings excluded as not within 130 days before to 59 days after mating start date (seasonal calving herds) or 120 days before to mating start date (split calving herds)
- no or inadequate pregnancy diagnoses in lactation.

For analyses of Australian Breeding Value for daughter fertility, further lactations would be lost to follow-up due to unrecorded breeding values.

Accordingly, these numbers of lactations were considered insufficient for precise assessments of interactions.

Additional reproductive data could have been obtained from the InCalf Fertility Data Project 2011. Nineteen herds from this project were also enrolled in the Feeding the Genes project, and some of these herds had adequate reproductive data for analyses in some of the years from 2008 to 2011. Approximate numbers of Feeding the Genes lactations for which additional reproductive data may have been available from the InCalf Fertility Data Project 2011 are shown in Table 1.4. In total, additional reproductive data may have been available for 3,918 Feeding the Genes lactations.

Table1.4 Numbers of lactations in 19 herds in the Feeding the Genes where additional reproductive data may have been available from the InCalf Fertility Data Project 2011*

Herd	2008	2009	2010	2011
1				
2		55		
3	104			
4				
5	264	244	279	
6			208	
7				
8	267			
9		178		
10				
11		294		
12	160	136		
13	125	128	140	
14	100	107		
15	202	147		
16				
17	48	25		
18	241	252		
19	214			
Pooled	1725	1566	627	0

* Calculated as numbers of lactations by year in the 19 herds in the Feeding the Genes with inadequate reproductive data for analyses where there were adequate reproductive data for analyses in the InCalf Fertility Data Project 2011

Fifty seven herd-year combinations from the InCalf Fertility Data Project 2011 were also enrolled in the Feeding the Genes project. Across these herd-years, there were, on average, 107 less calvings in the Feeding the Genes project. **This was presumably due to unrecorded and unidentifiable sires, and possibly failure of data processing centres to submit all calvings to ADHIS. Given possible**

selection biases due to missing data, this highlights the importance of reviewing strategies to maximise completeness of data in the ADHIS database.

Potentially, additional reproductive data could also have been obtained from the 10k Holstein genomes project and Jernomics.In total, 4,810 Holstein cows and 1,937 Jersey cows from these projects were in 74 of the Feeding the Genes herds (average of 91 cows per herd). Within these projects, cow selection was biased towards those with high quality records, resulting in bias towards lactations with better reproductive performance. Further reproductive data was being collected from additional cows in these herds and inclusion of these data in the Feeding the Genes project could be explored in a future project.

In summary, the number of lactations was insufficient for precise assessments of interactions between Australian Profit Ranking (and Australian Breeding Value) and herd feeding system on reproductive performance. These numbers would not be markedly increased by inclusion of additional reproductive data already collected for the InCalf Fertility Data Project 2011, the 10k Holstein genomes project, and Jernomics.

1.14 STATISTICAL ANALYSES

Effects were assessed of both the cow's sire's Australian Profit Ranking and the cow's Australian Profit Ranking as calculated above. Effects on milk volume, and fat and protein yield and percentages were assessed using multilevel linear models with lactations nested within cows, and cows nested within herds (ie herd and cow were random effects). Australian Profit Ranking was fitted as a continuous variable, and herd feeding system and age at calving were fitted as categorical variables. Effects of cow's sire's Australian Profit Ranking were assessed without and with the cow's maternal grandsire's Australian Profit Ranking fitted as a covariate. The latter was to reduce confounding if sires with high Australian Profit Rankings are used more commonly on cows with high (or low) Australian Profit Rankings. (No such covariate was fitted when effects of the cow's Australian Profit Ranking was assessed.)

Interactions between Australian Profit Ranking and herd feeding system were fitted and the joint significance of the four interaction terms assessed using joint Wald tests. Models were fitted using the -xtmixed- command in Stata (version 12.1, StataCorp, College Station, Texas, USA). Maximum likelihood estimation was used.

Effects of both the cow's sire's Australian Breeding Value and the cow's Australian Breeding Value were also assessed in the same way. When effects of cow's sire's Australian Breeding Value on milk volume, and fat and protein yield and percentages were assessed, the cow's maternal grandsire's corresponding Australian Breeding Value was fitted as a covariate.

These models did not specifically account for genetic interrelationships between cows contributing the study lactations (other than that accounted for by fitting herd and cow within herd as random effects). To explore the impact of this, an attempt was made to account for similarity of sires across lactations. The effect of cow's sire's Australian Profit Ranking on milk volume in Holstein cows was assessed using the same model as described above, but with sire of cow and cow within sire fitted as random effects and either herdyear of calving or herd fitted as a fixed effect. The cow's maternal grandsire's Australian Profit Ranking was fitted as a covariate in these models. Computer memory was inadequate for fitting either model. Further statistical modelling, including use of animal models, would be required if these are to be fully addressed.

To assess for curvilinear effects of cow's sire's Australian Profit Ranking on milk production, linear and quadratic terms for cow's sire's Australian Profit Ranking were fitted simultaneously with feeding system and all two- and three-way interactions, along with the cow's maternal grandsire's Australian Profit Ranking and age at calving. Interactions that included the quadratic term were jointly tested using Wald tests. Increases in milk production per 50 units increase in sire Australian Profit Ranking were estimated at each of the 5th percentile, mean and 95th percentile of sire Australian Profit Rankings (-104, 41 and 178 for Holsteins; -237, 6 and 184 for Jerseys), using Stata's-margins- command. There were relatively few Jersey cows in the hybrid and TMR feeding systems, so these systems were excluded from analyses for curvilinearity within Jerseys.

Effects on odds of recalving by 20 months were assessed similarly, but using logistic models with a random effect of herd, fitted using the -xtlogit- command in Stata. Linearity in the logit was assessed by categorising Australian Profit Ranking into deciles and plotting the crude logit for recalved by 20 months against the mean Australian Profit Ranking for the decile. Linearity in the logit for Australian Breeding Values was assessed in the same way. A multilevel logistic model with lactations nested within cows, and cows nested within herds (ie herd and cow as random effects) had not generated starting values after 3 hours so these models were not fitted.

Effects on Australian Profit Ranking on odds of short lactations were assessed as for odds of recalving by 20 months.

Holstein and Jersey cows were analysed in separate models. There were virtually no Jersey cows in the TMR feeding system, so this system was excluded from those analyses. For Jersey cows, for analyses of odds of recalving by 20 months, cow ages 15 and 16 years were merged to form a single age category, and for analyses of odds of short lactation, cow ages 15 and greater were merged.

The proportion of lactations that are followed by recalving within 20 months is determined by deaths, reproductive performance, and culling. Culling is based on numerous factors including low milk yield relative to herd average. Thus, even if lower Australian Profit Ranking cows have reduced reproductive performance, the proportion that recalve by 20 months may be similar to that in higher Australian Profit Ranking cows due to increased culling because of lower milk yield relative to herd average. To explore this, analyses of effects of cow's sire's Australian Profit Ranking on recalved by 20 months adjusted for cow's maternal grandsire's Australian Profit Ranking were repeated also adjusted variously for each lactation's deviation from the herd's mean milk volume, fat yield, and protein yield for that year.

1.15 METHODS SPECIFIC TO CHAPTER 4

Herd-year average milk yields per cow (average milk yields for each herd-year combination) were calculated as averages of 300- or 305-day milk yields (hereafter refered to as '305-day' milk yields), using all lactations with milk yield data. These averages were calculated for each of milk volume, fat, protein and solids (ie fat plus protein) yield, and metabolisable energy requirements for milk production.

Metabolisable energy requirements per cow for milk production were calculated for each lactation as:

> 305-day milk volume*((((fat yield*1000/milk volume)*0.0381)+((protein yield*1000/milk volume)*0.0245)+((50)*0.0165))/0.62)

This assumed that net energy requirements for fat, protein and lactose were 0.0381, 0.0245, and 0.0165 MJ/g, respectively, that lactose concentrations were 50 g/L, and that efficiency of use of energy for milk production was 0.62 (Anonymous 1990). Milk volume was expressed in litres, and fat and protein yields were expressed in kilograms.

Herd-year average solids per cow were also used in Chapter 5.

As described above, in total, 250,857 lactations were eligible for analyses of milk volume in Holstein cows. Of these, the cow's maternal grandsire's Australian Profit Ranking was recorded for 203,829 lactations (81%), and lactational fat and protein yields were recorded for 203,762 and 203,799 of these lactations, respectively. Interactions were assessed using these subsets of these lactations. Models were fitted as described above. For simplicity, effects of Australian Profit Ranking were assumed to be linear across the range of Australian Profit Rankings studied, even though for milk volume and protein yield, within all systems, estimated effects of the cow's sire's Australian Profit Ranking were higher at higher Australian Profit Rankings.

Effects of sire Australian Profit Ranking on 'milk profit' for the lactation were also assessed. Milk profit for the lactation was defined as total milk income for the lactation less feed costs for milk production. Feed costs for maintenance, pregnancy, growth and body condition change were not deducted. Unit milk incomes (milk prices for each unit of fat and protein, and price penalties for each unit of milk volume) were based on those received by southern region Murray Goulburn suppliers in 2013/14. Flat milk and growth incentives were disregarded as many herds do not receive these. Increases in milk yield per cow were assumed to not alter the herd's productivity incentive as the incremental steps in herd milk yield between each productivity incentive level were wide. Given these conditions, unit milk incomes equated to marginal unit milk incomes. Unit milk incomes for fat and protein were calculated as $4.39 per kg of fat and $9.61 per kg of protein. These were the unweighted averages of the monthly base prices for southern region Murray Goulburn suppliers from July 2013 to June 2014, plus the six step-up payments for that financial year that were announced up to 26th February 2104, plus the productivity incentive assuming 20,001 to 25,000 kg of solids are supplied each month. The price penalty for each unit of milk volume was 2.5 c/litre (the marginal fee for B-double pick-ups). All milk was assumed to be Premium 1 quality, pick-up fees were disregared, and external levies were not deducted.

Feed costs for milk production for the lactation were calculated assuming assuming all energy for milk was supplied by grain, costing $400 per tonne as fed, 90% dry matter and supplying 12 megajoules (MJ) of metabolisable energy per kg dry matter. Metabolisable energy requirements per cow for milk production were calculated as described above.

Accordingly, milk profit for each lactation was calculated as:

> Milk volume*-0.025 + fat yield*4.39 + protein yield*9.61 – energy required for milk production*(((400/1000)/0.90)/12)
>
> where milk volume for the lactation was expressed in litres, fat and protein yield for the lactation expressed in kg and energy required for milk production for the lactation expressed in MJ.

Feed costs for milk production for the lactation were calculated assuming assuming all energy for milk was supplied by grain. In reality, energy for milk can be partly supplied by other cheaper feeds in addition to grain. Where this occurred, actual milk profits would have been greater than these calculated values. However, provided grain was the marginal feed in all herds, as estimated effects are essentially within-herd effects, estimated changes in milk profit due to increases in Australian Profit Ranking would be correct.

This approach assumes that economic effects of increased milk yield for any particular lactation are independent of milk yields for all other lactations in the herd, that energetic costs of increases in milk yield due to increased Australian Profit Ranking are supplied through additional feed to the herd, and that higher Australian Profit Ranking cows do not achieve higher milk yields through outcompeting other cows from limited feed pools.

Milk profit values (assuming all energy for milk was supplied by grain) were calculated for 203,760 lactations (those with values for each of milk volume, and fat and protein yields). Interactions were assessed as for milk volume, and fat and protein yields.

As described above, in total, 186,351 lactations were eligible for analyses of recalving by 20 months in Holstein cows. After exclusion of lactations where either herd average solids per cow and/or the cow's maternal grandsire's Australian Profit Ranking was not recorded (7,231 and 35,096 lactations, respectively), 145,075 lactations (78%) were used to assess interactions.

Australian Profit Ranking by feeding system interactions were assessed without and with adjustment for herd-year average ('herd average') solids per cow, and Australian Profit Ranking by herd average solids per cow interaction. Australian Profit Ranking by herd average solids per cow interaction was assessed without and with adjustment for feeding system, and Australian Profit Ranking by feeding system interaction. Herd average solids per cow was fitted as a continuous variable; with interactions fitted, effects of sire Australian Profit Ranking were assessed at 400, 500, 600 and 700 kg herd average solids per cow. Overall p-values for interaction terms were calculated using Wald tests.

1.17 METHODS SPECIFIC TO CHAPTER 6

Absolute effect estimates of Australian Profit Ranking as reported above were expressed as proportions of crude means within each feeding system, and at predicted mean values for herd solids per cow values of 400, 500, 600 and 700 kg. The latter were obtained after separately regressing each milk yield variable on herd solids per cow, and calculating predicted mean values at herd solids per cow values of 400, 500, 600 and 700 kg.

1.18 METHODS SPECIFIC TO CHAPTER 7

Australian Profit Rankings and Australian Breeding Values were those calculated on 20th August 2012. Although a major change in the method for calculation of ABVs for daughter fertility was made after August 2012 (moving from a single trait model to a multi-trait model), ABVs for daughter fertility as calculated on 20th August 2012 were used because these were calculated using the same statistical method as used for the values available to herd managers at the time the relevant semen was selected.

From the source data as described above, Holstein cows that were born on or after 1st January 2005, whose sire's Australian Profit Ranking was recorded and had at least one enrolled lactation commencing in 2008, 2009, 2010 or 2011 were identified, and their first lactation that commenced in that period enrolled. Sires of these cows were identified, and the attributes of those sires described.

Using national sire identity numbers, each sire's herdbook country was identified. Herdbook country identifies the bull's country of registration rather than the country in which the bull was located when the semen were collected. However, for most bulls, the two were likely to be identical (Daniel Abernethy, *pers comm*).

Region of each herd was ascertained based on the herd's postcode as suppled by ADHIS.

TPIs for USA sires were kindly supplied by Rohan Butler, from the Holstein Australia, on 31st January 2014. These sires were matched with those supplied by ADHIS; registration numbers from these sires with the country code 'USA' attached as a prefix were matched with herdbook IDs for sires as supplied by ADHIS.

Changes in sire's Australian Profit Ranking by cow's birthdate were assessed as for changes in milk volume, fat and protein yield (and described above), but using a random effects model with herd fitted as a random effect rather than a multilevel model. Maximum likelihood estimation was used.

1.19 METHODS SPECIFIC TO CHAPTER 8

Bulls in the Profit list in the April 2013 Holstein Good Bulls Guide (including bulls with Australian Breeding Values and Australian Breeding Value(i)s) were identified. In total, 381 bulls were listed. Recommended retail prices in April 2013 were collected from recent price lists from bull company suppliers. Prices for conventional semen were used where available. For bulls where only sexed semen was available, the sexed semen price was used.

CHAPTER 2. DESCRIPTIVE RESULTS

2.1 LOCATIONS OF HERDS

The 505 enrolled herds were from all Australian states; the distribution of herds by state was similar to that for all Australian herds (Table 2.1).

Table 2.1 Distribution of enrolled herds by state/region and all Australian herds by state

State/region	No. herds enrolled	%	Total no. herds in state*	%
Queensland	24	4.8%	555	8.2%
New South Wales	52	10.3%	778	11.5%
Northern Victoria	123			
Gippsland	127	68.9%	4,556	67.3%
South West Victoria	98			
Tasmania	18	3.6%	444	6.6%
South Australia	38	7.5%	275	4.1%
Western Australia	25	5.0%	162	2.4%
Total	505	100.0%	6,770	100.0%

*Numbers of registered dairy farms 2011/2012; Dairy Australia; http://www.dairyaustralia.com.au/Statistics-and-markets/Farm-facts/Cows-and-Farms.aspx, viewed 20 May 2013

2.2 HERD FEEDING SYSTEMS

Data were adequate to identify the feeding system in 2011/12, 2010/11, 2009/10, and 2008/09 in 505 (100%), 502 (99%), 496 (98%) and 489 (97%) of these herds (Tables 2.2, 2.3 and 2.4). The moderate to high bail feeding system was the most common by far, being used by about two-thirds of herds. Within herds, feeding system was quite consistent across years.

Table 2.2 Distribution of enrolled herds by feeding system in 2011/12 and 2010/11

	Feeding system in 2010/11						
Feeding system in 2011/12	Low bail	Mod-high bail	PMR	Hybrid	TMR	Not recorded	Total
Low bail	70	2				1	73
Mod-high bail	7	337	2			1	347
PMR	1	1	64	1		1	68
Hybrid				11			11
TMR				1	5		6
Total	78	340	66	13	5	3	505

Table 2.3 Distribution of enrolled herds by feeding system in 2011/12 and 2009/10

	Feeding system in 2009/10						
Feeding system in 2011/12	Low bail	Mod-high bail	PMR	Hybrid	TMR	Not recorded	Total
Low bail	67	2	2			2	73
Mod-high bail	23	315	3	1		5	347
PMR	3	8	49	5	1	2	68
Hybrid				11			11
TMR				1	5		6
Total	93	325	54	18	6	9	505

Table 2.4 Distribution of enrolled herds by feeding system in 2011/12 and 2008/09

Feeding system in 2011/12	Feeding system in 2008/09						
	Low bail	Mod-high bail	PMR	Hybrid	TMR	Not recorded	Total
Low bail	65	4	2			2	73
Mod-high bail	31	302	2	2		10	347
PMR	5	10	42	6	1	4	68
Hybrid	1	1		9			11
TMR				1	5		6
Total	102	317	46	18	6	16	505

Feeding systems in the 505 Feeding the Genes herds in 2011/12 were compared to those from 400 herds enrolled in a Dairy Australia survey (Attitudes and Behaviour Linked to Dairy Herd Genetics, July 2013). Definitions of feeding systems were compared and percentages of herds in approximately matching categories calculated (Table 2.5).

Herds from the Attitudes and Behaviour Linked to Dairy Herd Genetics survey were selected randomly from the Dairy Australia levy payer list but the response rate was only 72%, potentially allowing important selection bias. Nevertheless, if the levy payer list is close to a complete list of all herds, the herds from the Attitudes and Behaviour Linked to Dairy Herd Genetics survey are more likely to be representative of all Australian herds than the Feeding the Genes herds.

These results show that most Australian herds use low bail (up to 1t of grain, grain mixes or grain-based concentrates fed per cow annually) and moderate to high bail (> 1t but feed pad and mixer wagon not used) feeding systems. However, a modest proportion of herds use partial mixed rations, hybrid and total mixed rations feeding systems.

Assuming the herds from the Attitudes and Behaviour Linked to Dairy Herd Genetics survey are representative, amongst the Feeding the Genes herds, those using the low bail feeding system were underrepresented and those using the moderate to high bail feeding system were over represented. This could, in turn, bias any results for herds from all feeding systems pooled, but would not have affected results within feeding system or estimated magnitudes of interactions.

Table 2.5 Distributions of herds from the Feeding the Genes study and the Attitudes and Behaviour Linked to Dairy Herd Genetics survey by feeding system

Feeding the Genes (n=505 herds)

	Feeding system in 2011/12				
	Low bail	**Mod-high bail**	**PMR**	**Hybrid**	**TMR**
Tonnes of grain, grain mixes or grain-based concentrates fed per cow in 12 month period	0 to 1t	>1t	>1t	>1t	>1t
Times when milking cows did not graze pasture but were fed entirely on conserved fodder, grains, grain-based concentrates or other supplements?		No or yes	No or yes	Yes	Yes
If yes, for how many months:		0 - 12	0 - 3	4-10	11-12
Used both a feed pad and a mixer wagon to feed conserved fodder, grains, grain-based concentrates and / or other supplements		No	Yes	Yes	Yes
% of herds	**14%**	**69%**	**13%**	**2%**	**1%**

Attitudes and Behaviour Linked to Dairy Herd Genetics survey (n=400 herds surveyed in 2013)

	Pasture only	Pasture and up to 1 tonne of grain, grain mixes or concentrates per cow per year	Pasture and more than 1 tonne of grain, grain mixes or concentrates per cow per year	Pasture most of the year plus partial mixed ration or PMR with or without grain in the bale	Total mixed ration or TMR with no grazing
% of herds	**6%**	**40%**	**41%**	**11%**	**2%**

2.3 HERD CALVING SYSTEMS

Study herds were predominantly seasonal or split-calving (Table 2.6).

Table 2.6 Distribution of enrolled herds by calving system

Calving system	**2011/12**	**2010/11**	**2009/10**	**2008/09**
Seasonal calving	194	196	192	213
Split calving	177	193	189	166
Year-round calving	112	107	108	106
Calving system not classified	21	9	12	11
No calvings in database	1		4	9
Total	505	505	505	505

2.4 COW SALES

Of the 505 herds, 21% (105) sold cows that calved in 2011 as breeding cows (ie cows to be milked in other herds) rather than culls. Most sold relatively small numbers of cows (median 20 cows; 25th percentile 10 cows; 75th percentile 32 cows) but 15 herds sold more than 50 cows.

2.5 NUMBERS OF LACTATIONS AND HERDS BY FEEDING SYSTEM

Lactations commencing in 2011 were assumed to be exposed to the 2011/12 feeding system, lactations commencing in 2010 were assumed to be exposed to the 2010/11 feeding system, and so on. For Holstein cows, over 11,000 lactations were enrolled in each feeding system (Table 2.7). However, lactations within hybrid and TMR feeding systems were from relatively few herds. There were far fewer lactations from Jersey cows, with few Jerseys in the hybrid feeding system and virtually none in the TMR feeding system (Table 2.8).

Table 2.7 Numbers of lactations analysed from Holstein cows and numbers of herds providing these lactations, by year and feeding system

	Feeding system					Pooled
	Low bail	Mod-high bail	PMR	Hybrid	TMR	
2008						
No. lactations*	10,821	37,615	8,747	4,144	2,947	64,274
No. herds	88	264	39	17	5	413
2009						
No. lactations*	9,163	37,208	10,406	4,159	3,069	64,005
No. herds	80	266	47	16	5	414
2010						
No. lactations*	7,581	38,131	11,252	3,385	2,641	62,990
No. herds	68	287	56	13	4	428
2011						
No. lactations*	6,614	37,232	10,216	2,913	2,613	59,588
No. herds	66	294	59	11	5	435
Pooled						
No. lactations*	34,179	150,186	40,621	14,601	11,270	250,857
No. herds**	103	317	65	20	6	511

*No. lactations with values for milk volume, cow's sire's Australian Profit Ranking, age; duplicate calvings excluded
**One herd could contribute lactations to different feeding systems in different years

Table 2.8 Numbers of lactations analysed from Jersey cows and numbers of herds providing these lactations, by year and feeding system

	Feeding system					Pooled
	Low bail	Mod-high bail	PMR	Hybrid	TMR	
2008						
No. lactations*	2,270	7,743	815	188	1	11,017
No. herds	43	105	8	3	1	160
2009						
No. lactations*	2,325	7,885	848	239	1	11,298
No. herds	39	116	10	5	1	171
2010						
No. lactations*	1,944	7,965	991	45	1	10,946
No. herds	34	126	10	3	1	174
2011						
No. lactations*	2,223	7,263	1,165	29		10,680
No. herds	34	119	12	4		169
Pooled						
No. lactations*	8,762	30,856	3,819	501	3	43,941
No. herds**	54	146	13	5	2	220

*No. lactations with values for milk volume, cow's sire's Australian Profit Ranking, age; duplicate calvings excluded
**One herd could contribute lactations to different feeding systems in different years

2.6 MILK PRODUCTION

Milk production variables are summarised in Tables 2.9 and 2.10. **For all milk yield variables, variation was greater between lactations within herds than between herds.**

Table 2.9 Means (and standard deviations) for milk production variables for lactations analysed from Holstein cows by feeding system

Milk production variable	Feeding system					Pooled
	Low bail	Mod-high bail	PMR	Hybrid*	TMR*	
Milk volume (l)	6121 (1724**)	7290 (2115)	7871 (2421)	8422 (2394)	9471 (3122)	7389 (2307)
	(1017***/1503****)	(1110/1844)	(1127/2194)	(1977/2218)	(1516/2984)	(1254/1956)
Fat yield (kg)	247 (71)	283 (81)	294 (88)	314 (91)	354 (117)	285 (86)
	(39/62)	(41/73)	(36/82)	(72/84)	(45/114)	(43/76)
Protein yield (kg)	201 (56)	239 (68)	257 (77)	274 (76)	298 (96)	242 (73)
	(32/49)	(36/59)	(36/70)	(65/70)	(48/92)	(40/62)
Fat percentage	4.06 (0.52)	3.92 (0.56)	3.79 (0.64)	3.77 (0.58)	3.79 (0.63)	3.90 (0.58)
	(0.31/0.47)	(0.25/0.51)	(0.28/0.55)	(0.43/0.54)	(0.23/0.62)	(0.28/0.52)
Protein percentage	3.29 (0.24)	3.30 (0.26)	3.27 (0.25)	3.27 (0.25)	3.16 (0.27)	3.29 (0.26)
	(0.12/0.22)	(0.13/0.23)	(0.10/0.23)	(0.13/0.24)	(0.08/0.26)	(0.12/0.23)

* Based on relatively few herds; for numbers of herds, see Table 10
**Pooled standard deviation
*** Between herd standard deviation (ie standard deviation of herd means)
**** Within-herd standard deviation, calculated as square root of residual mean square from ANOVA after fitting herd as a fixed effect

Table 2.10 Means (and standard deviations) for milk production variables for lactations analysed from Jersey cows by feeding system

Milk production variable	Feeding system					Pooled
	Low bail	Mod-high bail	PMR*	Hybrid*	TMR*	
Milk volume (l)	4033 (1270**) (996***/1027****)	5235 (1472) (1038/1332)	6201 (1660) (892/1629)	6568 (1795) (458/1755)	7730 (1736) (1416/1831)	5095 (1578) (1109/1313)
Fat yield (kg)	204 (68) (52/57)	258 (73) (45/67)	306 (84) (66/82)	318 (90) (39/82)	429 (41) (47/17)	252 (79) (54/67)
Protein yield (kg)	152 (48) (34/39)	197 (55) (35/50)	238 (64) (39/62)	245 (65) (17/63)	258 (40) (48/12)	192 (60) (39/49)
Fat percentage	5.08 (0.87) (0.39/0.83)	4.95 (0.58) (0.40/0.54)	4.95 (0.58) (0.40/0.56)	4.87 (0.64) (0.43/0.58)	5.80 (1.67) (1.71/1.29)	4.97 (0.65) (0.44/0.61)
Protein percentage	3.77 (0.26) (0.17/0.24)	3.77 (0.27) (0.21/0.24)	3.84 (0.26) (0.14/0.25)	3.73 (0.23) (0.07/0.23)	3.40 (0.63) (0.08/0.89)	3.78 (0.27) (0.20/0.24)

* Based on relatively few herds (and, for hybrid and TMR feeding systems, few lactations); for numbers of herds and lactations, see Table 11
**Pooled standard deviation
*** Between herd standard deviation (ie standard deviation of herd means)
**** Within-herd standard deviation, calculated as square root of residual mean square from ANOVA after fitting herd as a fixed effect

2.7 RECALVED BY 20 MONTHS

In total, recalved by 20 months could be ascertained for 218,328 lactations; for 66% of these, the cow recalved by 20 months.

Most cows that did not recalve by 20 months had lactations of less than 18 months and no subsequent calving date recorded. For 21% of the lactations where the cow did not recalve by 20 months, she was dried off more than 18 months after calving (Table 2.11)(19%, 23%, 21%, 17%, and 16% for the low bail, mod-high bail, PMR, hybrid and TMR feeding systems, respectively). For 19% of the lactations where the cow did not recalve by 20 months, the cow had a calving recorded more than 20 months after calving (19%, 21%, 17%, 16%, and 6% for the low bail, mod-high bail, PMR, hybrid and TMR feeding systems, respectively). As the data were truncated, the actual percentages of cows that recalved more than 20 months after calving would have been higher than these.

Table 2.11 Cumulative distributions of lactation durations* for lactations where the cow did not recalve by 20 months by feeding system

Lactation duration (months)	Feeding system					Pooled
	Low bail	Mod-high bail	PMR	Hybrid	TMR	
No. lactations	9,613	42,879	12,350	4,816	3,516	73,174
% (no.) with termination date recorded	97% (9,305)	91% (39,099)	88% (10,839)	94% (4,524)	95% (3,341)	92% (67,108)
0 to <1	1%	1%	2%	2%	2%	1%
1 to <2	4%	4%	5%	5%	5%	4%
2 to <3	7%	7%	9%	9%	9%	8%
3 to <4	10%	10%	13%	12%	13%	11%
4 to <5	14%	14%	17%	15%	17%	14%
5 to <6	17%	17%	21%	17%	21%	18%
6 to <7	22%	21%	24%	21%	26%	22%
7 to <8	29%	26%	28%	25%	32%	27%
8 to <9	38%	32%	34%	30%	38%	33%
9 to <10	51%	41%	41%	37%	46%	42%
10 to <11	60%	50%	50%	47%	53%	51%
11 to <12	65%	56%	56%	54%	60%	57%
12 to <13	69%	61%	61%	59%	65%	62%
13 to <14	72%	65%	65%	64%	70%	66%
14 to <15	74%	68%	69%	70%	74%	69%
15 to <16	76%	71%	72%	75%	78%	72%
16 to <17	78%	74%	76%	78%	81%	75%
17 to <18	81%	77%	79%	83%	84%	79%
18 to <19	85%	82%	83%	87%	87%	83%
19 to <20	89%	86%	88%	90%	90%	87%
≥20	100%	100%	100%	100%	100%	100%

*Cumulative % of lactations where termination date was recorded

Percentages of lactations where the cow recalved by 20 months are summarised in Tables 2.12 and 2.13. Percentages of lactations where the cow recalved by 20 months were highest in the low bail feeding system and lowest in the TMR feeding system, and were slightly higher for Jerseys. Percentages were highest in seasonal calving herds and lowest in year-round calving herds. This percentage was 69% in seasonal calving herds. In these herds, this means that approximately 69% of cows that calved in any particular study year recalved during the calving period in the following year. Accordingly, if herd size is to be maintained, each year 31% of cows that calve are replaced with heifers (either reared or purchased), introduced cows and carryover cows that previously calved two or more years earlier.

Table 2.12 Percentages of lactations where the cow recalved by 20 months (and numbers of lactations analysed*) by breed and feeding system

Breed	Feeding system					Pooled
	Low bail	Mod-high bail	PMR	Hybrid	TMR	
Holstein	69.8% (26,097)	66.5% (107,702)	64.4% (31,807)	61.6% (12,007)	59.8% (8,738)	65.9% (186,351)
Jersey	73.1% (6,406)	69.6% (22,282)	62.5% (2,694)	65.5% (591)	25.0% (4)	69.6% (31,977)

*No. lactations with values for recalved by 20 months, cow's sire's Australian Profit Ranking, and age; duplicate calvings excluded but all eligible study lactations foreach cow included

Table 2.13 Percentages of lactations where the cow recalved by 20 months (and numbers of lactations analysed*) by calving system and feeding system

Calving system	Feeding system					Pooled
	Low bail	Mod-high bail	PMR	Hybrid	TMR	
Seasonal calving	72.6% (18,684)	68.4% (52,362)	63.7% (9,619)	58.7% (2,076)		68.6% (82,741)
Split calving	67.0% (8,568)	67.4% (47,807)	67.5% (13,244)	62.3% (5,489)		67.0% (75,108)
Year-round calving	68.9% (4,775)	65.1% (27,748)	62.5% (10,537)	61.5% (4,130)	59.8% (8,742)	63.9% (55,932)
Calving system not classified	61.1% (476)	46.6% (2,067)	44.3% (1,101)	67.1% (903)		51.7% (4,547)

*No. lactations with values for recalved by 20 months, cow's sire's Australian Profit Ranking, and age; duplicate calvings excluded but all eligible study lactations foreach cow included

Calculated percentages of lactations where the cow recalved by 20 months would be biased low if not all recalvings had been submitted to the ADHIS database. To explore this, herd-years in the study dataset where less than 50% of cows that calved had a recalving by 20 months recorded were identified; exclusion of these only slightly increased these percentages.

2.8 SHORT LACTATIONS

Lactation length was not available because dry-off date was not recorded for 3.6% (16,106) of the 450,384 lactations. For remaining lactations, percentages that were short (ie less than 120 days) are summarised in Table 2.14.

Table 2.14 Percentages of lactations that were short (and numbers of lactations whose length was known*) by breed and feeding system

Breed	Feeding system					Pooled
	Low bail	Mod-high bail	PMR	Hybrid	TMR	
Holstein	2.9% (33,183)	3.2% (143,351)	4.2% (38,834)	3.8% (13,918)	5.5% (10,906)	4.0% (128,906)
Jersey	3.3% (8,701)	3.8% (29,842)	4.2% (3,567)	4.8% (500)	0.0% (3)	4.6% (22,567)

*No. lactations with values for lactation length, cow's sire's Australian Profit Ranking, and age; duplicate calvings excluded but all eligible study lactations for each cow included

2.9 AUSTRALIAN PROFIT RANKINGS

Distributions of Australian Profit Rankings are summarised in Figures 2.1 to 2.4.

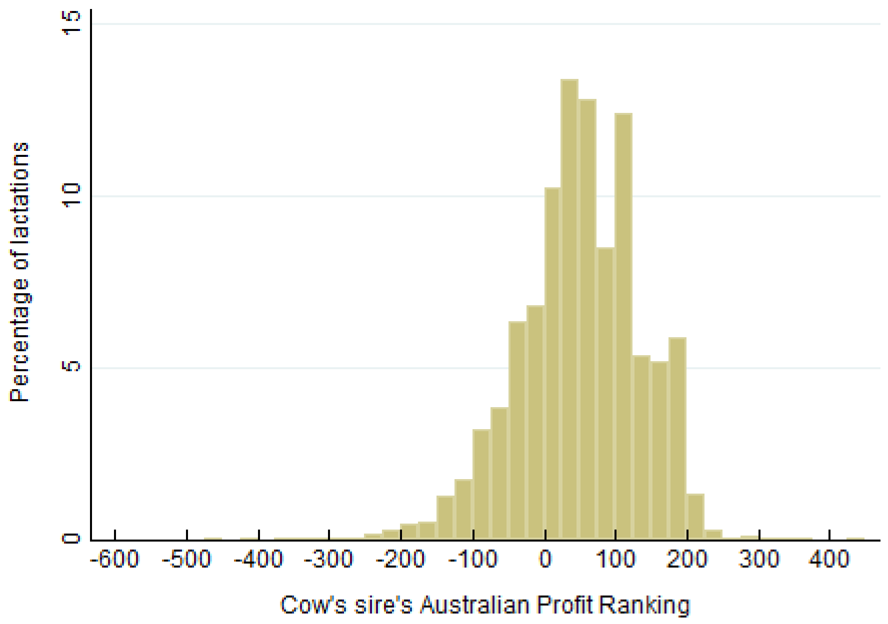


Figure 2.1 Distribution of cow's sire's Australian Profit Rankings for Holstein cows whose lactations were analysed, pooled across feeding system.

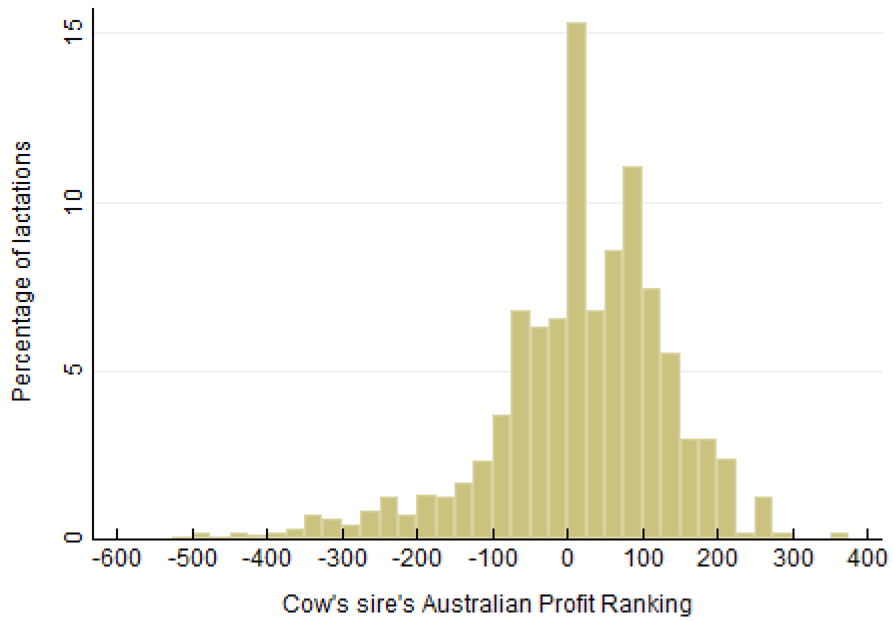


Figure 2.2 Distribution of cow's sire's Australian Profit Rankings for Jersey cows whose lactations were eligible for analyses, pooled across feeding system.

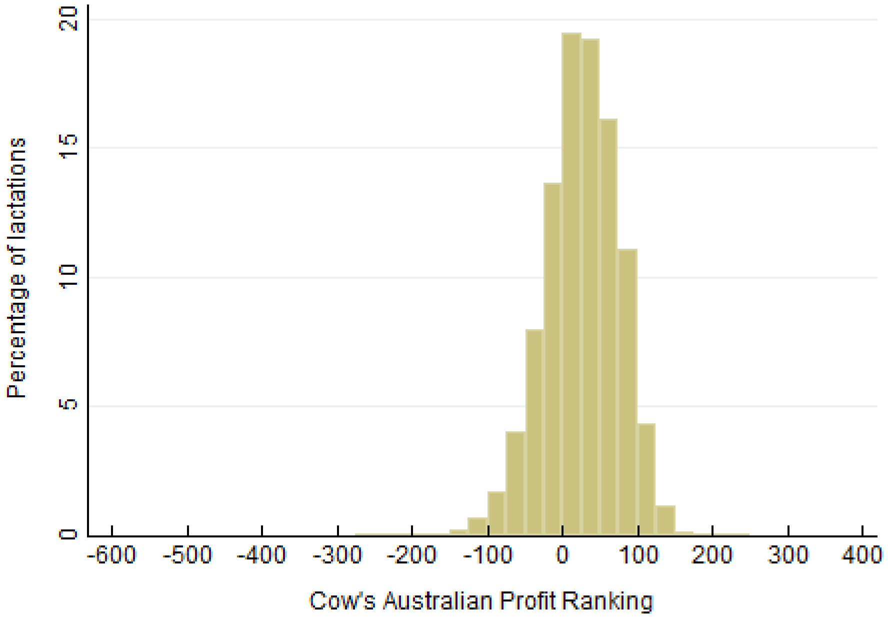


Figure 2.3 Distribution of cow's Australian Profit Rankings (estimated based on values for the sire and maternal grandsire) for Holstein cows whose lactations were analysed, pooled across feeding system.

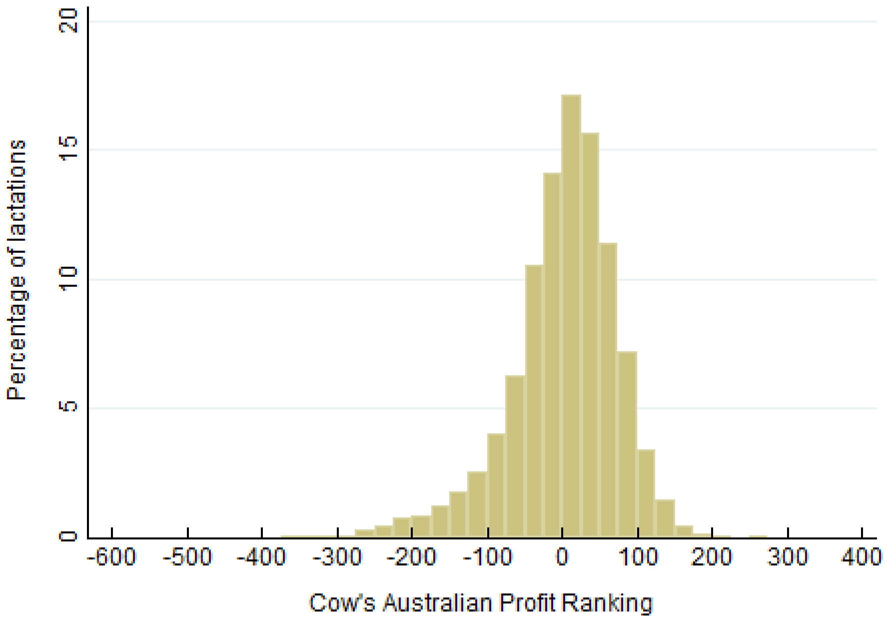


Figure 2.4 Distribution of cow's Australian Profit Rankings (estimated based on values for the sire and maternal grandsire) for Jersey cows whose lactations were analysed, pooled across feeding system.

The highest sire Australian Profit Rankings for study cows were similiar to those for current highest-ranked sires (Figures 2.5 and 2.6).

Holstein Profit

PROFIT RANK	BULL ID	BULL NAME	GENETIC CODES	GENOMICS INCLUDED	AUSTRALIAN PROVEN OR INTERNATIONAL	PROFIT: APR	PROFIT: RELIABILITY	PRODUCTION: ASI	PRODUCTION: RELIABILITY	AUSTRALIAN DAUGHTERS	AUSTRALIAN HERDS	FOREIGN DAUGHTERS FIRST	LONGEVITY: SURVIVAL	LONGEVITY: RELIABILITY	TYPE: OVERALL TYPE	TYPE: MAMMARY SYSTEM	TYPE: RELIABILITY	SOURCE
1	**ROUMARE**	ROUMARE		g	A	**316**	94	254	97	387	84		107	87	106	106	95	CRV
2	**GGGUARINI**	GUARINI-ET	TV		I	**309**	63	177	66			151	109	47	111	111	63	ABS
3	**29H013664**	MORNINGVIEW LEVI			I	**303**	59	175	66			159	107	54	105	104	63	ABS
4	**ROUFECTOR**	BUNDALONG ROUFECTOR		g	A	**295**	75	243	81	66	29		107	63	111	108	76	ALT
5	**NZGREMEDEE**	VAN HEUVENS VA REMEDY S1F			I	**294**	53	219	67			79	104	37	94	92	61	LIC
6	**29H012470**	INDUKS BABYLON		g	A	**288**	81	196	87	73	34		103	68	101	100	75	ABS
7	**USEAGE**	KAARMONA CALEB		g	A	**285**	84	199	90	100	45		108	69	102	109	78	GAC
8	**WYMAN**	PIROLO GOLDW. WYMAN			I	**285**	57	180	65			129	109	47	110	109	58	GAC
9	**REALM**	ECLIPSE ROUMARE REALM		g	A	**284**	71	271	77	57	28		105	59	98	102	70	GAC
10	**CARMARE**	KAARMONA CARMARE		g	A	**282**	69	212	73	41	22		106	60	105	103	72	GAC
11	**SHOLTZ**	ST. CLAIR SHOLTZ-TWIN			A	**281**	72	198	80	48	26		105	58	105	103	72	ABS
12	**7H9321**	RALMA GOLD CROWN		g	A	**281**	78	145	84	46	18		109	69	101	101	77	GAC
13	**CRVSTRAVA**	HSS R STRAVAGANZA S1F			I	**278**	52	225	65			56	105	36	102	102	61	CRV
14	**29H011942**	WA-DEL JUNCTION		g	I	**278**	74	175	76			2777	106	69	104	99	76	ABS
15	**WESTGATE**	GALLRAE JOCKO 3438		g	A	**269**	82	178	88	94	46		110	66	111	108	78	GAC
16	**NZGLANDSPER**	WESTLAND CL JASPER		g	I	**263**	66	153	75			97	105	48	85	83	60	LIC
17	**DEANCOX**	MANNA FARM DEANCOX		g	A	**262**	81	197	87	86	41		106	66	108	104	77	GAC
18	**DELSANTO**	MANNA FARM DEL SANTO		g	A	**261**	81	230	89	95	48		102	64	110	110	64	GAC
19	**NZGBLITZER**	GREENWELL TF BLITZ-ET S3F		g	I	**258**	70	212	80			1023	102	53	97	93	62	LIC
20	**COGENTTWIST**	COGENT TWIST	TLTV		I	**258**	62	191	69			83	106	48	105	103	63	ALT
21	**VOUSTERMAN**	VOUSTER			I	**258**	65	182	72			105	103	47	101	98	61	AGR
22	**CRVOMANOSCAR**	D OSCAR			I	**255**	66	144	68			197	106	54	100	99	62	CRV
23	**VIKLIMBO**	D LIMBO			I	**254**	68	174	69			2089	105	56	99	100	65	VIK
24	**CURIO**	COUNTRY ROAD ROUMARE CURIO		g	A	**253**	68	228	71	35	22		105	59	105	102	70	GAC
25	**HOMANIFOLD**	MAINSTREAM MANIFOLD			I	**253**	69	170	73			1848	106	53	105	104	70	SEM
26	**CRVMACCA**	MARCHEL FIRENZE MACCA			I	**253**	61	165	75			492	104*	43				CRV
27	**BOSLIEUTENT**	HSS R LIEUTENANT		g	I	**250**	71	212	77			78	105	59	102	102	70	CRV
28	**DOUBLEDUTCH**	DOUBLE DUTCH DT BENITO - ET			I	**250**	55	149	63			87	106	47	108	107	60	AGR
29	**NZGHOSANNA**	VALDEN HI APPLAUSE S2F		g	A	**248**	90	183	98	600	43		104	72	85#	83#	67	LIC
30	**BUDDHA**	BUSHLEA PERFECTOR BOLD-ET		g	A	**246**	82	175	89	99	47		104	67	109	106	79	GAC
31	**STOLJOC**	STOL JOC		g	A	**239**	90	194	93	108	40		106	82	107	105	89	AGR
32	**NZGWARDSBANQ**	EDWARDS BANQ OVATION		g	I	**238**	66	141	76			77	103	49	92	91	61	LIC
33	**7H10606**	DE-SU OBSERVER			I	**237**	59	132	67			218	109*	56	111	115	61	GAC
34	**NZGMETEORET**	WOODCOTE GR METEOR-ET S3F		g	I	**236**	68	136	79			1150	103	51	80	78	62	LIC
35	**29H013083**	SCHILLVIEW GARRETT		g	I	**236**	74	115	77			2442	108	68	107	102	78	ABS
36	**7H8081**	ENSENADA TABOO PLANET ET	TRTVTL		A	**235**	93	158	97	351	79		106	82	105	111	95	GAC
37	**CRVASTRO**	DELTA ASTRO			I	**232**	65	175	71			224	106	46	107	108	67	CRV
38	**CBTIERGAN**	BALLYCAIRN TIERGAN	TLTV		I	**232**	62	160	69			82	106	48	109	110	64	ALT
39	**BOSMEGASTUD**	AMBZED P MEGASTUD			I	**231**	68	162	76			3503	104	51	100	103	70	CRV
40	**NZGMILLER**	GLENMEAD MILLER		g	A	**230**	86	155	93	152	31		101	72	95	96	78	LIC
41	**GOLDPIPER**	CLYDEVALE SHOTTLE PERSIS		g	A	**230**	78	148	85	70	38		104	62	100	103	73	AGR
42	**29H012772**	BALLYCAIRN OMAN PELLO			A	**229**	76	150	83	53	25		104	66	96	96	80	ABS
43	**COCONUT**	COCONUT			I	**227**	59	121	67			70	104*	42	101	105	51	AGR
44	**COPIER**	CURRAJUGLE COPIER-ET			A	**225**	80	124	88	92	41		109	62	106	106	73	GAC
45	**THROTTLE**	ELMAR THROTTLE		g	A	**225**	83	75	89	103	49		108	69	105	110	82	ABS
46	**SHOTTLE**	PICSTON SHOTTLE		g	A	**225**	98	67	99	1609	351		110	94	109	106	98	ABS
47	**ALTASHOOTER**	KOEPON ALTASHOOTER			I	**224**	56	163	64			135	106*	47	109	108	57	ALT
48	**29H013363**	COPPERTOP DOBERMAN			I	**224**	57	131	64			111	106	52	110	109	60	ABS
49	**GGGUNNAR**	GUNNAR-ET	TV		I	**223**	59	142	66			119	108	49	112	114	61	ABS
50	**BOSFREDDIE**	BADGER-BLUFF FANNY FREDDIE			I	**221**	68	95	72			4243	108	61	110	107	68	AGR

Figure 2.5 Top 50 Holstein sires on Australian Profit Ranking; Good Bulls Guide, ADHIS, April 2013, page 6.

Jersey Profit

					PROFIT		PRODUCTION					LONGEVITY		TYPE			
PROFIT RANK	BULL ID	BULL NAME	GENOMICS INCLUDED	AUSTRALIAN PROVEN OR INTERNATIONAL	APR	RELIABILITY	ASI	RELIABILITY	AUSTRALIAN DAUGHTERS	AUSTRALIAN HERDS	FOREIGN DAUGHTERS FIRST	SURVIVAL	RELIABILITY	OVERALL TYPE	MAMMARY SYSTEM	RELIABILITY	SOURCE
1	**SANDBLAST**	NOWELL SANDBLAST	g	A	**320**	82	246	88	94	27		102	68	110	112	77	AGR
2	**TBONE**	RICHIES JACE TBONE A364		A	**272**	82	202	87	67	24		106	72	118	115	83	AGR
3	**ELTON**	CAIRNBRAE JACES ELTON	g	A	**266**	93	214	98	913	168		105	78	110	108	87	ABS
4	**NZGLOTJESTER**	HILLSTAR LOT JESTER S3J		I	**258**	53	200	67			68	105	33	97	97	55	LIC
5	**BOSMURMUR**	OKURA LIKA MURMUR S3J		I	**256**	60	209	71			94	104	42	99	99	53	CRV
6	**29JE3678**	CAL-MART NAVARA BLADE	g	I	**252**	56	188	69			141						ABS
7	**CRVMANZELLO**	PUKEROA TGM MANZELLO		I	**248**	59	214	72			250	103	37	97	96	59	CRV
8	**VANAHLEM**	PANNOO ABE VANAHLEM	g	A	**241**	76	179	81	50	26		107	62	123	117	74	ALT
9	**VAVOOM**	ROCKLEIGH PARK VALERIAN VAVOOM	g	A	**236**	72	234	79	53	21		102	59	102	99	71	ABS
10	**29JE3624**	ALL LYNNS MAXIMUM VERNON-ET		I	**233**	54	189	64			77	104	43	112	104	53	ABS
11	**LARFALOT**	LIGHTWOOD LUCRATIVE	g	A	**230**	93	187	98	894	193		105	81	110	106	90	GAC
12	**NZGHAYWARDS**	HAYWARDS TGM AIM S3J	g	I	**224**	66	222	77			1923	100	45	94	95	59	LIC
13	**VIKLURE**	VJ LURE		I	**221**	57	168	63			72	103*	40	98	93	45	VIK
14	**VIKJANTE**	DJ JANTE	g	I	**220**	69	130	76			1134	106	59	110	103	64	VIK
15	**NZGGEORGEY**	CENTRAL VALLEY GEORGE S3J	g	I	**219**	58	202	70			72	100	34	89	91	52	LIC
16	**NZGGREENY**	GREENPARK OM TARGET	g	I	**206**	69	219	79			6458	102	50	98	94	63	LIC
17	**GAINFUL**	KAARMONA GALEAO	g	A	**205**	82	174	88	84	46		105	67	114	111	75	GAC
18	**TAILBOARD**	NOWELL TARSAN	g	A	**203**	97	165	99	1246	239		103	91	105	103	88	GAC
19	**NZGSPEEDWAY**	KELLAND KC SPEEDWAY		I	**201**	50	199	64			66	103	32	101	101	56	LIC
20	**VIKHULK**	DJ HULK	g	I	**200**	62	177	70			2314	101	53	89	90	59	VIK
21	**CRVARRIETA**	ARRIETA TGM DIABLO ET		I	**200**	57	176	70			98	104	35	100	99	57	CRV
22	**NZGGLENGENI**	GLENHAVEN TGM GENIUS S3J	g	I	**199**	68	194	78			2034	102	48	91	95	59	LIC
23	**NZGFROSTING**	FOXTON NN FROSTY S3J	g	I	**198**	60	187	71			91	100	37	88	91	54	LIC
24	**0200JE00060**	BW RENEGADE	g	I	**197**	65	156	73			1766	103*	55	109	103	65	SEM
25	**AMBMANHATTEN**	OKURA MANHATTEN-ET SJ3	g	A	**194**	98	212	99	1732	246		100	95	98	95	95	CRV
26	**NZGCAPSGOLD**	PUHIPUHI CAPS GOLDIE S3J	g	I	**190**	61	176	73			151	103	38	100	95	55	LIC
27	**CRVCANAAN**	CANAAN NEVVY PIONEER		I	**188**	55	171	67			63	102	33	97	98	50	CRV
28	**DELIAN**	LOXLEIGH DELIAN	g	A	**187**	74	182	81	64	36		104	60	113	107	72	GAC
29	**NZGTOFFEEMAN**	LYNBROOK JONO TOFFEEMAN		I	**187**	52	154	66			76	102	31	100	100	56	LIC
30	**BOSDJZUMA**	DJ ZUMA		I	**183**	66	80	68			1460	106	46	102	104	56	CRV
31	**VALERAGAY**	BROADLIN 2429 VALERIAN	g	A	**179**	72	157	78	54	28		102	59	103	99	70	GAC
32	**NZGOKURAICE**	OKURA DE ICE	g	I	**179**	66	144	76			89	103	46	97	98	59	LIC
33	**29JE3487**	CAL-MART JACE SIMBA	g	I	**179**	71	144	78			129	104	61	110	102	68	ABS
34	**29JE3615**	SUN VALLEY IMPULS JUPITER		I	**175**	55	152	64			100	104	47	106	101	57	ABS
35	**NZGEDIFY**	DONALDS EDIFY	g	I	**175**	71	130	79			19669	101	54	90	96	64	LIC
36	**NZGIVINS**	OKURA LFB IVINS	g	I	**174**	67	142	76			7988	104	50	99	98	63	LIC
37	**NZGJOSKIN**	TIRONUI OM JOSKIN	g	I	**172**	64	170	74			68	101	46	100	97	58	LIC
38	**BOSCANYON**	SUNSET CANYON ANTHEMS ALLSTAR		I	**172**	57	136	68			300	104	50	109	105	62	AGR
39	**NZGDODDY**	MAGHERACANON DODDY GR	g	A	**171**	92	150	97	529	72		101	83	93#	98#	76	LIC

Figure 2.6 Top 39 Jersey sires on Australian Profit Ranking; Good Bulls Guide, ADHIS, April 2013, page 13.

Means and standard deviations for sire Australian Profit Rankings are shown in Table 2.15. **For Holstein cows, mean sire Australian Profit Rankings were lower in the PMR, hybrid and TMR feeding systems**; variability was similiar across feeding systems. Means of sire Australian Profit Rankings were markedly lower for Jersey cows. **For both breeds, there was greater variability in sire Australian Profit Rankings within herds than between herds**.

Table 2.15 Means and standard deviations for sire Australian Profit Rankings for lactations used for milk production analyses by feeding system

	Feeding system					Pooled
	Low bail	**Mod-high bail**	**PMR**	**Hybrid**	**TMR**	
Holstein cows						
No. lactations	34,179	150,186	40,621	14,601	11,270	250,857
No. herds*	103	317	65	20	6	511
Sire Australian Profit Rankings	52 (85**) (45***/76****)	54 (84) (43/76)	45 (84) (43/77)	42 (89) (47/82)	35 (85) (44/81)	51 (85) (44/77)
Jersey cows						
No. lactations	8,762	30,856	3,819	501	3	43,941
No. herds*	54	146	13	5	2	220
Sire Australian Profit Rankings	21 (130**) (80***/110****)	16 (119) (79/98)	32 (97) (57/94)	36 (81) (62/78)	-56 (113) (69/139)	19 (119) (78/100)

* One herd could contribute lactations to different feeding systems in different years
**Pooled standard deviation
*** Between herd standard deviation (ie standard deviation of herd means)
**** Within-herd standard deviation, calculated as square root of residual mean square from ANOVA after fitting herd as a fixed effect

2.10 REPORTING OF EFFECTS OF INCREASES IN AUSTRALIAN PROFIT RANKING

Estimated effects of (ie increases in) Australian Profit Ranking are reported per 50 unit increase in Australian Profit Ranking. For sire Australian Profit Rankings in April 2013, the difference between the first and sixteenth listed Holstein sires was approximately 50 units (Figure 2.5). For Jersey sires, the difference between the second and thirteenth listed sires was approximately 50 units (Figure 2.6).

For cow Australian Profit Rankings, 50 units equates to about half to two-thirds of the within-herd standard deviation (Table 2.15). Assuming cow Australian Profit Rankings within herds have a normal distribution, for a herd with this standard deviation, 50 units equates to the difference between the 25th or 30th percentile cow and the herd's mean Australian Profit Ranking.

CHAPTER 3. EFFECTS OF AUSTRALIAN PROFIT RANKING AND AUSTRALIAN BREEDING VALUES BY FEEDING SYSTEM

3.1 OBJECTIVES

The following research objectives are addressed in this chapter:

- to estimate the effects of Australian Profit Ranking on milk production, recalving by 20 months and occurrence of short lactations in Holstein and Jersey cows in commercial Australian dairy herds using various feeding systems, and to ascertain whether these effects differ substantially between herds with different feeding systems, and
- to investigate the effects of various Australian Breeding Values on the associated milk production trait or on recalving by 20 months in Holstein and Jersey cows, and to ascertain whether these effects differ substantially between herds with different feeding systems.

3.2 CONCLUSIONS

MILK PRODUCTION

For Holstein cows, increases in Australian Profit Ranking and Australian Breeding Values result in increased milk volume, and fat and protein yield in all feeding systems. The effects of increases in Australian Profit Ranking and Australian Breeding Values for specific traits are smallest in the low bail feeding system and largest in the total mixed ration feeding system.

For Jersey cows in herds using low and moderate to high bail feeding systems and partial mixed ration feeding, increases in both Australian Profit Ranking and Australian Breeding Values increase milk volume, and fat and protein yields. Increases in milk volume, and fat and protein yield are smaller for the low bail feeding system than for the other two feeding systems.

ABILITY TO LAST IN THE HERD

Cows with higher Australian Profit Rankings are just as likely (if not more likely) to last in the herd as cows with lower genetic merit.

For Holsteins, cows with higher Australian Breeding Values for daughter fertility and survival are more likely to recalve by 20 months in all feeding systems. The effects of Australian Breeding Value for survival are smallest in the low bail feeding system and largest in the total mixed ration feeding system.

For Jersey cows in herds using low and moderate to high bail feeding systems and partial mixed ration feeding, cows with higher Australian Breeding Values for daughter fertility and survival are just as likely (if not more likely) to recalve by 20 months as cows with lower Australian Breeding Values for these traits.

Cows with higher Australian Profit Rankings have a similar risk of a short lactation to other cows in the herd.

3.3 EFFECTS ON MILK PRODUCTION IN HOLSTEINS

EFFECTS OF COW'S SIRE'S AUSTRALIAN PROFIT RANKING IN HOLSTEINS

Estimated effects of cow's sire's Australian Profit Ranking on 305-day milk production by feeding system are shown in Table 3.1. Each coefficient represents the estimated change in the milk production variable per 50 unit increase in the cow's sire's Australian Profit Ranking. For example, for each 50 unit increase in the cow's sire's Australian Profit Ranking, milk volume for the 305-day lactation was estimated to increase by 54.4 l in the low bail feeding system, and by 144.3 l in the TMR feeding system.

For all milk production variables, the overall p-value for interaction between cow's sire's Australian Profit Ranking and feeding system was <0.001, indicating that effects of increases in the cow's sire's Australian Profit Ranking on 305-day milk production vary by feeding system. However, estimated effects of increases in the cow's sire's Australian Profit Ranking on milk volume, fat and protein yield were positive in all feeding systems, and were largest in the TMR feeding system. P-values for differences in estimated effects by feeding system relative to the moderate to high feeding system are shown in Table 3.2.

Table 3.1 Estimated effects*of cow's sire's Australian Profit Ranking on 305-day milk production for lactations from Holstein cows by feeding system (95% CI)

Milk production variable	Feeding system				
	Low bail	**Mod-high bail**	**PMR**	**Hybrid**	**TMR**
Milk volume (l)	54.4 (40.1 to 68.7)	67.0 (59.8 to 74.1)	52.1 (39.1 to 65.0)	72.4 (52.3 to 92.6)	144.3 (120.9 to 167.7)
Fat yield (kg)	2.5 (1.9 to 3.0)	2.6 (2.3 to 2.8)	1.6 (1.1 to 2.1)	3.4 (2.6 to 4.1)	7.4 (6.5 to 8.3)
Protein yield (kg)	2.5 (2.0 to 2.9)	3.4 (3.1 to 3.6)	2.8 (2.4 to 3.3)	3.8 (3.2 to 4.4)	6.4 (5.7 to 7.1)
Fat percentage	-0.003 (-0.007 to 0.001)	-0.002 (-0.004 to 0.000)	-0.008 (-0.011 to -0.004)	0.006 (0.000 to 0.012)	0.015 (0.008 to 0.022)
Protein percentage	0.008 (0.006 to 0.010)	0.016 (0.015 to 0.017)	0.014 (0.012 to 0.015)	0.017 (0.015 to 0.020)	0.017 (0.014 to 0.020)

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Profit Ranking; coefficients were adjusted for age at calving; herd and cow within herd were fitted as random effects

Table 3.2 P-values for differences in estimated effects of cow's sire's Australian Profit Ranking on 305-day milk production for lactations from Holstein cows by feeding system, relative to the moderate to high bail feeding system, for each milk production variable

Milk production variable	Feeding system				
	Low bail	**Mod-high bail**	**PMR**	**Hybrid**	**TMR**
Milk volume (l)	0.115	Reference group	0.044	0.615	<0.001
Fat yield (kg)	0.700	Reference group	0.001	0.058	<0.001
Protein yield (kg)	<0.001	Reference group	0.027	0.190	<0.001
Fat percentage	0.774	Reference group	0.008	0.011	<0.001
Protein percentage	<0.001	Reference group	0.009	0.402	0.704

Results were similar after adjustment for the cow's maternal grandsire's Australian Profit Ranking (Tables 3.3 and 3.4; Figures 3.1 and 3.2). For all milk production variables, the overall p-value for interaction between cow's sire's Australian Profit Ranking and feeding system was <0.001. After adjustment, for each

50 unit increase in the cow's sire's Australian Profit Ranking, estimated milk volume increases were 54 to 68 litres in the most common feeding systems (low and high bail feeding and PMR), and 110 litres in the TMR feeding system. Fat yield increases were estimated to be 1.5 to 2.6 kg in the most common feeding systems and 6 kg in the TMR feeding system, while protein yield increases were estimated to be 2.6 to 3.4 kg in the most common feeding systems and 5 kg in the TMR feeding system. R^2 values (proportional reductions in cow-level variances after fitting cow's sire's Australian Profit Ranking, maternal grand sire's Australian Profit Ranking, and interaction between cow's sire's Australian Profit Ranking and feeding system) were negligible to small; the highest R^2 value was 7.3%, for protein yield.

Table 3.3 Estimated effects*of cow's sire's Australian Profit Ranking on 305-day milk production for lactations from Holstein cows by feeding system adjusted for the cow's maternal grandsire's Australian Profit Ranking (95% CI)

Milk production variable	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
Milk volume (l)	56.2 (40.9 to 71.5)	68.0 (60.4 to 75.6)	53.7 (39.8 to 67.7)	79.7 (58.8 to 100.6)	109.9 (75.1 to 144.8)
Fat yield (kg)	2.6 (2.0 to 3.2)	2.5 (2.2 to 2.8)	1.5 (1.0 to 2.0)	3.5 (2.7 to 4.3)	5.7 (4.4 to 7.1)
Protein yield (kg)	2.6 (2.1 to 3.1)	3.4 (3.2 to 3.6)	2.9 (2.5 to 3.4)	4.0 (3.3 to 4.6)	5.1 (4.0 to 6.2)
Fat percentage	-0.002 (-0.006 to 0.003)	-0.003 (-0.006 to -0.001)	-0.009 (-0.013 to -0.005)	0.004 (-0.002 to 0.010)	0.016 (0.006 to 0.026)
Protein percentage	0.008 (0.006 to 0.010)	0.016 (0.015 to 0.017)	0.014 (0.012 to 0.016)	0.017 (0.014 to 0.019)	0.016 (0.012 to 0.021)

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Profit Ranking; coefficients were adjusted for age at calving; herd and cow within herd were fitted as random effects

Table 3.4 P-values for differences in estimated effects of cow's sire's Australian Profit Ranking on 305-day milk production for lactations from Holstein cows adjusted for the cow's maternal grandsire's Australian Profit Ranking by feeding system, relative to the moderate to high bail feeding system (reference group or Ref. group), for each milk production variable

Milk production variable	Feeding system					R^{2*}
	Low bail	Mod-high bail	PMR	Hybrid	TMR	
Milk volume (l)	0.164	Ref. group	0.074	0.298	0.021	2.5%
Fat yield (kg)	0.875	Ref. group	0.001	0.022	<0.001	3.6%
Protein yield (kg)	0.002	Ref. group	0.061	0.112	0.002	7.3%
Fat percentage	0.529	Ref. group	0.017	0.022	<0.001	-0.1%
Protein percentage	<0.001	Ref. group	0.054	0.711	0.926	2.7%

*Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and feeding system with the full model (ie the model with cow's sire's Australian Profit Ranking, maternal grand sire's Australian Profit Ranking, and interaction between cow's sire's Australian Profit Ranking and feeding system also added)

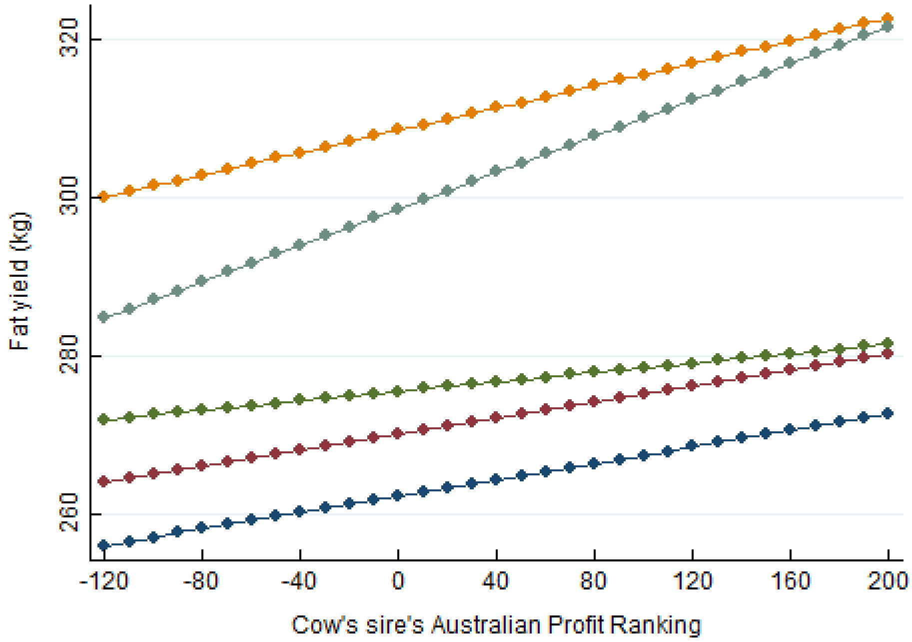


Figure 3.1 Predicted 305-day fat yields by cow's sire's Australian Profit Ranking for lactations from Holstein cows by feeding system, adjusted for the cow's maternal grandsire's Australian Profit Ranking. Feeding systems are low bail (blue), mod-high bail (red), PMR (green), hybrid (orange) and TMR (grey).

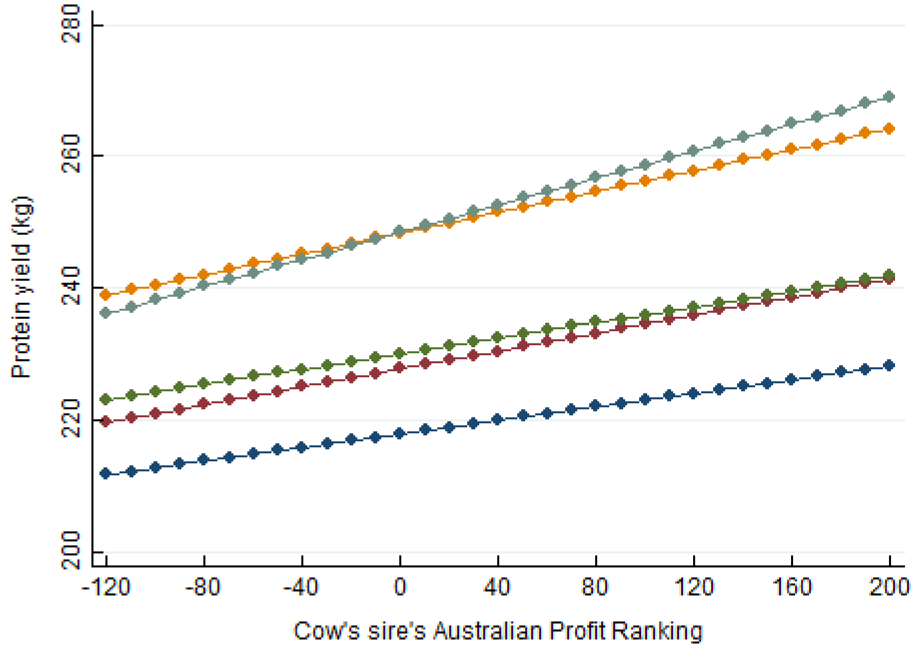


Figure 3.2 Predicted 305-day protein yields by cow's sire's Australian Profit Ranking for lactations from Holstein cows by feeding system, adjusted for the cow's maternal grandsire's Australian Profit Ranking. Feeding systems are low bail (blue), mod-high bail (red), PMR (green), hybrid (orange) and TMR (grey).

To assess for curvilinear effects of cow's sire's Australian Profit Ranking on milk production, linear and quadratic terms for cow’s sire’s Australian Profit Ranking were fitted simultaneously. Estimated increases in milk production per 50 units increase in sire Australian Profit Ranking were estimated at each of the 5th percentile, mean and 95th percentile of sire Australian Profit Ranking (Table 3.5). P-values for interactions that included the quadratic term were <0.001, 0.380, 0.003, <0.001 and <0.001, for milk volume, fat yield, protein yield, fat percentage and protein percentage, respectively. Thus, for fat yield, these results provided no support for curvilinear effects of cow's sire's Australian Profit Ranking. For milk volume and protein yield, within all systems, estimated effects of the cow's sire's Australian Profit Ranking were higher at higher Australian Profit Rankings.

Table 3.5 Estimated effects*of cow’s sire’s Australian Profit Ranking on 305-day milk production for lactations from Holstein cows by feeding system adjusted for the cow’s maternal grandsire’s Australian Profit Ranking (95% CI) at each of the 5th percentile, mean and 95th percentile of sire Australian Profit Ranking after fitting linear and quadratic terms

Milk production variable	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
Milk volume (l)					
-104**	21.9 (-14.4 to 58.1)	37.0 (19.4 to 54.5)	49.7 (15.9 to 83.5)	50.3 (5.6 to 95.0)	78.0 (0.5 to 155.5)
41**	57.0 (41.7 to 72.3)	68.2 (60.6 to 75.8)	53.9 (39.9 to 67.8)	81.2 (60.2 to 102.2)	114.8 (77.7 to 152.0)
178**	90.2 (54.2 to 126.2)	97.7 (80.7 to 114.6)	57.8 (24.3 to 91.2)	110.4 (64.1 to 156.8)	149.6 (53.1 to 246.2)
Fat yield (kg)					
-104	2.0 (0.6 to 3.4)	2.9 (2.3 to 3.6)	1.1 (-0.2 to 2.4)	3.8 (2.1 to 5.5)	3.7 (0.7 to 6.6)
41	2.6 (2.0 to 3.2)	2.5 (2.2 to 2.8)	1.5 (1.0 to 2.0)	3.5 (2.7 to 4.3)	6.1 (4.7 to 7.6)
178	3.2 (1.8 to 4.5)	2.2 (1.5 to 2.8)	1.8 (0.6 to 3.1)	3.3 (1.5 to 5.0)	8.5 (4.8 to 12.2)
Protein yield (kg)					
-104	1.2 (0.1 to 2.3)	2.7 (2.2 to 3.3)	2.4 (1.4 to 3.5)	3.5 (2.1 to 4.9)	3.0 (0.6 to 5.5)
41	2.6 (2.1 to 3.1)	3.4 (3.2 to 3.6)	2.9 (2.5 to 3.4)	4.0 (3.3 to 4.6)	5.5 (4.3 to 6.7)
178	3.9 (2.8 to 5.1)	4.0 (3.5 to 4.6)	3.4 (2.3 to 4.5)	4.4 (3.0 to 5.9)	7.9 (4.8 to 10.9)
Fat percentage					
-104	-0.001 (-0.011 to 0.010)	0.019 (0.013 to 0.024)	-0.009 (-0.019 to 0.001)	0.022 (0.008 to 0.035)	0.003 (-0.018 to 0.025)
41	-0.002 (-0.006 to 0.003)	-0.003 (-0.006 to -0.001)	-0.009 (-0.013 to -0.005)	0.003 (-0.003 to 0.009)	0.020 (0.009 to 0.031)
178	-0.003 (-0.013 to 0.008)	-0.024 (-0.030 to -0.019)	-0.009 (-0.019 to 0.001)	-0.014 (-0.028 to -0.001)	0.036 (0.008 to 0.064)
Protein percentage					
-104	-0.001 (-0.006 to 0.004)	0.020 (0.018 to 0.022)	0.009 (0.005 to 0.014)	0.024 (0.018 to 0.030)	0.006 (-0.004 to 0.015)
41	0.008 (0.006 to 0.010)	0.016 (0.015 to 0.017)	0.014 (0.012 to 0.016)	0.016 (0.013 to 0.019)	0.019 (0.014 to 0.024)
178	0.017 (0.013 to 0.022)	0.012 (0.010 to 0.015)	0.018 (0.014 to 0.023)	0.009 (0.003 to 0.015)	0.031 (0.019 to 0.044)

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow’s sire’s Australian Profit Ranking at the specified Australian Profit Ranking value; coefficients were adjusted for age at calving; herd and cow within herd were fitted as random effects
**5th percentile, mean and 95th percentile of sire Australian Profit Rankings

EFFECTS OF COW'S AUSTRALIAN PROFIT RANKING IN HOLSTEINS

Each cow's Australian Profit Ranking was estimated based on her sire's and maternal grandsire's Australian Profit Rankings (see above).

Estimated effects of cow's Australian Profit Ranking on 305-day milk volume, fat and protein yields were larger than effects of cow's sire's Australian Profit Ranking (Table 3.6). For all milk production variables, the overall p-value for interaction between cow's Australian Profit Ranking and feeding system was <0.001. P-values for differences in estimated effects by feeding system relative to the moderate to high bail feeding system are shown in Table 3.7. For each 50 unit increase in the cow's Australian Profit Ranking, estimated milk volume increases were 94 to 127 litres in the most common feeding systems and 288 litres in the TMR feeding system. Fat yield increases were estimated to be 3 to 5 kg in the most common feeding systems and 15 kg in the TMR feeding system, while protein yield increases were estimated to be 5 to 6kg in the most common feeding systems and 13 kg in the TMR feeding system.

Based on theoretical responses to selection using the Australian Profit Ranking (Pryce *et al* 2010), expected effects of a 50 unit increase in the cow's Australian Profit Ranking are 112 litres, 5.0 kg fat and 4.2 kg protein (J Pryce, personal communication). Thus, in the most common feeding systems, estimated effects for milk volume and fat yield were similar to those expected, but estimated effects for protein yield were higher than that expected.

Table 3.6 Estimated effects*of cow's Australian Profit Ranking on 305-day milk production for lactations from Holstein cows by feeding system (95% CI)

Milk production variable	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
Milk volume (l)	93.5 (68.6 to 118.4)	127.3 (114.7 to 140.0)	97.0 (74.1 to 119.8)	148.1 (112.5 to 183.6)	287.4 (243.0 to 331.9)
Fat yield (kg)	4.4 (3.4 to 5.3)	4.9 (4.4 to 5.3)	3.0 (2.1 to 3.8)	6.2 (4.8 to 7.5)	14.6 (12.9 to 16.3)
Protein yield (kg)	4.5 (3.7 to 5.3)	6.4 (6.1 to 6.8)	5.5 (4.8 to 6.2)	7.6 (6.5 to 8.7)	12.7 (11.3 to 14.1)
Fat percentage	-0.004 (-0.011 to 0.004)	-0.006 (-0.010 to -0.002)	-0.015 (-0.022 to -0.008)	0.003 (-0.007 to 0.013)	0.026 (0.013 to 0.039)
Protein percentage	0.017 (0.014 to 0.021)	0.031 (0.029 to 0.033)	0.027 (0.024 to 0.030)	0.033 (0.028 to 0.037)	0.033 (0.027 to 0.039)

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's Australian Profit Ranking; coefficients were adjusted for age at calving; herd and cow within herd were fitted as random effects

Table 3.7 P-values for differences in estimated effects of cow's Australian Profit Ranking on 305-day milk production for lactations from Holstein cows by feeding system, relative to the moderate to high feeding system, for each milk production variable

Milk production variable	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
Milk volume (l)	0.014	Reference group	0.020	0.278	<0.001
Fat yield (kg)	0.365	Reference group	<0.001	0.076	<0.001
Protein yield (kg)	<0.001	Reference group	0.016	0.054	<0.001
Fat percentage	0.499	Reference group	0.018	0.095	<0.001
Protein percentage	<0.001	Reference group	0.033	0.404	0.545

To assess for curvilinear effects of cow's Australian Profit Ranking on milk production, linear and quadratic terms for cow's Australian Profit Ranking were fitted simultaneously. Estimated increases in milk production per 50 units increase in cow's Australian Profit Ranking were estimated at each of the 5th percentile, mean and 95th percentile of sire Australian Profit Ranking (Table 3.8). P-values for interactions that included the quadratic term were <0.001. For milk volume and protein yield, within all systems, estimated effects ofcow's sire's Australian Profit Ranking were higher at higher Australian Profit Rankings.

Table 3.8 Estimated effects*of cow's Australian Profit Ranking on 305-day milk production for lactations from Holstein cows by feeding system adjusted (95% CI) at each of the 5th percentile, mean and 95th percentile of sire Australian Profit Ranking after fitting linear and quadratic terms

Milk production variable	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
Milk volume (l)					
-104	3.4 (-75.5 to 82.2)	51.9 (11.6 to 92.2)	88.2 (11.2 to 165.3)	68.5 (-42.8 to 179.9)	-107.1 (-260.9 to 46.8)
41	111.3 (82.3 to 140.3)	139.2 (125.2 to 153.1)	97.7 (70.5 to 124.8)	161.6 (119.9 to 203.3)	380.4 (323.8 to 437.0)
178	213.3 (110.6 to 316.0)	221.6 (172.2 to 271.0)	106.6 (6.1 to 207.1)	249.5 (103.2 to 395.8)	841.0 (629.1 to 1,052.9)
Fat yield (kg)					
-104	3.0 (-0.1 to 6.0)	5.7 (4.2 to 7.3)	2.1 (-0.8 to 5.1)	6.0 (1.7 to 10.3)	-2.7 (-8.6 to 3.2)
41	4.7 (3.6 to 5.8)	4.7 (4.2 to 5.3)	3.1 (2.1 to 4.1)	6.1 (4.5 to 7.7)	18.7 (16.5 to 20.9)
178	6.3 (2.4 to 10.2)	3.8 (1.9 to 5.7)	4.0 (0.2 to 7.9)	6.1 (0.5 to 11.7)	39.0 (30.8 to 47.1)
Protein yield (kg)					
-104	1.3 (-1.2 to 3.7)	4.9 (3.6 to 6.1)	4.4 (2.0 to 6.8)	6.8 (3.3 to 10.3)	-2.0 (-6.9 to 2.8)
41	5.1 (4.2 to 6.1)	6.7 (6.3 to 7.1)	5.7 (4.8 to 6.5)	7.7 (6.4 to 9.0)	16.2 (14.4 to 17.9)
178	8.8 (5.6 to 12.0)	8.4 (6.9 to 10.0)	6.8 (3.7 to 10.0)	8.5 (3.9 to 13.1)	33.3 (26.7 to 40.0)
Fat percentage					
-104	0.005 (-0.018 to 0.028)	0.041 (0.029 to 0.054)	-0.021 (-0.043 to 0.001)	0.042 (0.010 to 0.074)	-0.007 (-0.050 to 0.036)
41	-0.005 (-0.013 to 0.004)	-0.014 (-0.018 to -0.009)	-0.014 (-0.021 to -0.006)	-0.006 (-0.018 to 0.006)	0.036 (0.019 to 0.054)
178	-0.014 (-0.044 to 0.016)	-0.065 (-0.080 to -0.050)	-0.006 (-0.036 to 0.023)	-0.051 (-0.093 to -0.009)	0.077 (0.016 to 0.139)
Protein percentage					
-104	0.002 (-0.008 to 0.012)	0.041 (0.036 to 0.046)	0.015 (0.005 to 0.025)	0.054 (0.040 to 0.068)	0.014 (-0.005 to 0.033)
41	0.021 (0.017 to 0.024)	0.029 (0.027 to 0.031)	0.030 (0.026 to 0.033)	0.028 (0.023 to 0.033)	0.038 (0.031 to 0.046)
178	0.038 (0.025 to 0.052)	0.018 (0.012 to 0.025)	0.044 (0.031 to 0.057)	0.003 (-0.015 to 0.022)	0.061 (0.034 to 0.088)

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's Australian Profit Ranking at the specified Australian Profit Ranking value; coefficients were adjusted for age at calving; herd and cow within herd were fitted as random effects
**5th percentile, mean and 95th percentile of sire Australian Profit Rankings

EFFECTS OF COW'S SIRE'S AUSTRALIAN BREEDING VALUE IN HOLSTEINS

Estimated effects of cow's sire's Australian Breeding Values for milk production on the corresponding milk production variable are shown in Table 3.9. Effects of Australian Breeding Value for milk volume were assessed on 305-day milk volume; effects of Australian Breeding Value for fat yield were assessed on 305-day fat yield, and so on.

For all milk production variables, the overall p-value for interaction between Australian Breeding Value and feeding system was <0.05. P-values for differences in estimated effects by feeding system relative to the moderate to high feeding system are shown in Table 3.10.

For each 10 unit increase in the cow's sire's Australian Breeding Value for milk volume, milk volume increases were estimated as 4 to 5 litres in all feeding systems. Fat yield increases for each 10 unit increase in the cow's sire's Australian Breeding Value for fat yield were estimated to be approximately 4 kg in the low and moderate to high bail feeding systems and under PMR, and 4.7 and 5.6 kg in the hybrid and TMR feeding systems, respectively, while protein yield increases for each 10 unit increase in the cow's sire's Australian Breeding Value for protein yield were estimated to be 4.3 kg in the low bail feeding system and 5.0 to 6.2 kg in the other feeding systems.

Table 3.9 Estimated effects of cow's sire's Australian Breeding Values on 305-day milk production for lactations from Holstein cows by feeding system adjusted for the cow's maternal grandsire's Australian Breeding Value (95% CI)

Milk production variable	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
Milk volume (l)*	3.9 (3.4 to 4.4)	4.8 (4.6 to 5.1)	4.8 (4.3 to 5.2)	4.5 (3.8 to 5.2)	4.4 (3.2 to 5.7)
Fat yield (kg)*	3.5 (2.9 to 4.0)	3.9 (3.6 to 4.1)	4.1 (3.6 to 4.6)	4.7 (4.0 to 5.5)	5.6 (4.4 to 6.8)
Protein yield (kg)*	4.3 (3.7 to 5.0)	5.4 (5.0 to 5.7)	5.0 (4.4 to 5.6)	5.9 (4.9 to 6.8)	6.2 (4.6 to 7.8)
Fat percentage**	0.403 (0.380 to 0.426)	0.444 (0.432 to 0.455)	0.435 (0.415 to 0.456)	0.425 (0.394 to 0.456)	0.339 (0.282 to 0.397)
Protein percentage**	0.392 (0.371 to 0.413)	0.425 (0.415 to 0.435)	0.380 (0.361 to 0.399)	0.425 (0.396 to 0.455)	0.394 (0.343 to 0.446)

*Coefficients represent estimated change in milk production variable per 10 unit increase in the cow's sire's Australian Breeding Value
**Coefficients represent estimated change in milk production variable per 1 unit increase in the cow's sire's Australian Breeding Value
All coefficients were adjusted for age at calving; herd and cow within herd were fitted as random effects

Table 3.10 P-values for differences in estimated effects of cow's sire's Australian Breeding Values on 305-day milk production for lactations from Holstein cows adjusted for the cow's maternal grandsire's Australian Breeding Value by feeding system, relative to the moderate to high bail feeding system, for each milk production variable

Milk production variable	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
Milk volume (l)	0.003	Reference group	0.854	0.425	0.534
Fat yield (kg)	0.239	Reference group	0.471	0.033	0.006
Protein yield (kg)	0.007	Reference group	0.301	0.328	0.307
Fat percentage	0.001	Reference group	0.456	0.266	<0.001
Protein percentage	0.004	Reference group	<0.001	0.987	0.255

EFFECTS OF COW'S AUSTRALIAN BREEDING VALUE IN HOLSTEINS

Each cow's Australian Breeding Value was estimated based on her sire's and maternal grandsire's Australian Breeding Values (see Materials and Methods).

Estimated effects of cow's Australian Breeding Values for milk production on the corresponding milk production variable are shown in Table 3.11. Effects of Australian Breeding Value for milk volume were assessed on milk volume; effects of Australian Breeding Value for fat yield were assessed on fat yield, and so on.

For all milk production variables, the overall p-value for interaction between Australian Breeding Value and feeding system was <0.001. P-values for differences in estimated effects by feeding system relative to the moderate feeding system are shown in Table 3.12.

Effects of increases in the respective Australian Breeding Value on milk volume, fat and protein yield were smallest in the low bail feeding system and largest in the TMR feeding system. For each 10 unit increase in the cow's Australian Breeding Value for milk volume, milk volume increases were estimated as 7.2 litres in the low bail feeding system, about 9 litres in the most common feeding systems and 12.1 litres in the TMR feeding system. For each 10 unit increase in the cow's Australian Breeding Value for fat yield, estimated fat yield increases varied from 6.3 kg in the low bail feeding system to 11.8 kg in the TMR feeding system, while protein yield increase estimates for each 10 unit increase in the cow's Australian Breeding Value for protein yield varied from 7.6 kg in the low bail feeding system to 17.0 kg in the TMR feeding system.

In the most common feeding system (the moderate to high bail feeding system), estimated effects of Australian Breeding Value for milk volume and protein yield were approximately as predicted based on theoretical considerations (10 litres and 10 kgs protein, respectively) but estimated effects of Australian Breeding Value for fat yield were less than the theoretically expected amount of 10 kg.

Table 3.11 Estimated effects of cow's Australian Breeding Values on 305-day milk production for lactations from Holstein cows by feeding system (95% CI)

Milk production variable	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
Milk volume (l)*	7.2 (6.3 to 8.2)	9.2 (8.7 to 9.6)	9.4 (8.6 to 10.2)	9.2 (8.0 to 10.5)	12.1 (10.5 to 13.7)
Fat yield (kg)*	6.3 (5.3 to 7.3)	7.5 (7.0 to 8.0)	7.6 (6.8 to 8.5)	9.4 (8.1 to 10.7)	11.8 (10.3 to 13.3)
Protein yield (kg)*	7.6 (6.5 to 8.7)	10.2 (9.6 to 10.8)	9.7 (8.7 to 10.7)	11.9 (10.3 to 13.4)	17.0 (14.9 to 19.0)
Fat percentage**	0.823 (0.783 to 0.863)	0.875 (0.855 to 0.895)	0.847 (0.812 to 0.881)	0.848 (0.793 to 0.902)	0.665 (0.597 to 0.733)
Protein percentage**	0.789 (0.753 to 0.825)	0.837 (0.819 to 0.854)	0.756 (0.724 to 0.787)	0.839 (0.789 to 0.890)	0.788 (0.725 to 0.851)

*Coefficients represent estimated change in milk production variable per 10 unit increase in the cow's Australian Breeding Value
**Coefficients represent estimated change in milk production variable per 1 unit increase in the cow's Australian Breeding Value
All coefficients were adjusted for age at calving; herd and cow within herd were fitted as random effects

Table 3.12 P-values for differences in estimated effects of cow's Australian Breeding Values on 305-day milk production for lactations from Holstein cows by feeding system, relative to the moderate to high bail feeding system, for each milk production variable

Milk production variable	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
Milk volume (l)	<0.001	Reference group	0.621	0.918	<0.001
Fat yield (kg)	0.025	Reference group	0.835	0.009	<0.001
Protein yield (kg)	<0.001	Reference group	0.426	0.046	<0.001
Fat percentage	0.017	Reference group	0.149	0.345	<0.001
Protein percentage	0.016	Reference group	<0.001	0.921	0.144

3.4 EFFECTS ON MILK PRODUCTION IN JERSEYS

EFFECTS OF COW'S SIRE'S AUSTRALIAN PROFIT RANKING IN JERSEYS

Estimated effects of cow's sire's Australian Profit Ranking on 305-day milk production by feeding system are shown in Table 3.13. P-values for differences in estimated effects by feeding system relative to the moderate to high bail feeding system are shown in Table 3.14. Overall p-values for interaction between Australian Profit Ranking and feeding system were low for fat and protein yield and protein percentage.

All estimated effects on milk volume, and fat and protein yield were positive; estimated increases were smaller for the low bail feeding system than for the moderate to high bail feeding system and under PMR. Estimated increases in milk volume, and fat and protein yield were small for the hybrid feeding system but these were based on relatively few lactations and herds, and so potentially are not valid estimates.

Table 3.13 Estimated effects*of cow's sire's Australian Profit Ranking on 305-day milk production for lactations from Jersey cows by feeding system (95% CI)

Milk production variable	Feeding system			
	Low bail	Mod-high bail	PMR	Hybrid
Milk volume (l)	34.6 (20.2 to 49.1)	54.1 (45.5 to 62.7)	56.1 (32.0 to 80.2)	15.2 (-61.0 to 91.5)
Fat yield (kg)	2.3 (1.6 to 3.0)	3.4 (2.9 to 3.8)	4.2 (3.1 to 5.4)	1.4 (-2.4 to 5.2)
Protein yield (kg)	1.7 (1.2 to 2.2)	2.8 (2.4 to 3.1)	3.1 (2.2 to 4.0)	1.5 (-1.3 to 4.3)
Fat percentage	0.014 (0.007 to 0.021)	0.013 (0.009 to 0.017)	0.024 (0.013 to 0.036)	-0.013 (-0.049 to 0.023)
Protein percentage	0.009 (0.006 to 0.012)	0.013 (0.011 to 0.015)	0.018 (0.013 to 0.022)	0.011 (-0.003 to 0.025)

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Profit Ranking; coefficients were adjusted for age at calving; herd and cow within herd were fitted as random effects

Table 3.14 P-values for differences in estimated effects of cow's sire's Australian Profit Ranking on 305-day milk production for lactations from Jersey cows by feeding system, relative to the moderate to high bail feeding system, for each milk production variable

Milk production variable	Feeding system				P for interaction
	Low bail	Mod-high bail	PMR	Hybrid	
Milk volume (l)	0.022	Reference group	0.875	0.321	0.094
Fat yield (kg)	0.008	Reference group	0.163	0.325	0.010
Protein yield (kg)	0.001	Reference group	0.447	0.392	0.003
Fat percentage	0.797	Reference group	0.075	0.154	0.124
Protein percentage	0.007	Reference group	0.082	0.753	0.006

After adjustment for the cow's maternal grandsire's Australian Profit Ranking, estimated increases were similar for milk volume, but estimated increases in fat and protein yields were lower for the low bail feeding system (Tables 3.15 and 3.16, and Figures 3.3 and 3.4). R^2 values (proportional reductions in cow-level variances after fitting cow's sire's Australian Profit Ranking, maternal grand sire's Australian Profit Ranking, and interaction between cow's sire's Australian Profit Ranking and feeding system) were negligible to small; the highest R^2 values were 8.4%, for fat and protein yields.

Table 3.15 Estimated effects*of cow's sire's Australian Profit Ranking on 305-day milk production for lactations from Jersey cows by feeding system adjusted for the cow's maternal grandsire's Australian Profit Ranking (95% CI)

Milk production variable	Feeding system			
	Low bail	Mod-high bail	PMR	Hybrid
Milk volume (l)	42.1 (25.3 to 59.0)	55.9 (46.6 to 65.1)	49.5 (23.5 to 75.4)	-3.4 (-84.3 to 77.4)
Fat yield (kg)	2.6 (1.8 to 3.4)	3.4 (3.0 to 3.9)	3.7 (2.4 to 5.0)	1.3 (-2.8 to 5.3)
Protein yield (kg)	2.0 (1.3 to 2.6)	2.8 (2.5 to 3.1)	2.9 (1.9 to 3.8)	1.1 (-1.9 to 4.1)
Fat percentage	0.014 (0.006 to 0.022)	0.013 (0.009 to 0.018)	0.022 (0.009 to 0.034)	0.002 (-0.037 to 0.041)
Protein percentage	0.008 (0.005 to 0.012)	0.013 (0.011 to 0.015)	0.018 (0.013 to 0.023)	0.017 (0.003 to 0.032)

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Profit Ranking; coefficients were adjusted for age at calving; herd and cow within herd were fitted as random effects

Table 3.16 P-values for differences in estimated effects of cow's sire's Australian Profit Ranking on 305-day milk production for lactations from Jersey cows adjusted for the cow's maternal grandsire's Australian Profit Ranking by feeding system, relative to the moderate to high feeding system (reference group or Ref. group), for each milk production variable

Milk production variable	Feeding system				P for interaction	R^{2*}
	Low bail	Mod-high bail	PMR	Hybrid		
Milk volume (l)	0.156	Ref. group	0.646	0.153	0.276	3.7%
Fat yield (kg)	0.080	Ref. group	0.685	0.297	0.209	8.4%
Protein yield (kg)	0.015	Ref. group	0.914	0.274	0.068	8.4%
Fat percentage	0.835	Ref. group	0.212	0.573	0.564	0.8%
Protein percentage	0.027	Ref. group	0.069	0.561	0.020	2.4%

*Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and feeding system with the full model (ie the model with cow's sire's Australian Profit Ranking, maternal grand sire's Australian Profit Ranking, and interaction between cow's sire's Australian Profit Ranking and feeding system also added)

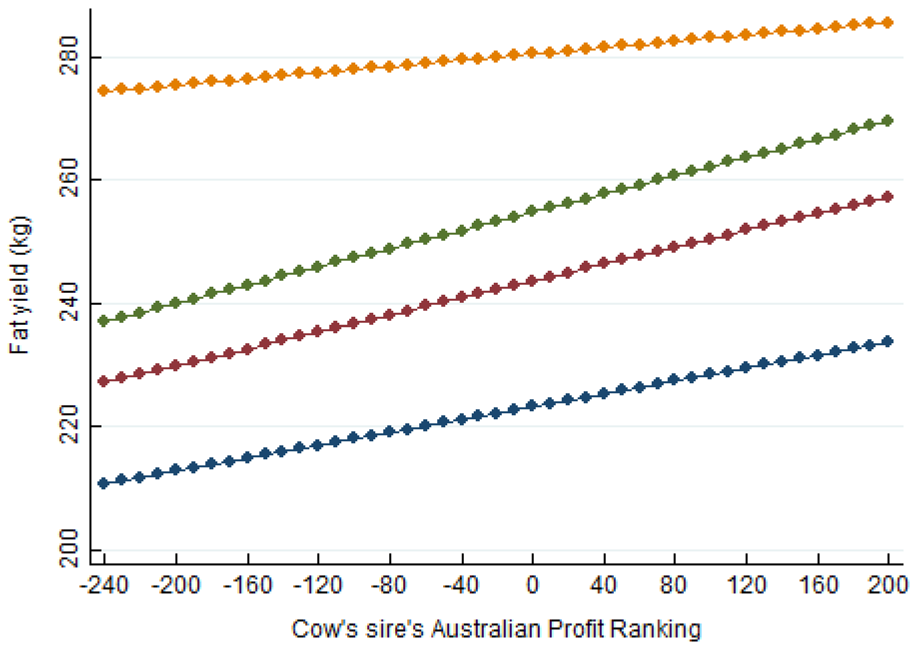


Figure 3.3 Predicted 305-day fat yields by cow's sire's Australian Profit Ranking for lactations from Jersey cows by feeding system, adjusted for the cow's maternal grandsire's Australian Profit Ranking. Feeding systems are low bail (blue), mod-high bail (red), PMR (green), and hybrid (orange).

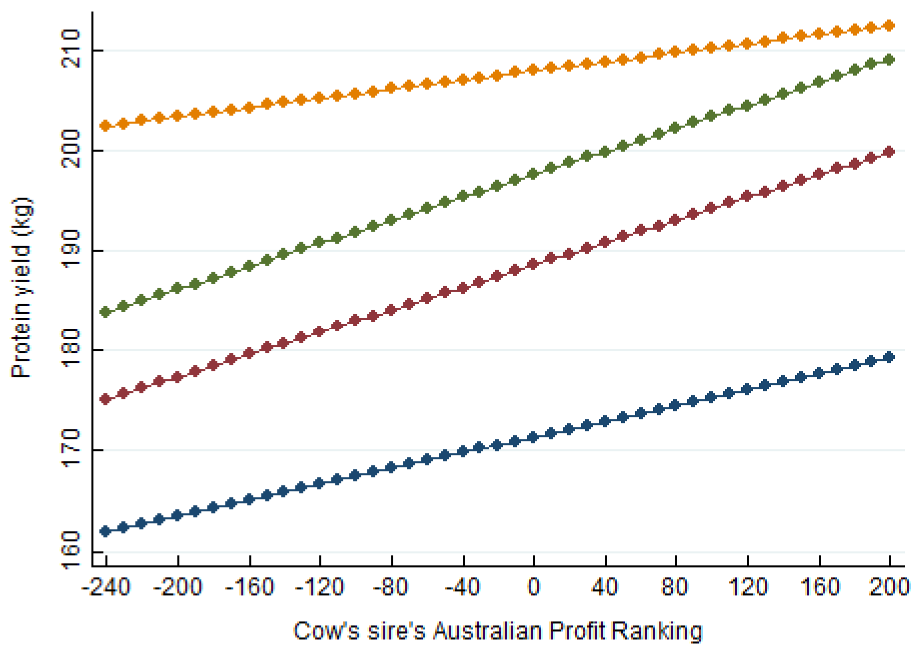


Figure 3.4 Predicted 305-day protein yields by cow's sire's Australian Profit Ranking for lactations from Jersey cows by feeding system, adjusted for the cow's maternal grandsire's Australian Profit Ranking. Feeding systems are low bail (blue), mod-high bail (red), PMR (green), and hybrid (orange).

To assess for curvilinear effects of cow's sire's Australian Profit Ranking on milk production, linear and quadratic terms for cow's sire's Australian Profit Ranking were fitted simultaneously. Estimated increases in milk production per 50 units increase in sire Australian Profit Ranking were estimated at each of the 5th percentile, mean and 95th percentile of sire Australian Profit Ranking (Table 3.17). P-values for interactions that included the quadratic term were <0.001, 0.840, 0.827, <0.001 and <0.001, for milk volume, fat yield, protein yield, fat percentage and protein percentage, respectively. Thus, for fat and protein yield, these results provided no support for curvilinear effects of cow's sire's Australian Profit Ranking. For milk volume, within all systems, estimated effects ofcow's sire's Australian Profit Ranking were lower at higher Australian Profit Rankings.

Table 3.17 Estimated effects*of cow's sire's Australian Profit Ranking on 305-day milk production for lactations from Jersey cows by feeding system adjusted for the cow's maternal grandsire's Australian Profit Ranking (95% CI) at each of the 5th percentile, mean and 95th percentile of sire Australian Profit Ranking after fitting linear and quadratic terms

Milk production variable	Feeding system		
	Low bail	Mod-high bail	PMR
Milk volume (l)			
-237**	63.2 (25.8 to 100.7)	86.8 (66.6 to 106.9)	72.1 (-3.4 to 147.7)
6**	38.3 (20.6 to 56.1)	53.2 (43.8 to 62.5)	48.4 (22.4 to 74.4)
184**	20.1 (-18.4 to 58.6)	28.6 (10.2 to 46.9)	31.0 (-23.5 to 85.5)
Fat yield (kg)			
-237	2.0 (0.2 to 3.8)	3.4 (2.4 to 4.4)	2.7 (-1.0 to 6.4)
6	2.7 (1.9 to 3.6)	3.4 (3.0 to 3.9)	3.6 (2.4 to 4.9)
184	3.3 (1.4 to 5.1)	3.5 (2.6 to 4.4)	4.3 (1.6 to 7.0)
Protein yield (kg)			
-237	1.7 (0.4 to 3.1)	3.1 (2.4 to 3.8)	2.7 (-0.1 to 5.5)
6	2.0 (1.4 to 2.6)	2.8 (2.5 to 3.1)	2.8 (1.9 to 3.8)
184	2.2 (0.8 to 3.6)	2.6 (1.9 to 3.2)	2.9 (0.9 to 4.9)
Fat percentage			
-237	-0.020 (-0.038 to -0.001)	-0.018 (-0.028 to -0.008)	-0.005 (-0.042 to 0.032)
6	0.020 (0.012 to 0.029)	0.016 (0.011 to 0.021)	0.021 (0.009 to 0.034)
184	0.049 (0.031 to 0.068)	0.041 (0.032 to 0.050)	0.041 (0.014 to 0.067)
Protein percentage			
-237	-0.013 (-0.021 to -0.006)	-0.005 (-0.009 to -0.001)	0.001 (-0.014 to 0.016)
6	0.012 (0.009 to 0.016)	0.014 (0.012 to 0.016)	0.017 (0.012 to 0.022)
184	0.031 (0.023 to 0.038)	0.028 (0.024 to 0.032)	0.029 (0.018 to 0.039)

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Profit Ranking at the specified Australian Profit Ranking value; coefficients were adjusted for age at calving; herd and cow within herd were fitted as random effects
**5th percentile, mean and 95th percentile of sire Australian Profit Rankings

EFFECTS OF COW'S AUSTRALIAN PROFIT RANKING IN JERSEYS

Each cow's Australian Profit Ranking was estimated based on her sire's and maternal grandsire's Australian Profit Rankings (see Materials and Methods).

Estimated effects of cow's Australian Profit Ranking on milk volume, fat and protein yields were larger than effects of cow's sire's Australian Profit Ranking (Table 3.18). P-values for differences in estimated effects by feeding system relative to the moderate to high feeding system are shown in Table 3.19. All estimated effects on milk volume, and fat and protein yield were positive; estimated increases were smaller for the low bail feeding system than for the most common feeding systems.

Based on theoretical responses to selection using the Australian Profit Ranking (Pryce *et al* 2010), expected effects of a 50 unit increase in the cow's Australian Profit Ranking are 112 litres, 5.0 kg fat and 4.2 kg protein (J Pryce, personal communication). Thus, in the moderate to high bail feeding system, the estimated effect for milk volume was similar to that expected, but estimated effects for fat and protein yield were higher than those expected.

Table 3.18 Estimated effects*of cow's Australian Profit Ranking on 305-day milk production for lactations from Jersey cows by feeding system (95% CI)

Milk production variable	Feeding system			
	Low bail	Mod-high bail	PMR	Hybrid
Milk volume (l)	66.1 (40.6 to 91.5)	101.6 (86.4 to 116.9)	97.4 (54.7 to 140.0)	11.9 (-123.1 to 146.9)
Fat yield (kg)	4.2 (2.9 to 5.4)	6.3 (5.6 to 7.1)	7.6 (5.5 to 9.7)	2.4 (-4.3 to 9.1)
Protein yield (kg)	3.2 (2.3 to 4.1)	5.2 (4.6 to 5.7)	5.6 (4.1 to 7.2)	2.6 (-2.4 to 7.6)
Fat percentage	0.022 (0.010 to 0.035)	0.023 (0.016 to 0.030)	0.048 (0.027 to 0.068)	-0.010 (-0.074 to 0.053)
Protein percentage	0.014 (0.008 to 0.019)	0.024 (0.021 to 0.027)	0.033 (0.025 to 0.041)	0.026 (0.002 to 0.051)

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's Australian Profit Ranking; coefficients were adjusted for age at calving; herd and cow within herd were fitted as random effects

Table 3.19 P-values for differences in estimated effects of cow's Australian Profit Ranking on 305-day milk production for lactations from Jersey cows by feeding system, relative to the moderate to high bail feeding system, for each milk production variable

Milk production variable	Feeding system				P for interaction
	Low bail	Mod-high bail	PMR	Hybrid	
Milk volume (l)	0.016	Reference group	0.853	0.195	0.065
Fat yield (kg)	0.003	Reference group	0.264	0.257	0.005
Protein yield (kg)	<0.001	Reference group	0.599	0.311	0.001
Fat percentage	0.917	Reference group	0.025	0.305	0.079
Protein percentage	<0.001	Reference group	0.052	0.872	<0.001

To assess for curvilinear effects of cow's Australian Profit Ranking on milk production, linear and quadratic terms for cow's Australian Profit Ranking were fitted simultaneously. Estimated increases in milk production per 50 units increase in sire Australian Profit Ranking were estimated at each of the 5th percentile, mean and 95th percentile of sire Australian Profit Ranking (Table 3.20). P-values for interactions that included the quadratic term were <0.001, 0.848, 0.611, <0.001 and <0.001, for milk volume, fat yield, protein yield, fat percentage and protein percentage, respectively. Thus, for fat and protein yield, these results provided no support for curvilinear effects of cow's Australian Profit Ranking. For milk volume, within all systems, estimated effects ofcow's sire's Australian Profit Ranking were lower at higher Australian Profit Rankings.

Table 3.20 Estimated effects*of cow's Australian Profit Ranking on 305-day milk production for lactations from Jersey cows by feeding system (95% CI) at each of the 5th percentile, mean and 95th percentile of sire Australian Profit Ranking after fitting linear and quadratic terms

Milk production variable	Feeding system		
	Low bail	Mod-high bail	PMR
Milk volume (l)			
-237**	147.6 (60.8 to 234.4)	200.8 (151.5 to 250.1)	175.8 (-34.6 to 386.1)
6**	52.4 (23.4 to 81.4)	90.9 (74.9 to 106.9)	92.5 (49.8 to 135.2)
184**	-17.4 (-106.3 to 71.5)	10.4 (-35.4 to 56.2)	31.5 (-130.5 to 193.6)
Fat yield (kg)			
-237	3.0 (-1.3 to 7.2)	6.3 (3.9 to 8.7)	3.9 (-6.4 to 14.3)
6	4.4 (3.0 to 5.8)	6.3 (5.6 to 7.1)	7.6 (5.5 to 9.6)
184	5.4 (1.1 to 9.7)	6.3 (4.1 to 8.6)	10.2 (2.2 to 18.2)
Protein yield (kg)			
-237	2.8 (-0.4 to 5.9)	6.3 (4.5 to 8.1)	5.1 (-2.6 to 12.8)
6	3.3 (2.2 to 4.3)	5.1 (4.5 to 5.6)	5.5 (4.0 to 7.1)
184	3.6 (0.4 to 6.9)	4.1 (2.5 to 5.8)	5.8 (-0.1 to 11.7)
Fat percentage			
-237	-0.083 (-0.125 to -0.041)	-0.076 (-0.100 to -0.052)	-0.055 (-0.156 to 0.046)
6	0.041 (0.026 to 0.055)	0.034 (0.027 to 0.042)	0.051 (0.031 to 0.072)
184	0.131 (0.088 to 0.174)	0.115 (0.093 to 0.137)	0.129 (0.051 to 0.207)
Protein percentage			
-237	-0.055 (-0.073 to -0.037)	-0.026 (-0.036 to -0.016)	-0.022 (-0.064 to 0.020)
6	0.025 (0.019 to 0.031)	0.030 (0.026 to 0.033)	0.034 (0.026 to 0.043)
184	0.083 (0.066 to 0.101)	0.070 (0.061 to 0.080)	0.076 (0.044 to 0.108)

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's Australian Profit Ranking at the specified Australian Profit Ranking value; coefficients were adjusted for age at calving; herd and cow within herd were fitted as random effects
**5th percentile, mean and 95th percentile of sire Australian Profit Rankings

EFFECTS OF COW'S SIRE'S AUSTRALIAN BREEDING VALUE IN JERSEYS

Estimated effects of cow's sire's Australian Breeding Values for 305-day milk production on the corresponding milk production variable are shown in Table 3.21. Effects of Australian Breeding Value for milk volume were assessed on milk volume; effects of Australian Breeding Value for fat yield were assessed on fat yield, and so on.

P-values for differences in estimated effects by feeding system relative to the moderate to high bail feeding system are shown in Table 3.22.

Estimated increases in milk volume and protein yield were smaller for the low bail feeding system than for the most common feeding systems.

Table 3.21 Estimated effects of cow's sire's Australian Breeding Values on 305-day milk production for lactations from Jersey cows by feeding system adjusted for the cow's maternal grandsire's Australian Breeding Value (95% CI)

Milk production variable	Feeding system			
	Low bail	Mod-high bail	PMR	Hybrid
Milk volume (l)*	2.8 (2.0 to 3.6)	4.2 (3.8 to 4.6)	3.4 (2.3 to 4.4)	4.2 (1.8 to 6.5)
Fat yield (kg)*	3.5 (2.6 to 4.3)	4.0 (3.5 to 4.5)	4.8 (3.5 to 6.1)	0.9 (-3.0 to 4.8)
Protein yield (kg)*	3.2 (2.2 to 4.2)	5.0 (4.5 to 5.6)	4.0 (2.5 to 5.5)	3.7 (-0.1 to 7.5)
Fat percentage**	0.386 (0.351 to 0.421)	0.370 (0.353 to 0.387)	0.311 (0.265 to 0.357)	0.310 (0.199 to 0.420)
Protein percentage**	0.400 (0.363 to 0.437)	0.368 (0.351 to 0.385)	0.386 (0.341 to 0.430)	0.324 (0.217 to 0.431)

*Coefficients represent estimated change in milk production variable per 10 unit increase in the cow's sire's Australian Breeding Value
**Coefficients represent estimated change in milk production variable per 1 unit increase in the cow's sire's Australian Breeding Value
All coefficients were adjusted for age at calving; herd and cow within herd were fitted as random effects

Table 3.22 P-values for differences in estimated effects of cow's sire's Australian Breeding Values on 305-day milk production for lactations from Jersey cows adjusted for the cow's maternal grandsire's Australian Breeding Value by feeding system, relative to the moderate to high feeding system, for each milk production variable

Milk production variable	Feeding system				P for interaction
	Low bail	Mod-high bail	PMR	Hybrid	
Milk volume (l)	0.001	Reference group	0.112	0.956	0.008
Fat yield (kg)	0.267	Reference group	0.264	0.126	0.145
Protein yield (kg)	0.001	Reference group	0.191	0.494	0.012
Fat percentage	0.427	Reference group	0.018	0.290	0.054
Protein percentage	0.122	Reference group	0.463	0.424	0.299

EFFECTS OF COW'S AUSTRALIAN BREEDING VALUE IN JERSEYS

Each cow's Australian Breeding Value was estimated based on her sire's and maternal grandsire's Australian Breeding Values (see above).

Estimated effects of cow's Australian Breeding Values for milk production on the corresponding milk production variable are shown in Table 3.23. Effects of Australian Breeding Value for milk volume were assessed on 305-day milk volume; effects of Australian Breeding Value for fat yield were assessed on 305-day fat yield, and so on.

P-values for differences in estimated effects by feeding system relative to the moderate to high feeding system are shown in Table 3.24.

Estimated increases in milk volume, and fat and protein yield for each 10 unit increase in the cow's Australian Breeding Value for the respective trait were smaller for the low bail feeding system than for the most common feeding systems. For each 10 unit increase in the cow's Australian Breeding Value for milk volume, estimated milk volume increases were 5 litres in the low bail feeding system, and about 7 to 8 litres in the most common feeding systems. Estimated fat yield increases for each 10 unit increase in the cow's Australian Breeding Value for fat yield varied from 6.0 kg in the low bail feeding system to 7.5 to 9.1

kg in the most common feeding systems, while estimated protein yield increases for each 10 unit increase in the cow's Australian Breeding Value for protein yield varied from 5.3 kg in the low bail feeding system to 8.8 to 9.3 kg in the most common feeding systems.

In the moderate to high bail feeding system, estimated effects of Australian Breeding Value for milk volume and fat yield were less than those predicted based on theoretical considerations (10 litres and 10 kgs protein, respectively) but estimated effects of Australian Breeding Value for protein yield were similar to that theoretically expected (10kg).

Table 3.23 Estimated effects of cow's Australian Breeding Values on 305-day milk production for lactations from Jersey cows by feeding system (95% CI)

Milk production variable	Feeding system			
	Low bail	Mod-high bail	PMR	Hybrid
Milk volume (l)*	5.0 (3.8 to 6.2)	7.8 (7.2 to 8.5)	6.9 (5.1 to 8.6)	8.0 (3.7 to 12.3)
Fat yield (kg)*	6.0 (4.6 to 7.3)	7.5 (6.7 to 8.3)	9.1 (6.9 to 11.2)	4.0 (-2.4 to 10.4)
Protein yield (kg)*	5.3 (3.7 to 6.8)	9.3 (8.4 to 10.2)	8.8 (6.3 to 11.3)	7.0 (0.2 to 13.7)
Fat percentage**	0.768 (0.711 to 0.825)	0.702 (0.672 to 0.731)	0.661 (0.580 to 0.741)	0.652 (0.443 to 0.861)
Protein percentage**	0.762 (0.703 to 0.821)	0.717 (0.688 to 0.747)	0.752 (0.674 to 0.829)	0.638 (0.442 to 0.835)

*Coefficients represent estimated change in milk production variable per 10 unit increase in the cow's Australian Breeding Value
**Coefficients represent estimated change in milk production variable per 1 unit increase in the cow's Australian Breeding Value
All coefficients were adjusted for age at calving; herd and cow within herd were fitted as random effects

Table 3.24. P-values for differences in estimated effects of cow's Australian Breeding Values on 305-day milk production for lactations from Jersey cows by feeding system, relative to the moderate to high bail feeding system, for each milk production variable

Milk production variable	Feeding system				P for interaction
	Low bail	Mod-high bail	PMR	Hybrid	
Milk volume (l)	<0.001	Reference group	0.319	0.948	0.001
Fat yield (kg)	0.046	Reference group	0.177	0.289	0.046
Protein yield (kg)	<0.001	Reference group	0.739	0.512	<0.001
Fat percentage	0.041	Reference group	0.343	0.645	0.111
Protein percentage	0.177	Reference group	0.411	0.434	0.364

3.5 EFFECTS ON ODDS OF RECALVING BY 20 MONTHS IN HOLSTEINS

INTRODUCTION

Effects on odds of recalving by 20 months were assessed using all eligible lactations for each cow. These results are detailed below.

In general, cows that have not recalved by 20 months are at markedly increased risk of being culled. Accordingly, by including all eligible lactations for each cow, these analyses may be unduly influenced by cows that tend to remain in the herd and recalve within 20 months. So effects on odds of recalving by 20 months were also assessed using only the first eligible lactation for each cow in the study database. Results of these analyses are shown in Appendix 2.

EFFECTS OF AUSTRALIAN PROFIT RANKING IN HOLSTEINS

Estimated effects of Australian Profit Ranking on odds and probability of recalving by 20 months are shown in Table 3.25 and Figure 3.5, respectively. Each coefficient in Table 3.25 represents the estimated odds ratio for recalving by 20 months per 50 unit increase in the Australian Profit Ranking. For example, for each 50 unit increase in the cow's sire's Australian Profit Ranking, the odds of recalving by 20 months were estimated as increasing by 1.012 in the low bail feeding system and by 1.055 in the TMR feeding system.

An odds ratio of 1.0 indicates no effect. An odds ratio of 1.115 (the highest estimated odds ratio in Table 3.25) would indicate that the odds of recalving by 20 months increase by a factor of 1.115 (ie 11.5 percentage points) for each 50 unit increase in the Australian Profit Ranking. An odds ratio of 0.992 (the lowest estimated odds ratio in Table 3.25) would indicate that the odds of recalving by 20 months decrease by a factor of 0.992 (ie a decrease of 0.8 percentage points) for each 50 unit increase in the Australian Profit Ranking.

At a reference value of percentage recalved by 20 months of 65.9% (the crude value for the study lactations in Holstein cows), an odds ratio of 1.115 equates to an increase of approximately 2.4 percentage points ie to 68.3% (a moderately large increase), while an odds ratio of 0.992 equates to a decrease of only approximately 0.2 percentage points ie to 65.7%.

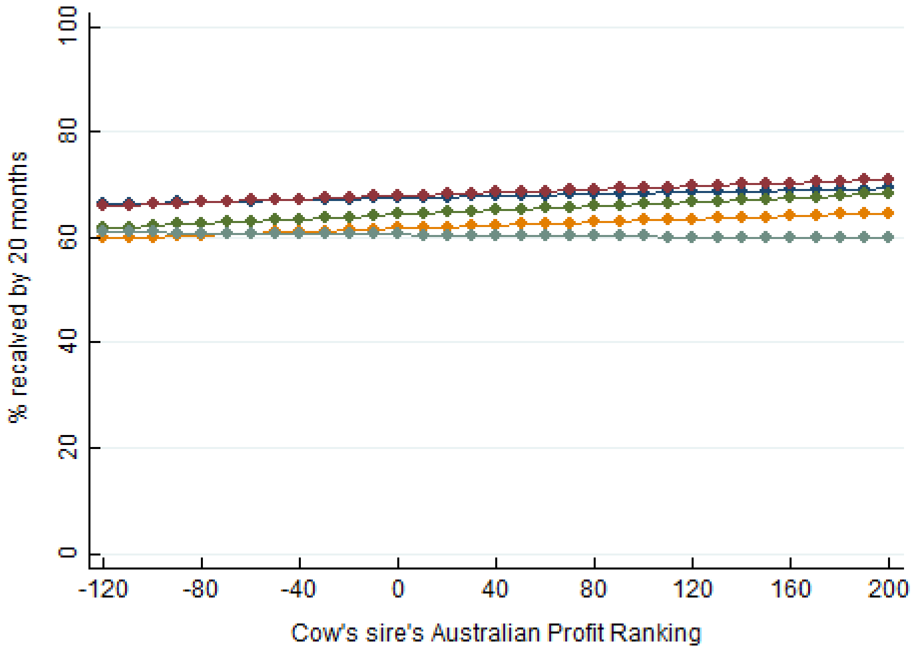


Figure 3.5 Predicted percentages of cows that recalved by 20 months by cow's sire's Australian Profit Ranking for lactations from Holstein cows by feeding system, adjusted for the cow's maternal grandsire's Australian Profit Ranking. Feeding systems are low bail (blue), mod-high bail (red), PMR (green), hybrid (orange) and TMR (grey).

P-values for differences in estimated effects by feeding system relative to the moderate to high feeding system are shown in Table 3.26. Overall p-values for interaction between Australian Profit Ranking and feeding system were moderately high (0.088 and 0.144) for cow's sire's Australian Profit Ranking but low (0.014) for cow's Australian Profit Ranking.

Most odds ratio estimates were slightly above 1.0 with relatively narrow confidence intervals. This indicates that, in Holstein cows, increases in Australian Profit Ranking do not markedly decrease (and probably slightly increase) the odds of recalving by 20 months.

Table 3.25 Estimated effects*of cow's sire's Australian Profit Ranking on odds of recalving by 20 months for lactations from Holstein cows by feeding system (95% CI)

Breeding value	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
Cow's sire's Australian Profit Ranking					
Not adjusted**	1.012 (0.994 to 1.030)	1.035 (1.026 to 1.044)	1.035 (1.019 to 1.051)	1.025 (1.002 to 1.050)	1.055 (1.027 to 1.085)
Adjusted**	1.021 (1.001 to 1.042)	1.036 (1.026 to 1.047)	1.046 (1.028 to 1.065)	1.033 (1.007 to 1.059)	0.992 (0.950 to 1.037)
Cow's Australian Profit Ranking	1.011 (0.980 to 1.044)	1.061 (1.045 to 1.078)	1.059 (1.030 to 1.089)	1.043 (1.001 to 1.087)	1.115 (1.058 to 1.175)

*Coefficients represent odds ratios for recalving by 20 month for each extra 50 units in Australian Profit Ranking; coefficients were adjusted for age at calving; herd was fitted as a random effect

**Not adjusted or adjusted for maternal grandsire's Australian Profit Ranking

Based on theoretical responses to selection using the Australian Profit Ranking and assuming a linear response on the probability scale (Pryce *et al* 2010), the percentage of animals 'surviving' should increase by 2.3% (percentage points) for a 50 unit increase in the cow's Australian Profit Ranking (J Pryce, personal communication). Survival is defined by ADHIS as recalving within 18 months after calving. As this is similar to recalved by 20 months, the estimated effects of a 50 unit increase in the cow's Australian Profit Ranking can be validly compared to this theoretical responses to selection; the estimated effects were less than those expected except in the TMR feeding system.

Table 3.26 P-values for differences in estimated effects of Australian Profit Ranking on odds of recalving by 20 months for lactations from Holstein cows by feeding system, relative to the moderate to high feeding system

Breeding value	Feeding system					P for interaction
	Low bail	Mod-high bail	PMR	Hybrid	TMR	
Cow's sire's Australian Profit Ranking						
Not adjusted*	0.025	Reference group	0.979	0.450	0.188	0.088
Adjusted*	0.181	Reference group	0.377	0.799	0.056	0.144
Cow's Australian Profit Ranking	0.006	Reference group	0.881	0.425	0.077	0.014

*Not adjusted or adjusted for maternal grandsire's Australian Profit Ranking

The proportion of lactations that are followed by recalving within 20 months is determined by deaths, reproductive performance, and culling. Culling is based on numerous factors including low milk yield relative to herd average. Thus, recalving within 20 months will not reflect just reproductive performance. The proportion of higher Australian Profit Ranking cows that recalve by 20 months may be higher than that in lower Australian Profit Ranking cows due to reduced risk of culling because of higher milk yield relative to herd average even if higher Australian Profit Ranking cows have reduced reproductive performance. To explore this, analyses of effects of cow's sire's Australian Profit Ranking on recalved by 20 months adjusted for cow's maternal grandsire's Australian Profit Ranking were repeated also adjusted variously for each lactation's deviation from the herd's mean milk volume, fat yield, and protein yield for that year.

These results are shown in Tables 3.27 and 3.28. After adjustment, odds ratio estimates were closer to 1. The reduction in odds ratios in the most common feeding systems indicates the increased odds of recalving with increases in cow's sire's Australian Profit Ranking is partly due to reduced risk of culling because of lower milk yield in cows with sires with higher Australian Profit Rankings. However, after this adjustment, estimated effects of increases in cow's sire's Australian Profit Ranking on odds of recalving were smaller but still positive. This indicates that cows with sires with higher Australian Profit Rankings have similar or slightly increased odds of recalving by 20 months to those for other cows after accounting for differences in milk production.

Table 3.27 Estimated effects*of cow's sire's Australian Profit Ranking on odds of recalving by 20 months for lactations from Holstein cows adjusted for the cow's maternal grandsire's Australian Profit Ranking and variously by each lactation's deviation from the herd's mean milk volume, fat yield, and protein yield for that year by feeding system (95% CI)

Adjusted for each lactation's milk production deviation from herd mean	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
No	1.021 (1.001 to 1.042)	1.036 (1.026 to 1.047)	1.046 (1.028 to 1.065)	1.033 (1.007 to 1.059)	0.992 (0.950 to 1.037)
Adjusted for milk volume	1.005 (0.984 to 1.026)	1.015 (1.005 to 1.026)	1.022 (1.002 to 1.042)	1.011 (0.984 to 1.038)	0.965 (0.920 to 1.013)
Adjusted for fat yield	1.005 (0.985 to 1.026)	1.016 (1.005 to 1.026)	1.023 (1.003 to 1.043)	1.012 (0.985 to 1.039)	0.964 (0.918 to 1.011)
Adjusted for protein yield	1.005 (0.985 to 1.026)	1.016 (1.005 to 1.026)	1.023 (1.003 to 1.043)	1.012 (0.985 to 1.039)	0.964 (0.918 to 1.011)

*Coefficients represent odds ratios for recalving by 20 month for each extra 50 units in Australian Profit Ranking; coefficients were adjusted for age at calving; herd was fitted as a random effect

Table 3.28 P-values for differences in estimated effects of Australian Profit Ranking on odds of recalving by 20 months for lactations from Holstein cows adjusted for the cow's maternal grandsire's Australian Profit Ranking and variously by each lactation's deviation from the herd's mean milk volume, fat yield, and protein yield for that year by feeding system, relative to the moderate to high feeding system

Adjusted for each lactation's milk production deviation from herd mean	Feeding system					P for interaction
	Low bail	Mod-high bail	PMR	Hybrid	TMR	
No	0.181	Reference group	0.377	0.799	0.056	0.144
Adjusted for milk volume	0.365	Reference group	0.590	0.744	0.045	0.250
Adjusted for fat yield	0.383	Reference group	0.512	0.790	0.037	0.210
Adjusted for protein yield	0.383	Reference group	0.509	0.787	0.037	0.014

EFFECTS OF AUSTRALIAN BREEDING VALUES IN HOLSTEINS

Estimated effects of Australian Breeding Values on odds of recalving by 20 months are shown in Table 3.29. P-values for differences in estimated effects by feeding system relative to the moderate to high feeding system are shown in Table 3.30. The overall p-values for interactions between Australian Breeding Values and feeding system were high for daughter fertility but low for survival.

At a reference value of percentage recalved by 20 months of 65.9% (the crude value for the study lactations in Holstein cows), an odds ratio of 1.15 (the highest estimated odds ratio in Table 3.29) equates to an increase of approximately 3.1 percentage points ie to 69.0% (a moderately large increase), while an odds ratio of 1.02 (the lowest estimated odds ratio in Table 3.29) equates to an increase of approximately 0.5 percentage points ie to 66.4%.

All estimated effects of Australian Breeding Values for daughter fertility and survival were positive with relatively narrow confidence intervals, indicating that odds of recalving by 20 months increase with these Australian Breeding Values in all feeding systems. Estimated effects of Australian Breeding Value for survival were smallest in the low bail feeding system and largest in the TMR feeding system.

Table 3.29 Estimated effects*of Australian Breeding Values on odds of recalving by 20 months for lactations from Holstein cows by feeding system (95% CI)

Breeding value	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
Cow's sire's Australian Breeding Value for daughter fertility**	1.04 (1.03 to 1.05)	1.03 (1.03 to 1.04)	1.03 (1.02 to 1.04)	1.03 (1.02 to 1.04)	1.04 (1.02 to 1.06)
Cow's Australian Breeding Value for daughter fertility	1.08 (1.07 to 1.10)	1.07 (1.06 to 1.08)	1.06 (1.04 to 1.07)	1.06 (1.04 to 1.08)	1.08 (1.06 to 1.10)
Cow's sire's Australian Breeding Value for survival**	1.02 (1.01 to 1.03)	1.05 (1.04 to 1.05)	1.04 (1.03 to 1.05)	1.05 (1.04 to 1.07)	1.05 (1.03 to 1.08)
Cow's Australian Breeding Value for survival	1.04 (1.02 to 1.05)	1.09 (1.08 to 1.10)	1.06 (1.05 to 1.08)	1.10 (1.07 to 1.12)	1.15 (1.12 to 1.19)

*Coefficients represent odds ratios for recalving by 20 month for each extra unit in Australian Breeding Value; coefficients were adjusted for age at calving; herd was fitted as a random effect
**Coefficients were adjusted for maternal grandsire's Australian Breeding Value

Table 3.30 P-values for differences in estimated effects of Australian Breeding Values on odds of recalving by 20 months for lactations from Holstein cows by feeding system, relative to the moderate to high feeding system

Breeding value	Feeding system					P for interaction
	Low bail	Mod-high bail	PMR	Hybrid	TMR	
Cow's sire's Australian Breeding Value for daughter fertility*	0.256	Reference group	0.588	0.655	0.885	0.700
Cow's Australian Breeding Value for daughter fertility	0.215	Reference group	0.129	0.331	0.623	0.193
Cow's sire's Australian Breeding Value for survival*	<0.001	Reference group	0.205	0.658	0.692	0.001
Cow's Australian Breeding Value for survival	<0.001	Reference group	0.004	0.548	<0.001	<0.001

*Coefficients were adjusted for maternal grandsire's Australian Breeding Value

3.6 EFFECTS OF AUSTRALIAN PROFIT RANKING AND AUSTRALIAN BREEDING VALUES ON ODDS OF RECALVING BY 20 MONTHS IN JERSEYS

INTRODUCTION

Effects on odds of recalving by 20 months assessed using all eligible lactations for each cow are detailed below. Estimated effects on odds of recalving by 20 months using only the first eligible lactation for each cow in the study database are shown in Appendix 2.

EFFECTS OF AUSTRALIAN PROFIT RANKING IN JERSEYS

Estimated effects of Australian Profit Ranking on odds and probabilityof recalving by 20 months are shown in Table 3.31 and Figure 3.6, respectively.

P-values for differences in estimated effects by feeding system relative to the moderate to high feeding system are shown in Table 3.32. Overall p-values for interaction between Australian Profit Ranking and feeding system were high.

At a reference value of percentage recalved by 20 months of 69.6% (the crude value for the study lactations in Jersey cows), an odds ratio of 1.069 (the highest estimated odds ratio in Table 3.31) equates to an increase of approximately 1.4 percentage points ie to 71.0%, while an odds ratio of 1.026 (the lowest estimated odds ratio in Table 3.31) equates to an increase of approximately 0.5 percentage points ie to 70.1%.

In the low and moderate to high bail feeding systems, and under partial mixed rations, odds ratio estimates were slightly above 1.0 with relatively narrow confidence intervals. This indicates that, in Jersey cows within these feeding systems, increases in Australian Profit Ranking do not markedly decrease (and probably slightly increase) the odds of recalving by 20 months.

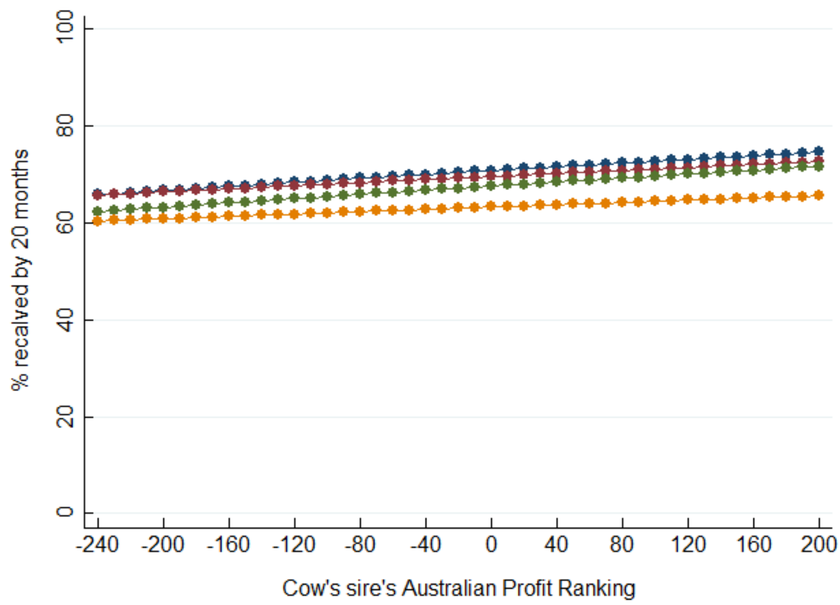


Figure 3.6 Predicted percentages of cows that recalved by 20 months by cow's sire's Australian Profit Ranking for lactations from Jersey cows by feeding system, adjusted for the cow's maternal grandsire's Australian Profit Ranking. Feeding systems are low bail (blue), mod-high bail (red), PMR (green), and hybrid (orange).

Based on theoretical responses to selection using the Australian Profit Ranking and assuming a linear response on the probability scale (Pryce *et al* 2010), the percentage of animals 'surviving' should increase by 2.3% (percentage points) for a 50 unit increase in the cow's Australian Profit Ranking (J Pryce, personal communication). Survival is defined by ADHIS as recalving within 18 months after calving. As this is similar to recalved by 20 months, the estimated effects of a 50 unit increase in the cow's Australian Profit Ranking can be validly compared to this theoretical responses to selection; the estimated effects were less than those expected in all feeding systems.

Table 3.31 Estimated effects*of cow's sire's Australian Profit Ranking on odds of recalving by 20 months for lactations from Jersey cows by feeding system (95% CI)

Breeding value	Feeding system			
	Low bail	**Mod-high bail**	**PMR**	**Hybrid**
Cow's sire's Australian Profit Ranking				
Not adjusted**	1.049 (1.022 to 1.076)	1.033 (1.017 to 1.049)	1.044 (1.000 to 1.091)	1.027 (0.924 to 1.142)
Adjusted**	1.049 (1.018 to 1.081)	1.038 (1.021 to 1.055)	1.049 (1.000 to 1.101)	1.026 (0.917 to 1.147)
Cow's Australian Profit Ranking	1.069 (1.022 to 1.119)	1.045 (1.017 to 1.074)	1.066 (0.987 to 1.150)	1.028 (0.851 to 1.242)

*Coefficients represent odds ratios for recalving by 20 month for each extra 10 units in Australian Profit Ranking; coefficients were adjusted for age at calving; herd was fitted as a random effect

**Not adjusted or adjusted for maternal grandsire's Australian Profit Ranking

Table 3.32 P-values for differences in estimated effects of Australian Profit Ranking on odds of recalving by 20 months for lactations from Jersey cows by feeding system, relative to the moderate to high bail feeding system

Breeding value	Feeding system				P for interaction
	Low bail	**Mod-high bail**	**PMR**	**Hybrid**	
Cow's sire's Australian Profit Ranking					
Not adjusted*	0.323	Reference group	0.636	0.918	0.774
Adjusted*	0.534	Reference group	0.663	0.844	0.903
Cow's Australian Profit Ranking	0.386	Reference group	0.638	0.866	0.820

*Not adjusted or adjusted for maternal grandsire's Australian Profit Ranking

Analyses of effects of cow's sire's Australian Profit Ranking on recalved by 20 months adjusted for cow's maternal grandsire's Australian Profit Ranking were repeated also adjusted variously for each lactation's deviation from the herd's mean milk volume, fat yield, and protein yield for that year. These results are shown in Tables 3.33 and 3.34.

After adjustment, odds ratio estimates were closer to 1. The reduction in odds ratios in the most common feeding systems indicates the increased odds of recalving with increases in cow's sire's Australian Profit Ranking is partly due to to increased culling because of lower milk yield in cows with sires with lower Australian Profit Rankings. However, after this adjustment, estimated effects of increases in cow's sire's Australian Profit Ranking on odds of recalving were smaller but still positive. This indicates that cows with sires with higher Australian Profit Rankings have similar or slightly increased odds of recalving by 20 months to those for other cows after accounting for differences in milk production.

Table 3.33 Estimated effects*of cow's sire's Australian Profit Ranking on odds of recalving by 20 months for lactations from Jersey cows adjusted for the cow's maternal grandsire's Australian Profit Ranking and variously by each lactation's deviation from the herd's mean milk volume, fat yield, and protein yield for that year by feeding system (95% CI)

Adjusted for each lactation's milk production deviation from herd mean	Feeding system			
	Low bail	Mod-high bail	PMR	Hybrid
No	1.049 (1.018 to 1.081)	1.038 (1.021 to 1.055)	1.049 (1.000 to 1.101)	1.026 (0.917 to 1.147)
Adjusted for milk volume	1.026 (0.994 to 1.059)	1.010 (0.991 to 1.029)	1.033 (0.981 to 1.088)	0.991 (0.860 to 1.141)
Adjusted for fat yield	1.025 (0.993 to 1.058)	1.008 (0.990 to 1.027)	1.035 (0.983 to 1.090)	1.007 (0.875 to 1.160)
Adjusted for protein yield	1.025 (0.993 to 1.058)	1.008 (0.990 to 1.027)	1.035 (0.983 to 1.090)	1.007 (0.875 to 1.160)

*Coefficients represent odds ratios for recalving by 20 month for each extra 50 units in Australian Profit Ranking; coefficients were adjusted for age at calving; herd was fitted as a random effect

Table 3.34 P-values for differences in estimated effects of Australian Profit Ranking on odds of recalving by 20 months for lactations from Jersey cows adjusted for the cow's maternal grandsire's Australian Profit Ranking and variously by each lactation's deviation from the herd's mean milk volume, fat yield, and protein yield for that year by feeding system, relative to the moderate to high feeding system

Adjusted for each lactation's milk production deviation from herd mean	Feeding system				P for interaction
	Low bail	Mod-high bail	PMR	Hybrid	
No	0.534	Reference group	0.663	0.844	0.903
Adjusted for milk volume	0.390	Reference group	0.405	0.792	0.718
Adjusted for fat yield	0.375	Reference group	0.338	0.992	0.688
Adjusted for protein yield	0.378	Reference group	0.343	0.992	0.694

EFFECTS OF AUSTRALIAN BREEDING VALUES IN JERSEYS

Estimated effects of Australian Breeding Values on odds of recalving by 20 months are shown in Table 3.35.

P-values for differences in estimated effects by feeding system relative to the moderate to high bail feeding system are shown in Table 3.36. The overall p-values for interactions between Australian Breeding Values and feeding system were moderate (0.114) to high.

Estimated effects of increases in cow's Australian Breeding Value on odds of recalving by 20 months were relatively small. At a reference value of percentage recalved by 20 months of 69.6% (the crude value for the study lactations in Jersey cows), an odds ratio of 1.10 (the highest estimated odds ratio in Table 3.35) equates to an increase of approximately 2.0 percentage points ie to 71.6%, while an odds ratio of 1.01 (the lowest estimated odds ratio in Table 3.35) equates to an increase of approximately 0.2 percentage points ie to 69.8%.

Within the low and moderate to high bail feeding systems and under partial mixed rations, estimated effects of Australian Breeding Values for daughter fertility and survival were close to or slightly above 1 with relatively narrow confidence intervals. This indicates that, in Jersey cows in these feeding systems, the odds of recalving by 20 months do not decrease markedly (and probably slightly increase) with increases in these Australian Breeding Values.

Table 3.35 Estimated effects*of Australian Breeding Values on odds of recalving by 20 months for lactations from Jersey cows by feeding system (95% CI)

Breeding value	Feeding system			
	Low bail	Mod-high bail	PMR	Hybrid
Cow's sire's Australian Breeding Value for daughter fertility**	1.06 (1.04 to 1.09)	1.03 (1.02 to 1.05)	1.02 (0.99 to 1.05)	1.05 (0.98 to 1.11)
Cow's Australian Breeding Value for daughter fertility	1.09 (1.04 to 1.13)	1.07 (1.05 to 1.09)	1.04 (0.99 to 1.09)	1.10 (0.99 to 1.22)
Cow's sire's Australian Breeding Value for survival**	1.03 (1.01 to 1.04)	1.03 (1.03 to 1.04)	1.02 (1.00 to 1.05)	1.03 (0.97 to 1.10)
Cow's Australian Breeding Value for survival	1.05 (1.02 to 1.07)	1.05 (1.04 to 1.07)	1.03 (0.98 to 1.07)	1.08 (0.96 to 1.22)

*Coefficients represent odds ratios for recalving by 20 month for each extra unit in Australian Breeding Value; coefficients were adjusted for age at calving; herd was fitted as a random effect
**Coefficients were adjusted for maternal grandsire's Australian Breeding Value

Table 3.36 P-values for differences in estimated effects of Australian Breeding Values on odds of recalving by 20 months for lactations from Jersey cows by feeding system, relative to the moderate to high bail feeding system

Breeding value	Feeding system				P for interaction
	Low bail	Mod-high bail	PMR	Hybrid	
Cow's sire's Australian Breeding Value for daughter fertility*	0.037	Reference group	0.344	0.744	0.114
Cow's Australian Breeding Value for daughter fertility	0.410	Reference group	0.373	0.614	0.579
Cow's sire's Australian Breeding Value for survival*	0.500	Reference group	0.531	0.986	0.862
Cow's Australian Breeding Value for survival	0.744	Reference group	0.290	0.655	0.701

*Coefficients were adjusted for maternal grandsire's Australian Breeding Value

3.7 EFFECTS ON ODDS OF SHORT LACTATIONS IN HOLSTEINS

Odds of short lactations (less than 120 days) were assessed as a substantial proportion of cows with short lactations are likely to have had post partum disease(s) that seriously affected milk production.

Estimated effects of Australian Profit Ranking on odds and probability of short lactations are shown in Table 3.37 and Figure 3.7, respectively. Each coefficient in Table 3.37 represents the estimated odds ratio for short lactations per 50 unit increase in the Australian Profit Ranking.

At a reference value of percentage of short lactations of 4.0% (the crude value for the study lactations in Holstein cows), an odds ratio of 0.895 (the lowest estimated odds ratio in Table 3.37) equates to a decrease of approximately 0.4 percentage points ie to 3.6%, while an odds ratio of 1.047 (the highest estimated odds ratio in Table 3.37) equates to an increase of approximately 0.2 percentage points ie to 4.2%.

All odds ratios were close to 1.0 with relatively narrow confidence intervals, indicating that any effects of Australian Profit Ranking on odds of short lactations in Holstein cows are probably small. There is some evidence for small reductions in odds of short lactations as Australian Profit Ranking increases in some feeding systems.

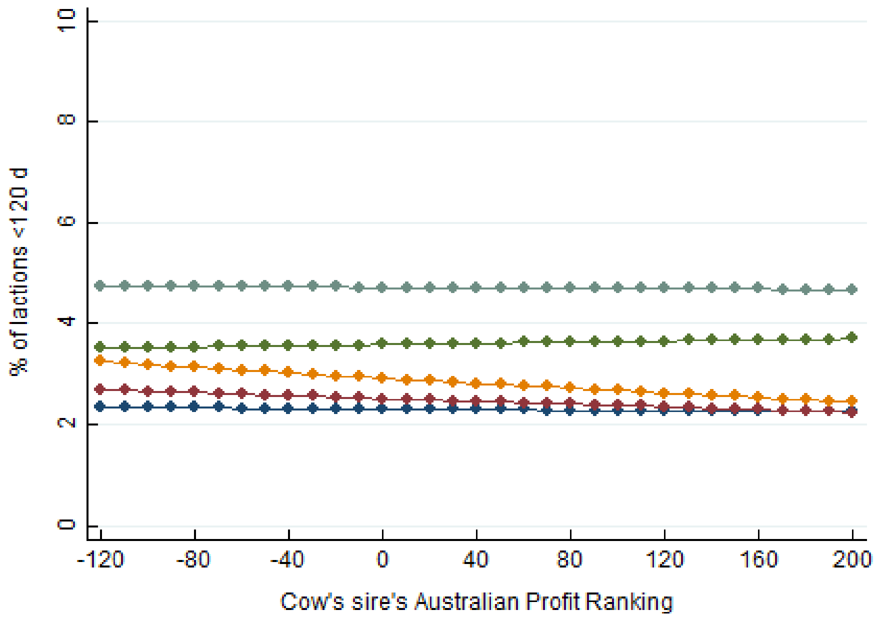


Figure 3.7 Predicted percentages of lactations that were short (<120 days) by cow's sire's Australian Profit Ranking for lactations from Holstein cows by feeding system, adjusted for the cow's maternal grandsire's Australian Profit Ranking. Feeding systems are low bail (blue), mod-high bail (red), PMR (green), hybrid (orange) and TMR (grey).

P-values for differences in estimated effects by feeding system relative to the moderate to high bail feeding system are shown in Table 3.38. Overall p-value for interaction between Australian Profit Ranking and feeding system was high (0.357) for cow's sire's Australian Profit Ranking after adjustment but low (0.017) for cow's Australian Profit Ranking.

Table 3.37 Estimated effects*of Australian Profit Ranking on odds of short lactations in Holstein cows by feeding system (95% CI)

Breeding value	Feeding system				
	Low bail	**Mod-high bail**	**PMR**	**Hybrid**	**TMR**
Cow's sire's Australian Profit Ranking					
Not adjusted**	1.000 (0.960 to 1.041)	0.968 (0.949 to 0.986)	1.018 (0.986 to 1.052)	0.968 (0.920 to 1.019)	0.949 (0.902 to 0.999)
Adjusted**	0.994 (0.950 to 1.039)	0.972 (0.951 to 0.993)	1.008 (0.972 to 1.046)	0.956 (0.904 to 1.010)	0.998 (0.913 to 1.091)
Cow's Australian Profit Ranking	1.004 (0.937 to 1.077)	0.952 (0.920 to 0.985)	1.047 (0.989 to 1.108)	0.954 (0.872 to 1.044)	0.895 (0.812 to 0.987)

*Coefficients represent odds ratios for recalving by 20 month for each extra 50 units in Australian Profit Ranking; coefficients were adjusted for age at calving; herd was fitted as a random effect

**Not adjusted or adjusted for maternal grandsire's Australian Profit Ranking

Table 3.38 P-values for differences in estimated effects of Australian Profit Ranking on odds of short lactations in Holstein cows by feeding system, relative to the moderate to high bail feeding system

Breeding value	Feeding system					P for interaction
	Low bail	**Mod-high bail**	**PMR**	**Hybrid**	**TMR**	
Cow's sire's Australian Profit Ranking						
Not adjusted*	0.142	Reference group	0.007	0.977	0.490	0.041
Adjusted*	0.367	Reference group	0.083	0.586	0.571	0.357
Cow's Australian Profit Ranking	0.165	Reference group	0.004	0.961	0.244	0.017

*Not adjusted or adjusted for maternal grandsire's Australian Profit Ranking

3.8 EFFECTS ON ODDS OF SHORT LACTATIONS IN JERSEYS

Estimated effects of Australian Profit Ranking on odds of short lactations are shown in Table 3.39 and Figure 3.8, respectively.

At a reference value of percentage of short lactations of 4.6% (the crude value for the study lactations in Jersey cows), an odds ratio of 0.873 (the lowest estimated odds ratio in Table 3.39) equates to a decrease of approximately 0.6 percentage points ie to 4.0%, while an odds ratio of 0.984 (the highest estimated odds ratio in Table 3.39) equates to a decrease of approximately 0.1 percentage point ie to 4.5%.

For the low and moderate to high bail feeding systems, and under partial mixed rations, all odds ratios were close to 1.0 with relatively narrow confidence intervals, indicating that any effects of Australian Profit Ranking on odds of short lactations in Jersey cows are probably small.

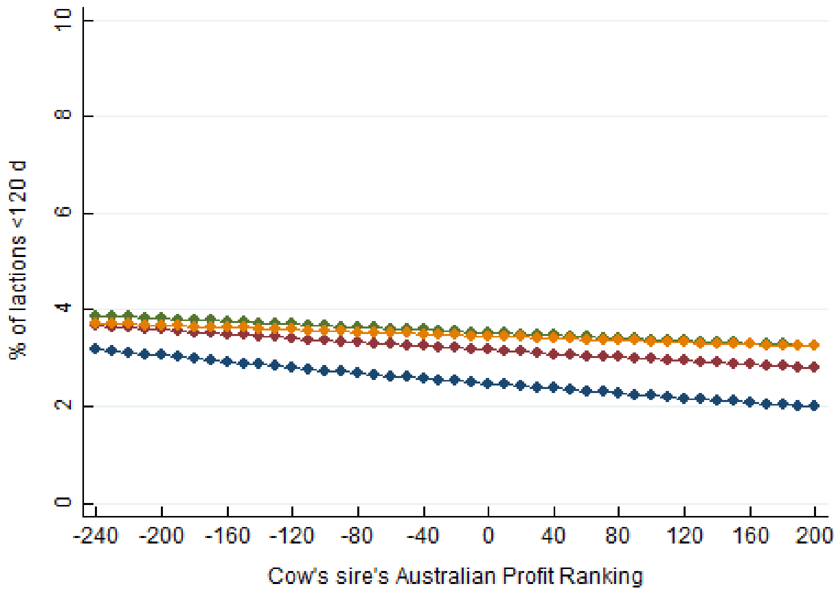


Figure 3.8 Predicted percentages of lactations that were short (<120 days) by cow's sire's Australian Profit Ranking for lactations from Jersey cows by feeding system, adjusted for the cow's maternal grandsire's Australian Profit Ranking. Feeding systems are low bail (blue), mod-high bail (red), PMR (green) and hybrid (orange).

P-values for differences in estimated effects by feeding system relative to the moderate to high bail feeding system are shown in Table 3.40. Overall p-values for interaction between Australian Profit Ranking and feeding system were high.

Table 3.39 Estimated effects*of Australian Profit Ranking on odds of short lactations in Jersey cows by feeding system (95% CI)

Breeding value	Feeding system			
	Low bail	Mod-high bail	PMR	Hybrid
Cow's sire's Australian Profit Ranking				
Not adjusted**	0.927 (0.883 to 0.973)	0.976 (0.946 to 1.007)	0.960 (0.881 to 1.047)	0.929 (0.719 to 1.201)
Adjusted**	0.947 (0.895 to 1.002)	0.968 (0.936 to 1.001)	0.979 (0.892 to 1.076)	0.984 (0.740 to 1.308)
Cow's Australian Profit Ranking	0.873 (0.802 to 0.951)	0.954 (0.903 to 1.007)	0.927 (0.797 to 1.078)	0.943 (0.600 to 1.482)

*Coefficients represent odds ratios for recalving by 20 month for each extra 50 units in Australian Profit Ranking; coefficients were adjusted for age at calving; herd was fitted as a random effect
**Not adjusted or adjusted for maternal grandsire's Australian Profit Ranking

Table 3.40 P-values for differences in estimated effects of Australian Profit Ranking on odds of short lactations in Jersey cows by feeding system, relative to the moderate to high bail feeding system

Breeding value	Feeding system				P for interaction
	Low bail	Mod-high bail	PMR	Hybrid	
Cow's sire's Australian Profit Ranking					
Not adjusted*	0.075	Reference group	0.719	0.707	0.356
Adjusted*	0.501	Reference group	0.820	0.914	0.899
Cow's Australian Profit Ranking	0.082	Reference group	0.726	0.959	0.388

*Not adjusted or adjusted for maternal grandsire's Australian Profit Ranking

CHAPTER 4: IS FEEDING SYSTEM A SURROGATE 'ENVIRONMENT' FOR HERD AVERAGE MILK YIELD?

4.1 OBJECTIVES

The following research objective is addressed in this chapter:

- to assess whether feeding system is a surrogate environment for herd average milk yield when assessing G*E

Specifically, statistical analyses were performed:

i. to assess whether the magnitude of effects of G*E (Australian Profit Ranking by feeding system) on milk yield and recalving by 20 months at the phenotypic level are altered substantially after accounting for herd average milk yield ie by fitting herd average milk yield, does the G*E observed for Australian Profit Ranking by feeding system disappear?
ii. to assess whether there is important G*E (Australian Profit Ranking by herd average milk yield) after accounting for Australian Profit Ranking by feeding system G*E.
iii. to assess whether there is important G*E (Australian Profit Ranking by feeding system) after accounting for Australian Profit Ranking by herd average milk yield G*E.
iv. to assess the magnitude of effects of G*E (Australian Profit Ranking by herd average milk yield) on milk yield and recalving by 20 months at phenotypic level.

Effects of sire Australian Profit Ranking on 'milk profit' for the lactation were also assessed.

4.2 KEY FINDINGS AND CONCLUSIONS

Effects of sire Australian Profit Ranking on milk yield variables differed by feeding system. Effects were positive in all feeding systems. They were approximately twice as large in TMR herds compared with low bail feeding herds. However, effects were more similar for the most popular feeding systems (low bail, moderate to high bail, and PMR).

Effects of sire Australian Profit Ranking on milk volume and protein yield also differed by herd average solids per cow. Effects were positive at all herd average solids per cow levels. However, no such interaction was evident for fat yield.

For milk volume and protein yield, adjustment for interaction between Australian Profit Ranking and herd average solids per cow removed the interaction between Australian Profit Ranking and feeding system. Thus, for milk volume and protein yield, the interaction between Australian Profit Ranking and feeding system is largely accounted for by interaction between Australian Profit Ranking and herd average solids per cow. For every 50 units increase in sire Australian Profit Ranking, estimated increases in milk volume were 40, 55, 70 and 85 litres at herd solids per cow of 400, 500, 600 and 700 kg per cow. Corresponding estimated increases in protein yield were 2.0, 2.8, 3.7 and 4.6 kg.

In contrast, the interaction between Australian Profit Ranking and feeding system for fat yield is not accounted for by interaction between Australian Profit Ranking and herd average solids per cow. For

every 50 units increase in sire Australian Profit Ranking, estimated increases in fat yield were 2.1 to 2.3 kg over herd solids per cow ranging from 400 to 700 kg per cow, and estimated increases in fat yield were 2.6, 2.5, 1.5, 3.5, and 5.7 kg in low bail, moderate-high bail, PMR, hybrid, and TMR feeding systems, respectively.

These results indicate that the biological determinants of G*E for fat yield differ from those for milk volume and protein yield. Features of feeding systems determine Australian Profit Ranking effects on fat yield. In contrast, determinants associated with herd average milk yield determine Australian Profit Ranking effects on milk volume and protein yield. Increases in sire Australian Profit Ranking result in greater increases in milk volume in herds with higher average milk yields than in lower-producing herds, but increases in fat yield are similar at all herd average milk yields. Thus marginal effects on rate of lactose synthesis are greater than marginal effects on rate of fat synthesis in higher producing herds. In contrast, increases in sire Australian Profit Ranking result in greater rates of synthesis of both lactose and fat in higher input feeding systems (PMR, hybrid and TMR) relative to lower input systems (low bail and moderate to high bail). Reasons for this difference in response to increases in sire Australian Profit Ranking are not known. Fat yield and fat concentration are more variable within herd than protein yield and protein concentration. Fat concentration variability (within-herd standard deviation) was approximately twice that of protein concentration, and is influenced more by nutritional interventions.

Implications of these relationships for calculating sire Australian Breeding Values depend, in part, on the extent of sire re-ranking due to these interactions, and the relative economic values of milk volume, fat and protein yields.

Effects of sire Australian Profit Ranking on 'milk profit' for the lactation were also assessed. Milk profit for each lactation was defined as total milk income for the lactation less feed costs for milk production. Effects of sire Australian Profit Ranking on milk profit differed by both feeding system and herd milk yield. Effects were positive in all environments (ie in all feeding systems and herd average solids per cow values that were assessed), and were approximately twice as large in TMR and high-producing herds relative to low bail feeding and low-producing herds.

The estimated effect of sire's Australian Profit Ranking on milk profit was $28 per 50 unit increase in the cow's sire's Australian Profit Ranking in the most common feeding system (moderate to high bail). This was slightly higher than that theoretically expected of $25. Increases in Australian Profit Ranking theoretically have additional effects on herd profitability if Australian Breeding Values for other traits including daughter fertility and survival also increase in association with increases in Australian Profit Ranking.

As for milk volume and protein yield, the interaction between Australian Profit Ranking and feeding system for milk profit was largely accounted for by interaction between Australian Profit Ranking and herd average solids per cow.

Effects of increasing the Australian Profit Ranking on whether a cow recalved by 20 months were weakly positive across all except the TMR feeding system, and across all herd milk yield categories; effects were stronger in herds with higher herd average solids per cow. For every 50 units increase in sire Australian Profit Ranking, odds of recalving by 20 months were estimated as increasing by factors of 1.008 (ie a 0.8% increase), 1.029 (ie a 2.9% increase), 1.049, and 1.071 over herd solids values of 400, 500, 600 and 700 kg per cow, respectively.

4.3 DESCRIPTION OF HERD MILK YIELDS

The study data consisted of 450,384 lactations from 505 herds, including 300,295 lactations that commenced between 2008 and 2011. These latter lactations were from 1909 herd-years, from 489 herds. Exploratory data analyses were performed to determine which herd-year measures of milk yield best described herd milk yield, so that the most appropriate measures were used in subsequent analyses.

Herd-year average milk yield variables were closely correlated (Table 4.1 and Figure 4.1); the weakest correlations were between fat yield and each of milk volume (r=0.88) and protein yield (r=0.92). For these, correlations were weakest at high milk yields (Figure 4.1). All other correlation coefficients were above 0.90. Average energy required for milk production per cow was extremely closely correlated with average solids per cow; the only sources of variation between these two variables were differences in average fat and protein concentrations.

Table 4.1 Pearson's correlation coefficients for associations between herd-year averages for milk yield variables for 1909 herd-years[1]

	Milk volume per cow	Fat per cow	Protein per cow	Solids per cow
Fat per cow	0.88			
Protein per cow	0.97	0.92		
Solids per cow	0.94	0.98	0.98	
Energy required for milk per cow	0.96	0.97	0.98	1.00

1 For all correlation coefficients, P <0.001; these p-values do not account for clustering of herd-year within herd

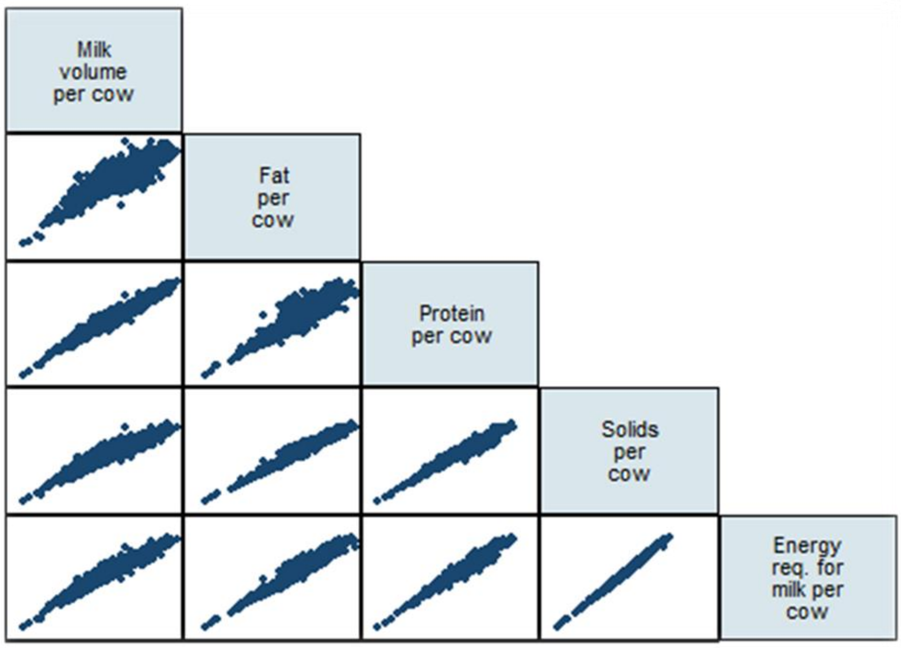


Figure 4.1 Scatterplots for associations between herd-year averages for milk yield variables for 1909 herd-years

Most correlations were similar within each feeding system (Table 4.2.)

Table 4.2 Pearson's correlation coefficients[1] for associations between herd-year averages for milk yield variables by feeding system[2]

	Milk volume per cow	Fat per cow	Protein per cow	Solids per cow
Low bail (n=336 herd-years)				
Fat per cow	0.88			
Protein per cow	0.97	0.92		
Solids per cow	0.94	0.98	0.98	
Energy required for milk per cow	0.96	0.97	0.98	1.00
Mod-high bail (n=1252 herd-years)				
Fat per cow	0.87			
Protein per cow	0.96	0.91		
Solids per cow	0.93	0.98	0.98	
Energy required for milk per cow	0.96	0.97	0.98	1.00
PMR (n=219 herd-years)				
Fat per cow	0.75			
Protein per cow	0.95	0.82		
Solids per cow	0.89	0.96	0.95	
Energy required for milk per cow	0.93	0.93	0.96	0.99
Hybrid (n=59 herd-years)				
Fat per cow	0.84			
Protein per cow	0.98	0.88		
Solids per cow	0.94	0.97	0.97	
Energy required for milk per cow	0.96	0.96	0.98	1.00
TMR (n=19 herd-years)				
Fat per cow	0.81			
Protein per cow	0.98	0.79		
Solids per cow	0.94	0.95	0.94	
Energy required for milk per cow	0.96	0.94	0.95	1.00

1 For all correlation coefficients, P <0.001; these p-values do not account for clustering of herd-year within herd
2 Feeding system was not recorded for 24 herd-years.

Based on these results, for subsequent analyses, herd-year average milk yield was described using average solids per cow. For all feeding systems pooled, this was closely correlated with each other milk yield variable (r ≥ 0.94). The distribution of herd-year average solids per cow is shown in Figure 4.2. Based on this distribution, values of 400 kg, 500 kg, 600 kg, and 700 kg average solids per cow were used in further analyses.

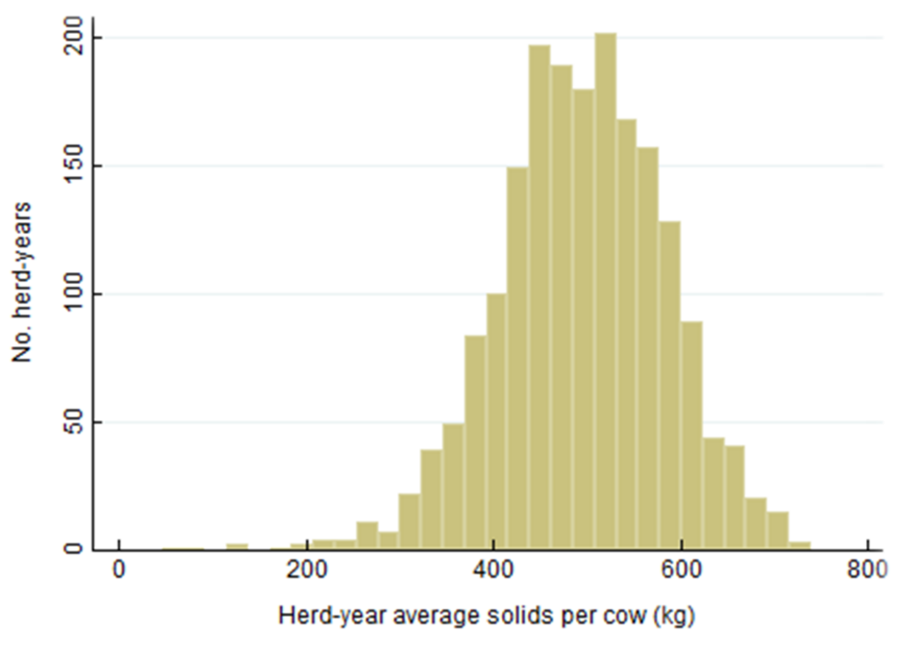


Figure 4.2 Distribution of herd-year average solids per cow for 1909 herd-years

The distribution of lactations by feeding system and herd-year average solids per cow is shown in Table 4.3. Herd average solids per cow were generally higher with higher input feeding systems, but there was considerable variation in herd-year average milk yield within each feeding system. This is also explored in Figure 4.3; this also shows that herd-year average solids per cow overlaps considerably between feeding systems.

These findings indicate that feeding system is only modestly predictive of herd average milk yield, and that management varies substantially within herds using the same feeding system. Similarly, management varies substantially across herds with the same average milk yield; management within multiple feeding systems can result in the same average milk yield.

Table 4.3 Distribution of 250,857 lactations in Holstein cows by feeding system and herd-year average solids per cow

Herd-year average solids per cow (kg)	Feeding system					Pooled
	Low bail	Mod-high bail	PMR	Hybrid	TMR	
<400	8,039	6,680	355	1	0	15,075
400 to <500	20,108	51,635	7,731	1,513	610	81,597
500 to <600	5,862	70,347	23,468	7,021	307	107,005
≥600	170	21,524	9,067	6,066	10,353	47,180
Pooled	34,179	150,186	40,621	14,601	11,270	250,857

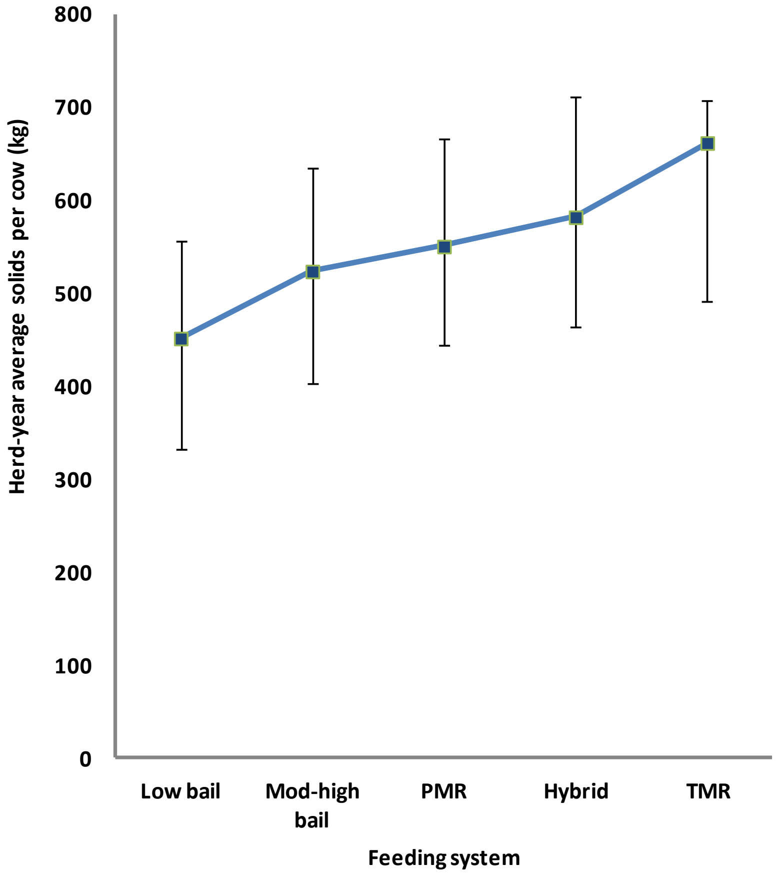


Figure 4.3 Distribution of 250,857 lactations in Holstein cows by herd-year average solids per cow (kg) within feeding system; squares indicate medians and error bars indicate 5th and 95th percentiles within each feeding system.

Hereafter, for simplicity, herd-year average solids per cow is referred to as 'herd average solids per cow'.

4.4 G*E FOR MILK VOLUME, AND FAT AND PROTEIN YIELD

For analyses of interactions for milk volume, the 203,829 lactations were from 437 herds (mean number of lactations per herd: 466; range 1 to 2997) and from 100,971 cows (mean number of lactations per cow: 2.0; range 1 to 5). A total of 223 cows contributed different lactations in different herds. Effects of cow's sire's Australian Profit Ranking on 305-day milk yield variables are shown in Tables 4.4 to 4.9, and Figures 4.4 to 4.7.

As reported above, **effects of sire Australian Profit Ranking on milk yield variables differed by feeding system. Effects were positive in all feeding systems. They were approximately twice as large in TMR herds compared with low bail feeding herds. However, effects were more similar for the most popular feeding systems (low bail, moderate to high bail, and PMR).**

Effects of sire Australian Profit Ranking on milk volume and protein yield also differed by herd average solids per cow. Effects were positive at all herd average solids per cow levels. However, no such interaction was evident for fat yield.

For milk volume and protein yield, adjustment for interaction between Australian Profit Ranking and herd average solids per cow removed the interaction between Australian Profit Ranking and feeding system (Tables 4.4 and 4.8). **Thus, for milk volume and protein yield, the interaction between Australian Profit Ranking and feeding system is largely accounted for by interaction between Australian Profit Ranking and herd average solids per cow**. This is supported by results in Tables 4.5 and 4.9 and Figure 4.7, where interaction between Australian Profit Ranking and herd average solids per cow is evident, including after adjustment for feeding system and interaction between Australian Profit Ranking and feeding system. For every 50 units increase in sire Australian Profit Ranking, estimated increases in milk volume were 40, 55, 70 and 85 litres at herd solids per cow of 400, 500, 600 and 700 kg per cow. Corresponding estimated increases in protein yield were 2.0, 2.8, 3.7 and 4.6 kg.

In contrast, the interaction between Australian Profit Ranking and feeding system for fat yield is not accounted for by interaction between Australian Profit Ranking and herd average solids per cow. Adjustment for interaction between Australian Profit Ranking and herd average solids per cow for fat yield did not remove the interaction between Australian Profit Ranking and feeding system (Table 4.6) and there was no evidence of even modest interaction between Australian Profit Ranking and herd average solids per cow (Table 4.7 and Figure 4.5). For every 50 units increase in sire Australian Profit Ranking, estimated increases in fat yield were 2.1 to 2.3 kg over herd solids per cow ranging from 400 to 700 kg per cow, while estimated increases in fat yield were 2.6, 2.5, 1.5, 3.5, and 5.7 kg in low bail, moderate-high bail, PMR, hybrid, and TMR feeding systems, respectively.

These results indicate that the biological determinants of G*E for fat yield differ from those for milk volume and protein yield. Features of feeding systems determine Australian Profit Ranking effects on fat yield. In contrast, determinants associated with herd average milk yield determine Australian Profit Ranking effects on milk volume and protein yield. Increases in sire Australian Profit Ranking result in greater increases in milk volume in herds with higher average milk yields than in lower-producing herds, but increases in fat yield are similar at all herd average milk yields. Thus marginal effects on rate of lactose synthesis are greater than marginal effects on rate of fat synthesis in higher producing herds. In contrast, increases in sire Australian Profit Ranking result in greater rates of synthesis of both lactose and fat in higher input feeding systems (PMR, hybrid and TMR) relative to lower input systems (low bail and

moderate to high bail). Reasons for this difference in response to increases in sire Australian Profit Ranking are not known. Fat yield and fat concentration are more variable within herd than protein yield and protein concentration (see above). Fat concentration variability (within-herd standard deviation) was approximately twice that of protein concentration, and is influenced more by nutritional interventions.

Implications of these relationships for calculating sire Australian Breeding Values depend, in part, on the extent of sire re-ranking due to these interactions, and the relative economic values of milk volume, fat and protein yields. Interactions between Australian Profit Ranking and herd average milk yield have been explored recently by Rob Woolaston using the Feeding the Genes dataset.

Table 4.4 Estimated effects*of cow's sire's Australian Profit Ranking on 305-day milk volume (litres) for lactations from Holstein cows by feeding system (95% CI)

Adjustment*	Feeding system					P for interaction
	Low bail	Mod-high bail	PMR	Hybrid	TMR	
No other adjustments						
	56.2 (40.9 to 71.5)	68.0 (60.4 to 75.6)	53.7 (39.8 to 67.7)	79.7 (58.8 to 100.6)	109.9 (75.1 to 144.8)	0.013
Adjusted for herd average solids per cow						
	43.8 (28.8 to 58.7)	56.8 (49.3 to 64.3)	63.5 (49.8 to 77.2)	67.0 (46.4 to 87.6)	102.3 (68.0 to 136.6)	0.024
Adjusted for herd average solids per cow and herd average solids*Australian Profit Ranking						
	-15.2 (-52.7 to 22.2)	-10.7 (-50.8 to 29.3)	-8.0 (-51.9 to 35.9)	-9.7 (-58.9 to 39.5)	21.3 (-37.1 to 79.6)	0.490

*Coefficients represent estimated change in milk volume (litres) per 50 unit increase in the cow's sire's Australian Profit Ranking; coefficients were adjusted for the cow's maternal grandsire's Australian Profit Ranking and age at calving; herd and cow within herd were fitted as random effects

Table 4.5 Estimated effects*of cow's sire's Australian Profit Ranking on 305-day milk volume (litres) for lactations from Holstein cows by herd average solids per cow (95% CI)

Adjustment*	Herd average solids per cow (kg)				P for interaction
	400	500	600	700	
No other adjustments**					
	39.6 (29.2 to 50.0)	54.6 (48.3 to 60.8)	69.6 (61.8 to 77.4)	84.6 (71.5 to 97.7)	<0.001
Adjusted for feeding system					
	39.2 (28.8 to 49.6)	54.2 (47.9 to 60.4)	69.2 (61.4 to 77.0)	84.2 (71.1 to 97.3)	<0.001
Adjusted for feeding system and feeding system*Australian Profit Ranking					
	36.5 (21.0 to 52.0)	49.4 (34.1 to 64.8)	62.4 (43.9 to 80.8)	75.3 (51.6 to 99.0)	0.001

*Coefficients represent estimated change in milk volume (litres) per 50 unit increase in the cow's sire's Australian Profit Ranking; coefficients were adjusted for the cow's maternal grandsire's Australian Profit Ranking and age at calving; herd and cow within herd were fitted as random effects
** R^2 was 2.3% (calculated as proportional reduction in estimated cow-level variance comparing model with cow's age at calving and herd average solids per cow with the full model (ie the model with cow's sire's Australian Profit Ranking, maternal grand sire's Australian Profit Ranking, and interaction between cow's sire's Australian Profit Ranking and herd average solids per cow also added)

Table 4.6 Estimated effects*of cow's sire's Australian Profit Ranking on 305-day fat yield (kg) for lactations from Holstein cows by feeding system (95% CI)

Adjustment *	Feeding system					P for interaction
	Low bail	Mod-high bail	PMR	Hybrid	TMR	
No other adjustments						
	2.6 (2.0 to 3.2)	2.5 (2.2 to 2.8)	1.5 (1.0 to 2.0)	3.5 (2.7 to 4.3)	5.7 (4.4 to 7.1)	<0.001
Adjusted for herd average solids per cow						
	2.2 (1.6 to 2.7)	2.1 (1.8 to 2.4)	1.7 (1.2 to 2.3)	2.9 (2.1 to 3.7)	5.4 (4.1 to 6.7)	<0.001
Adjusted for herd average solids per cow and herd average solids*Australian Profit Ranking						
	2.6 (1.2 to 4.1)	2.7 (1.1 to 4.2)	2.3 (0.6 to 4.0)	3.5 (1.7 to 5.4)	6.0 (3.8 to 8.2)	<0.001

*Coefficients represent estimated change in fat yield (kg) per 50 unit increase in the cow's sire's Australian Profit Ranking; coefficients were adjusted for the cow's maternal grandsire's Australian Profit Ranking and age at calving; herd and cow within herd were fitted as random effects

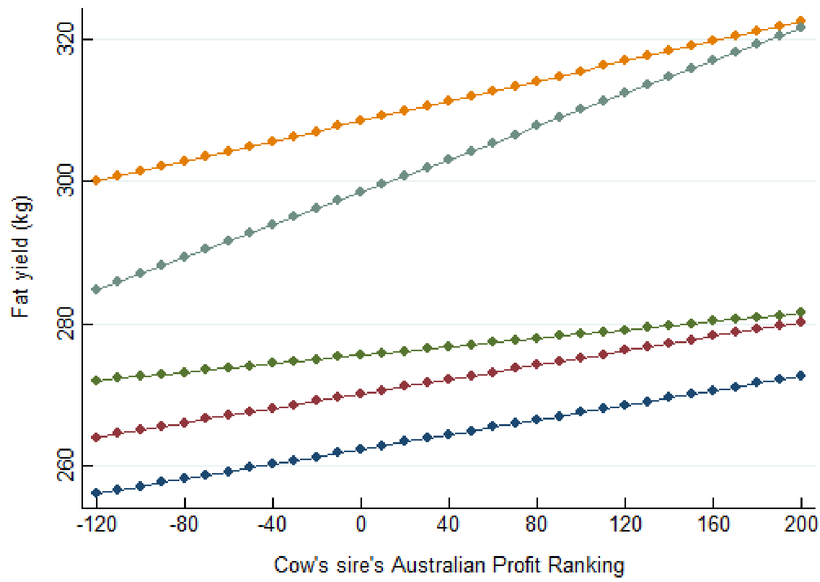


Figure 4.4 Predicted 305-day fat yields by cow's sire's Australian Profit Ranking for lactations from Holstein cows by feeding system, adjusted for the cow's maternal grandsire's Australian Profit Ranking. feeding systems are low bail (blue), mod-high bail (red), PMR (green), hybrid (orange) and TMR (grey).

Table 4.7 Estimated effects*of cow's sire's Australian Profit Ranking on 305-day fat yield (kg) for lactations from Holstein cows by herd average solids per cow (95% CI)

Adjustment*	Herd average solids per cow (kg)				P for interaction
	400	500	600	700	
No other adjustments**					
	2.1 (1.7 to 2.5)	2.2 (1.9 to 2.4)	2.2 (1.9 to 2.5)	2.3 (1.8 to 2.8)	0.612
Adjusted for feeding system					
	2.1 (1.7 to 2.5)	2.2 (2.0 to 2.4)	2.2 (2.0 to 2.5)	2.3 (1.8 to 2.8)	0.662
Adjusted for feeding system and feeding system*Australian Profit Ranking					
	2.2 (1.6 to 2.8)	2.1 (1.5 to 2.7)	2.0 (1.3 to 2.7)	1.9 (1.0 to 2.8)	0.474

*Coefficients represent estimated change in fat yield (kg) per 50 unit increase in the cow's sire's Australian Profit Ranking; coefficients were adjusted for the cow's maternal grandsire's Australian Profit Ranking and age at calving; herd and cow within herd were fitted as random effects
** R^2 was 3.0% (calculated as proportional reduction in estimated cow-level variance comparing model with cow's age at calving and herd average solids per cow with the full model (ie the model with cow's sire's Australian Profit Ranking, maternal grand sire's Australian Profit Ranking, and interaction between cow's sire's Australian Profit Ranking and herd average solids per cow also added

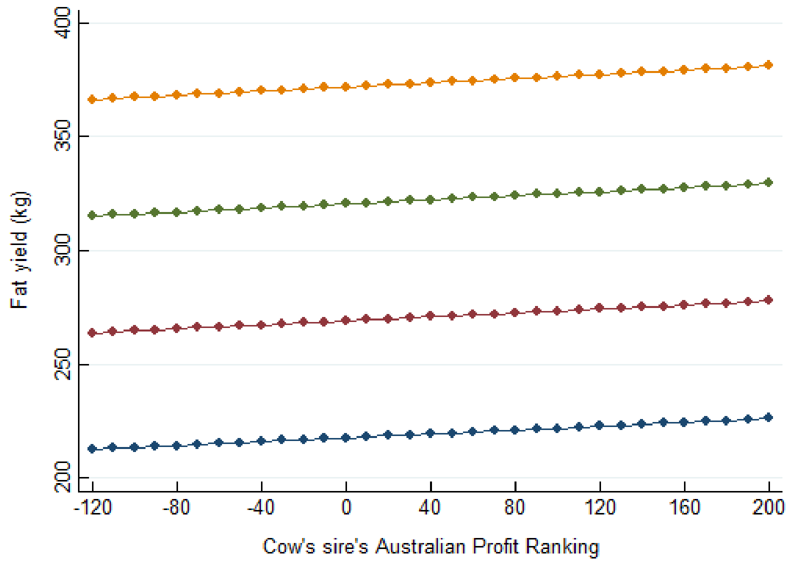


Figure 4.5 Predicted 305-day fat yields by cow's sire's Australian Profit Ranking for lactations from Holstein cows by herd average solids per cow, adjusted for the cow's maternal grandsire's Australian Profit Ranking. Herd average solids per cow are 400 kg (blue), 500 kg (red), 600 kg (green), and 700 kg (orange).

Table 4.8 Estimated effects*of cow's sire's Australian Profit Ranking on 305-day protein yield (kg) for lactations from Holstein cows by feeding system (95% CI)

Adjustment*	Feeding system					P for interaction
	Low bail	Mod-high bail	PMR	Hybrid	TMR	
No other adjustments						
	2.6 (2.1 to 3.1)	3.4 (3.2 to 3.6)	2.9 (2.5 to 3.4)	4.0 (3.3 to 4.6)	5.1 (4.0 to 6.2)	<0.001
Adjusted for herd average solids per cow						
	2.2 (1.7 to 2.6)	3.0 (2.8 to 3.3)	3.3 (2.8 to 3.7)	3.6 (2.9 to 4.2)	4.8 (3.7 to 5.9)	<0.001
Adjusted for herd average solids per cow and herd average solids*Australian Profit Ranking						
	-1.4 (-2.6 to -0.2)	-1.0 (-2.3 to 0.2)	-1.1 (-2.4 to 0.3)	-1.1 (-2.6 to 0.5)	-0.1 (-1.9 to 1.7)	0.325

*Coefficients represent estimated change in protein yield (kg) per 50 unit increase in the cow's sire's Australian Profit Ranking; coefficients were adjusted for the cow's maternal grandsire's Australian Profit Ranking and age at calving; herd and cow within herd were fitted as random effects

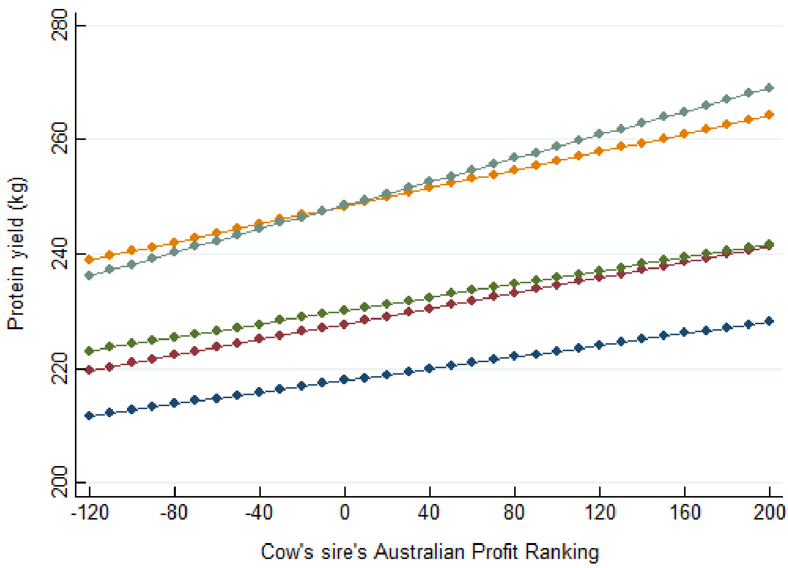


Figure 4.6 Predicted 305-day protein yields by cow's sire's Australian Profit Ranking for lactations from Holstein cows by feeding system, adjusted for the cow's maternal grandsire's Australian Profit Ranking. feeding systems are low bail (blue), mod-high bail (red), PMR (green), hybrid (orange) and TMR (grey).

Table 4.9 Estimated effects*of cow's sire's Australian Profit Ranking on 305-day protein yield (kg) for lactations from Holstein cows by herd average solids per cow (95% CI)

Adjustment*	Herd average solids per cow (kg)				P for interaction
	400	500	600	700	
No other adjustments**					
	2.0 (1.6 to 2.3)	2.8 (2.6 to 3.0)	3.7 (3.5 to 3.9)	4.6 (4.2 to 5.0)	<0.001
Adjusted for feeding system					
	2.0 (1.6 to 2.3)	2.8 (2.6 to 3.0)	3.7 (3.4 to 3.9)	4.6 (4.1 to 5.0)	<0.001
Adjusted for feeding system and feeding system*Australian Profit Ranking					
	1.7 (1.2 to 2.2)	2.5 (2.0 to 3.0)	3.3 (2.7 to 3.9)	4.1 (3.3 to 4.8)	<0.001

*Coefficients represent estimated change in protein yield (kg) per 50 unit increase in the cow's sire's Australian Profit Ranking; coefficients were adjusted for the cow's maternal grandsire's Australian Profit Ranking, age at calving; herd and cow within herd were fitted as random effects
** R^2 was 6.6% (calculated as proportional reduction in estimated cow-level variance comparing model with cow's age at calving and herd average solids per cow with the full model (ie the model with cow's sire's Australian Profit Ranking, maternal grand sire's Australian Profit Ranking, and interaction between cow's sire's Australian Profit Ranking and herd average solids per cow also added)

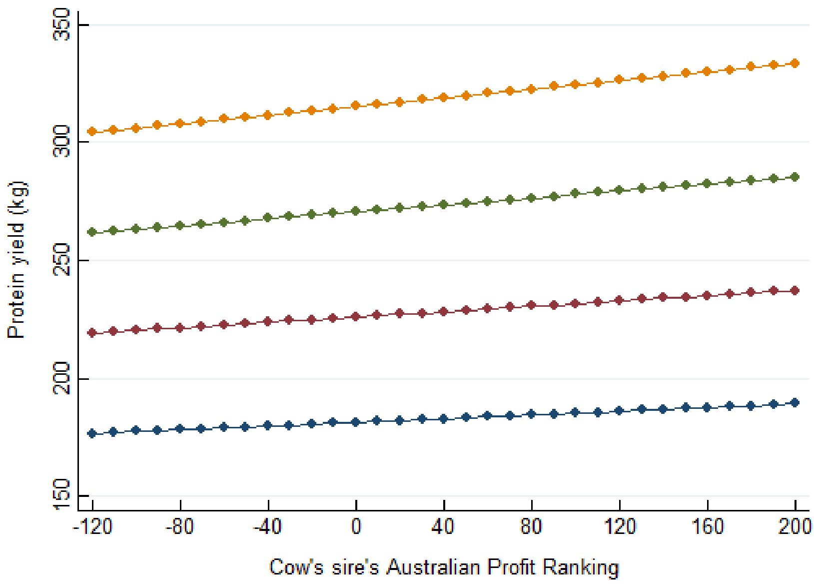


Figure 4.7 Predicted 305-day protein yields by cow's sire's Australian Profit Ranking for lactations from Holstein cows by herd average solids per cow, adjusted for the cow's maternal grandsire's Australian Profit Ranking. Herd average solids per cow are 400 kg (blue), 500 kg (red), 600 kg (green), and 700 kg (orange).

4.5 G*E FOR MILK PROFIT

Estimated effects of sire's Australian Profit Ranking on milk profit are shown in Tables 4.10 and 4.11. **Effects of sire Australian Profit Ranking differed by both feeding system and herd milk yield. Effects were positive in all environments, and were approximately twice as large in TMR and high-producing herds relative to low bail feeding and low-producing herds.**

The estimated effect of $28 per 50 unit increase in the cow's sire's Australian Profit Ranking in the most popular feeding system (moderate to high bail) was slightly higher than that theoretically expected of $25. Increases in Australian Profit Ranking should theoretically have additional effects on herd profitability through increases in other traits including daughter fertility and survival.

As for milk volume and protein yield, the interaction between Australian Profit Ranking and feeding system for milk profit is largely accounted for by interaction between Australian Profit Ranking and herd average solids per cow. For each 50 unit increase in the cow's sire's Australian Profit Ranking, milk profit increased by between $17 and $36 (Table 4.11), with largest responses at higher herd average solids per cow.

Table 4.10 Estimated effects*of cow's sire's Australian Profit Ranking on milk profit ($) for lactations from Holstein cows by feeding system (95% CI)

Adjustment*	Feeding system					P for interaction
	Low bail	Mod-high bail	PMR	Hybrid	TMR	
No other adjustments						
	22.4 (18.4 to 26.3)	28.0 (26.1 to 30.0)	23.2 (19.5 to 26.8)	33.7 (28.3 to 39.2)	45.8 (36.8 to 54.9)	<0.001
Adjusted for herd average solids per cow						
	18.7 (14.9 to 22.5)	24.9 (23.0 to 26.8)	25.8 (22.3 to 29.3)	30.1 (24.8 to 35.4)	42.5 (33.7 to 51.4)	<0.001
Adjusted for herd average solids per cow and herd average solids*Australian Profit Ranking						
	-4.9 (-14.4 to 4.7)	-2.1 (-12.4 to 8.1)	-2.8 (-14.1 to 8.4)	-0.6 (-13.2 to 12.0)	10.2 (-4.8 to 25.1)	0.066

*Coefficients represent estimated change in milk profit ($) per 50 unit increase in the cow's sire's Australian Profit Ranking; coefficients were adjusted for the cow's maternal grandsire's Australian Profit Ranking and age at calving; herd and cow within herd were fitted as random effects

Table 4.11 Estimated effects*of cow's sire's Australian Profit Ranking on milk profit ($) for lactations from Holstein cows by herd average solids per cow (95% CI)

Adjustment*	Herd average solids per cow (kg)				P for interaction
	400	500	600	700	
No other adjustments					
	17.4 (14.7 to 20.0)	23.5 (21.9 to 25.1)	29.6 (27.6 to 31.6)	35.7 (32.3 to 39.0)	<0.001
Adjusted for feeding system					
	17.4 (14.8 to 20.1)	23.5 (21.9 to 25.1)	29.6 (27.6 to 31.6)	35.7 (32.3 to 39.0)	<0.001
Adjusted for feeding system and feeding system*Australian Profit Ranking					
	15.9 (11.9 to 19.8)	21.0 (17.1 to 25.0)	26.2 (21.5 to 31.0)	31.4 (25.3 to 37.5)	<0.001

*Coefficients represent estimated change in milk profit ($) per 50 unit increase in the cow's sire's Australian Profit Ranking; coefficients were adjusted for the cow's maternal grandsire's Australian Profit Ranking, age at calving; herd and cow within herd were fitted as random effects

4.6 G*E AND RECALVED BY 20 MONTHS

For analyses of interactions for recalved by 20 months, the 145,075 lactations were from 410 herds (mean number of lactations per herd: 354; range 1 to 2237).

Effects of Australian Profit Ranking on recalved by 20 months are shown in Tables 4.12 and 4.13. Each coefficient in these tables represents the estimated odds ratio for recalving by 20 months per 50 unit increase in the Australian Profit Ranking. For example, with no adjustments, for each 50 unit increase in the cow's sire's Australian Profit Ranking, the odds of recalving by 20 months were estimated as increasing by a factor of 1.022in the low bail feeding system.

An odds ratio of 1.0 indicates no effect. An odds ratio of 1.089 (the highest estimated odds ratio in Tables 4.12 and 4.13) would indicate that the odds of recalving by 20 months increase by a factor of 1.089 (ie 8.9%) for each 50 unit increase in the Australian Profit Ranking. An odds ratio of 0.852 (the lowest estimated odds ratio in Tables 4.12 and 4.13) would indicate that the odds of recalving by 20 months decrease by a factor of 0.852 (ie a decrease of 14.8%) for each 50 unit increase in the Australian Profit Ranking.

At a reference value of percentage recalved by 20 months of 65.9% (the crude value for the study lactations in Holstein cows), an odds ratio of 1.089 equates to an increase of 1.9 percentage points ie to 67.8% (ie a modest increase), while an odds ratio of 0.852 equates to a decrease of approximately 3.7 percentage points ie to 62.2% (a moderately large decrease).

For recalved by 20 months, there was no evidence for substantial interaction between Australian Profit Ranking and feeding system (Table 4.12). **Effects of Australian Profit Ranking on recalved by 20 months were weakly positive across all except the TMR feeding system, and across all herd milk yield categories; effects were stronger in herds with higher herd average solids per cow** (p for interaction <0.001; Table 4.13). For every 50 units increase in sire Australian Profit Ranking, odds of recalving by 20 months were estimated as increasing by factors of 1.008 (ie an 0.8% increase), 1.029 (ie a 2.9% increase), 1.049, and 1.071 over herd solids values of 400, 500, 600 and 700 kg per cow, respectively.

Table 4.12 Estimated effects*of cow's sire's Australian Profit Ranking on odds of recalving by 20 months for lactations from Holstein cows by feeding system (95% CI)

Adjustment*	Feeding system					P for inter-action
	Low bail	Mod-high bail	PMR	Hybrid	TMR	
No other adjustments						
	1.022 (1.002 to 1.043)	1.037 (1.026 to 1.047)	1.041 (1.022 to 1.060)	1.032 (1.006 to 1.058)	0.994 (0.950 to 1.041)	0.287
Adjusted for herd average solids per cow						
	1.022 (1.002 to 1.043)	1.037 (1.026 to 1.047)	1.041 (1.022 to 1.061)	1.032 (1.006 to 1.058)	0.994 (0.950 to 1.040)	0.275
Adjusted for herd average solids per cow and herd average solids*Australian Profit Ranking						
	0.914 (0.870 to 0.960)	0.910 (0.862 to 0.960)	0.907 (0.855 to 0.962)	0.890 (0.834 to 0.950)	0.852 (0.788 to 0.920)	0.058

*Coefficients represent estimated odds ratios for recalving by 20 month per 50 unit increase in the cow's sire's Australian Profit Ranking; coefficients were adjusted for the cow's maternal grandsire's Australian Profit Ranking and age at calving; herd was fitted as a random effect

Table 4.13 Estimated effects*of cow's sire's Australian Profit Ranking on odds of recalving by 20 months for lactations from Holstein cows by herd average solids per cow (95% CI)

Adjustment*	Herd average solids per cow (kg)				P for interaction
	400	500	600	700	
No other adjustments					
	1.008 (0.994 to 1.022)	1.029 (1.020 to 1.037)	1.049 (1.039 to 1.060)	1.071 (1.052 to 1.089)	<0.001
Adjusted for feeding system					
	1.008 (0.995 to 1.022)	1.029 (1.020 to 1.037)	1.049 (1.039 to 1.060)	1.070 (1.052 to 1.089)	<0.001
Adjusted for feeding system and feeding system*Australian Profit Ranking					
	1.010 (0.990 to 1.031)	1.036 (1.014 to 1.057)	1.062 (1.035 to 1.089)	1.089 (1.054 to 1.125)	<0.001

*Coefficients represent estimated change in protein yield (kg) per 50 unit increase in the cow's sire's Australian Profit Ranking; coefficients were adjusted for the cow's maternal grandsire's Australian Profit Ranking and age at calving; herd was fitted as a random effect

CHAPTER 5. EFFECTS OF AUSTRALIAN SELECTION INDEX AND OTHER EFFECTS OF AUSTRALIAN BREEDING VALUES

5.1 OBJECTIVES

The following research objective is addressed in this chapter:

- to assess effects of Australian Selection Index and Australian Breeding Values within various feeding systems and herd average milk solids yields on the associated and other milk production traits, and on recalving by 20 months and occurrence of short lactations

The closeness of association between Australian Selection Index and Australian Profit Ranking is also relevant; if these indices are closely associated, any G*E would be expected to be due to the same mechanisms for both. Thus this was also assessed.

5.2 ASSOCIATION BETWEEN AUSTRALIAN SELECTION INDEX AND AUSTRALIAN PROFIT RANKING

Associations between Australian Selection Index and Australian Profit Ranking are depicted in Figures 5.1 and 5.2. **Australian Selection Index and Australian Profit Ranking were closely correlated** (Holstein sires: r = 0.904; 95% CI: 0.900 to 0.909; Jersey sires: r = 0.964; 95% CI: 0.960 to 0.968). From linear regression models, for each unit increase in Australian Selection Index, Australian Profit Ranking increased in Holstein sires by 1.17 units (95% CI 1.15 to 1.19) and in Jersey sires by 0.79 units (95% CI 0.78 to 0.81).

Figure 5.1 Scattergraph of Australian Profit Ranking versus Australian Selection Index for 5,806 Holstein sires; the outlying sire's Australian Selection Index and Australian Profit Ranking were 430 and -154, respectively, and its Australian Breeding Values for milk volume, fat yield and protein yield were -979, -3, and -33, respectively.

Figure 5.2 Scattergraph of Australian Profit Ranking versus Australian Selection Index for 1,342 Jersey sires

5.3 SUMMARY OF EFFECTS

Estimated effects of cow's sire's Australian Selection Index and Australian Breeding Values are summarised for Holsteins in Table 5.1 and for Jerseys in Table 5.2. Detailed results are reported in subsequent sections of this chapter.

These results inform the likely phenotypic effects of selection of sires based solely or heavily on Australian Selection Index or one of the Australian Breeding Value for milk volume, fat or protein yield or concentration, survival or daughter fertility. Interactions between Australian Selection Index and environment were similar to those for Australian Profit Ranking. In Holstein cows, effects on milk volume, fat and protein yield, and recalved by 20 months were generally as expected based on genetic correlations (Pryce *et al* 2010). Where important G*E was detected, increases in milk volume, fat and protein yield associated with increases in the genetic measure were mostly larger in higher feed input feeding systems and/or at higher herd average solids per cow. Increases in Australian Breeding Values for fat and protein yield resulted in moderately large decreases in odds of recalving by 20 months in the total mixed ration feeding system, and small to moderate reductions in other systems. Increases in Australian Breeding Values for survival and daughter fertility resulted in small to modest increases in odds of recalving by 20 months in all systems.

In Jerseys, G*E could only be sensibly assessed across a narrower range of environments, but results were generally similar to those for Holsteins.

Table 5.1 Summary of estimated effects of cow's sire's Australian Selection Index and Australian Breeding Values in Holsteins

Index or breeding value Trait	General effect of increasing sire's index or breeding value	Interactions
Australian Selection Index		
Milk volume, fat yield, protein yield	Increased in all systems*	Larger effects in higher feed input feeding systems and/or at higher herd average solids per cow
Recalved by 20 months	Decreased odds of recalving by 20 months in all systems	Moderately large decrease in TMR feeding system; small to moderate reduction in other systems
Australian Breeding Value for milk volume		
Milk volume	Estimated increase: 19 to 27 litres per 50 unit increase in sire's Australian Breeding Value (theoretically expected: 25 litres)	Larger effects in higher feed input feeding systems and/or at higher herd average solids per cow
Fat yield	Small increases because fat percentage decreases	
Protein yield	Small increases because protein percentage decreases	
Recalved by 20 months	Negligible reductions in all systems	
Australian Breeding Value for fat yield		
Milk volume	Increased in all systems	Largest increase in TMR feeding system and at higher herd average solids per cow
Fat yield	Estimated increase: 2.7 to 5.6 kgs per 10 unit increase in sire's Australian Breeding Value (theoretically expected: 5.0 kg)	Larger effects in higher feed input feeding systems and at higher herd average solids per cow
Protein yield	Modest increases in all systems	Largest increase in TMR feeding system and at higher herd average solids per cow
Recalved by 20 months	Reduced in some systems	Moderately large decrease in TMR feeding system; small to moderate reduction in other systems
Australian Breeding Value for protein yield		
Milk volume	Increased in all systems	Larger increases at higher herd average solids per cow
Fat yield	Modest increases in all systems	
Protein yield	Estimated increase: 3.5 to 6.8 kgs per 10 unit increase in sire's Australian Breeding Value (theoretically expected: 5.0 kg)	Larger increases in higher feed input feeding systems and at higher herd average solids per cow
Recalved by 20 months	Reduced in some systems	Moderately large decrease in TMR feeding system; small to moderate reduction in other systems
Australian Breeding Value for fat percentage*		
Milk volume	Decreased in all systems	Inconsistent across feeding systems; larger reductions at higher herd average solids per cow
Fat yield	Increased in all systems	Larger increases in higher feed input feeding systems and at higher herd average solids per cow
Protein yield	Increased in all systems	Larger increases in higher feed input feeding systems
Recalved by 20 months	Effect estimates imprecise	

Table 5.1 (cont) Summary of estimated effects of cow's sire's Australian Selection Index and Australian Breeding Values in Holsteins

Index or breeding value **Trait**	**General effect of increasing sire's index or breeding value**	**Interactions**
Australian Breeding Value for protein percentage*		
Milk volume	Decreased in all systems	Inconsistent across feeding systems; similar reductions across herd average solids per cow categories
Fat yield	Increased in most systems	
Protein yield	Increased in most systems	Inconsistent across feeding systems; much larger effect at high herd average solids per cow
Recalved by 20 months	Effect estimates imprecise	
Australian Breeding Value for daughter fertility		
Milk volume	Decreased in most systems	Inconsistent across feeding systems; similar reductions across herd average solids per cow categories
Fat yield, protein yield	Decreased in most systems	Similar reduction across feeding systems; larger reduction at high herd average solids per cow
Recalved by 20 months	Small increases in odds of recalving by 20 months in all systems	
Australian Breeding Value for survival		
Milk volume	Increased in all systems	Larger increases in higher feed input feeding systems and at higher herd average solids per cow
Fat yield	Increased in most systems	Larger increases in higher feed input feeding systems; smaller increases at higher herd average solids per cow
Protein yield	Increased in all systems	Larger increases in higher feed input feeding systems; similar increases across herd average solids per cow categories
Recalved by 20 months	Small to modest increases in odds of recalving by 20 months in all systems	

*'Systems' in this table refers to both feeding systems and herd average solids per cow categories.
** Estimated fat percentage increases: 0.339 to 0.458 percentage points per 1 unit increase in sire's Australian Breeding Value (theoretically expected: 0.500)
*** Estimated protein percentage increases: 0.380 to 0.427 percentage points per 1 unit increase in sire's Australian Breeding Value (theoretically expected: 0.500)

Table 5.2 Summary of estimated effects of cow's sire's Australian Selection Index and Australian Breeding Values in Jerseys

Index or breeding value **Trait**	**General effect of increasing sire's index or breeding value**	**Interactions****
Australian Selection Index		
Milk volume, fat yield, protein yield	Increased in all systems*	Similar effects across feeding systems; larger increases at higher herd average solids per cow
Recalved by 20 months	No large effect in any system; small increases in some systems	
Australian Breeding Value for milk volume		
Milk volume	Estimated increase: 14 to 26 litres per 50 unit increase in sire's Australian Breeding Value (theoretically expected: 25 litres)	Larger effects in higher feed input feeding systems and/or at higher herd average solids per cow
Fat yield	Small increases because fat percentage decreases	
Protein yield	Small increases because protein percentage decreases	
Recalved by 20 months	Negligible reductions in all systems	
Australian Breeding Value for fat yield		
Milk volume	Increased in all systems	Similar increases across feeding system and herd average solids per cow categories
Fat yield	Estimated increase: 3.4 to 4.8 kgs per 10 unit increase in sire's Australian Breeding Value (theoretically expected: 5.0 kg)	Larger effects at higher herd average solids per cow
Protein yield	Modest increases in all systems	
Recalved by 20 months	Small increases in some systems	
Australian Breeding Value for protein yield		
Milk volume	Increased in all systems	Larger increases in higher feed input feeding systems and at higher herd average solids per cow
Fat yield	Modest increases in all systems	
Protein yield	Estimated increase: 3.2 to 5.9 kgs per 10 unit increase in sire's Australian Breeding Value (theoretically expected: 5.0 kg)	Larger increases in higher feed input feeding systems and at higher herd average solids per cow
Recalved by 20 months	No large effects in any system	
Australian Breeding Value for fat percentage***		
Milk volume	Decreased in all systems	Inconsistent across feeding systems; larger reductions at higher herd average solids per cow
Fat yield	Increased in most systems	Larger increases in higher feed input feeding systems; smaller increases at higher herd average solids per cow
Protein yield	Reduced in some systems	Larger reductions in higher feed input feeding systems and at higher herd average solids per cow
Recalved by 20 months	Effect estimates imprecise	
Australian Breeding Value for protein percentage****		
Milk volume	Decreased in all systems	Inconsistent across feeding systems; larger reductions at higher herd average solids per cow
Fat yield	Decreased in some systems	Increased in higher feed input feeding systems and at higher herd average solids per cow
Protein yield	Effect estimates imprecise	
Recalved by 20 months	Effect estimates imprecise	

Table 5.2 (cont) Summary of estimated effects of cow's sire's Australian Selection Index and Australian Breeding Values in Jerseys

Index or breeding value Trait	General effect of increasing sire's index or breeding value	Interactions**
Australian Breeding Value for daughter fertility		
Milk volume	Decreased in most systems	Similar reductions across feeding systems and herd average solids per cow categories
Fat yield, protein yield	Decreased in most systems	Similar reduction across feeding systems; larger reduction at high herd average solids per cow
Recalved by 20 months	Small increases in odds of recalving by 20 months in all systems	
Australian Breeding Value for survival		
Milk volume	Increased in all systems	Larger increases in higher feed input feeding systems and at higher herd average solids per cow
Fat yield	Increased in all systems	Larger increases in higher feed input feeding systems; smaller increases at higher herd average solids per cow
Protein yield	Increased in all systems	Larger increases in higher feed input feeding systems; similar increases across herd average solids per cow categories
Recalved by 20 months	Small increases in odds of recalving by 20 months in all systems	

*'Systems' in this table refers to both feeding systems and herd average solids per cow categories.
** 'Higher' inputs refers to moderate-high and PMR feeding systems, and 500 and 600 kg herd average herd average solids per cow.
*** Estimated fat percentage increases: 0.314 to 0.386 percentage points per 1 unit increase in sire's Australian Breeding Value (theoretically expected: 0.500)
**** Estimated protein percentage increases: 0.360 to 0.400 percentage points per 1 unit increase in sire's Australian Breeding Value (theoretically expected: 0.500)

5.4 EFFECTS ON MILK PRODUCTION IN HOLSTEINS

Estimated effects of cow's sire's Australian Selection Index and Australian Breeding Values on milk production in Holsteins are detailed in Tables 5.3 to 5.26.

AUSTRALIAN SELECTION INDEX

Table 5.3 Estimated effects*of cow's sire's Australian Selection Index on 305-day milk production for lactations from Holstein cows by feeding system (95% CI)

Milk production variable	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
Milk volume (l)	61.3 (43.8 to 78.7)	62.1 (53.5 to 70.6)	55.7 (40.0 to 71.3)	76.1 (52.1 to 100.1)	84.7 (45.0 to 124.4)
Fat yield (kg)	3.2 (2.5 to 3.8)	3.1 (2.7 to 3.4)	2.3 (1.7 to 2.9)	3.9 (3.0 to 4.8)	4.9 (3.4 to 6.4)
Protein yield (kg)	3.2 (2.6 to 3.7)	3.7 (3.4 to 4.0)	3.5 (3.0 to 3.9)	4.5 (3.7 to 5.2)	5.0 (3.7 to 6.2)
Fat percentage	0.004 (-0.002 to 0.009)	0.007 (0.005 to 0.010)	0.003 (-0.002 to 0.007)	0.010 (0.003 to 0.017)	0.017 (0.006 to 0.029)
Protein percentage	0.014 (0.012 to 0.016)	0.022 (0.021 to 0.023)	0.020 (0.018 to 0.022)	0.024 (0.020 to 0.027)	0.024 (0.019 to 0.029)

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Selection Index; coefficients were adjusted for maternal grand sire's Australian Selection Index and cow's age at calving; herd and cow within herd were fitted as random effects

Table 5.4 P-values for differences in estimated effects of cow's sire's Australian Selection Index on 305-day milk production for lactations from Holstein cows by feeding system, relative to the moderate to high bail feeding system (reference group or Ref. group), for each milk production variable

Milk production variable	Feeding system					P for interaction	R^{2*}
	Low bail	Mod-high bail	PMR	Hybrid	TMR		
Milk volume (l)	0.934	Ref. group	0.477	0.279	0.274	0.522	1.9%
Fat yield (kg)	0.808	Ref. group	0.032	0.086	0.021	0.005	3.9%
Protein yield (kg)	0.076	Ref. group	0.391	0.055	0.052	0.013	7.4%
Fat percentage	0.154	Ref. group	0.077	0.441	0.105	0.059	0.1%
Protein percentage	<0.001	Ref. group	0.035	0.430	0.601	<0.001	3.8%

*Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and feeding system with the full model (ie the model with cow's sire's Australian Selection Index, maternal grand sire's Australian Selection Index, and interaction between cow's sire's Australian Selection Index and feeding system also added)

Table 5.5 Estimated effects*of cow's sire's Australian Selection Index on 305-day milk production for lactations from Holstein cows by herd average solids per cow (95% CI)

Milk production variable	Herd average solids per cow (kg)				P for interaction	R^{2**}
	400	500	600	700		
Milk volume (l)	38.4 (26.6 to 50.3)	51.6 (44.6 to 58.6)	64.8 (56.0 to 73.5)	78.0 (63.0 to 92.9)	0.001	1.7%
Fat yield (kg)	Model did not converge	2.7 (2.4 to 2.9)	2.9 (2.6 to 3.2)	3.1 (2.5 to 3.7)	0.138	3.3%
Protein yield (kg)	2.2 (1.8 to 2.6)	3.2 (3.0 to 3.4)	4.2 (3.9 to 4.4)	5.1 (4.7 to 5.6)	<0.001	6.6%
Fat percentage	0.010 (0.006 to 0.014)	0.007 (0.005 to 0.009)	0.004 (0.001 to 0.007)	0.001 (-0.003 to 0.006)	0.011	0.1%
Protein percentage	0.015 (0.014 to 0.017)	0.020 (0.019 to 0.020)	0.024 (0.023 to 0.025)	0.028 (0.026 to 0.030)	<0.001	4.1%

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Selection Index; coefficients were adjusted for maternal grand sire's Australian Selection Index and cow's age at calving; herd and cow within herd were fitted as random effects
**Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and herd average solids per cow with the full model (ie the model with cow's sire's Australian Selection Index, maternal grand sire's Australian Selection Index, and interaction between cow's sire's Australian Selection Index and herd average solids per cow also added)

Table 5.6 Estimated effects*of cow's sire's Australian Breeding Value for milk volume on 305-day milk production for lactations from Holstein cows by feeding system (95% CI)

Milk production variable	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
Milk volume (l)	19.5 (16.8 to 22.2)	24.1 (22.8 to 25.4)	23.8 (21.4 to 26.2)	22.6 (19.1 to 26.2)	22.0 (15.9 to 28.2)
Fat yield (kg)	0.2 (0.1 to 0.3)	0.2 (0.1 to 0.2)	0.1 (0.0 to 0.2)	0.1 (0.0 to 0.2)	0.4 (0.1 to 0.6)
Protein yield (kg)	0.4 (0.3 to 0.5)	0.5 (0.5 to 0.5)	0.5 (0.4 to 0.6)	0.5 (0.3 to 0.6)	0.6 (0.4 to 0.7)
Fat percentage	-0.010 (-0.011 to -0.010)	-0.011 (-0.011 to -0.010)	-0.011 (-0.011 to -0.010)	-0.009 (-0.010 to -0.008)	-0.006 (-0.008 to -0.005)
Protein percentage	-0.004 (-0.005 to -0.004)	-0.004 (-0.004 to -0.004)	-0.003 (-0.004 to -0.003)	-0.003 (-0.003 to -0.003)	-0.002 (-0.003 to -0.002)

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Breeding Value for milk volume; coefficients were adjusted for maternal grand sire's Australian Breeding Value for milk volume and cow's age at calving; herd and cow within herd were fitted as random effects

Table 5.7 P-values for differences in estimated effects of cow's sire's Australian Breeding Value for milk volume on 305-day milk production for lactations from Holstein cows by feeding system, relative to the moderate to high bail feeding system (reference group or Ref. group), for each milk production variable

Milk production variable	Feeding system					P for interaction	R^{2*}
	Low bail	Mod-high bail	PMR	Hybrid	TMR		
Milk volume (l)	0.003	Ref. group	0.863	0.448	0.525	0.048	5.6%
Fat yield (kg)	0.827	Ref. group	0.213	0.535	0.078	0.225	3.1%
Protein yield (kg)	0.010	Ref. group	0.773	0.435	0.663	0.090	5.1%
Fat percentage	0.342	Ref. group	0.660	<0.001	<0.001	<0.001	3.2%
Protein percentage	0.016	Ref. group	0.002	0.001	0.001	<0.001	1.7%

*Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and feeding system with the full model (ie the model with cow's sire's Australian Breeding Value for milk volume, maternal grand sire's Australian Breeding Value for milk volume, and interaction between cow's sire's Australian Breeding Value for milk volume and feeding system also added)

Table 5.8 Estimated effects*of cow's sire's Australian Breeding Value for milk volume on 305-day milk production for lactations from Holstein cows by herd average solids per cow (95% CI)

Milk production variable	Herd average solids per cow (kg)				P for interaction	R^{2**}
	400	500	600	700		
Milk volume (l)	19.0 (17.2 to 20.9)	21.8 (20.7 to 22.9)	24.6 (23.3 to 25.9)	27.4 (25.1 to 29.6)	<0.001	8.2%
Fat yield (kg)	0.2 (0.1 to 0.2)	0.1 (0.1 to 0.2)	0.1 (0.0 to 0.1)	0.1 (0.0 to 0.1)	0.141	0.3%
Protein yield (kg)	0.4 (0.3 to 0.4)	0.5 (0.4 to 0.5)	0.5 (0.5 to 0.6)	0.6 (0.5 to 0.6)	0.001	4.4%
Fat percentage	-0.011 (-0.011 to -0.010)	-0.011 (-0.011 to -0.010)	-0.010 (-0.011 to -0.010)	-0.010 (-0.011 to -0.010)	0.257	5.9%
Protein percentage	-0.004 (-0.004 to -0.004)	-0.004 (-0.004 to -0.004)	-0.003 (-0.004 to -0.003)	-0.003 (-0.003 to -0.003)	<0.001	4.4%

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Breeding Value for milk volume; coefficients were adjusted for maternal grand sire's Australian Breeding Value for milk volume and cow's age at calving; herd and cow within herd were fitted as random effects
**Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and herd average solids per cow with the full model (ie the model with cow's sire's Australian Breeding Value for milk volume, maternal grand sire's Australian Breeding Value for milk volume, and interaction between cow's sire's Australian Breeding Value for milk volume and herd average solids per cow also added)

Table 5.9 Estimated effects*of cow's sire's Australian Breeding Value for fat yield on 305-day milk production for lactations from Holstein cows by feeding system (95% CI)

Milk production variable	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
Milk volume (l)	35.5 (20.5 to 50.4)	25.8 (18.6 to 33.0)	30.8 (17.6 to 43.9)	28.7 (8.5 to 49.0)	79.6 (47.9 to 111.3)
Fat yield (kg)	3.5 (2.9 to 4.1)	3.9 (3.6 to 4.1)	4.1 (3.6 to 4.6)	4.8 (4.0 to 5.5)	5.6 (4.4 to 6.8)
Protein yield (kg)	1.4 (0.9 to 1.8)	1.4 (1.2 to 1.7)	1.4 (1.0 to 1.9)	1.5 (0.9 to 2.2)	3.5 (2.5 to 4.5)
Fat percentage	0.029 (0.025 to 0.033)	0.038 (0.036 to 0.040)	0.036 (0.032 to 0.040)	0.044 (0.038 to 0.050)	0.031 (0.022 to 0.041)
Protein percentage	0.001 (-0.001 to 0.003)	0.008 (0.007 to 0.009)	0.006 (0.004 to 0.008)	0.007 (0.005 to 0.010)	0.009 (0.005 to 0.013)

*Coefficients represent estimated change in milk production variable per 10 unit increase in the cow's sire's Australian Breeding Value for fat yield; coefficients were adjusted for maternal grand sire's Australian Breeding Value for fat yield and cow's age at calving; herd and cow within herd were fitted as random effects

Table 5.10 P-values for differences in estimated effects of cow's sire's Australian Breeding Value for fat yield on 305-day milk production for lactations from Holstein cows by feeding system, relative to the moderate to high bail feeding system (reference group or Ref. group), for each milk production variable

Milk production variable	Feeding system					P for interaction	R^{2*}
	Low bail	Mod-high bail	PMR	Hybrid	TMR		
Milk volume (l)	0.245	Ref. group	0.513	0.788	0.001	0.023	4.0%
Fat yield (kg)	0.242	Ref. group	0.469	0.030	0.007	0.007	3.2%
Protein yield (kg)	0.813	Ref. group	0.948	0.822	<0.001	0.003	4.2%
Fat percentage	<0.001	Ref. group	0.423	0.048	0.173	<0.001	1.7%
Protein percentage	<0.001	Ref. group	0.026	0.535	0.662	<0.001	1.3%

*Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and feeding system with the full model (ie the model with cow's sire's Australian Breeding Value for fat yield, maternal grand sire's Australian Breeding Value for fat yield, and interaction between cow's sire's Australian Breeding Value for fat yield and feeding system also added)

Table 5.11 Estimated effects*of cow's sire's Australian Breeding Value for fat yield on 305-day milk production for lactations from Holstein cows by herd average solids per cow (95% CI)

Milk production variable	Herd average solids per cow (kg)				P for interaction	R^{2**}
	400	500	600	700		
Milk volume (l)	19.4 (9.4 to 29.4)	25.0 (19.1 to 30.9)	30.6 (23.3 to 38.0)	36.2 (23.6 to 48.8)	0.091	0.4%
Fat yield (kg)	2.7 (2.3 to 3.0)	3.6 (3.3 to 3.8)	4.4 (4.2 to 4.7)	5.3 (4.8 to 5.8)	<0.001	6.5%
Protein yield (kg)	0.9 (0.6 to 1.2)	1.3 (1.1 to 1.5)	1.7 (1.5 to 2.0)	2.2 (1.8 to 2.6)	<0.001	1.4%
Fat percentage	0.030 (0.027 to 0.033)	0.035 (0.033 to 0.037)	0.040 (0.038 to 0.042)	0.045 (0.041 to 0.049)	<0.001	3.1%
Protein percentage	0.003 (0.002 to 0.005)	0.006 (0.005 to 0.007)	0.009 (0.008 to 0.010)	0.012 (0.010 to 0.013)	<0.001	0.7%

*Coefficients represent estimated change in milk production variable per 10 unit increase in the cow's sire's Australian Breeding Value for fat yield; coefficients were adjusted for maternal grand sire's Australian Breeding Value for fat yield and cow's age at calving; herd and cow within herd were fitted as random effects

**Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and herd average solids per cow with the full model (ie the model with cow's sire's Australian Breeding Value for fat yield, maternal grand sire's Australian Breeding Value for fat yield, and interaction between cow's sire's Australian Breeding Value for fat yield and herd average solids per cow also added)

Table 5.12 Estimated effects*of cow's sire's Australian Breeding Value for protein yield on 305-day milk production for lactations from Holstein cows by feeding system (95% CI)

Milk production variable	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
Milk volume (l)	127.6 (105.9 to 149.4)	149.4 (138.9 to 159.9)	137.4 (118.3 to 156.5)	157.1 (128.3 to 185.9)	145.3 (94.1 to 196.4)
Fat yield (kg)	2.5 (1.7 to 3.4)	2.2 (1.8 to 2.6)	1.0 (0.2 to 1.7)	2.5 (1.4 to 3.6)	4.3 (2.3 to 6.2)
Protein yield (kg)	4.3 (3.7 to 5.0)	5.4 (5.0 to 5.7)	5.0 (4.4 to 5.6)	5.9 (5.0 to 6.8)	6.2 (4.6 to 7.8)
Fat percentage	-0.049 (-0.055 to -0.043)	-0.050 (-0.053 to -0.047)	-0.054 (-0.060 to -0.049)	-0.043 (-0.052 to -0.035)	-0.022 (-0.037 to -0.007)
Protein percentage	-0.002 (-0.005 to 0.001)	0.006 (0.005 to 0.007)	0.006 (0.003 to 0.008)	0.010 (0.006 to 0.014)	0.013 (0.006 to 0.020)

*Coefficients represent estimated change in milk production variable per 10 unit increase in the cow's sire's Australian Breeding Value for protein yield; coefficients were adjusted for maternal grand sire's Australian Breeding Value for protein yield and cow's age at calving; herd and cow within herd were fitted as random effects

Table 5.13 P-values for differences in estimated effects of cow's sire's Australian Breeding Value for protein yield on 305-day milk production for lactations from Holstein cows by feeding system, relative to the moderate to high bail feeding system (reference group or Ref. group), for each milk production variable

Milk production variable	Feeding system					P for interaction	R^{2*}
	Low bail	Mod-high bail	PMR	Hybrid	TMR		
Milk volume (l)	0.071	Ref. group	0.275	0.618	0.878	0.333	4.0%
Fat yield (kg)	0.534	Ref. group	0.003	0.698	0.049	0.003	2.9%
Protein yield (kg)	0.007	Ref. group	0.298	0.306	0.316	0.024	4.6%
Fat percentage	0.733	Ref. group	0.184	0.125	<0.001	0.001	0.1%
Protein percentage	<0.001	Ref. group	0.790	0.073	0.041	<0.001	0.7%

*Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and feeding system with the full model (ie the model with cow's sire's Australian Breeding Value for protein yield, maternal grand sire's Australian Breeding Value for protein yield, and interaction between cow's sire's Australian Breeding Value for protein yield and feeding system also added)

Table 5.14 Estimated effects*of cow's sire's Australian Breeding Value for protein yield on 305-day milk production for lactations from Holstein cows by herd average solids per cow (95% CI)

Milk production variable	Herd average solids per cow (kg)				P for interaction	R^{2**}
	400	500	600	700		
Milk volume (l)	107.3 (92.6 to 121.9)	129.4 (120.7 to 138.0)	151.5 (140.8 to 162.2)	173.6 (155.3 to 192.0)	<0.001	5.4%
Fat yield (kg)	2.1 (1.6 to 2.7)	1.8 (1.5 to 2.2)	1.5 (1.1 to 1.9)	1.2 (0.5 to 2.0)	0.121	1.2%
Protein yield (kg)	3.5 (3.1 to 4.0)	4.6 (4.4 to 4.9)	5.7 (5.4 to 6.1)	6.8 (6.3 to 7.4)	<0.001	8.4%
Fat percentage	-0.044 (-0.049 to -0.040)	-0.049 (-0.052 to -0.046)	-0.054 (-0.057 to -0.050)	-0.059 (-0.064 to -0.053)	0.001	1.7%
Protein percentage	-0.001 (-0.003 to 0.001)	0.004 (0.002 to 0.005)	0.008 (0.007 to 0.010)	0.013 (0.011 to 0.016)	<0.001	0.3%

*Coefficients represent estimated change in milk production variable per 10 unit increase in the cow's sire's Australian Breeding Value for protein yield; coefficients were adjusted for maternal grand sire's Australian Breeding Value for protein yield and cow's age at calving; herd and cow within herd were fitted as random effects

**Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and herd average solids per cow with the full model (ie the model with cow's sire's Australian Breeding Value for protein yield, maternal grand sire's Australian Breeding Value for protein yield, and interaction between cow's sire's Australian Breeding Value for protein yield and herd average solids per cow also added)

Table 5.15 Estimated effects*of cow's sire's Australian Breeding Value for fat percentage on 305-day milk production for lactations from Holstein cows by feeding system (95% CI)

Milk production variable	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
Milk volume (l)	-367.9 (-449.0 to -286.9)	-521.3 (-559.3 to -483.3)	-498.9 (-569.5 to -428.3)	-499.3 (-606.8 to -391.8)	-210.0 (-408.1 to -11.8)
Fat yield (kg)	10.2 (7.1 to 13.3)	11.8 (10.3 to 13.3)	14.4 (11.7 to 17.2)	16.6 (12.5 to 20.8)	18.9 (11.2 to 26.5)
Protein yield (kg)	-4.4 (-6.9 to -1.8)	-7.3 (-8.5 to -6.1)	-7.7 (-9.9 to -5.5)	-6.3 (-9.7 to -2.9)	2.9 (-3.4 to 9.2)
Fat percentage	0.403 (0.380 to 0.426)	0.444 (0.432 to 0.455)	0.435 (0.415 to 0.456)	0.425 (0.394 to 0.456)	0.339 (0.282 to 0.397)
Protein percentage	0.122 (0.112 to 0.133)	0.135 (0.130 to 0.141)	0.111 (0.102 to 0.120)	0.112 (0.098 to 0.127)	0.120 (0.094 to 0.146)

*Coefficients represent estimated change in milk production variable per 1 unit increase in the cow's sire's Australian Breeding Value for fat percentage; coefficients were adjusted for maternal grand sire's Australian Breeding Value for fat percentage and cow's age at calving; herd and cow within herd were fitted as random effects

Table 5.16 P-values for differences in estimated effects of cow's sire's Australian Breeding Value for fat percentage on 305-day milk production for lactations from Holstein cows by feeding system, relative to the moderate to high bail feeding system (reference group or Ref. group), for each milk production variable

Milk production variable	Feeding system					P for interaction	R^{2*}
	Low bail	Mod-high bail	PMR	Hybrid	TMR		
Milk volume (l)	0.001	Ref. group	0.582	0.705	0.002	0.001	5.5%
Fat yield (kg)	0.357	Ref. group	0.091	0.031	0.075	0.024	2.8%
Protein yield (kg)	0.040	Ref. group	0.756	0.597	0.002	0.007	4.6%
Fat percentage	0.001	Ref. group	0.457	0.265	<0.001	<0.001	7.9%
Protein percentage	0.025	Ref. group	<0.001	0.003	0.258	<0.001	4.7%

*Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and feeding system with the full model (ie the model with cow's sire's Australian Breeding Value fat percentage, maternal grand sire's Australian Breeding Value for fat percentage, and interaction between cow's sire's Australian Breeding Value for fat percentage and feeding system also added)

Table5. 17 Estimated effects*of cow's sire's Australian Breeding Value for fat percentage on 305-day milk production for lactations from Holstein cows by herd average solids per cow (95% CI)

Milk production variable	Herd average solids per cow (kg)				P for interaction	R^{2**}
	400	500	600	700		
Milk volume (l)	-419.8 (-473.9 to -365.7)	-470.8 (-502.2 to -439.5)	-521.9 (-561.0 to -482.8)	-572.9 (-640.5 to -505.4)	0.005	4.1%
Fat yield (kg)	7.1 (5.0 to 9.2)	11.6 (10.4 to 12.8)	16.0 (14.5 to 17.5)	20.4 (17.8 to 23.0)	<0.001	2.0%
Protein yield (kg)	-6.4 (-8.1 to -4.7)	-6.4 (-7.4 to -5.4)	Model did not converge	-6.3 (-8.4 to -4.1)	0.926	0.9%
Fat percentage	0.417 (0.401 to 0.433)	0.431 (0.421 to 0.440)	0.444 (0.433 to 0.456)	0.458 (0.439 to 0.478)	0.008	12.7%
Protein percentage	0.126 (0.118 to 0.133)	0.127 (0.123 to 0.132)	0.129 (0.124 to 0.135)	0.131 (0.122 to 0.140)	0.451	6.4%

*Coefficients represent estimated change in milk production variable per 1 unit increase in the cow's sire's Australian Breeding Value for fat percentage; coefficients were adjusted for maternal grand sire's Australian Breeding Value for fat percentage and cow's age at calving; herd and cow within herd were fitted as random effects

**Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and herd average solids per cow with the full model (ie the model with cow's sire's Australian Breeding Value for fat percentage, maternal grand sire's Australian Breeding Value for fat percentage, and interaction between cow's sire's Australian Breeding Value for fat percentage and herd average solids per cow also added)

Table 5.18 Estimated effects*of cow's sire's Australian Breeding Value for protein percentage on 305-day milk production for lactations from Holstein cows by feeding system (95% CI)

Milk production variable	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
Milk volume (l)	-496.9 (-663.3 to -330.6)	-662.7 (-742.3 to -583.2)	-808.7 (-956.4 to -661.1)	-532.3 (-765.8 to -298.9)	-624.9 (-1,027.3 to -222.5)
Fat yield (kg)	11.1 (4.7 to 17.5)	9.0 (6.0 to 12.1)	1.4 (-4.3 to 7.1)	17.5 (8.5 to 26.4)	9.3 (-6.1 to 24.8)
Protein yield (kg)	9.5 (4.2 to 14.7)	9.4 (6.9 to 11.9)	4.0 (-0.7 to 8.6)	20.2 (12.8 to 27.6)	12.5 (-0.2 to 25.2)
Fat percentage	0.462 (0.414 to 0.510)	0.480 (0.455 to 0.504)	0.438 (0.394 to 0.481)	0.413 (0.344 to 0.482)	0.414 (0.294 to 0.533)
Protein percentage	0.392 (0.371 to 0.413)	0.425 (0.415 to 0.435)	0.380 (0.361 to 0.399)	0.425 (0.396 to 0.455)	0.394 (0.343 to 0.446)

*Coefficients represent estimated change in milk production variable per 1 unit increase in the cow's sire's Australian Breeding Value for protein percentage; coefficients were adjusted for maternal grand sire's Australian Breeding Value for protein percentage and cow's age at calving; herd and cow within herd were fitted as random effects

Table 5.19 P-values for differences in estimated effects of cow's sire's Australian Breeding Value for protein percentage on 305-day milk production for lactations from Holstein cows by feeding system, relative to the moderate to high bail feeding system (reference group or Ref. group), for each milk production variable

Milk production variable	Feeding system					P for interaction	R^{2*}
	Low bail	Mod-high bail	PMR	Hybrid	TMR		
Milk volume (l)	0.073	Ref. group	0.085	0.300	0.857	0.057	5.1%
Fat yield (kg)	0.554	Ref. group	0.019	0.080	0.971	0.027	2.8%
Protein yield (kg)	0.994	Ref. group	0.042	0.007	0.645	0.008	3.9%
Fat percentage	0.497	Ref. group	0.088	0.071	0.288	0.228	2.7%
Protein percentage	0.004	Ref. group	<0.001	0.981	0.254	<0.001	10.9%

*Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and feeding system with the full model (ie the model with cow's sire's Australian Breeding Value protein percentage, maternal grand sire's Australian Breeding Value for protein percentage, and interaction between cow's sire's Australian Breeding Value for protein percentage and feeding system also added)

Table 5.20 Estimated effects*of cow's sire's Australian Breeding Value for protein percentage on 305-day milk production for lactations from Holstein cows by herd average solids per cow (95% CI)

Milk production variable	Herd average solids per cow (kg)				P for interaction	R^{2**}
	400	500	600	700		
Milk volume (l)	-669.9 (-784.1 to -555.7)	-677.6 (-743.9 to -611.4)	-685.4 (-766.5 to -604.3)	-693.2 (-833.3 to -553.0)	0.837	1.2%
Fat yield (kg)	8.1 (3.7 to 12.4)	7.8 (5.3 to 10.3)	7.6 (4.5 to 10.7)	7.3 (2.0 to 12.7)	0.868	0.5%
Protein yield (kg)	1.3 (-2.3 to 4.9)	7.1 (5.0 to 9.2)	12.8 (10.3 to 15.4)	18.6 (14.2 to 23.0)	<0.001	0.8%
Fat percentage	0.564 (0.530 to 0.599)	0.487 (0.466 to 0.508)	0.410 (0.385 to 0.435)	0.334 (0.292 to 0.375)	<0.001	3.7%
Protein percentage	0.401 (0.386 to 0.416)	0.410 (0.401 to 0.419)	0.418 (0.407 to 0.429)	0.427 (0.408 to 0.445)	0.080	15.9%

*Coefficients represent estimated change in milk production variable per 1 unit increase in the cow's sire's Australian Breeding Value for protein percentage; coefficients were adjusted for maternal grand sire's Australian Breeding Value for protein percentage and cow's age at calving; herd and cow within herd were fitted as random effects
**Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and herd average solids per cow with the full model (ie the model with cow's sire's Australian Breeding Value for protein percentage, maternal grand sire's Australian Breeding Value for protein percentage, and interaction between cow's sire's Australian Breeding Value for protein percentage and herd average solids per cow also added)

Table 5.21 Estimated effects*of cow's sire's Australian Breeding Value for daughter fertility on 305-day milk production for lactations from Holstein cows by feeding system (95% CI)

Milk production variable	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
Milk volume (l)	-10.5 (-15.8 to -5.1)	-8.4 (-11.0 to -5.9)	-7.8 (-12.7 to -2.9)	-3.3 (-11.0 to 4.3)	-7.5 (-19.5 to 4.6)
Fat yield (kg)	-0.3 (-0.5 to -0.1)	-0.4 (-0.5 to -0.3)	-0.4 (-0.6 to -0.2)	-0.1 (-0.4 to 0.2)	-0.2 (-0.7 to 0.3)
Protein yield (kg)	-0.2 (-0.4 to -0.1)	-0.2 (-0.2 to -0.1)	-0.2 (-0.3 to 0.0)	0.0 (-0.3 to 0.2)	-0.3 (-0.7 to 0.1)
Fat percentage	0.002 (0.000 to 0.003)	0.000 (-0.001 to 0.001)	-0.001 (-0.002 to 0.000)	0.000 (-0.003 to 0.002)	0.002 (-0.002 to 0.005)
Protein percentage	0.002 (0.001 to 0.003)	0.002 (0.002 to 0.002)	0.002 (0.001 to 0.002)	0.001 (0.000 to 0.002)	-0.001 (-0.002 to 0.001)

*Coefficients represent estimated change in milk production variable per 1 unit increase in the cow's sire's Australian Breeding Value for daughter fertility; coefficients were adjusted for maternal grand sire's Australian Breeding Value for daughter fertility and cow's age at calving; herd and cow within herd were fitted as random effects

Table 5.22 P-values for differences in estimated effects of cow's sire's Australian Breeding Value for daughter fertility on 305-day milk production for lactations from Holstein cows by feeding system, relative to the moderate to high bail feeding system (reference group or Ref. group), for each milk production variable

Milk production variable	Feeding system					P for interaction	R^{2*}
	Low bail	Mod-high bail	PMR	Hybrid	TMR		
Milk volume (l)	0.497	Ref. group	0.809	0.218	0.879	0.681	0.3%
Fat yield (kg)	0.868	Ref. group	0.884	0.126	0.550	0.600	0.3%
Protein yield (kg)	0.427	Ref. group	0.976	0.288	0.405	0.598	0.2%
Fat percentage	0.014	Ref. group	0.383	0.947	0.302	0.057	0.0%
Protein percentage	0.945	Ref. group	0.283	0.175	0.001	0.017	0.3%

*Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and feeding system with the full model (ie the model with cow's sire's Australian Breeding Value for daughter fertility, maternal grand sire's Australian Breeding Value for daughter fertility, and interaction between cow's sire's Australian Breeding Value for daughter fertility and feeding system also added)

Table 5.23 Estimated effects*of cow's sire's Australian Breeding Value for daughter fertility on 305-day milk production for lactations from Holstein cows by herd average solids per cow (95% CI)

Milk production variable	Herd average solids per cow (kg)				P for interaction	R^{2**}
	400	500	600	700		
Milk volume (l)	-7.9 (-11.5 to -4.3)	-8.4 (-10.6 to -6.3)	-9.0 (-11.7 to -6.3)	-9.5 (-14.2 to -4.9)	0.650	0.3%
Fat yield (kg)	-0.1 (-0.3 to 0.0)	-0.3 (-0.4 to -0.2)	-0.5 (-0.6 to -0.4)	-0.6 (-0.8 to -0.4)	0.001	0.3%
Protein yield (kg)	-0.1 (-0.2 to 0.0)	-0.2 (-0.2 to -0.1)	-0.2 (-0.3 to -0.1)	-0.2 (-0.4 to -0.1)	0.221	0.0%
Fat percentage	0.003 (0.002 to 0.004)	0.000 (0.000 to 0.001)	-0.002 (-0.003 to -0.001)	-0.004 (-0.005 to -0.003)	<0.001	0.0%
Protein percentage	0.003 (0.002 to 0.003)	0.002 (0.002 to 0.002)	0.001 (0.001 to 0.002)	0.000 (0.000 to 0.001)	<0.001	0.3%

*Coefficients represent estimated change in milk production variable per 1 unit increase in the cow's sire's Australian Breeding Value for daughter fertility; coefficients were adjusted for maternal grand sire's Australian Breeding Value for daughter fertility and cow's age at calving; herd and cow within herd were fitted as random effects

**Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and herd average solids per cow with the full model (ie the model with cow's sire's Australian Breeding Value for daughter fertility, maternal grand sire's Australian Breeding Value for daughter fertility, and interaction between cow's sire's Australian Breeding Value for daughter fertility and herd average solids per cow also added)

Table 5.24 Estimated effects*of cow's sire's Australian Breeding Value for survival on 305-day milk production for lactations from Holstein cows by feeding system (95% CI)

Milk production variable	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
Milk volume (l)	17.9 (10.1 to 25.8)	33.5 (29.6 to 37.5)	17.5 (10.1 to 24.8)	41.2 (30.1 to 52.4)	50.6 (29.9 to 71.4)
Fat yield (kg)	0.4 (0.1 to 0.7)	0.4 (0.3 to 0.6)	-0.2 (-0.5 to 0.0)	0.9 (0.5 to 1.3)	2.2 (1.4 to 3.0)
Protein yield (kg)	0.3 (0.1 to 0.6)	0.8 (0.7 to 0.9)	0.3 (0.1 to 0.6)	1.0 (0.7 to 1.4)	1.5 (0.9 to 2.2)
Fat percentage	-0.008 (-0.010 to -0.005)	-0.013 (-0.014 to -0.012)	-0.014 (-0.016 to -0.012)	-0.007 (-0.011 to -0.004)	0.003 (-0.003 to 0.009)
Protein percentage	-0.005 (-0.006 to -0.004)	-0.003 (-0.004 to -0.003)	-0.003 (-0.004 to -0.002)	-0.003 (-0.005 to -0.002)	-0.001 (-0.004 to 0.002)

*Coefficients represent estimated change in milk production variable per 1 unit increase in the cow's sire's Australian Breeding Value for survival; coefficients were adjusted for maternal grand sire's Australian Breeding Value for survival and cow's age at calving; herd and cow within herd were fitted as random effects

Table 5.25 P-values for differences in estimated effects of cow's sire's Australian Breeding Value for survival on 305-day milk production for lactations from Holstein cows by feeding system, relative to the moderate to high bail feeding system (reference group or Ref. group), for each milk production variable

Milk production variable	Feeding system					P for interaction	R^{2*}
	Low bail	Mod-high bail	PMR	Hybrid	TMR		
Milk volume (l)	<0.001	Ref. group	<0.001	0.199	0.113	<0.001	5.0%
Fat yield (kg)	0.903	Ref. group	<0.001	0.043	<0.001	<0.001	3.2%
Protein yield (kg)	0.001	Ref. group	<0.001	0.322	0.037	<0.001	1.4%
Fat percentage	<0.001	Ref. group	0.318	0.002	<0.001	<0.001	0.5%
Protein percentage	0.008	Ref. group	0.496	0.797	0.135	0.021	0.3%

*Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and feeding system with the full model (ie the model with cow's sire's Australian Breeding Value for survival, maternal grand sire's Australian Breeding Value for survival, and interaction between cow's sire's Australian Breeding Value for survival and feeding system also added)

Table 5.26 Estimated effects*of cow's sire's Australian Breeding Value for survival on 305-day milk production for lactations from Holstein cows by herd average solids per cow (95% CI)

Milk production variable	Herd average solids per cow (kg)				P for interaction	R^{2**}
	400	500	600	700		
Milk volume (l)	21.4 (15.9 to 27.0)	26.4 (23.2 to 29.7)	31.5 (27.4 to 35.5)	36.5 (29.5 to 43.4)	0.006	1.6%
Fat yield (kg)	0.5 (0.3 to 0.7)	0.3 (0.2 to 0.4)	0.1 (0.0 to 0.3)	-0.1 (-0.3 to 0.2)	0.011	0.3%
Protein yield (kg)	0.5 (0.3 to 0.7)	0.6 (0.5 to 0.7)	0.7 (0.6 to 0.8)	0.8 (0.6 to 1.0)	0.106	1.1%
Fat percentage	-0.009 (-0.011 to -0.008)	-0.012 (-0.013 to -0.010)	-0.014 (-0.015 to -0.013)	-0.016 (-0.018 to -0.014)	<0.001	0.5%
Protein percentage	-0.003 (-0.004 to -0.002)	-0.003 (-0.004 to -0.003)	-0.004 (-0.004 to -0.003)	-0.004 (-0.005 to -0.003)	0.084	0.3%

*Coefficients represent estimated change in milk production variable per 1 unit increase in the cow's sire's Australian Breeding Value for survival; coefficients were adjusted for maternal grand sire's Australian Breeding Value for survival and cow's age at calving; herd and cow within herd were fitted as random effects

**Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and herd average solids per cow with the full model (ie the model with cow's sire's Australian Breeding Value for survival, maternal grand sire's Australian Breeding Value for survival, and interaction between cow's sire's Australian Breeding Value for survival and herd average solids per cow also added)

5.5 EFFECTS ON MILK PRODUCTION IN JERSEYS

Estimated effects of cow's sire's Australian Selection Index and Australian Breeding Values on milk production in Jerseys are detailed in Tables 5.27 to 5.50.

AUSTRALIAN SELECTION INDEX

Table5. 27 Estimated effects*of cow's sire's Australian Selection Index on 305-day milk production for lactations from Jersey cows by feeding system (95% CI)

Milk production variable	Feeding system		
	Low bail	Mod-high bail	PMR
Milk volume (l)	49.1 (28.4 to 69.7)	67.0 (55.7 to 78.2)	51.0 (19.2 to 82.7)
Fat yield (kg)	3.1 (2.1 to 4.1)	4.1 (3.6 to 4.7)	3.9 (2.4 to 5.5)
Protein yield (kg)	2.4 (1.7 to 3.2)	3.4 (3.0 to 3.8)	3.2 (2.1 to 4.4)
Fat percentage	0.017 (0.007 to 0.028)	0.016 (0.011 to 0.022)	0.025 (0.010 to 0.041)
Protein percentage	0.013 (0.009 to 0.017)	0.017 (0.014 to 0.019)	0.023 (0.017 to 0.029)

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Selection Index; coefficients were adjusted for maternal grand sire's Australian Selection Index and cow's age at calving; herd and cow within herd were fitted as random effects

Table 5.28 P-values for differences in estimated effects of cow's sire's Australian Selection Index on 305-day milk production for lactations from Jersey cows by feeding system, relative to the moderate to high bail feeding system (reference group or Ref. group), for each milk production variable

Milk production variable	Feeding system			P for interaction	R^{2*}
	Low bail	Mod-high bail	PMR		
Milk volume (l)	0.132	Ref. group	0.349	0.249	4.1%
Fat yield (kg)	0.074	Ref. group	0.817	0.203	8.9%
Protein yield (kg)	0.021	Ref. group	0.756	0.069	9.5%
Fat percentage	0.843	Ref. group	0.275	0.552	0.8%
Protein percentage	0.145	Ref. group	0.064	0.038	2.7%

*Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and feeding system with the full model (ie the model with cow's sire's Australian Selection Index, maternal grand sire's Australian Selection Index, and interaction between cow's sire's Australian Selection Index and feeding system also added)

Table 5.29 Estimated effects*of cow's sire's Australian Selection Index on 305-day milk production for lactations from Jersey cows by herd average solids per cow (95% CI)

Milk production variable	Herd average solids per cow (kg)			P for interaction	R^{2**}
	400	500	600		
Milk volume (l)	49.0 (37.8 to 60.2)	59.3 (48.5 to 70.1)	69.6 (50.7 to 88.4)	0.07	3.4%
Fat yield (kg)	3.2 (2.7 to 3.8)	3.8 (3.3 to 4.4)	4.5 (3.6 to 5.4)	0.023	7.3%
Protein yield (kg)	2.6 (2.2 to 3.0)	3.2 (2.8 to 3.6)	3.8 (3.2 to 4.5)	0.003	8.0%
Fat percentage	0.018 (0.012 to 0.024)	0.016 (0.010 to 0.021)	0.013 (0.004 to 0.023)	0.394	0.7%
Protein percentage	0.017 (0.014 to 0.019)	0.016 (0.014 to 0.018)	0.015 (0.011 to 0.019)	0.414	2.6%

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Selection Index; coefficients were adjusted for maternal grand sire's Australian Selection Index and cow's age at calving; herd and cow within herd were fitted as random effects
**Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and herd average solids per cow with the full model (ie the model with cow's sire's Australian Selection Index, maternal grand sire's Australian Selection Index, and interaction between cow's sire's Australian Selection Index and herd average solids per cow also added)

Table 5.30 Estimated effects*of cow's sire's Australian Breeding Value for milk volume on 305-day milk production for lactations from Jersey cows by feeding system (95% CI)

Milk production variable	Feeding system		
	Low bail	Mod-high bail	PMR
Milk volume (l)	14.1 (10.2 to 17.9)	21.1 (19.2 to 23.0)	16.7 (11.6 to 21.7)
Fat yield (kg)	0.1 (0.0 to 0.3)	0.4 (0.3 to 0.5)	0.2 (0.0 to 0.5)
Protein yield (kg)	0.3 (0.2 to 0.5)	0.5 (0.5 to 0.6)	0.4 (0.2 to 0.6)
Fat percentage	-0.013 (-0.015 to -0.011)	-0.013 (-0.014 to -0.012)	-0.009 (-0.012 to -0.007)
Protein percentage	-0.005 (-0.005 to -0.004)	-0.005 (-0.005 to -0.004)	-0.005 (-0.006 to -0.004)

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Breeding Value for milk volume; coefficients were adjusted for maternal grand sire's Australian Breeding Value for milk volume and cow's age at calving; herd and cow within herd were fitted as random effects

Table 5.31 P-values for differences in estimated effects of cow's sire's Australian Breeding Value for milk volume on 305-day milk production for lactations from Jersey cows by feeding system, relative to the moderate to high bail feeding system (reference group or Ref. group), for each milk production variable

Milk production variable	Feeding system			P for interaction	R^{2*}
	Low bail	Mod-high bail	PMR		
Milk volume (l)	0.001	Ref. group	0.105	0.003	11.5%
Fat yield (kg)	0.050	Ref. group	0.361	0.120	1.5%
Protein yield (kg)	0.011	Ref. group	0.092	0.017	6.2%
Fat percentage	0.954	Ref. group	0.006	0.022	11.6%
Protein percentage	0.693	Ref. group	0.603	0.829	7.2%

*Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and feeding system with the full model (ie the model with cow's sire's Australian Breeding Value for milk volume, maternal grand sire's Australian Breeding Value for milk volume, and interaction between cow's sire's Australian Breeding Value for milk volume and feeding system also added)

Table 5.32 Estimated effects*of cow's sire's Australian Breeding Value for milk volume on 305-day milk production for lactations from Jersey cows by herd average solids per cow (95% CI)

Milk production variable	Herd average solids per cow (kg)			P for interaction	R^{2**}
	400	500	600		
Milk volume (l)	15.6 (13.6 to 17.6)	20.9 (19.1 to 22.7)	26.1 (22.8 to 29.4)	<0.001	10.1%
Fat yield (kg)	0.2 (0.1 to 0.3)	0.3 (0.2 to 0.4)	0.5 (0.3 to 0.7)	0.003	1.2%
Protein yield (kg)	0.4 (0.3 to 0.4)	0.5 (0.5 to 0.6)	0.7 (0.6 to 0.8)	<0.001	5.3%
Fat percentage	-0.013 (-0.014 to -0.012)	-0.013 (-0.014 to -0.012)	-0.012 (-0.014 to -0.011)	0.370	11.5%
Protein percentage	-0.005 (-0.005 to -0.004)	-0.005 (-0.005 to -0.005)	-0.005 (-0.006 to -0.005)	0.188	7.2%

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Breeding Value for milk volume; coefficients were adjusted for maternal grand sire's Australian Breeding Value for milk volume and cow's age at calving; herd and cow within herd were fitted as random effects
**Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and herd average solids per cow with the full model (ie the model with cow's sire's Australian Breeding Value for milk volume, maternal grand sire's Australian Breeding Value for milk volume, and interaction between cow's sire's Australian Breeding Value for milk volume and herd average solids per cow also added)

AUSTRALIAN BREEDING VALUE FOR FAT YIELD

Table 5.33 Estimated effects*of cow's sire's Australian Breeding Value for fat yield on 305-day milk production for lactations from Jersey cows by feeding system (95% CI)

Milk production variable	Feeding system		
	Low bail	Mod-high bail	PMR
Milk volume (l)	41.9 (24.5 to 59.4)	38.4 (28.8 to 48.1)	42.5 (15.4 to 69.5)
Fat yield (kg)	3.5 (2.6 to 4.3)	4.0 (3.5 to 4.5)	4.8 (3.5 to 6.1)
Protein yield (kg)	2.0 (1.3 to 2.6)	2.1 (1.8 to 2.5)	2.5 (1.5 to 3.4)
Fat percentage	0.034 (0.026 to 0.043)	0.040 (0.036 to 0.045)	0.046 (0.033 to 0.060)
Protein percentage	0.008 (0.005 to 0.012)	0.012 (0.010 to 0.014)	0.015 (0.010 to 0.020)

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Breeding Value for fat yield; coefficients were adjusted for maternal grand sire's Australian Breeding Value for fat yield and cow's age at calving; herd and cow within herd were fitted as random effects

Table 5.34 P-values for differences in estimated effects of cow's sire's Australian Breeding Value for fat yield on 305-day milk production for lactations from Jersey cows by feeding system, relative to the moderate to high bail feeding system (reference group or Ref. group), for each milk production variable

Milk production variable	Feeding system			P for interaction	R^{2*}
	Low bail	Mod-high bail	PMR		
Milk volume (l)	0.727	Ref. group	0.783	0.918	2.3%
Fat yield (kg)	0.273	Ref. group	0.277	0.243	11.5%
Protein yield (kg)	0.620	Ref. group	0.552	0.702	5.3%
Fat percentage	0.231	Ref. group	0.375	0.271	4.9%
Protein percentage	0.059	Ref. group	0.341	0.077	1.8%

*Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and feeding system with the full model (ie the model with cow's sire's Australian Breeding Value for fat yield, maternal grand sire's Australian Breeding Value for fat yield, and interaction between cow's sire's Australian Breeding Value for fat yield and feeding system also added)

Table 5.35 Estimated effects*of cow's sire's Australian Breeding Value for fat yield on 305-day milk production for lactations from Jersey cows by herd average solids per cow (95% CI)

Milk production variable	Herd average solids per cow (kg)			P for interaction	R^{2**}
	400	500	600		
Milk volume (l)	32.6 (23.0 to 42.1)	34.7 (25.4 to 44.0)	36.8 (20.8 to 52.9)	0.656	1.9%
Fat yield (kg)	3.4 (2.9 to 3.8)	3.9 (3.5 to 4.4)	4.5 (3.7 to 5.3)	0.016	9.7%
Protein yield (kg)	1.8 (1.4 to 2.1)	2.0 (1.7 to 2.4)	2.3 (1.7 to 2.9)	0.105	4.5%
Fat percentage	0.039 (0.034 to 0.043)	0.039 (0.035 to 0.044)	0.040 (0.032 to 0.048)	0.731	4.8%
Protein percentage	0.011 (0.009 to 0.013)	0.012 (0.010 to 0.014)	0.012 (0.009 to 0.015)	0.820	1.8%

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Breeding Value for fat yield; coefficients were adjusted for maternal grand sire's Australian Breeding Value for fat yield and cow's age at calving; herd and cow within herd were fitted as random effects

**Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and herd average solids per cow with the full model (ie the model with cow's sire's Australian Breeding Value for fat yield, maternal grand sire's Australian Breeding Value for fat yield, and interaction between cow's sire's Australian Breeding Value for fat yield and herd average solids per cow also added)

Table 5.36 Estimated effects*of cow's sire's Australian Breeding Value for protein yield on 305-day milk production for lactations from Jersey cows by feeding system (95% CI)

Milk production variable	Feeding system		
	Low bail	Mod-high bail	PMR
Milk volume (l)	85.3 (57.5 to 113.2)	137.0 (122.5 to 151.5)	100.3 (60.5 to 140.0)
Fat yield (kg)	2.7 (1.3 to 4.1)	4.4 (3.7 to 5.1)	3.2 (1.3 to 5.2)
Protein yield (kg)	3.2 (2.2 to 4.2)	5.0 (4.5 to 5.6)	3.9 (2.5 to 5.4)
Fat percentage	-0.035 (-0.049 to -0.021)	-0.044 (-0.052 to -0.037)	-0.026 (-0.045 to -0.006)
Protein percentage	-0.001 (-0.007 to 0.004)	-0.002 (-0.005 to 0.001)	0.003 (-0.005 to 0.011)

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Breeding Value for protein yield; coefficients were adjusted for maternal grand sire's Australian Breeding Value for protein yield and cow's age at calving; herd and cow within herd were fitted as random effects

Table 5.37 P-values for differences in estimated effects of cow's sire's Australian Breeding Value for protein yield on 305-day milk production for lactations from Jersey cows by feeding system, relative to the moderate to high bail feeding system (reference group or Ref. group), for each milk production variable

Milk production variable	Feeding system			P for interaction	R^{2*}
	Low bail	Mod-high bail	PMR		
Milk volume (l)	0.001	Ref. group	0.088	0.002	8.8%
Fat yield (kg)	0.031	Ref. group	0.286	0.075	5.1%
Protein yield (kg)	0.001	Ref. group	0.168	0.004	10.6%
Fat percentage	0.224	Ref. group	0.078	0.134	2.0%
Protein percentage	0.850	Ref. group	0.224	0.477	0.0%

*Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and feeding system with the full model (ie the model with cow's sire's Australian Breeding Value for protein yield, maternal grand sire's Australian Breeding Value for protein yield, and interaction between cow's sire's Australian Breeding Value for protein yield and feeding system also added)

Table 5.38 Estimated effects*of cow's sire's Australian Breeding Value for protein yield on 305-day milk production for lactations from Jersey cows by herd average solids per cow (95% CI)

Milk production variable	Herd average solids per cow (kg)			P for interaction	R^{2**}
	400	500	600		
Milk volume (l)	97.8 (82.9 to 112.7)	127.3 (113.3 to 141.3)	156.9 (132.0 to 181.7)	<0.001	7.5%
Fat yield (kg)	3.0 (2.2 to 3.7)	4.0 (3.3 to 4.7)	5.0 (3.7 to 6.2)	0.008	4.1%
Protein yield (kg)	3.6 (3.0 to 4.1)	4.7 (4.2 to 5.3)	5.9 (5.0 to 6.8)	<0.001	9.0%
Fat percentage	-0.040 (-0.048 to -0.033)	-0.043 (-0.050 to -0.036)	-0.046 (-0.058 to -0.034)	0.451	1.9%
Protein percentage	0.000 (-0.003 to 0.003)	-0.003 (-0.006 to 0.000)	-0.006 (-0.011 to -0.001)	0.058	-0.1%

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Breeding Value for protein yield; coefficients were adjusted for maternal grand sire's Australian Breeding Value for protein yield and cow's age at calving; herd and cow within herd were fitted as random effects
**Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and herd average solids per cow with the full model (ie the model with cow's sire's Australian Breeding Value for protein yield, maternal grand sire's Australian Breeding Value for protein yield, and interaction between cow's sire's Australian Breeding Value for protein yield and herd average solids per cow also added)

AUSTRALIAN BREEDING VALUE FOR FAT PERCENTAGE

Table 5.39 Estimated effects*of cow's sire's Australian Breeding Value for fat percentage on 305-day milk production for lactations from Jersey cows by feeding system (95% CI)

Milk production variable	Feeding system		
	Low bail	Mod-high bail	PMR
Milk volume (l)	-130.5 (-206.2 to -54.7)	-300.4 (-337.2 to -263.6)	-219.4 (-319.5 to -119.4)
Fat yield (kg)	9.5 (5.8 to 13.2)	4.3 (2.5 to 6.1)	8.1 (3.1 to 13.1)
Protein yield (kg)	0.3 (-2.5 to 3.1)	-4.5 (-5.8 to -3.1)	-0.9 (-4.6 to 2.9)
Fat percentage	0.386 (0.351 to 0.421)	0.370 (0.353 to 0.387)	0.314 (0.268 to 0.360)
Protein percentage	0.124 (0.109 to 0.138)	0.130 (0.123 to 0.138)	0.131 (0.112 to 0.150)

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Breeding Value for fat percentage; coefficients were adjusted for maternal grand sire's Australian Breeding Value for fat percentage and cow's age at calving; herd and cow within herd were fitted as random effects

Table 5.40 P-values for differences in estimated effects of cow's sire's Australian Breeding Value for fat percentage on 305-day milk production for lactations from Jersey cows by feeding system, relative to the moderate to high bail feeding system (reference group or Ref. group), for each milk production variable

Milk production variable	Feeding system			P for interaction	R^{2*}
	Low bail	Mod-high bail	PMR		
Milk volume (l)	<0.001	Ref. group	0.135	<0.001	5.5%
Fat yield (kg)	0.013	Ref. group	0.160	0.026	1.7%
Protein yield (kg)	0.003	Ref. group	0.074	0.004	0.8%
Fat percentage	0.410	Ref. group	0.025	0.041	25.3%
Protein percentage	0.423	Ref. group	0.941	0.714	13.6%

*Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and feeding system with the full model (ie the model with cow's sire's Australian Breeding Value for fat percentage, maternal grand sire's Australian Breeding Value for fat percentage, and interaction between cow's sire's Australian Breeding Value for fat percentage and feeding system also added)

Table 5.41 Estimated effects*of cow's sire's Australian Breeding Value for fat percentage on 305-day milk production for lactations from Jersey cows by herd average solids per cow (95% CI)

Milk production variable	Herd average solids per cow (kg)			P for interaction	R^{2**}
	400	500	600		
Milk volume (l)	-211.3 (-250.4 to -172.1)	-303.0 (-338.6 to -267.5)	-394.8 (-458.2 to -331.4)	<0.001	4.6%
Fat yield (kg)	6.6 (4.7 to 8.6)	4.7 (2.9 to 6.4)	2.7 (-0.5 to 5.8)	0.046	1.4%
Protein yield (kg)	-2.0 (-3.4 to -0.5)	-4.3 (-5.6 to -3.0)	-6.6 (-9.0 to -4.3)	0.002	0.6%
Fat percentage	0.381 (0.362 to 0.399)	0.358 (0.342 to 0.374)	0.335 (0.306 to 0.365)	0.015	25.2%
Protein percentage	0.129 (0.121 to 0.136)	0.130 (0.123 to 0.137)	0.131 (0.119 to 0.143)	0.786	13.6%

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Breeding Value for fat percentage; coefficients were adjusted for maternal grand sire's Australian Breeding Value for fat percentage and cow's age at calving; herd and cow within herd were fitted as random effects

**Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and herd average solids per cow with the full model (ie the model with cow's sire's Australian Breeding Value for fat percentage, maternal grand sire's Australian Breeding Value for fat percentage, and interaction between cow's sire's Australian Breeding Value for fat percentage and herd average solids per cow also added)

Table 5.42 Estimated effects*of cow's sire's Australian Breeding Value for protein percentage on 305-day milk production for lactations from Jersey cows by feeding system (95% CI)

Milk production variable	Feeding system		
	Low bail	Mod-high bail	PMR
Milk volume (l)	-385.6 (-579.1 to -192.1)	-593.4 (-681.8 to -504.9)	-578.9 (-819.9 to -337.8)
Fat yield (kg)	14.3 (4.8 to 23.8)	6.1 (1.8 to 10.5)	5.8 (-6.2 to 17.8)
Protein yield (kg)	2.4 (-4.7 to 9.5)	-3.1 (-6.3 to 0.2)	0.6 (-8.3 to 9.5)
Fat percentage	0.816 (0.725 to 0.908)	0.688 (0.646 to 0.730)	0.560 (0.446 to 0.674)
Protein percentage	0.400 (0.363 to 0.437)	0.368 (0.351 to 0.385)	0.389 (0.344 to 0.434)

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Breeding Value for protein percentage; coefficients were adjusted for maternal grand sire's Australian Breeding Value for protein percentage and cow's age at calving; herd and cow within herd were fitted as random effects

Table 5.43 P-values for differences in estimated effects of cow's sire's Australian Breeding Value for protein percentage on 305-day milk production for lactations from Jersey cows by feeding system, relative to the moderate to high bail feeding system (reference group or Ref. group), for each milk production variable

Milk production variable	Feeding system			P for interaction	R^{2*}
	Low bail	Mod-high bail	PMR		
Milk volume (l)	0.054	Ref. group	0.911	0.155	3.8%
Fat yield (kg)	0.123	Ref. group	0.966	0.294	0.8%
Protein yield (kg)	0.168	Ref. group	0.448	0.327	0.0%
Fat percentage	0.012	Ref. group	0.038	0.002	16.4%
Protein percentage	0.121	Ref. group	0.388	0.241	20.5%

*Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and feeding system with the full model (ie the model with cow's sire's Australian Breeding Value for protein percentage, maternal grand sire's Australian Breeding Value for protein percentage, and interaction between cow's sire's Australian Breeding Value for protein percentage and feeding system also added)

Table 5.44 Estimated effects*of cow's sire's Australian Breeding Value for protein percentage on 305-day milk production for lactations from Jersey cows by herd average solids per cow (95% CI)

Milk production variable	Herd average solids per cow (kg)			P for interaction	R^{2**}
	400	500	600		
Milk volume (l)	-460.0 (-555.3 to -364.8)	-642.1 (-728.4 to -555.9)	-824.2 (-979.5 to -668.9)	<0.001	3.3%
Fat yield (kg)	9.8 (5.1 to 14.5)	4.9 (0.6 to 9.1)	0.0 (-7.8 to 7.7)	0.045	0.6%
Protein yield (kg)	0.1 (-3.4 to 3.6)	-3.7 (-6.9 to -0.5)	-7.4 (-13.2 to -1.7)	0.038	0.1%
Fat percentage	0.735 (0.689 to 0.780)	0.667 (0.626 to 0.708)	0.599 (0.525 to 0.673)	0.004	16.3%
Protein percentage	0.382 (0.363 to 0.400)	0.371 (0.354 to 0.387)	0.360 (0.331 to 0.388)	0.221	20.6%

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Breeding Value for protein percentage; coefficients were adjusted for maternal grand sire's Australian Breeding Value for protein percentage and cow's age at calving; herd and cow within herd were fitted as random effects
**Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and herd average solids per cow with the full model (ie the model with cow's sire's Australian Breeding Value for protein percentage, maternal grand sire's Australian Breeding Value for protein percentage, and interaction between cow's sire's Australian Breeding Value for protein percentage and herd average solids per cow also added)

Table 5.45 Estimated effects*of cow's sire's Australian Breeding Value for daughter fertility on 305-day milk production for lactations from Jersey cows by feeding system (95% CI)

Milk production variable	Feeding system		
	Low bail	Mod-high bail	PMR
Milk volume (l)	-18.6 (-31.8 to -5.4)	-19.7 (-25.6 to -13.9)	-15.8 (-32.0 to 0.5)
Fat yield (kg)	-0.4 (-1.0 to 0.3)	-0.5 (-0.8 to -0.2)	-0.3 (-1.1 to 0.5)
Protein yield (kg)	-0.5 (-0.9 to 0.0)	-0.4 (-0.6 to -0.2)	-0.2 (-0.8 to 0.4)
Fat percentage	0.013 (0.006 to 0.019)	0.010 (0.007 to 0.013)	0.006 (-0.002 to 0.014)
Protein percentage	0.006 (0.003 to 0.008)	0.006 (0.005 to 0.007)	0.007 (0.004 to 0.010)

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Breeding Value for daughter fertility; coefficients were adjusted for maternal grand sire's Australian Breeding Value for daughter fertility and cow's age at calving; herd and cow within herd were fitted as random effects

Table 5.46 P-values for differences in estimated effects of cow's sire's Australian Breeding Value for daughter fertility on 305-day milk production for lactations from Jersey cows by feeding system, relative to the moderate to high bail feeding system (reference group or Ref. group), for each milk production variable

Milk production variable	Feeding system			P for interaction	R^{2*}
	Low bail	Mod-high bail	PMR		
Milk volume (l)	0.878	Ref. group	0.652	0.899	0.9%
Fat yield (kg)	0.796	Ref. group	0.710	0.913	0.1%
Protein yield (kg)	0.895	Ref. group	0.447	0.729	0.2%
Fat percentage	0.356	Ref. group	0.392	0.404	0.9%
Protein percentage	0.916	Ref. group	0.462	0.748	1.3%

*Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and feeding system with the full model (ie the model with cow's sire's Australian Breeding Value for daughter fertility, maternal grand sire's Australian Breeding Value for daughter fertility, and interaction between cow's sire's Australian Breeding Value for daughter fertility and feeding system also added)

Table 5.47 Estimated effects*of cow's sire's Australian Breeding Value for daughter fertility on 305-day milk production for lactations from Jersey cows by herd average solids per cow (95% CI)

Milk production variable	Herd average solids per cow (kg)			P for interaction	R^{2**}
	400	500	600		
Milk volume (l)	-17.7 (-24.2 to -11.2)	-21.8 (-27.5 to -16.0)	-25.8 (-36.3 to -15.4)	0.222	0.8%
Fat yield (kg)	-0.4 (-0.8 to -0.1)	-0.6 (-0.8 to -0.3)	-0.7 (-1.2 to -0.2)	0.42	0.1%
Protein yield (kg)	-0.4 (-0.6 to -0.2)	-0.5 (-0.7 to -0.3)	-0.6 (-0.9 to -0.2)	0.517	0.2%
Fat percentage	0.000 (0.000 to 0.007)	0.009 (0.007 to 0.012)	0.009 (0.004 to 0.014)	0.725	0.9%
Protein percentage	0.005 (0.004 to 0.007)	0.006 (0.005 to 0.007)	0.007 (0.005 to 0.009)	0.242	1.3%

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Breeding Value for daughter fertility; coefficients were adjusted for maternal grand sire's Australian Breeding Value for daughter fertility and cow's age at calving; herd and cow within herd were fitted as random effects

**Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and herd average solids per cow with the full model (ie the model with cow's sire's Australian Breeding Value for daughter fertility, maternal grand sire's Australian Breeding Value for daughter fertility, and interaction between cow's sire's Australian Breeding Value for daughter fertility and herd average solids per cow also added)

Table 5.48 Estimated effects*of cow's sire's Australian Breeding Value for survival on 305-day milk production for lactations from Jersey cows by feeding system (95% CI)

Milk production variable	Feeding system		
	Low bail	Mod-high bail	PMR
Milk volume (l)	14.7 (5.8 to 23.6)	27.0 (21.8 to 32.3)	27.1 (11.3 to 43.0)
Fat yield (kg)	0.8 (0.3 to 1.2)	1.4 (1.1 to 1.6)	1.7 (0.9 to 2.5)
Protein yield (kg)	0.5 (0.2 to 0.8)	1.1 (0.9 to 1.3)	1.1 (0.5 to 1.6)
Fat percentage	0.002 (-0.003 to 0.006)	0.000 (-0.003 to 0.002)	0.006 (-0.001 to 0.014)
Protein percentage	-0.001 (-0.003 to 0.001)	0.001 (0.000 to 0.002)	0.001 (-0.003 to 0.004)

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Breeding Value for survival; coefficients were adjusted for maternal grand sire's Australian Breeding Value for survival and cow's age at calving; herd and cow within herd were fitted as random effects

Table 5.49 P-values for differences in estimated effects of cow's sire's Australian Breeding Value for survival on 305-day milk production for lactations from Jersey cows by feeding system, relative to the moderate to high bail feeding system (reference group or Ref. group), for each milk production variable

Milk production variable	Feeding system			P for interaction	R^{2*}
	Low bail	Mod-high bail	PMR		
Milk volume (l)	0.019	Ref. group	0.988	0.058	2.6%
Fat yield (kg)	0.021	Ref. group	0.367	0.031	4.0%
Protein yield (kg)	0.003	Ref. group	0.928	0.011	3.6%
Fat percentage	0.414	Ref. group	0.110	0.235	0.1%
Protein percentage	0.239	Ref. group	0.971	0.496	0.0%

*Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and feeding system with the full model (ie the model with cow's sire's Australian Breeding Value for survival, maternal grand sire's Australian Breeding Value for survival, and interaction between cow's sire's Australian Breeding Value for survival and feeding system also added)

Table 5.50 Estimated effects*of cow's sire's Australian Breeding Value for survival on 305-day milk production for lactations from Jersey cows by herd average solids per cow (95% CI)

Milk production variable	Herd average solids per cow (kg)			P for interaction	R^{2**}
	400	500	600		
Milk volume (l)	19.1 (14.2 to 23.9)	25.3 (20.1 to 30.5)	31.6 (22.8 to 40.4)	0.011	2.4%
Fat yield (kg)	1.0 (0.7 to 1.2)	1.3 (1.1 to 1.6)	1.7 (1.2 to 2.1)	0.003	3.4%
Protein yield (kg)	0.7 (0.6 to 0.9)	1.0 (0.8 to 1.2)	1.3 (0.9 to 1.6)	0.003	3.3%
Fat percentage	0.000 (-0.002 to 0.003)	0.000 (-0.002 to 0.003)	0.000 (-0.004 to 0.004)	0.934	0.0%
Protein percentage	0.000 (-0.001 to 0.001)	0.000 (-0.001 to 0.001)	-0.001 (-0.002 to 0.001)	0.306	0.0%

*Coefficients represent estimated change in milk production variable per 50 unit increase in the cow's sire's Australian Breeding Value for survival; coefficients were adjusted for maternal grand sire's Australian Breeding Value for survival and cow's age at calving; herd and cow within herd were fitted as random effects

**Proportional reduction in estimated cow-level variance comparing model with cow's age at calving and herd average solids per cow with the full model (ie the model with cow's sire's Australian Breeding Value for survival, maternal grand sire's Australian Breeding Value for survival, and interaction between cow's sire's Australian Breeding Value for survival and herd average solids per cow also added)

5.6 EFFECTS ON ODDS OF RECALVING BY 20 MONTHS IN HOLSTEINS

Estimated effects on odds of recalving by 20 months in Holsteins are shown in Tables 5.51 to 5.53.

Table 5.51 Estimated effects*of cow's sire's Australian Selection Index and Australian Breeding Values on odds of recalving by 20 months for lactations from Holstein cows by feeding system (95% CI)

Breeding value	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
Australian Selection Index	0.974 (0.952 to 0.996)	0.976 (0.966 to 0.987)	0.996 (0.977 to 1.016)	0.964 (0.937 to 0.993)	0.912 (0.868 to 0.959)
Australian Breeding Value:					
Milk volume (l)	0.994 (0.991 to 0.998)	0.996 (0.995 to 0.998)	0.999 (0.996 to 1.002)	0.998 (0.994 to 1.003)	0.996 (0.989 to 1.003)
Fat yield (kg)	0.983 (0.964 to 1.002)	0.973 (0.964 to 0.983)	0.990 (0.974 to 1.007)	0.970 (0.947 to 0.994)	0.929 (0.891 to 0.968)
Protein yield (kg)	0.958 (0.931 to 0.986)	0.972 (0.959 to 0.985)	0.996 (0.972 to 1.020)	0.968 (0.935 to 1.002)	0.914 (0.858 to 0.974)
Fat percentage	1.079 (0.968 to 1.203)	0.986 (0.939 to 1.036)	0.987 (0.905 to 1.078)	0.926 (0.815 to 1.053)	0.791 (0.620 to 1.008)
Protein percentage	1.059 (0.850 to 1.320)	1.038 (0.937 to 1.151)	1.087 (0.904 to 1.307)	0.825 (0.623 to 1.092)	0.608 (0.377 to 0.982)
Daughter fertility	1.037 (1.030 to 1.044)	1.036 (1.033 to 1.040)	1.032 (1.025 to 1.038)	1.034 (1.025 to 1.044)	1.046 (1.030 to 1.061)
Survival	1.024 (1.013 to 1.034)	1.048 (1.043 to 1.054)	1.041 (1.032 to 1.051)	1.052 (1.038 to 1.066)	1.054 (1.027 to 1.082)

*Coefficients represent estimated odds ratios for recalving by 20 months for each extra 50 units (Australian Selection Index, Australian Breeding Value for milk volume) or 10 units (Australian Breeding Values for fat and protein yield) or 1 unit (other Australian Breeding Values) in the cow's sire's Australian Selection Index/Australian Breeding Value; coefficients were adjusted for maternal grand sire's Australian Selection Index/Australian Breeding Value and cow's age at calving; herd was fitted as a random effect

Table 5.52 P-values for differences in estimated effects of cow's sire's Australian Selection Index and Australian Breeding Values on odds of recalving by 20 months for lactations from Holstein cows by feeding system, relative to the moderate to high feeding system (reference group or Ref. group)

Breeding value	Feeding system					P for interaction
	Low bail	Mod-high bail	PMR	Hybrid	TMR	
Australian Selection Index	0.825	Ref. group	0.074	0.432	0.009	0.017
Australian Breeding Value:						
Milk volume (l)	0.356	Ref. group	0.138	0.405	0.919	0.359
Fat yield (kg)	0.381	Ref. group	0.081	0.797	0.029	0.051
Protein yield (kg)	0.397	Ref. group	0.079	0.854	0.064	0.075
Fat percentage	0.137	Ref. group	0.984	0.371	0.080	0.149
Protein percentage	0.873	Ref. group	0.672	0.131	0.032	0.119
Daughter fertility	0.874	Ref. group	0.204	0.698	0.255	0.488
Survival	<0.001	Ref. group	0.202	0.658	0.692	0.001

Table 5.53 Estimated effects*of cow's sire's Australian Selection Index and Australian Breeding Values on odds of recalving by 20 months for lactations from Holstein cows by herd average solids per cow (95% CI)

Breeding value	Herd average solids per cow (kg)				P for interaction
	400	500	600	700	
Australian Selection Index	0.967 (0.952 to 0.982)	0.975 (0.966 to 0.983)	0.982 (0.971 to 0.993)	0.990 (0.970 to 1.009)	0.140
Australian Breeding Value:					
Milk volume (l)	0.993 (0.991 to 0.995)	0.996 (0.994 to 0.997)	0.999 (0.997 to 1.000)	1.001 (0.998 to 1.004)	<0.001
Fat yield (kg)	0.982 (0.969 to 0.995)	0.978 (0.970 to 0.985)	0.974 (0.964 to 0.983)	0.970 (0.954 to 0.986)	0.346
Protein yield (kg)	0.947 (0.929 to 0.965)	0.966 (0.955 to 0.977)	0.986 (0.972 to 1.000)	1.006 (0.982 to 1.031)	0.001
Fat percentage	1.119 (1.042 to 1.202)	1.020 (0.979 to 1.063)	0.930 (0.884 to 0.978)	0.848 (0.776 to 0.926)	<0.001
Protein percentage	1.076 (0.927 to 1.250)	1.032 (0.947 to 1.125)	0.990 (0.890 to 1.100)	0.949 (0.790 to 1.140)	0.394
Daughter fertility	1.031 (1.026 to 1.036)	1.035 (1.032 to 1.038)	1.039 (1.035 to 1.042)	1.043 (1.037 to 1.049)	0.014
Survival	1.023 (1.016 to 1.031)	1.039 (1.035 to 1.044)	1.055 (1.050 to 1.061)	1.072 (1.062 to 1.081)	<0.001

*Coefficients represent estimated odds ratios for recalving by 20 months for each extra 50 units (Australian Selection Index, Australian Breeding Value for milk volume) or 10 units (Australian Breeding Values for fat and protein yield) or 1 unit (other Australian Breeding Values) in the cow's sire's Australian Selection Index/Australian Breeding Value; coefficients were adjusted for maternal grand sire's Australian Selection Index/Australian Breeding Value and cow's age at calving; herd was fitted as a random effect

5.7 EFFECTS ON ODDS OF RECALVING BY 20 MONTHS IN JERSEYS

Estimated effects on odds of recalving by 20 months in Jerseys are shown in Tables 5.54 to 5.56.

Table 5.54 Estimated effects*of cow's sire's Australian Selection Index and Australian Breeding Values on odds of recalving by 20 months for lactations from Jersey cows by feeding system (95% CI)

Breeding value	Feeding system		
	Low bail	Mod-high bail	PMR
Australian Selection Index	1.036 (0.998 to 1.075)	1.018 (0.998 to 1.039)	1.048 (0.988 to 1.111)
Australian Breeding Value:			
Milk volume (l)	1.001 (0.994 to 1.008)	0.997 (0.993 to 1.000)	1.000 (0.990 to 1.009)
Fat yield (kg)	1.043 (1.011 to 1.076)	1.018 (1.001 to 1.036)	1.024 (0.974 to 1.077)
Protein yield (kg)	1.026 (0.976 to 1.079)	1.001 (0.975 to 1.027)	1.041 (0.967 to 1.121)
Fat percentage	1.149 (1.001 to 1.320)	1.123 (1.052 to 1.199)	1.070 (0.887 to 1.292)
Protein percentage	1.208 (0.845 to 1.726)	1.306 (1.116 to 1.529)	1.398 (0.888 to 2.200)
Daughter fertility	1.065 (1.038 to 1.092)	1.034 (1.023 to 1.045)	1.018 (0.989 to 1.049)
Survival	1.027 (1.011 to 1.044)	1.034 (1.025 to 1.043)	1.022 (0.994 to 1.052)

*Coefficients represent estimated odds ratios for recalving by 20 months for each extra 50 units (Australian Selection Index, Australian Breeding Value for milk volume) or 10 units (Australian Breeding Values for fat and protein yield) or 1 unit (other Australian Breeding Values) in the cow's sire's Australian Selection Index/Australian Breeding Value; coefficients were adjusted for maternal grand sire's Australian Selection Index/Australian Breeding Value and cow's age at calving; herd was fitted as a random effect

Table 5.55 P-values for differences in estimated effects of cow's sire's Australian Selection Index and Australian Breeding Values on odds of recalving by 20 months for lactations from Jersey cows by feeding system, relative to the moderate to high feeding system (reference group or Ref. group)

Breeding value	Feeding system			P for interaction
	Low bail	Mod-high bail	PMR	
Australian Selection Index	0.419	Ref. group	0.369	0.531
Australian Breeding Value:				
Milk volume (l)	0.312	Ref. group	0.553	0.541
Fat yield (kg)	0.186	Ref. group	0.839	0.418
Protein yield (kg)	0.381	Ref. group	0.316	0.463
Fat percentage	0.766	Ref. group	0.637	0.836
Protein percentage	0.693	Ref. group	0.782	0.876
Daughter fertility	0.039	Ref. group	0.333	0.054
Survival	0.489	Ref. group	0.464	0.639

Table 5.56 Estimated effects*of cow's sire's Australian Selection Index and Australian Breeding Values on odds of recalving by 20 months for lactations from Jersey cows by herd average solids per cow (95% CI)

Breeding value	Herd average solids per cow (kg)			P for interaction
	400	500	600	
Australian Selection Index	1.021 (0.999 to 1.043)	1.023 (1.003 to 1.045)	1.026 (0.989 to 1.065)	0.806
Australian Breeding Value:				
Milk volume (l)	0.999 (0.995 to 1.003)	0.996 (0.993 to 1.000)	0.994 (0.987 to 1.000)	0.168
Fat yield (kg)	1.022 (1.005 to 1.040)	1.022 (1.005 to 1.040)	1.023 (0.992 to 1.055)	0.980
Protein yield (kg)	1.011 (0.982 to 1.040)	1.004 (0.977 to 1.031)	0.997 (0.949 to 1.046)	0.647
Fat percentage	1.090 (1.013 to 1.172)	1.139 (1.066 to 1.217)	1.191 (1.054 to 1.346)	0.250
Protein percentage	1.164 (0.973 to 1.392)	1.377 (1.171 to 1.620)	1.630 (1.205 to 2.206)	0.079
Daughter fertility	1.047 (1.033 to 1.060)	1.035 (1.024 to 1.046)	1.024 (1.003 to 1.044)	0.094
Survival	1.029 (1.020 to 1.038)	1.037 (1.027 to 1.047)	1.046 (1.028 to 1.064)	0.092

*Coefficients represent estimated odds ratios for recalving by 20 months for each extra 50 units
(Australian Selection Index, Australian Breeding Value for milk volume) or 10 units
(Australian Breeding Values for fat and protein yield) or 1 unit
(other Australian Breeding Values) in the cow's sire's Australian Selection Index/Australian Breeding Value; coefficients were adjusted for maternal grand sire's Australian Selection Index/Australian Breeding Value and cow's age at calving; herd was fitted as a random effect

5.8 EFFECTS ON ODDS OF SHORT LACTATION IN HOLSTEINS

Estimated effects on odds of short lactation in Holsteins are shown in Tables 5.57 to 5.59.

Table 5.57 Estimated effects*of cow's sire's Australian Selection Index and Australian Breeding Values on odds of short lactation in Holstein cows by feeding system (95% CI)

Breeding value	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
Australian Selection Index	1.025 (0.973 to 1.079)	1.025 (1.000 to 1.051)	1.047 (1.005 to 1.091)	0.999 (0.937 to 1.065)	1.090 (0.984 to 1.208)
Australian Breeding Value:					
Milk volume (l)	1.003 (0.995 to 1.011)	1.002 (0.998 to 1.006)	1.009 (1.003 to 1.016)	0.994 (0.984 to 1.004)	1.011 (0.995 to 1.027)
Fat yield (kg)	0.976 (0.933 to 1.020)	1.023 (1.002 to 1.045)	1.025 (0.989 to 1.062)	1.047 (0.990 to 1.106)	1.046 (0.962 to 1.136)
Protein yield (kg)	1.050 (0.984 to 1.119)	1.024 (0.993 to 1.056)	1.075 (1.023 to 1.131)	0.961 (0.890 to 1.039)	1.131 (0.992 to 1.290)
Fat percentage	0.819 (0.636 to 1.055)	1.048 (0.938 to 1.170)	0.866 (0.718 to 1.045)	1.397 (1.046 to 1.866)	0.912 (0.552 to 1.508)
Protein percentage	1.278 (0.766 to 2.134)	1.093 (0.866 to 1.378)	0.957 (0.648 to 1.413)	1.080 (0.569 to 2.050)	1.271 (0.465 to 3.474)
Daughter fertility	0.998 (0.982 to 1.015)	0.984 (0.977 to 0.992)	0.972 (0.959 to 0.985)	0.973 (0.953 to 0.994)	0.957 (0.928 to 0.987)
Survival	0.973 (0.951 to 0.995)	0.952 (0.942 to 0.963)	0.986 (0.968 to 1.005)	0.942 (0.914 to 0.970)	0.946 (0.898 to 0.996)

*Coefficients represent estimated odds ratios for short lactation for each extra 50 units (Australian Selection Index, Australian Breeding Value for milk volume) or 10 units (Australian Breeding Values for fat and protein yield) or 1 unit (other Australian Breeding Values) in the cow's sire's Australian Selection Index/Australian Breeding Value; coefficients were adjusted for maternal grand sire's Australian Selection Index/Australian Breeding Value and cow's age at calving; herd was fitted as a random effect

Table 5.58 P-values for differences in estimated effects of cow's sire's Australian Selection Index and Australian Breeding Values on odds of short lactation in Holstein cows by feeding system, relative to the moderate to high feeding system (reference group or Ref. group)

Breeding value	Feeding system					P for interaction
	Low bail	Mod-high bail	PMR	Hybrid	TMR	
Australian Selection Index	0.994	Ref. group	0.379	0.466	0.253	0.575
Australian Breeding Value:						
Milk volume (l)	0.772	Ref. group	0.047	0.164	0.279	0.088
Fat yield (kg)	0.059	Ref. group	0.950	0.452	0.620	0.275
Protein yield (kg)	0.492	Ref. group	0.100	0.134	0.148	0.080
Fat percentage	0.080	Ref. group	0.087	0.069	0.599	0.032
Protein percentage	0.583	Ref. group	0.565	0.974	0.774	0.925
Daughter fertility	0.116	Ref. group	0.101	0.326	0.079	0.037
Survival	0.088	Ref. group	0.002	0.492	0.799	0.009

Table 5.59 Estimated effects*of cow's sire's Australian Selection Index and Australian Breeding Values on odds of short lactation in Holstein cows by herd average solids per cow (95% CI)

Breeding value	Herd average solids per cow (kg)				P for interaction
	400	500	600	700	
Australian Selection Index	1.030 (0.996 to 1.066)	1.028 (1.008 to 1.049)	1.027 (1.001 to 1.053)	1.025 (0.981 to 1.071)	0.885
Australian Breeding Value:					
Milk volume (l)	1.005 (0.999 to 1.010)	1.004 (1.000 to 1.007)	1.003 (0.999 to 1.006)	1.002 (0.995 to 1.008)	0.585
Fat yield (kg)	1.011 (0.982 to 1.040)	1.018 (1.001 to 1.035)	1.024 (1.002 to 1.047)	1.031 (0.993 to 1.071)	0.513
Protein yield (kg)	1.044 (1.002 to 1.089)	1.036 (1.011 to 1.062)	1.028 (0.997 to 1.061)	1.020 (0.967 to 1.077)	0.588
Fat percentage	0.929 (0.794 to 1.087)	0.979 (0.896 to 1.070)	1.032 (0.920 to 1.157)	1.087 (0.889 to 1.330)	0.327
Protein percentage	1.072 (0.770 to 1.494)	1.069 (0.886 to 1.289)	1.065 (0.837 to 1.355)	1.061 (0.696 to 1.618)	0.976
Daughter fertility	0.981 (0.971 to 0.992)	0.982 (0.976 to 0.987)	0.982 (0.974 to 0.989)	0.982 (0.968 to 0.995)	0.987
Survival	0.976 (0.962 to 0.991)	0.965 (0.956 to 0.973)	0.953 (0.942 to 0.964)	0.942 (0.923 to 0.961)	0.020

*Coefficients represent estimated odds ratios for short lactation for each extra 50 units (Australian Selection Index, Australian Breeding Value for milk volume) or 10 units (Australian Breeding Values for fat and protein yield) or 1 unit (other Australian Breeding Values) in the cow's sire's Australian Selection Index/Australian Breeding Value; coefficients were adjusted for maternal grand sire's Australian Selection Index/Australian Breeding Value and cow's age at calving; herd was fitted as a random effect

5.9 EFFECTS ON ODDS OF SHORT LACTATION IN JERSEYS

Estimated effects on odds of short lactation in Jerseys are shown in Tables 5.60 to 5.62.

Table 5.60 Estimated effects*of cow's sire's Australian Selection Index and Australian Breeding Values on odds of short lactation in Jersey cows by feeding system (95% CI)

Breeding value	Feeding system		
	Low bail	Mod-high bail	PMR
Australian Selection Index	0.949 (0.884 to 1.018)	0.981 (0.941 to 1.022)	1.033 (0.918 to 1.162)
Australian Breeding Value:			
Milk volume (l)	0.993 (0.980 to 1.007)	0.995 (0.988 to 1.002)	0.996 (0.978 to 1.015)
Fat yield (kg)	0.954 (0.898 to 1.014)	0.986 (0.952 to 1.021)	0.982 (0.890 to 1.082)
Protein yield (kg)	0.936 (0.850 to 1.029)	0.965 (0.914 to 1.019)	1.032 (0.887 to 1.200)
Fat percentage	0.948 (0.711 to 1.264)	1.048 (0.917 to 1.199)	1.011 (0.693 to 1.476)
Protein percentage	0.898 (0.431 to 1.869)	1.115 (0.808 to 1.537)	1.755 (0.715 to 4.310)
Daughter fertility	0.996 (0.946 to 1.048)	0.988 (0.967 to 1.010)	0.986 (0.929 to 1.046)
Survival	0.978 (0.949 to 1.008)	0.973 (0.956 to 0.991)	0.941 (0.890 to 0.994)

*Coefficients represent estimated odds ratios for short lactation for each extra 50 units (Australian Selection Index, Australian Breeding Value for milk volume) or 10 units (Australian Breeding Values for fat and protein yield) or 1 unit (other Australian Breeding Values) in the cow's sire's Australian Selection Index/Australian Breeding Value; coefficients were adjusted for maternal grand sire's Australian Selection Index/Australian Breeding Value and cow's age at calving; herd was fitted as a random effect

Table 5.61 P-values for differences in estimated effects of cow's sire's Australian Selection Index and Australian Breeding Values on odds of short lactation in Jersey cows by feeding system, relative to the moderate to high feeding system (reference group or Ref. group)

Breeding value	Feeding system			P for interaction
	Low bail	Mod-high bail	PMR	
Australian Selection Index	0.426	Ref. group	0.416	0.460
Australian Breeding Value:				
Milk volume (l)	0.812	Ref. group	0.908	0.961
Fat yield (kg)	0.360	Ref. group	0.935	0.656
Protein yield (kg)	0.575	Ref. group	0.415	0.559
Fat percentage	0.533	Ref. group	0.859	0.820
Protein percentage	0.596	Ref. group	0.351	0.520
Daughter fertility	0.781	Ref. group	0.939	0.956
Survival	0.791	Ref. group	0.243	0.456

Table 5.62 Estimated effects*of cow's sire's Australian Selection Index and Australian Breeding Values on odds of short lactation in Jersey cows by herd average solids per cow (95% CI)

Breeding value	Herd average solids per cow (kg)			P for interaction
	400	500	600	
Australian Selection Index	0.971 (0.932 to 1.012)	0.983 (0.944 to 1.023)	0.994 (0.925 to 1.069)	0.583
Australian Breeding Value:				
Milk volume (l)	0.996 (0.989 to 1.004)	0.994 (0.987 to 1.001)	0.992 (0.979 to 1.004)	0.552
Fat yield (kg)	0.975 (0.942 to 1.010)	0.980 (0.947 to 1.014)	0.985 (0.927 to 1.047)	0.779
Protein yield (kg)	0.961 (0.910 to 1.016)	0.967 (0.917 to 1.019)	0.973 (0.884 to 1.070)	0.843
Fat percentage	0.982 (0.848 to 1.137)	1.051 (0.922 to 1.198)	1.125 (0.884 to 1.431)	0.376
Protein percentage	0.954 (0.668 to 1.361)	1.235 (0.898 to 1.699)	1.599 (0.886 to 2.884)	0.170
Daughter fertility	0.994 (0.970 to 1.019)	0.986 (0.965 to 1.007)	0.977 (0.940 to 1.016)	0.496
Survival	0.974 (0.957 to 0.991)	0.971 (0.954 to 0.990)	0.969 (0.937 to 1.001)	0.774

*Coefficients represent estimated odds ratios for short lactation for each extra 50 units (Australian Selection Index, Australian Breeding Value for milk volume) or 10 units (Australian Breeding Values for fat and protein yield) or 1 unit (other Australian Breeding Values) in the cow's sire's Australian Selection Index/Australian Breeding Value; coefficients were adjusted for maternal grand sire's Australian Selection Index/Australian Breeding Value and cow's age at calving; herd was fitted as a random effect

CHAPTER 6: DOES AUSTRALIAN PROFIT RANKING INCREASE MILK YIELD BY THE SAME PERCENTAGE IN EACH ENVIRONMENT?

6.1 OBJECTIVES

The following research objective is addressed in this chapter:

- to assess whether Australian Profit Ranking increases milk yield by the same percentage in each feeding system and over a range of herd average milk yields per cow.

6.2 RESULTS

Absolute effect estimates of Australian Profit Ranking expressed as proportions of means are shown in Tables 6.1 and 6.2. **Proportional effects on milk volume, and fat and protein yields were highest in TMR herds; proportional effects on protein yield were similar in low bail, moderate to high bail, and hybrid feeding systems** (Table 6.1).

Proportional effects on milk volume and protein yield increased slightly with increasing herd average solids per cow, while fat responses declined with increasing herd average solids per cow (Table 6.2).

Table 6.1 Estimated effects*of cow's sire's Australian Profit Ranking on 305-day milk yields for lactations from Holstein cows by feeding system (95% CI)

Milk yield variable and effect estimate type	feeding system					P for inter-action
	Low bail	Mod-high bail	PMR	Hybrid	TMR	
Milk volume						
Absolute effect (litres)	56.2 (40.9 to 71.5)	68.0 (60.4 to 75.6)	53.7 (39.8 to 67.7)	79.7 (58.8 to 100.6)	109.9 (75.1 to 144.8)	0.013
Crude mean	6,144	7,335	7,877	8,432	9,107	
Absolute effect as proportion of crude mean	0.91% (0.67 to 1.16%)	0.93% (0.82 to 1.03%)	0.68% (0.51 to 0.86%)	0.95% (0.70 to 1.19%)	1.21% (0.82 to 1.59%)	
Fat yield						
Absolute effect (kg)	2.6 (2.0 to 3.2)	2.5 (2.2 to 2.8)	1.5 (1.0 to 2.0)	3.5 (2.7 to 4.3)	5.7 (4.4 to 7.1)	<0.001
Crude mean	247	284	295	314	341	
Absolute effect as proportion of crude mean	1.05% (0.81 to 1.30%)	0.88% (0.78 to 0.99%)	0.51% (0.34 to 0.68%)	1.11% (0.86 to 1.37%)	1.67% (1.29 to 2.08%)	
Protein yield						
Absolute effect (kg)	2.6 (2.1 to 3.1)	3.4 (3.2 to 3.6)	2.9 (2.5 to 3.4)	4.0 (3.3 to 4.6)	5.1 (4.0 to 6.2)	<0.001
Crude mean	201	240	256	274	289	
Absolute effect as proportion of crude mean	1.29% (1.04 to 1.54%)	1.41% (1.33 to 1.50%)	1.13% (0.97 to 1.33%)	1.46% (1.20 to 1.68%)	1.77% (1.39 to 2.15%)	

*Absolute effect coefficients represent estimated changes in milk yield per 50 unit increase in the cow's sire's Australian Profit Ranking; coefficients were adjusted for the cow's maternal grandsire's Australian Profit Ranking and age at calving; herd and cow within herd were fitted as random effects

Table 6.2 Estimated effects[1] of cow's sire's Australian Profit Ranking on 305-day milk yield for lactations from Holstein cows by herd average solids per cow (95% CI)

Milk yield variable and effect estimate type	Herd average solids per cow (kg)				P for interaction
	400	500	600	700	
Milk volume					
Absolute effect (litres)	39.6 (29.2 to 50.0)	54.6 (48.3 to 60.8)	69.6 (61.8 to 77.4)	84.6 (71.5 to 97.7)	<0.001
Predicted mean[2]	5,529	7,025	8,521	10,017	
Absolute effect as proportion of crude mean	0.72% (0.53 to 0.90%)	0.78% (0.69 to 0.87%)	0.82% (0.73 to 0.91%)	0.84% (0.71 to 0.98%)	
Fat yield					
Absolute effect (kg)	2.1 (1.7 to 2.5)	2.2 (1.9 to 2.4)	2.2 (1.9 to 2.5)	2.3 (1.8 to 2.8)	0.612
Predicted mean[2]	221	272	323	374	
Absolute effect as proportion of crude mean	0.95% (0.77 to 1.13%)	0.81% (0.70 to 0.88%)	0.68% (0.59 to 0.77%)	0.61% (0.48 to 0.75%)	
Protein yield					
Absolute effect (kg)	2.0 (1.6 to 2.3)	2.8 (2.6 to 3.0)	3.7 (3.5 to 3.9)	4.6 (4.2 to 5.0)	<0.001
Predicted mean[2]	182	230	278	326	
Absolute effect as proportion of crude mean	1.10% (0.88 to 1.26%)	1.22% (1.13 to 1.30%)	1.33% (1.26 to 1.40%)	1.41% (1.29 to 1.53%)	

1 Absolute effect coefficients represent estimated changes in milk yield per 50 unit increase in the cow's sire's Australian Profit Ranking; coefficients were adjusted for the cow's maternal grandsire's Australian Profit Ranking and age at calving; herd and cow within herd were fitted as random effects

2 Predicted after separately regressing each milk yield variable on herd solids per cow, and calculating predicted mean values at herd solids per cow values of 400, 500, 600 and 700 kg

CHAPTER 7: CHOICES OF SIRES

7.1 OBJECTIVES

The following research objective is addressed in this chapter:

- to describe sire usage by feeding system and herd average milk yield per cow

Specifically, statistical analyses were performed:

i. to compare distributions of popular sires (more than 300 daughters) by feeding system and herd average milk yield categories,
ii. to compare the proportions of sires that were born in Australia by feeding system and herd average milk yield categories,
iii. to compare means and variation for sires' Australian Profit Rankings and Australian Breeding Values by feeding system and herd average milk yield categories, and
iv. to compare mean Australian Breeding Values for sires with similar Australian Profit Rankings by feeding system and herd average milk yield categories.

Additional analyses were performed to explore further questions.

7.2 KEY FINDINGS

Other than in TMR herds, between 52% and 68% of cows were sired by Australian sires. In the TMR herds, 39% of cows were sired by Australian sires. USA and Canadian sires were used more commonly in higher feed input herds.

Relatively few cows were sired by New Zealand sires in any feeding system.

Within each feeding system, a large number of sires had been used over the 5 years from mid 2004 to early 2009.

Similar sires were most popular in herds using low bail, moderate to high bail, PMR, and hybrid feeding systems, but many of these differed from the most popular sires in herds using the TMR system.

Within each herd average solids per cow category, a large number of sires had been used.

Sires with a wide range of Australian Profit Rankings had been used (-303 to 430), indicating that rate of increase in Australian Profit Ranking was markedly less than that possible.

PMR and TMR herds and high milk yield herds made less rapid progress in increasing Australian Profit Ranking than other herds. Rates of increase varied from 12-13 units per year in low bail feeding and low-producing herds to 8 units per year in TMR and high-producing herds.

Mean sire Australian Profit Rankings were lower in herds using higher input feeding systems and with higher average milk yields; the average sire Australian Profit Ranking was 68, ranging from 77 for the herds using low bail feeding to only 47 for TMR herds. The average sire Australian Profit Ranking was also highest in herds averaging around 400 kg MS/cow (77) and lowest in the highest producing herds (55).

Sire Australian Breeding Values for milk volume were higher in herds using higher input feeding systems, and herds with higher average milk yields. Mean sire Australian Breeding Values for fat and protein yields were lower in herds using higher input feeding systems, and herds with higher average milk yields. Mean sire Australian Breeding Values for fat and protein concentrations were lowest in TMR herds and high-producing herds.

These finding indicate that when USA sires were selected, sires with low Australian Profit Rankings were being selected in preference to Australian sires with higher Australian Profit Rankings. The lower mean sire Australian Profit Rankings in PMR, hybrid and TMR feeding systems were due to both a) selection of lower Australian Profit Rankings Australian sires and b) increased use of USA sires.

Sires with low reliabilities were commonly used, but these patterns in Australian Profit Rankings were not due to use of lower reliability sires.

For USA sires, selection priority for TPI was similar across systems.

Rate of increase in Australian Profit Ranking is substantially reduced if sires are selected based on TPI rather than Australian Profit Ranking.

7.2 NUMBERS OF COWS AND HERDS

In total, 77,144 Holstein cows met the selection criteria and were enrolled. Numbers of cows and herds by feeding system and herd average solids per cow are shown in Tables 7.1 and 7.2, respectively.

The 77,144 study cows included 4,649 cows from six TMR herds (Table 7.1). Even though there are only approximately 20 TMR herds in Australia, atypical sire choices by one herd could have important effects on the descriptive results for this group. Accordingly, descriptive statistics reported below for TMR herds should be interpreted with caution. In contrast, 96 herds had high average solids per cow (≥600 kg; Table 7.2) and so any particular individual herd would have much less influence on the descriptive statistics for this herd milk yield category.

Table 7.1 Numbers of Holstein cows and herds enrolled by feeding system

	Feeding system						Pooled
	Low bail	Mod-high bail	PMR	Hybrid	TMR	Not recorded	
No. cows	8,869	45,215	13,112	4,827	4,649	472	77,144
No. herds[1]	101	312	65	19	6	11	438

1 Because herds could change feeding systems between years, one herd could contribute cows to more than one feeding system

Table 7.2 Numbers of Holstein cows and herds enrolled, by herd average solids per cow

	Herd average solids per cow (kg)				Pooled
	<400	400 to <500	500 to <600	≥600	
No. cows	3,861	23,394	33,219	16,670	77,144
No. herds[1]	93	255	268	96	438

1 Because herds could change milk yield categories between years, one herd could contribute cows to more than one milk yield category

7.3 AGES OF COWS

Years of birth of enrolled cows are summarised in Table 7.3. Within each feeding system, median year of birth of selected cows was 2007. Study cows were almost all born between 2005 and 2009 (with 15 cows born in 2010), and hence virtually all were conceived by inseminations from mid 2004 to early 2009. Thus, results in this chapter reflect sire selection decisions over this period that resulted in cows entering study herds and these may have changed since then. Further studies would be required to document more recent sire choices.

Table 7.3 Numbers of Holstein cows by year of birth and feeding system

Year of birth	Feeding system						Pooled (n=77,144)
	Low bail (n=8,869)	Mod-high bail (n=45,215)	PMR (n=13,112)	Hybrid (n=4,827)	TMR (n=4,649)	Not recorded (n=472)	
2005	22%	21%	21%	20%	19%	35%	21%
2006	21%	20%	23%	23%	23%	21%	21%
2007	25%	22%	23%	23%	21%	35%	23%
2008	18%	20%	20%	18%	19%	10%	19%
2009	14%	16%	14%	16%	19%	0%	15%
2010	0%	0%	0%	0%	0%	0%	0%

7.4 SIRE'S HERDBOOK COUNTRY

Herdbook country was not recorded for sires of 2149 (3%) of the 77,144 Holstein cows. Countries of sires for the remaining 74,995 Holstein cows are summarised in Tables 7.4, 7.5 and 7.6, and Figures 7.1 and 7.2. **Other than in TMR herds, between 52% and 68% of cows were sired by Australian sires. In the TMR herds, 39% of cows were sired by Australian sires. USA and Canadian sires were used more commonly in higher feed input herds**. Whereas 47% of cows in TMR herds were sired by USA sires, only 8% and 17% of cows were daughters of USA sires in the other four feeding systems. Similarly, in herds with higher herd average milk yields, lower percentages of sires were Australian, and higher percentages from USA (Table 7.5 and Figure 7.2).

Relatively few cows were sired by New Zealand sires in any feeding system; only 4% of cows in low bail feeding herds were sired by New Zealand sires (Table 7.4 and Figure 7.1).

Across the 3 Victorian regions and NSW, the highest percentages of sires were Australian in Gippsland and lowest in NSW (Table 7.6). Percentages of daughters whose sire was from USA were highest in NSW and lowest in Gippsland. Approximately 8% of cows from Tasmanian herds were sired by NZ sires, but only between 0% and 3% of cows in other regions were sired by NZ sires (Table 7.6).

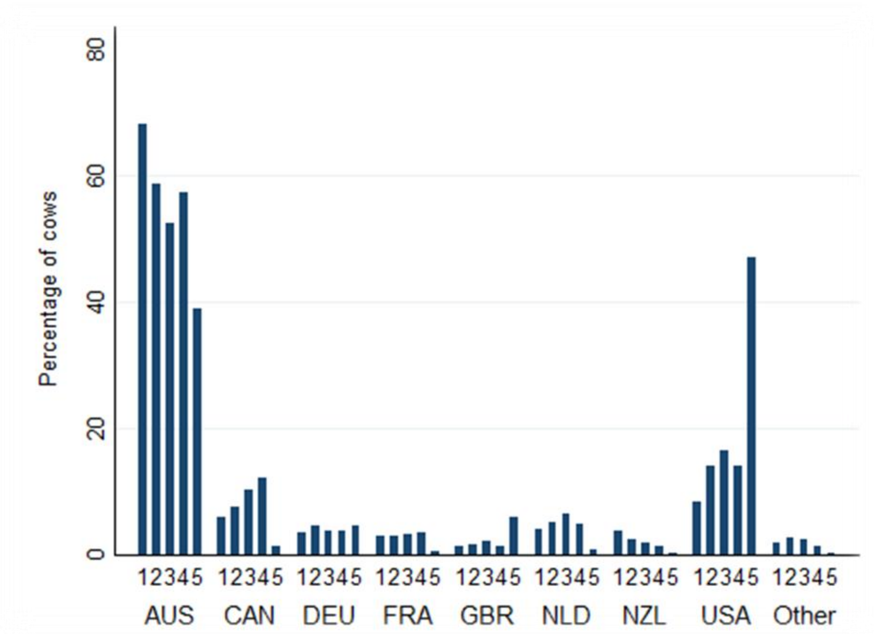


Figure 7.1 Percentages of Holstein cows by sire's herdbook country within feeding system (1 Low bail; 2 Mod-high bail, 3 PMR, 4 Hybrid, 5 TMR). (AUS Australia, CAN Canada, DEU Germany, FRA France, GBR Great Britain, NLD Netherlands, NZL New Zealand, USA United States of America)

Table 7.4 Distributions of Holstein cows by herdbook country of sire and feeding system

Herdbook country of sire	Feeding system						Pooled (n=74,995)
	Low bail (n=8,607)	Mod-high bail (n=43,925)	PMR (n=12,608)	Hybrid (n=4,774)	TMR (n=4,642)	Not recorded (n=439)	
Australia	68%	59%	52%	57%	39%	57%	57%
Canada	6%	8%	10%	12%	1%	13%	8%
France	3%	3%	3%	4%	1%	7%	3%
Germany	4%	5%	4%	4%	5%	0%	4%
Great Britain	1%	2%	2%	1%	6%	0%	2%
Netherlands	4%	5%	7%	5%	1%	5%	5%
New Zealand	4%	3%	2%	2%	0%	7%	2%
USA	8%	14%	17%	14%	47%	10%	16%
Other[1]	2%	3%	3%	1%	0%	1%	2%

1 Denmark, Hungary, Ireland, Italy, Spain, Sweden, Switzerland

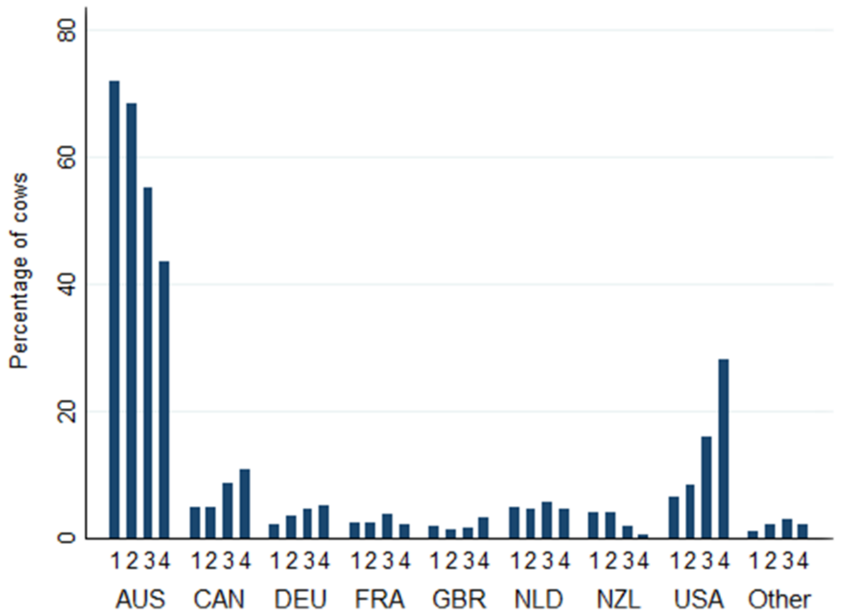


Figure 7.2 Percentages of Holstein cows by sire's herdbook country within herd average solids per cow category (1 <400 kg; 2 400 to < 500 kg, 3 500 to <600 kg, 4 ≥600 kg). (AUS Australia, CAN Canada, DEU Germany, FRA France, GBR Great Britain, NLD Netherlands, NZL New Zealand, USA United States of America)

Table 7.5 Distributions of Holstein cows by herdbook country of sire and herd average solids per cow

Herdbook country of sire	Herd average solids per cow (kg)				Pooled (n=74,995)
	<400 (n=3,612)	400 to <500 (n=22,817)	500 to <600 (n=32,172)	≥600 (n=16,394)	
Australia	72%	68%	55%	43%	57%
Canada	5%	5%	9%	11%	8%
France	2%	3%	4%	2%	3%
Germany	2%	4%	5%	5%	4%
Great Britain	2%	1%	2%	3%	2%
Netherlands	5%	5%	6%	5%	5%
New Zealand	4%	4%	2%	0%	2%
USA	6%	8%	16%	28%	16%
Other[1]	1%	2%	3%	2%	2%

1 Denmark, Hungary, Ireland, Italy, Spain, Sweden, Switzerland

Table 7.6 Distributions of Holstein cows by herdbook country of sire and region of herd

Herdbook country of sire	Qld	NSW	Northern Victoria	South West Victoria	Gipps-land	Tasmania	SA	WA	Pooled
All feeding systems									
No. cows	1,312	13,654	13,394	13,972	18,123	1,933	7,116	5,491	74,995
Australia	68%	48%	58%	57%	69%	64%	39%	57%	57%
Canada	10%	10%	8%	10%	5%	3%	7%	4%	8%
France	1%	4%	3%	3%	3%	2%	2%	3%	3%
Germany	4%	3%	5%	4%	3%	6%	7%	6%	4%
Great Britain	1%	3%	2%	2%	1%	3%	2%	2%	2%
Netherlands	2%	4%	5%	5%	7%	5%	3%	4%	5%
New Zealand	1%	0%	2%	3%	3%	8%	2%	2%	2%
USA	13%	25%	14%	13%	5%	10%	36%	15%	16%
Other[1]	1%	2%	2%	3%	2%	0%	2%	5%	2%
Moderate to high bail feeding herds									
No. cows	372	4,203	9,015	9,494	12,094	1,024	5,059	2,664	43,925
Australia	64%	52%	62%	53%	68%	58%	39%	46%	57%
Canada	11%	13%	5%	12%	5%	4%	6%	4%	7%
France	1%	4%	3%	2%	3%	1%	2%	3%	3%
Germany	1%	3%	5%	4%	3%	7%	7%	6%	4%
Great Britain	2%	2%	1%	2%	1%	3%	2%	2%	2%
Netherlands	7%	6%	5%	5%	5%	4%	4%	6%	5%
New Zealand	2%	1%	2%	2%	4%	5%	3%	2%	3%
USA	8%	16%	12%	15%	5%	16%	35%	12%	14%
Other[1]	9%	19%	14%	18%	7%	16%	37%	21%	16%

1 Denmark, Hungary, Ireland, Italy, Spain, Sweden, Switzerland

7.5 COMMONLY USED SIRES

Numbers of cows sired by each sire were calculated for each feeding system, and within each feeding system, sires were then ranked on their number of daughters. **Within each feeding system, a large number of sires had been used over the 5 years from mid 2004 to early 2009**. The 20 most popular sires within each feeding system accounted for only 28% to 33% of Holstein cows in low bail, moderate to high bail, PMR, and hybrid feeding systems, and 51% of cows in herds using the TMR feeding system.

Sires that were used most commonly (ie in the top 20 based on numbers of Holstein cows sired by that bull) within any feeding system are listed in Table 7.7. Ranks within feeding system are highlighted yellow. Sires with ranks of 1 were the most popular within the specified feeding system, sires with ranks of 2 were the second most popular, and so on. **Similar sires were most popular in herds using low bail, moderate to high bail, PMR, and hybrid feeding systems, but many of these differed from the most popular sires in herds using the TMR system.** Of the top 20 most popular sires across herds using the moderate to high bail feeding system (the most commonly used system), 14 were also in the top 20 across low bail feeding system herds, 16 across PMR herds, and 14 across hybrid herds, but only 6 across the TMR herds.

Table 7.7 Numbers of Holstein cows by sire and feeding system

Sire National ID	Feeding system											Pooled (n= 77,144)
	Low bail (n=8,869)		Mod-high bail (n=45,214)		PMR (n=13,112)		Hybrid (n=4,827)		TMR (n=4,649)		Not recorded (n=472)	
	No.	Rank[1]	No.	Rank	No.	Rank	No.	Rank	No.	Rank	No.	
H00956582	284	1	1,560	1	299	2	173	2	8		4	2,328
A00010550	204	5	1,113	2	168	11	40	18	117	9	1	1,643
H01059976	205	4	1,026	3	224	5	123	3	2		2	1,582
H00930377	120	12	988	4	388	1	182	1	20		7	1,705
H00869155	131	10	978	5	194	9	87	6			2	1,392
H00851470	211	3	906	6	171	10	50	13	6		5	1,349
H01080932	258	2	901	7	209	6	104	4			4	1,476
A00011306	142	9	870	8	202	7	45	15	98	17	1	1,358
A00009209	112	13	794	9	199	8	21		106	13	2	1,234
H01132669	187	7	779	10	122	15	84	8				1,172
A00016676	58		748	11	167	12	90	5	155	5		1,218
A00013878	57		627	12	240	3	86	7	5		10	1,025
A00013014	75	20	590	13	229	4	82	9	7		1	984
H01012112	41		452	14	34		18		1		15	561
H00934796	160	8	443	15	137	13	74	10	1		7	822
H01036699	197	6	432	16	116	16	4					749
A00016677	61		425	17	99		6		114	10		705
H00913259	100	15	373	18	107	20	41	17			7	628
A00013699	55		358	19	69		25		99	15	6	612
A00013716	41		312	20	63		10		2			428
A00013411	45		184		125	14	7		211	1		572
A00013794	16		206		96		36	20	164	2		518
A00014148	19		230		66		2		114	11		431
A00014288	98	16	241		96		33					468
A00015426	34		225		61		1		61	19		382
A00015601			7		5		2		58	20		72
A00015659	10		283		111	18	21		5			430
A00015870	16		50		49				164	3		279
A00015871	15		202		59		11		110	12		397
A00015994	21		226		109	19	36	19	2		1	395
A00016526			34		17		2		99	16		152
A00016577			183		39				163	4		385
A00016852	38		127		43		29		118	8		355
A00016853	7		2		1				126	7		136
A00016854	2		110		49		8		140	6		309
A00016857	27		127		25		42	16	2			223
A00016914	1		52		35		63	12				151
A00016973	7		107		26		46	14	103	14		289
A00017127	4		129		53		65	11	2			253
A00017405	12		119		67		29		63	18		290
H00908766	81	17	156		84		12				1	334
H00935164	78	19	142		33		14				1	268
H01017650	122	11	236		113	17	4				4	479
H01019151	101	14	140		47		17					305
H01061468	79	18	140		3				58		1	281
Other sires	5,337		26,882		8,263		3,002		2,145		390	46,019

1 Within each feeding system, sires were ranked on their number of daughters. Sires with ranks of 1 were the most popular within the specified feeding system, sires with ranks of 2 were the second most popular, and so on.

Sires were also ranked based on their number of daughters in each herd average solids per cow category. **Within each herd average solids per cow category, a large number of sires had been used.** The 20 most popular sires accounted for only 31% to 33% of Holstein cows in herds in each herd average solids per cow category.

Sires used most commonly (ie in the top 20 based on numbers of Holstein cows sired by that bull) within any herd average solids per cow category are listed in Table 7.8. Of the 20 most popular sires across herds with average solids per cow of 500 to <600 kg (the most commonly used system), 15 were also in the top 20 across herds producing each of <400 kg and 400 to <500 kg, but only 12 across herds producing ≥600 kg.

Table 7.8 Numbers of Holstein cows by sire and herd average solids per cow

Sire National ID	Herd average solids per cow (kg) <400 (n=3,861)		400 to <500 (n=23,394)		500 to <600 (n=33,219)		≥600 (n=16,670)		Pooled (n=77,144)
	No.	Rank[1]	No.	Rank	No.	Rank	No.	Rank	
H00956582	110	2	769	1	1035	1	414	3	2328
H01059976	74	5	512	5	758	2	238	9	1582
H00930377	27		364	11	743	3	571	1	1705
A00010550	116	1	444	7	728	4	355	5	1643
H01080932	82	4	605	2	665	5	124		1476
H00869155	64	8	492	6	622	6	214	12	1392
H00851470	97	3	517	4	601	7	134		1349
A00011306	68	7	384	10	586	8	320	6	1358
A00016676	14		173	18	580	9	451	2	1218
A00013878	25		226	15	538	10	236	10	1025
A00009209	42	14	427	8	529	11	236	11	1234
A00013014	36	18	171	19	498	12	279	7	984
H01132669	69	6	521	3	478	13	104		1172
H00934796	59	9	345	12	350	14	68		822
A00016677	23		163		320	15	199	14	705
H00913259	46	13	224	16	284	16	74		628
A00013699	35	19	131		257	17	189	15	612
A00013716	7		89		233	19	99		428
A00014288	40	15	133		233	18	62		468
A00011462	46	12	131		227	20	10		414
H01036699	55	10	418	9	226		50		749
H01012112	26		255	13	217		63		561
A00013794	7		45		206		260	8	518
A00013411	5		30		165		372	4	572
A00015871	2		41		165		189	16	397
H01017650	52	11	251	14	145		31		479
A00016852	1		29		137		188	17	355
H00876599	39	16	126		133		81		379
A00014576	5		58		126		188	18	377
H00931684	38	17	157		121		41		357
H00908766	18		214	17	91		11		334
A00016973	3		38		88		160	20	289
A00016854	2		12		81		214	13	309
H01019151	33	20	167	20	81		24		305
A00015870	14		32		63		170	19	279
Other sires	2,481		14,700		20,909		10,251		48,341

1 Within each herd milk yield category, sires were ranked on their number of daughters. Sires with ranks of 1 were the most popular within the specified herd milk yield category, sires with ranks of 2 were the second most popular, and so on.

7.6 SIRE AUSTRALIAN PROFIT RANKINGS AND AUSTRALIAN BREEDING VALUES

The distribution of the 77,144 Holstein cows by their sire's Australian Profit Ranking is shown in Figure 7.3. **Sires with a wide range of Australian Profit Rankings had been used (-303 to 430), indicating that rate of increase in Australian Profit Ranking was markedly less than that possible.**Overall, 20% of cows had sires with a negative Australian Profit Ranking (<0), varying from 16% in low bail feeding herds to 25% in TMR herds. Six percent of cows were daughters of sires with Australian Profit Rankings of less than -80.

Sires' Australian Profit Ranking reliabilities are shown in Figures 7.4 and 7.5. Lower reliability sires were commonly used. Only 57% of the cows had sires with reliabilities of 97 or above and one quarter of cows had sires with reliabilities below 85. There were small secondary peaks of reliabilities around 78 and 30.

Sires' Australian Profit Ranking's were only weakly correlated with reliability (r = 0.286; 95% CI: 0.279 to 0.292; P<0.001); a positive correlation was evident only at very low Australian Profit Rankings (Figure 7.5).

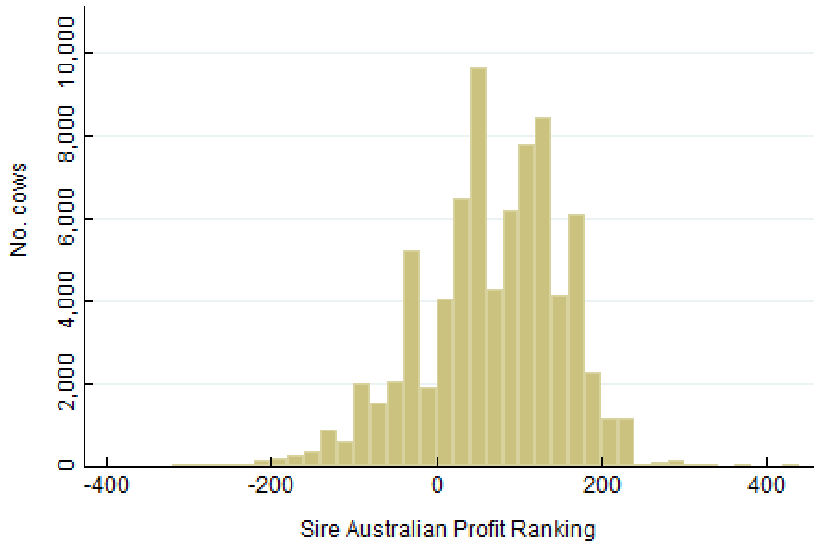


Figure 7.3 Distribution of 77,144 Holstein cows by their sire's Australian Profit Ranking

Figure 7.4 Distribution of 77,144 Holstein cows by their sire's Australian Profit Ranking reliability. Bar width is 1 unit.

a) b)

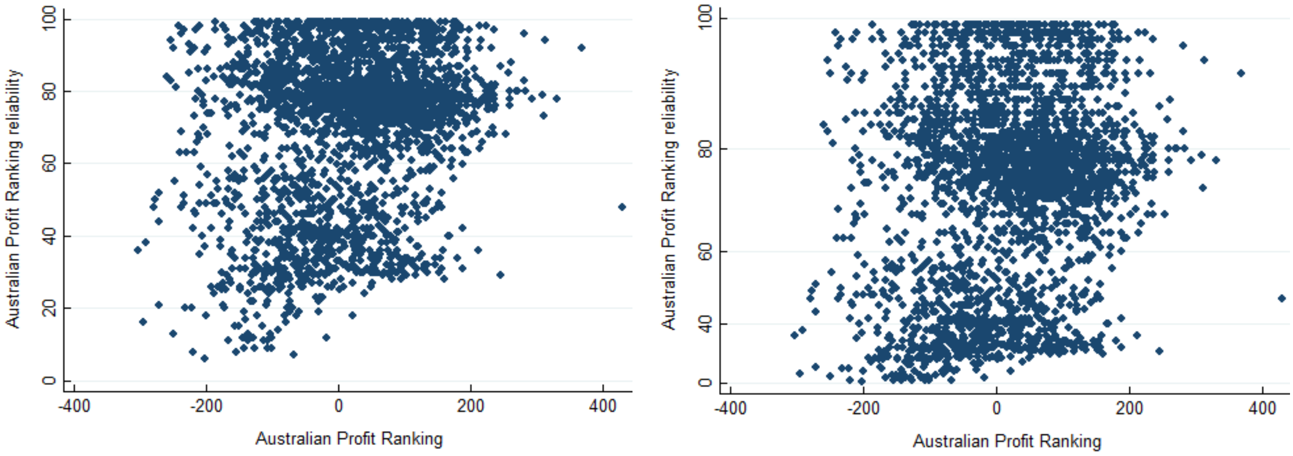
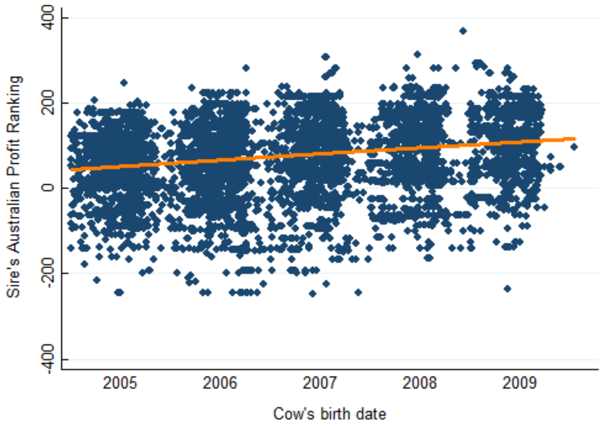


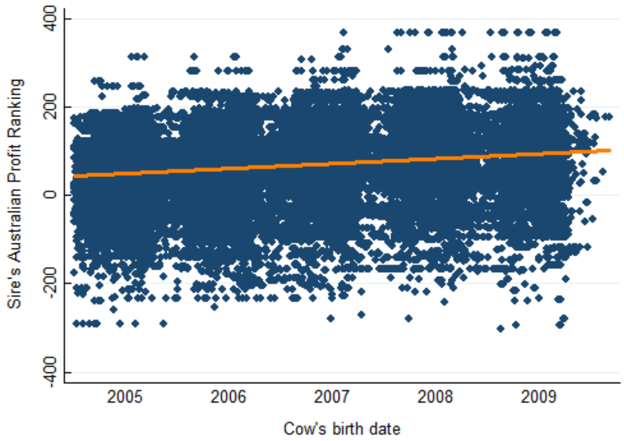
Figure 7.5 Scattergraph of sire's Australian Profit Ranking by Australian Profit Ranking reliability for 77,144 Holstein cows with reliability on linear (a) and squared (b) scales

Scattergraphs of sires' Australian Profit Rankings by cow birth dates are shown in Figure 7.6, and rates of increase in sires' Australian Profit Rankings over time are shown in Tables 7.9 and 7.10. Rates of increase in sires' Australian Profit Ranking varied by both feeding system and herd average solids per cow (p-values for interactions both <0.001), with smallest increases in PMR and TMR herds and high milk yield herds. **PMR and TMR herds and high milk yield herds made less rapid progress in increasing Australian Profit Ranking than other herds. Rates of increase varied from 12-13 units per year in low bail feeding and low-producing herds to 8 units per year in TMR and high-producing herds.**

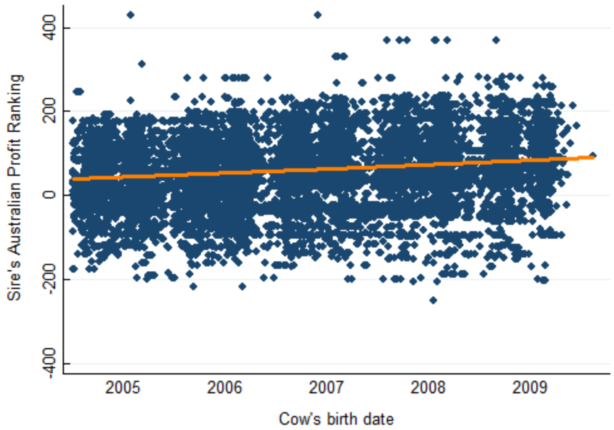
a) Low bail



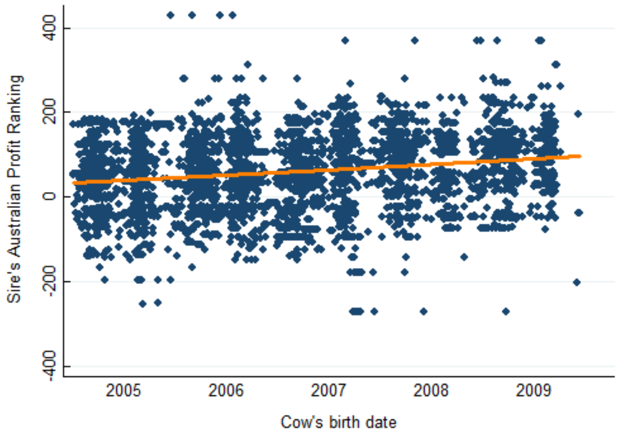
b) Mod-high bail



c) PMR



d) Hybrid



e) TMR

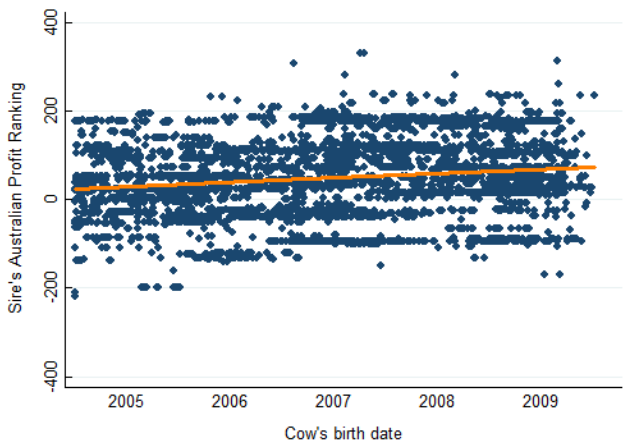


Figure 7.6 Scattergraphs of sire's Australian Profit Ranking by cow's birthdate for 77,144 Holstein cows by feeding system; lines of best fit are shown in orange

Table 7.9 Annual rates of increase in mean Australian Profit Rankings of sires of Holstein cows by feeding system

Feeding system				
Low bail (n=8,869)	**Mod-high bail (n=45,215)**	**PMR (n=13,112)**	**Hybrid (n=4,827)**	**TMR (n=4,649)**
13.0 (11.9 to 14.4)	10.0 (9.6 to 10.6)	8.8 (7.9 to 9.9)	12.1 (10.6 to 13.9)	7.8 (6.4 to 9.5)

Table 7.10 Annual rates of increase in mean Australian Profit Rankings of sires of Holstein cows by herd average solids per cow

Herd average solids per cow (kg)			
<400 (n=3,861)	**400 to <500 (n=23,394)**	**500 to <600 (n=33,219)**	**≥600 (n=16,670)**
11.8 (11.2 to 12.7)	10.6 (10.3 to 11.1)	9.4 (9.0 to 10.0)	8.1 (7.4 to 9.2)

Mean Australian Profit Rankings and Australian Breeding Values of sires are shown by feeding system in Figure 7.7 and Table 7.11, and by herd average milk yield in Figure 7.8 and Table 7.12. **Mean sire Australian Profit Rankings were lower in herds using higher input feeding systems and with higher average milk yields; the average sire Australian Profit Ranking was 68, ranging from 77 for the herds using low bail feeding to only 47 for TMR herds. The average sire Australian Profit Ranking was also highest in herds averaging around 400 kg MS/cow (77) and lowest in the highest producing herds (55). Sire Australian Breeding Values for milk volume were higher in herds using higher input feeding systems, and herds with higher average milk yields. Mean sire Australian Breeding Values for fat and protein yields were lower in herds using higher input feeding systems, and herds with higher average milk yields. Mean sire Australian Breeding Values for fat and protein concentrations were lowest in TMR herds and high-producing herds.**

These same general patterns were evident within groups of sires with similar Australian Profit Rankings (Table 7.13), although some comparisons were limited by small numbers. Further consideration of these results may inform planning of extension aiming to improve the rate of increase in cow Australian Profit Rankings.

Medians of sires' Australian Profit Ranking reliabilities were 96 or 97 across all feeding systems (Table 7.11) and herd average milk yield categories (Table 7.12).

We estimate that Australian Profit Rankings of selected sires would have been at least 100 units higher, if only sires from the Good Bulls Guide (or the equivalent sires for the earlier years studied) had been used in the study herds.

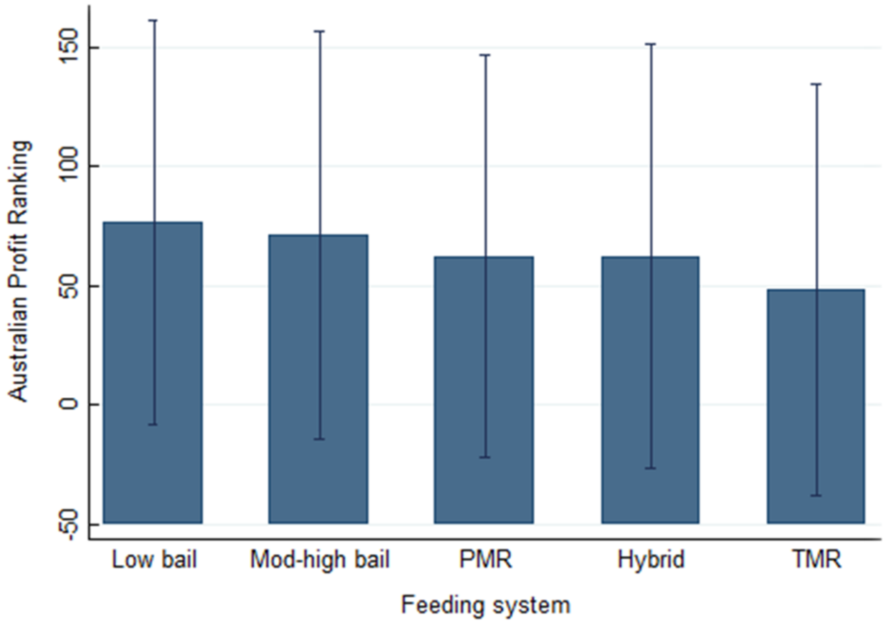


Figure 7.7 Mean (±SD) Australian Profit Rankings of sires of Holstein cows by feeding system.

Table 7.11 Mean (SD[1]) Australian Profit Rankings and Australian Breeding Values, and median Australian Profit Ranking reliabilities, of sires of Holstein cows by feeding system

Genetic variable	**Feeding system**						**Pooled (n=77,144)**
	Low bail (n=8,869)[2]	**Mod-high bail (n=45,215)**	**PMR (n=13,112)**	**Hybrid (n=4,827)**	**TMR (n=4,649)**	**Not recorded (n=472)**	
Australian Profit Ranking	77 (85)	71 (85)	62 (84)	62 (89)	48 (86)	47 (92)	68 (86)
Australian Profit Ranking reliability (median)	97	97	97	97	96	96	97
Australian Breeding Value:							
Milk volume (l)	259 (461)	289 (472)	302 (470)	296 (482)	311 (459)	201 (427)	289 (470)
Fat yield (kg)	9 (17)	8 (18)	5 (18)	7 (19)	2 (19)	3 (17)	7 (18)
Protein yield (kg)	9 (12)	8 (12)	7 (12)	7 (12)	6 (12)	6 (12)	8 (12)
Fat percentage (g/100 mL)	-0.04 (0.32)	-0.07 (0.33)	-0.11 (0.34)	-0.08 (0.34)	-0.16 (0.31)	-0.09 (0.31)	-0.08 (0.33)
Protein percentage (g/100mL)	0.03 (0.16)	0.01 (0.16)	-0.01 (0.17)	-0.01 (0.16)	-0.05 (0.14)	0.01 (0.17)	0.00 (0.16)
Daughter fertility	101 (4)	101 (4)	101 (4)	101 (4)	101 (5)	101 (5)	101 (4)

1 Standard deviation pooled (ie within and between herd combined)
2 Number of cows whose sires were used in analyses

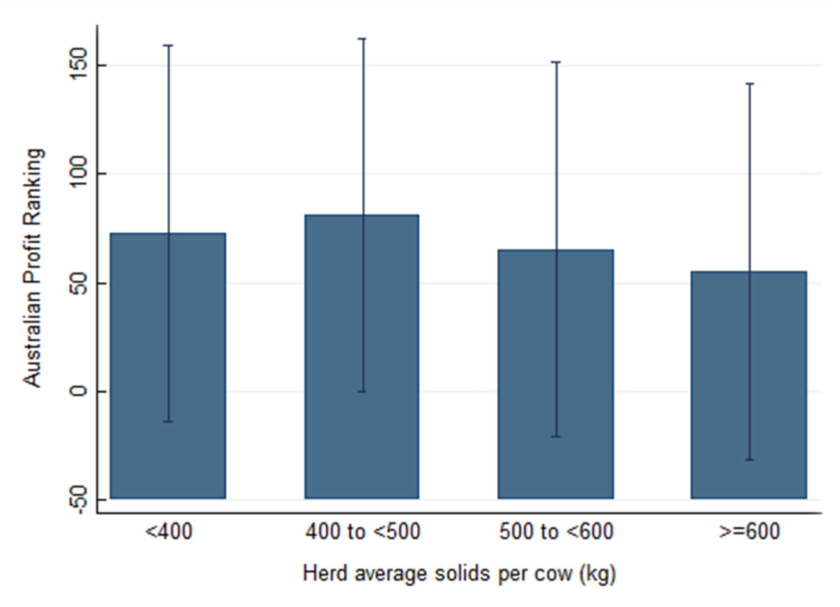


Figure 7.8 Mean (±SD) Australian Profit Rankings of sires of Holstein cows by herd average solids per cow

Table 7.12 Mean (SD[1]) Australian Profit Rankings and Australian Breeding Values and median Australian Profit Ranking reliabilities, of sires of Holstein cows by herd average solids per cow

Genetic variable	Herd average solids per cow (kg)				Pooled (n=77,144)
	<400 (n=3,861)	400 to <500 (n=23,394)	500 to <600 (n=33,219)	≥600 (n=16,670)	
Australian Profit Ranking	73 (87)	81 (81)	65 (86)	55 (87)	68 (86)
Australian Profit Ranking reliability (median)	97	97	97	97	97
Australian Breeding Value:					
Milk volume (l)	229 (460)	275 (456)	289 (477)	323 (475)	289 (470)
Fat yield (kg)	9 (17)	9 (17)	7 (18)	4 (19)	7 (18)
Protein yield (kg)	8 (12)	9 (12)	8 (12)	7 (12)	8 (12)
Fat percentage (g/100 mL)	-0.02 (0.30)	-0.04 (0.32)	-0.08 (0.33)	-0.14 (0.34)	-0.08 (0.33)
Protein percentage (g/100mL)	0.04 (0.15)	0.04 (0.15)	0.00 (0.17)	-0.04 (0.16)	0.00 (0.16)
Daughter fertility	101 (4)	101 (4)	101 (4)	101 (5)	101 (4)

1 Standard deviation pooled (ie within and between herd combined)
2 Number of cows whose sires were used in analyses

Table 7.13 Mean Australian Profit Rankings and Australian Breeding Values of sires of Holstein cows by feeding system for various Australian Profit Ranking categories

Genetic variable	Feeding system						Pooled (n=77144)
	Low bail (n=8869)	Mod-high bail (n=45215)	PMR (n=13112)	Hybrid (n=4827)	TMR (n=4649)	Not recorded (n=472)	
Australian Profit Ranking <-80							
No. lactations	466	2,434	780	305	511	40	4,536
Australian Profit Ranking	-128	-125	-117	-122	-104	-139	-121
Australian Breeding Value:							
Milk volume (l)	-339	-291	-140	-91	-16	35	-223
Fat yield (kg)	-21	-22	-21	-20	-22	-23	-22
Protein yield (kg)	-16	-15	-13	-13	-11	-12	-14
Fat percentage (g/100mL)	-0.10	-0.14	-0.22	-0.23	-0.30	-0.35	-0.17
Protein percentage (g/100mL)	-0.12	-0.14	-0.17	-0.19	-0.20	-0.24	-0.16
Daughter fertility	100	100	99	100	101	96	100
Australian Profit Ranking -80 to <-40							
No. lactations	377	1,951	679	413	141	41	3,602
Australian Profit Ranking	-60	-57	-58	-58	-56	-61	-58
Australian Breeding Value:							
Milk volume (l)	-45	58	127	81	390	169	77
Fat yield (kg)	-10	-8	-11	-10	5	-9	-8
Protein yield (kg)	-7	-5	-6	-7	1	-4	-5
Fat percentage (g/100mL)	-0.12	-0.15	-0.24	-0.19	-0.16	-0.23	-0.17
Protein percentage (g/100mL)	-0.10	-0.12	-0.18	-0.17	-0.18	-0.16	-0.13
Daughter fertility	100	99	99	100	95	98	99
Australian Profit Ranking -40 to <0							
No. lactations	580	4,058	1439	442	533	54	7,106
Australian Profit Ranking	-24	-24	-25	-25	-28	-17	-25
Australian Breeding Value:							
Milk volume (l)	232	229	169	128	366	-229	218
Fat yield (kg)	1	-2	-3	-1	-1	-3	-2
Protein yield (kg)	0	-1	-2	-3	2	-5	-1
Fat percentage (g/100mL)	-0.13	-0.17	-0.15	-0.10	-0.25	0.10	-0.16
Protein percentage (g/100mL))	-0.11	-0.14	-0.13	-0.11	-0.14	0.03	-0.13
Daughter fertility	98	98	99	99	96	103	98
Australian Profit Ranking 0 to <40							
No. lactations	989	6,052	1,837	577	962	67	10,484
Australian Profit Ranking	22	22	23	23	20	20	22
Australian Breeding Value:							
Milk volume (l)	110	121	165	104	176	269	133
Fat yield (kg)	3	3	0	6	-3	1	2
Protein yield (kg)	1	2	2	2	2	4	2
Fat percentage (g/100mL)	-0.03	-0.03	-0.11	0.02	-0.15	-0.15	-0.05
Protein percentage (g/100mL)	-0.03	-0.03	-0.05	-0.02	-0.05	-0.07	-0.04
Daughter fertility	101	101	101	100	102	98	101

Table 7.13 (cont.) Mean Australian Profit Rankings and Australian Breeding Values of sires of Holstein cows by feeding system for various Australian Profit Ranking categories

Genetic variable	Feeding system						Pooled (n=77144)
	Low bail (n=8869)	Mod-high bail (n=45215)	PMR (n=13112)	Hybrid (n=4827)	TMR (n=4649)	Not recorded (n=472)	
Australian Profit Ranking 40 to <80							
No. lactations	1,688	8,050	2,540	727	779	91	13,875
Australian Profit Ranking	56	56	57	56	58	58	56
Australian Breeding Value:							
Milk volume (l)	238	289	323	286	230	302	286
Fat yield (kg)	8	6	7	8	-3	0	6
Protein yield (kg)	6	7	7	7	6	8	7
Fat percentage (g/100mL)	-0.04	-0.09	-0.10	-0.06	-0.19	-0.19	-0.09
Protein percentage (g/100mL)	-0.01	-0.02	-0.03	-0.02	-0.01	-0.01	-0.02
Daughter fertility	101	101	101	101	103	101	101
Australian Profit Ranking 80 to <120							
No. lactations	1,750	8,043	2,358	957	791	75	13,974
Australian Profit Ranking	99	100	99	98	101	99	99
Australian Breeding Value:							
Milk volume (l)	247	296	324	356	262	263	297
Fat yield (kg)	9	6	5	6	9	11	7
Protein yield (kg)	11	12	11	12	8	12	11
Fat percentage (g/100mL)	-0.02	-0.09	-0.12	-0.13	-0.04	-0.01	-0.09
Protein percentage (g/100mL)	0.09	0.07	0.04	0.04	0.02	0.09	0.06
Daughter fertility	101	101	101	101	100	101	101
Australian Profit Ranking 120 to <160							
No. lactations	1,490	7,905	1,919	835	309	53	12,511
Australian Profit Ranking	134	134	136	136	133	138	134
Australian Breeding Value:							
Milk volume (l)	459	501	509	541	463	148	497
Fat yield (kg)	18	19	18	21	16	15	19
Protein yield (kg)	16	17	17	17	14	14	17
Fat percentage (g/100mL)	-0.03	-0.03	-0.06	-0.03	-0.06	0.13	-0.04
Protein percentage (g/100mL)	0.07	0.06	0.06	0.05	0.03	0.19	0.06
Daughter fertility	102	101	101	101	102	102	101
Australian Profit Ranking 160 to <200							
No. lactations	1,182	4,985	1,155	445	560	36	8,363
Australian Profit Ranking	178	178	180	178	179	184	178
Australian Breeding Value:							
Milk volume (l)	460	469	549	492	825	527	504
Fat yield (kg)	16	18	17	19	23	16	18
Protein yield (kg)	18	19	21	18	22	18	19
Fat percentage (g/100mL))	-0.05	-0.03	-0.09	-0.03	-0.18	-0.09	-0.05
Protein percentage (g/100mL)	0.11	0.11	0.11	0.09	0.00	0.08	0.10
Daughter fertility	103	103	103	104	102	104	103

Table 7.13 (cont.) Mean Australian Profit Rankings and Australian Breeding Values of sires of Holstein cows by feeding system for various Australian Profit Ranking categories

Genetic variable	Feeding system						Pooled (n=77144)
	Low bail (n=8869)	Mod-high bail (n=45215)	PMR (n=13112)	Hybrid (n=4827)	TMR (n=4649)	Not recorded (n=472)	
Australian Profit Ranking ≥200							
No. lactations	347	1,737	405	126	63	15	2,693
Australian Profit Ranking	225	230	232	250	235	223	231
Australian Breeding Value:							
Milk volume (l)	490	575	602	701	658	452	575
Fat yield (kg)	38	32	32	26	21	29	32
Protein yield (kg)	26	26	26	25	23	26	26
Fat percentage (g/100mL)	0.24	0.11	0.10	-0.04	-0.10	0.14	0.11
Protein percentage ((g/100mL)	0.24	0.20	0.19	0.12	0.11	0.26	0.20
Daughter fertility	99	100	100	100	103	99	100

7.8 AUSTRALIAN PROFIT RANKINGS AND TPI VALUES

Australian Profit Rankings and TPIs (for cows with USA sires) are shown in Figures 7.9, 7.10 and 7.11, and Tables 7.14 and 7.15. TPIs were available for most sires; TPIs were more commonly unavailable for less popular sires. Sire Australian Profit Rankings from cows with Australian sires are also shown for comparison.

Within Australian-sired cows, sire Australian Profit Rankings were highest in low and moderate to high bail feeding herds, and lower in PMR, hybrid amd TMR feeding systems. Relative to Australian-sired cows, sire Australian Profit Rankings were generally lower for USA-sired cows. Of the 11,868 cows with USA sires, only 6% (667) had sires with Australian Profit Rankings of 160 or above compared with 17% (7,251) of the 42,976 cows with Australian sires. Mean sire Australian Profit Rankings were markedly lower for USA-sired cows in all feeding systems and across all herd milk yield categories. Standard deviations were similar across feeding systems and herd milk yield categories. Sire Australian Profit Rankings reliabilities were similar for Australian- and USA-sired cows.

These finding indicate that when USA sires were selected, sires with low Australian Profit Rankings were being selected in preference to Australian sires with higher Australian Profit Rankings. The lower mean sire Australian Profit Rankings in PMR, hybrid and TMR feeding systems were due to both a) selection of lower Australian Profit Rankings Australian sires and b) increased use of USA sires. Only half of the cows had sires with Australian Profit Ranking reliabilities of 97 or 98 or above (Tables 7.14 and 7.15), and **sires with low reliabilities were commonly used (Figure 7.12), but these patterns in Australian Profit Rankings were not due to use of lower reliability sires.**

For USA-sired cows, mean sire TPIs varied between 1421 and 1529. Means were slightly higher for cows in higher feed input herds, but these differences in means were small compared to the variability in TPIs within each feeding system and herd milk yield category. Thus, **for USA sires, selection priority for TPI was similar across systems**.

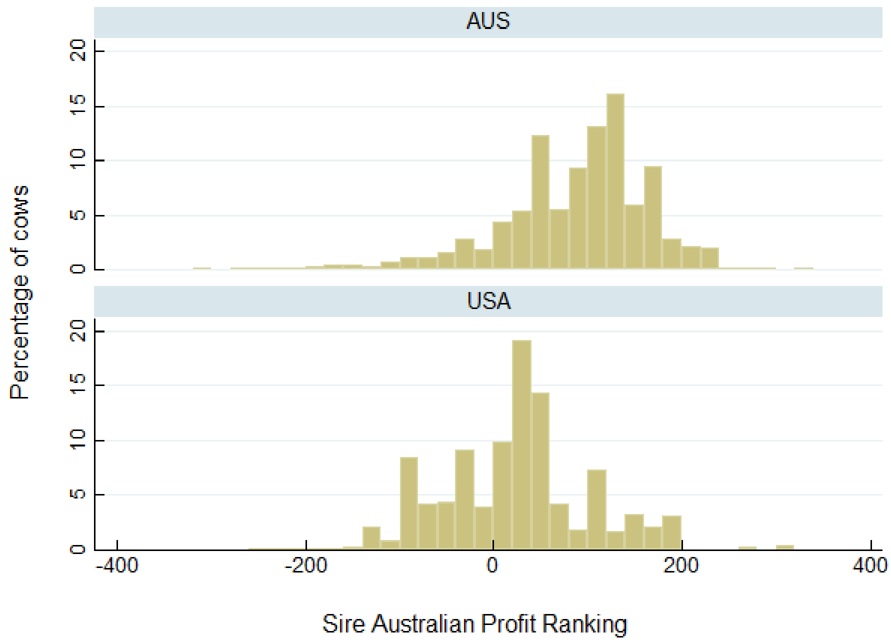


Figure 7.9 Distributions of Australian Profit Rankings of Australian (AUS) and USA sires of Holstein cows

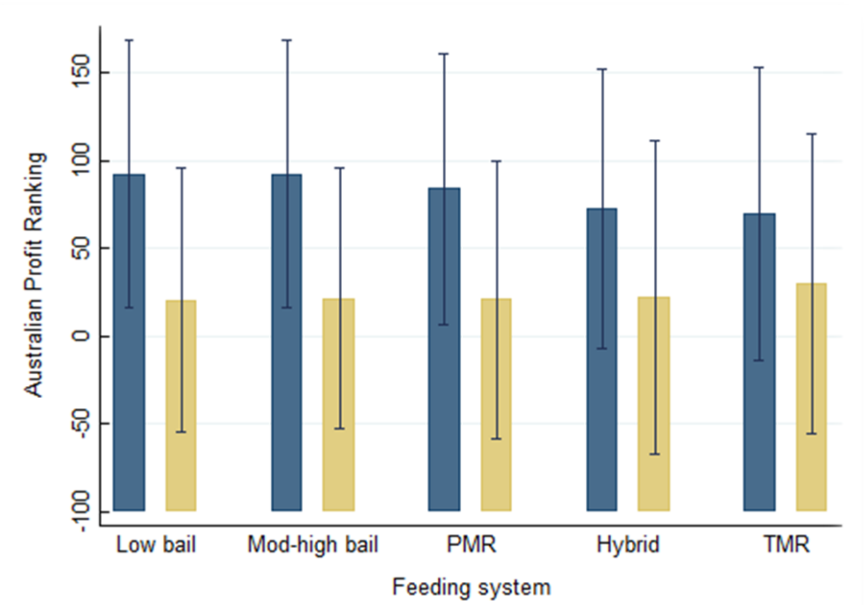


Figure 7.10 Mean (±SD) Australian Profit Rankings of Australian (blue bars) and USA (yellow bars) sires of Holstein cows by feeding system

Table 7.14 Australian Profit Rankings, reliabilities and TPIs for sires of Holstein cows from Australia and USA by feeding system

Herdbook country of sire	Feeding system						Pooled
	Low bail	Mod-high bail	PMR	Hybrid	TMR	Not recorded	
No. cows							
Australia	5,850	25,713	6,617	2,737	1,810	249	42,976
USA							
With Australian Profit Rankings[1]	714	6,152	2,094	680	2,185	43	11,868
With TPIs[2]	621	5,684	1,846	631	2,143	30	10,955
Mean Australian Profit Ranking (SD)							
Australia	92 (77)	92 (76)	84 (78)	72 (80)	70 (84)	59 (87)	89 (77)
USA	20 (75)	21 (74)	21 (79)	22 (89)	30 (85)	-33 (67)	23 (78)
Median Australian Profit Ranking reliability							
Australia	98	98	97	92	84	93	98
USA	98	97	97	97	97	98	97
Mean TPI (SD)							
USA	1,450 (216)	1,484 (219)	1,481 (223)	1,529 (234)	1,521 (235)	1,244 (185)	1,491 (225)

1 Number of cows whose sire's Australian Profit Ranking was available
2 Number of cows whose sire's TPI was available

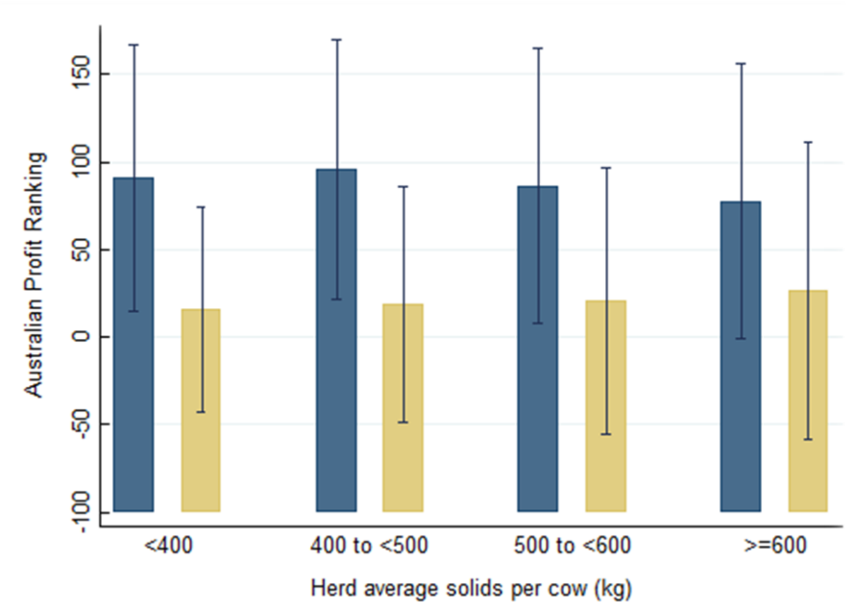


Figure 7.11 Mean (±SD) Australian Profit Rankings of Australian (blue bars) and USA (yellow bars) sires of Holstein cows by herd average solids per cow

Table 7.15 Australian Profit Rankings, reliabilities and TPIs for sires of Holstein cows from Australia and USA by herd average solids per cow

Herdbook country of sire	Herd average solids per cow				Pooled
	<400	400 to <500	500 to <600	≥600	
No. cows					
Australia	2,593	15,561	17,705	7,117	42,976
USA					
With Australian Profit Rankings[1]	231	1,915	5,115	4,607	11,868
With TPIs[2]	207	1,705	4,662	4,381	10,955
Mean Australian Profit Ranking (SD)					
Australia	91 (76)	96 (74)	86 (79)	78 (79)	89 (77)
USA	16 (58)	19 (67)	21 (76)	27 (85)	23 (78)
Median Australian Profit Ranking reliability					
Australia	97	98	98	98	98
USA	98	97	97	97	97
Mean TPI(SD)					
USA	1,421 (174)	1,464 (226)	1,486 (217)	1,509 (232)	1,491 (225)

1 Number of cows whose sire's Australian Profit Ranking was available
2 Number of cows whose sire's TPI was available

Sire TPI was only moderately closely correlated with Australian Profit Ranking (Figure 7.12; r= 0.711; 95% CI: 0.702 to 0.720; P<0.001). **This indicates that rate of increase in Australian Profit Ranking is substantially reduced if sires are selected based on TPI rather than Australian Profit Ranking.**

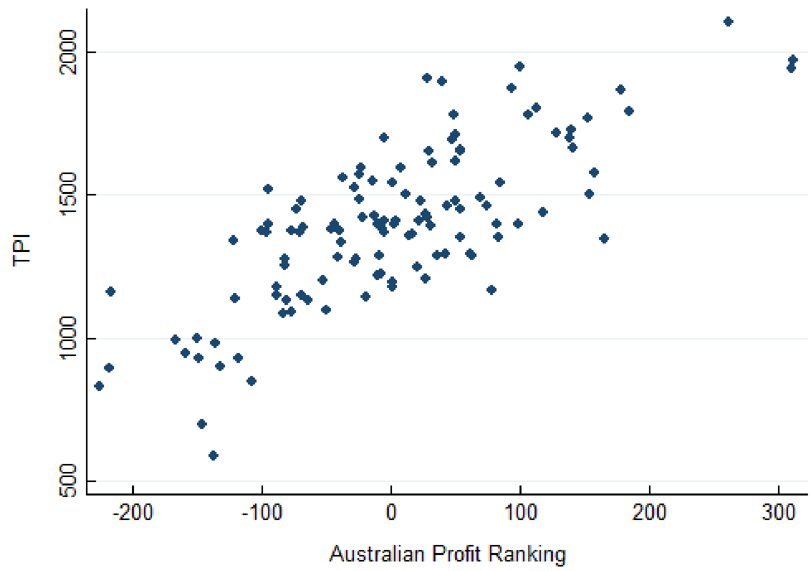


Figure 7.12 Association between sire Australian Profit Ranking and TPI for 10,955 Holstein cows with USA sires

CHAPTER 8: ASSOCIATION BETWEEN SIRE AUSTRALIAN PROFIT RANKING AND SEMEN PRICE

8.1 OBJECTIVE

The following research objective is addressed in this chapter:

- to describe semen prices for low and high Australian Profit Ranking sires

8.2 RESULTS

Results are shown in Figure 8.1 and Table 8.1. **There was no important association between Australian Profit Ranking and recommended retail price for semen.** The average recommended retail price for semen for the top 50 bulls ranked on Australian Profit Ranking was less than that for the next 50 bulls.

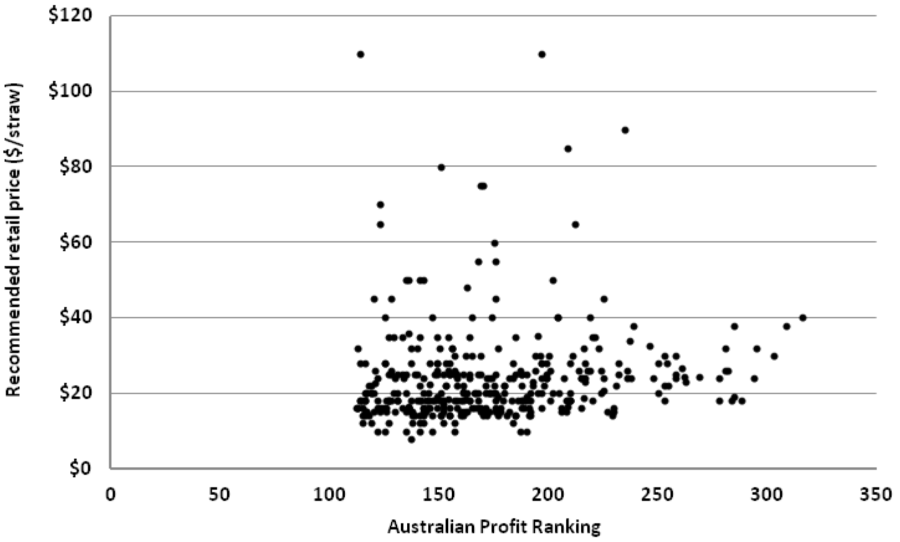


Figure 8.1 Association between Australian Profit Ranking and recommended retail price in April 2013 for bulls in the Profit list in the April 2013 Holstein Good Bulls Guide

Table 8.1 Average (range) of recommended retail prices in April 2013 for bulls in the Profit list in the April 2013 Holstein Good Bulls Guide by rank on Australian Profit Ranking

Rank	Recommended retail prices
1st to 50th	$27.17 ($14-90)
51st to 100th	$28.01($15-110)
101st to 150th	$20.05 ($10-35)
151st to 200th	$26.57 ($14-75)
201st to 250th	$21.76 ($10-80)
251st to 300th	$20.92 ($8-50)
Below 300	$23.58 ($10-110)

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- Nina Philadelphoff-Puren for inputs into collection of herd feeding system data,
- Paul Koh for extraction of data from the ADHIS database,
- and last but certainly not least, the managers of the study herds for supplying data to identify their herds' feeding systems.

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APPENDIX 1. QUESTIONNAIRE

Feeding the Genes Farmer Survey

Dairy Australia's Feed2Milk program has a set of questions to help determine what category your feeding practices fit into. Thank you for participating in this survey, by doing so you agree to allow ADHIS to use your cow records for this study. Your records will remain confidential and will only be used as part of a bulk analysis of herds within the Australian dairy industry.

Grains and concentrates

✷In recent years, how many tonnes of grain, grain mixes or grain-based concentrates did you feed per cow?

	No grain	0.1 to 1.0 tonnes	More than 1 tonne	Can't remember
In the last 12 months 2011/12	❍	❍	❍	❍
2010/2011	❍	❍	❍	❍
2009/2010	❍	❍	❍	❍
2008/2009	❍	❍	❍	❍

Feed pads and mixer wagons

✷In recent years, did you use a feed pad and/or a mixer wagon to feed conserved fodder, grains, grain-based concentrates and / or other supplements?

	Neither	Only a feed pad	Only a mixer wagon	Yes, I used BOTH	Can't remember
In the last 12 months 2011/12	❍	❍	❍	❍	❍
2010/2011	❍	❍	❍	❍	❍
2009/2010	❍	❍	❍	❍	❍
2008/2009	❍	❍	❍	❍	❍

Feed pad: a semi-permanent or permanent feed-out area with a compacted or cement surface.
Mixer wagon: a wagon used to mix and feed a partial mixed ration (PMR) or total mixed ration (TMR)

Access to pasture

✷ In recent years, have there been any times when your milking cows did NOT graze pasture but were fed entirely on conserved fodder, grains, grain-based concentrates or other supplements?

	Grazed pasture all year	Did NOT graze pasture for 0-3 months	Did NOT graze pasture for 4-10 months	Did NOT graze pasture for 11-12 months	Can't remember
In the last 12 months 2011/12	❍	❍	❍	❍	❍
2010/2011	❍	❍	❍	❍	❍
2009/2010	❍	❍	❍	❍	❍
2008/2009	❍	❍	❍	❍	❍

Differential bail feeding

✷ In recent years, have you ever offered different daily feeding rates or blends of grain, grain mixes or concentrates to different cows in the milking herd?

	No	Yes	Can't remember
In the last 12 months 2011/12	❍	❍	❍
2010/2011	❍	❍	❍
2009/2010	❍	❍	❍
2008/2009	❍	❍	❍

✷ If yes, which of the following did you use to decide which ration to feed each milking cow and the daily feeding rate used? (Please tick one or more options):

❍ Stage of lactation (number of days in milk)
❍ Current milk yield
❍ Body condition score
❍ Body weight
❍ Breed
❍ Stage of pregnancy
❍ Age/parity
❍ Other (please specify):____

Sales of breeding cows

✷Did you sell any cows that calved in 2011 as breeding cows (ie cows to be milked in other herds) rather than as cull cows?

❍ No
❍ Don't know
❍ Yes ➔ approximately how many ___________?

Thank you for participating.

Any other comments?

....

....

APPENDIX 2. EFFECTS ON ODDS OF RECALVING BY 20 MONTHS: FIRST ELIGIBLE LACTATIONS ONLY

A2.1 SUMMARY

Effects on odds of recalving by 20 months were assessed using all eligible lactations for each cow. These results are reported above.

In general, cows that have not recalved by 20 months are at markedly increased risk of being culled. Accordingly, by including all eligible lactations for each cow, these analyses may be unduly influenced by cows that tend to remain in the herd and recalve within 20 months. So effects on odds of recalving by 20 months were also assessed using only the first eligible lactation for each cow in the study database. Results of these analyses are shown below.

For both Holstein and Jersey cows, results from these analyses were similar to those where all eligible lactations for each cow were used.

A2.2 EFFECTS OF AUSTRALIAN PROFIT RANKING IN HOLSTEINS

Estimated effects of Australian Profit Ranking on odds of recalving by 20 months are shown in Table A2.1. P-values for differences in estimated effects by feeding system relative to the moderate to high bail feeding system are shown in Table A2.2.

Table A2.1 Estimated effects*of cow's sire's Australian Profit Ranking on odds of recalving by 20 months for lactations from Holstein cows by feeding system (95% CI)

Breeding value	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
Cow's sire's Australian Profit Ranking					
Not adjusted**	1.010 (0.987 to 1.034)	1.036 (1.024 to 1.048)	1.028 (1.006 to 1.049)	1.039 (1.008 to 1.070)	1.077 (1.040 to 1.114)
Adjusted**	1.019 (0.993 to 1.046)	1.039 (1.026 to 1.052)	1.040 (1.016 to 1.065)	1.051 (1.017 to 1.085)	0.989 (0.935 to 1.046)
Cow's Australian Profit Ranking	1.011 (0.971 to 1.053)	1.064 (1.043 to 1.087)	1.048 (1.009 to 1.087)	1.065 (1.010 to 1.123)	1.150 (1.077 to 1.229)

*Coefficients represent odds ratios for recalving by 20 month for each extra 50 units in Australian Profit Ranking; coefficients were adjusted for age at calving; herd was fitted as a random effect

**Not adjusted or adjusted for maternal grandsire's Australian Profit Ranking

Table A2.2 P-values for differences in estimated effects of Australian Profit Ranking on odds of recalving by 20 months for lactations from Holstein cows by feeding system, relative to the moderate to high bail feeding system

Breeding value	Feeding system					P for interaction
	Low bail	Mod-high bail	PMR	Hybrid	TMR	
Cow's sire's Australian Profit Ranking						
Not adjusted*	0.048	Reference group	0.488	0.894	0.037	0.041
Adjusted*	0.182	Reference group	0.947	0.535	0.090	0.258
Cow's Australian Profit Ranking	0.022	Reference group	0.450	0.989	0.028	0.018

*Not adjusted or adjusted for maternal grandsire's Australian Profit Ranking

A2.3 EFFECTS OF AUSTRALIAN BREEDING VALUES IN HOLSTEINS

Estimated effects of Australian Breeding Values on odds of recalving by 20 months are shown in Table A2.3.

P-values for differences in estimated effects by feeding system relative to the moderate to high bail feeding system are shown in Table A2.4. The overall p-values for interactions between Australian Breeding Values and feeding system were high for daughter fertility Australian Breeding Value but low for cow's Australian Breeding Value for survival.

Table A2.3 Estimated effects*of Australian Breeding Values on odds of recalving by 20 months for lactations from Holstein cows by feeding system (95% CI)

Breeding value	Feeding system				
	Low bail	Mod-high bail	PMR	Hybrid	TMR
Cow's sire's Australian Breeding Value for daughter fertility**	1.04 (1.03 to 1.05)	1.03 (1.03 to 1.04)	1.03 (1.02 to 1.04)	1.03 (1.02 to 1.04)	1.04 (1.02 to 1.06)
Cow's Australian Breeding Value for daughter fertility	1.08 (1.07 to 1.10)	1.07 (1.06 to 1.08)	1.06 (1.04 to 1.07)	1.06 (1.04 to 1.08)	1.08 (1.06 to 1.10)
Cow's sire's Australian Breeding Value for survival**	1.03 (1.02 to 1.04)	1.04 (1.04 to 1.05)	1.04 (1.03 to 1.06)	1.06 (1.04 to 1.08)	1.05 (1.02 to 1.09)
Cow's Australian Breeding Value for survival	1.05 (1.03 to 1.07)	1.08 (1.07 to 1.10)	1.06 (1.04 to 1.08)	1.10 (1.07 to 1.13)	1.15 (1.11 to 1.19)

*Coefficients represent odds ratios for recalving by 20 month for each extra unit in Australian Breeding Value; coefficients were adjusted for age at calving; herd was fitted as a random effect
**Coefficients were adjusted for maternal grandsire's Australian Breeding Value

Table A2.4 P-values for differences in estimated effects of Australian Breeding Values on odds of recalving by 20 months for lactations from Holstein cows by feeding system, relative to the moderate to high bail feeding system

Breeding value	Feeding system					P for interaction
	Low bail	Mod-high bail	PMR	Hybrid	TMR	
Cow's sire's Australian Breeding Value for daughter fertility*	0.256	Reference group	0.588	0.655	0.885	0.700
Cow's Australian Breeding Value for daughter fertility	0.215	Reference group	0.129	0.331	0.623	0.193
Cow's sire's Australian Breeding Value for survival*	0.070	Reference group	0.885	0.176	0.756	0.187
Cow's Australian Breeding Value for survival	0.005	Reference group	0.103	0.273	0.002	<0.001

*Coefficients were adjusted for maternal grandsire's Australian Breeding Value

A2.4 EFFECTS OF AUSTRALIAN PROFIT RANKING IN JERSEYS

Estimated effects of Australian Profit Ranking on odds of recalving by 20 months are shown in Table A2.5. P-values for differences in estimated effects by feeding system relative to the moderate to high bail feeding system are shown in Table A2.6. Overall p-values for interaction between Australian Profit Ranking and feeding system were high.

Table A2.5 Estimated effects*of cow's sire's Australian Profit Ranking on odds of recalving by 20 months for lactations from Jersey cows by feeding system (95% CI)

Breeding value	Feeding system			
	Low bail	Mod-high bail	PMR	Hybrid
Cow's sire's Australian Profit Ranking				
Not adjusted**	1.028 (0.991 to 1.067)	1.033 (1.012 to 1.054)	1.044 (0.987 to 1.105)	1.034 (0.907 to 1.178)
Adjusted**	1.042 (0.999 to 1.087)	1.041 (1.019 to 1.064)	1.049 (0.987 to 1.116)	1.034 (0.900 to 1.187)
Cow's Australian Profit Ranking	1.050 (0.985 to 1.119)	1.043 (1.006 to 1.081)	1.040 (0.942 to 1.147)	1.056 (0.835 to 1.337)

*Coefficients represent odds ratios for recalving by 20 month for each extra 50 units in Australian Profit Ranking; coefficients were adjusted for age at calving; herd was fitted as a random effect

**Not adjusted or adjusted for maternal grandsire's Australian Profit Ranking

Table A2.6 P-values for differences in estimated effects of Australian Profit Ranking on odds of recalving by 20 months for lactations from Jersey cows by feeding system, relative to the moderate to high bail feeding system

Breeding value	Feeding system				P for interaction
	Low bail	Mod-high bail	PMR	Hybrid	
Cow's sire's Australian Profit Ranking					
Not adjusted*	0.827	Reference group	0.712	0.992	0.975
Adjusted*	0.954	Reference group	0.813	0.921	0.995
Cow's Australian Profit Ranking	0.848	Reference group	0.959	0.915	0.997

*Not adjusted or adjusted for maternal grandsire's Australian Profit Ranking

A2.5 EFFECTS OF AUSTRALIAN BREEDING VALUES IN JERSEYS

Estimated effects of Australian Breeding Values on odds of recalving by 20 months are shown in Table A2.7. P-values for differences in estimated effects by feeding system relative to the moderate to high bail feeding system are shown in Table A2.8. The overall p-values for interactions between Australian Breeding Values and feeding system were high.

Table A2.7 Estimated effects*of Australian Breeding Values on odds of recalving by 20 months for lactations from Jersey cows by feeding system (95% CI)

Breeding value	Feeding system			
	Low bail	Mod-high bail	PMR	Hybrid
Cow's sire's Australian Breeding Value for daughter fertility**	1.06 (1.02 to 1.09)	1.04 (1.02 to 1.05)	1.01 (0.97 to 1.05)	1.07 (0.99 to 1.15)
Cow's Australian Breeding Value for daughter fertility	1.11 (1.04 to 1.17)	1.07 (1.04 to 1.09)	1.03 (0.97 to 1.10)	1.14 (1.00 to 1.30)
Cow's sire's Australian Breeding Value for survival**	1.01 (0.99 to 1.04)	1.03 (1.02 to 1.04)	1.03 (0.99 to 1.07)	1.07 (0.99 to 1.16)
Cow's Australian Breeding Value for survival	1.02 (0.99 to 1.06)	1.05 (1.03 to 1.07)	1.00 (0.95 to 1.07)	1.14 (0.99 to 1.32)

*Coefficients represent odds ratios for recalving by 20 month for each extra unit in Australian Breeding Value; coefficients were adjusted for age at calving; herd was fitted as a random effect
**Coefficients were adjusted for maternal grandsire's Australian Breeding Value

Table A2.8 P-values for differences in estimated effects of Australian Breeding Values on odds of recalving by 20 months for lactations from Jersey cows by feeding system, relative to the moderate to high bail feeding system

Breeding value	Feeding system				P for interaction
	Low bail	Mod-high bail	PMR	Hybrid	
Cow's sire's Australian Breeding Value for daughter fertility*	0.295	Reference group	0.184	0.412	0.264
Cow's Australian Breeding Value for daughter fertility	0.274	Reference group	0.331	0.347	0.341
Cow's sire's Australian Breeding Value for survival*	0.196	Reference group	0.828	0.391	0.464
Cow's Australian Breeding Value for survival	0.214	Reference group	0.202	0.237	0.212

*Coefficients were adjusted for maternal grandsire's Australian Breeding Value

LITERATURE REVIEW

SUMMARY

OBJECTIVES AND IDENTIFICATION OF STUDIES

The objectives of this review were:

- to define genotype by environment interaction, and to briefly discuss the importance of this interaction, and
- to summarise key design features and results from studies that compare the effects of genetic merit in dairy cows on milk yield, reproductive performance and/or survival between environments with high versus lower energy intake within the same study.

Concepts of interaction were defined, effects of genotype by environment interactions on sire selection for dairy herds described, and methods for identifying genotype by environment interaction detailed. Strategies for addressing genotype by environment interaction in dairy populations are briefly discussed.

Relevant studies that compare the effects of genetic merit in dairy cows on milk yield, reproductive performance and/or survival between environments were identified by searching bibliographic databases, by reviewing lists of references in selected papers and from papers nominated by members of the Feeding the Genes Project Reference Group.

KEY FINDINGS

GENERAL

Genotype by environment interactions in dairy cows have been estimated using both cohort studies in controlled environments (in research herds) and large scale cohort studies in commercial herds. Details of the most relevant studies of each type were presented and effects of genetic merit in different environments summarised.

COHORT STUDIES IN CONTROLLED ENVIRONMENTS

Five cohort studies using controlled environments to assess interactions on milk production were identified. In the two earliest studies, none of the interactions between genetic merit group and feeding system were significantly different from zero other than fat%, which declined more with genetic merit on the high energy density ration. In a later study, significant interactions were detected for solids-corrected milk yield, fat yield and fat%. However the interactions were complex as effects of genetic merit on milk and fat yield were smallest in the medium concentrate intake group, with larger effects in the low concentrate intake group. In the two most recent studies, genetic merit had larger effects on energy-corrected milk when cows were fed a high caloric density ration, and on protein yield when cows were fed larger amounts of concentrates. These findings suggest that genetic merit by energy intake interactions are occurring, with effects of genetic merit larger when cows have higher energy intakes.

Four studies using controlled environments to assess interactions on reproductive traits were identified. A wide variety of measures of reproductive performance were reported. Significant genetic merit by energy intake interactions were reported in only one of these studies (Fulkerson *et al* 2001); reductions in pregnancy rates by 24 days and 6 weeks after mating start date with genetic merit were smaller amongst cows fed more concentrates. Unfortunately, in this study, the statistical methods did not account for clustering of lactation within cow so p-values may be too low. In addition, genetic merit was confounded by % Holstein genes. However, these findings suggest that adverse effects of genetic merit and/or % Holstein genes on reproductive performance are partly ameliorated by increased energy intake.

LARGE SCALE COHORT STUDIES IN COMMERCIAL HERDS

Environment was defined in many ways in large scale cohort studies in commercial herds. Numerous studies met the selection criteria, with environments based on feeding system (6 studies) or mean milk production (15 studies). Some examples of studies that used other definitions of environment are listed in Literature Review Appendix 2**. These results indicate that in studies assessing genotype by environment interactions in dairy cow populations, environments are rarely based on feeding system. Herd mean milk production variables are used much more commonly but better estimates of genotype by environment interactions would be obtained if environments are based on feeding management. There is evidence that nutritional factors are important causes of genotype by environment interaction in dairy cow populations.**

For comparisons between pasture-fed and housed cows, genetic correlations for milk producton traits varied from 0.62 to 0.94. Regression slopes for milk production on sire predicted transmitting abilities werere higher in housed cows. Genetic correlations for days open and calving interval were inconsistent.

For comparisons where the environment was based on herd milk production, genetic correlations for milk producton traits varied from 0.64 to 1.00. Highest estimates were from non-pasture-fed herds; most estimates were above 0.92. Estimates were generally lower (mostly 0.64 to 0.93) when various environments were compared across pasture-fed herds.

Correlations were lowest when environment were more different.

Genetic correlations for reproduction traits were reported in four of the selected studies. Estimates for calving interval varied widely, from 0.58 to 0.92, and for calving to first service, from 0.47 to 0.84.

These results indicate that genotype by environment interaction for milk production is generally low to modest, but important reranking may be occurring in some circumstances. Genotype by environment interaction may be most important between feeding systems, and across pasture-fed herds with different feed intakes.

Evidence about genotype by environment interactions for reproductive traits is limited, but these results suggest that important reranking may be occurring in some circumstances. This should be investigated in various Australian environments in future. Genetic correlations for reproductive intervals may have been reduced due to incomplete data (eg from periods when bulls run with herds) errors in ascribing conception dates (commonly due to lack of early rectal pregnancy test data, selection bias due to exclusion of animals not experiencing the interval endpoint, and failure to account for right censoring in statistical models. Intervals from calving are very poor phenotypic descriptors of reproductive

performance in seasonal and split calving herds. The impact of using these intervals in seasonal and split calving herds requires investigation.

Environment has also been defined based solely on country of location of the cows and herds. Some examples of such studies are listed in Literature Review Appendix 3. **In addition, Interbull (the International Bull Evaluation Service) routinely assesses genetic correlations between participating countries for numerous traits. For Holstein cows, in 2014, genetic correlations for protein yield between Australian and North American sires were 0.75, between Australian and and European sires 0.75 to 0.79, between Australian and New Zealand sires 0.85, and between various European countries, USA and Canada 0.85 to 0.92. These results are further evidence that interactions between genotype by environment (country in this case) are greatest when environments are more different. Interbull also assesses genetic correlations between participating countries for numerous reproductive traits. Genetic correlations between Australian sires and those from other countries vary widely, from 0.26 to 0.88, with most between 0.65 and 0.80. For calving interval, the genetic correlation between Australian and USA sires was 0.85. Reproductive traits were not assessed in the same way in all countries; reduced genetic correlations would be expected where measurement methods are markedly different.**

OBJECTIVES AND IDENTIFICATION OF STUDIES

The objectives of this review were:

- to define genotype by environment interaction, and to briefly discuss the importance of this interaction, and
- to summarise key design features and results from studies that compare the effects of genetic merit in dairy cows on milk yield, reproductive performance and/or survival between environments with high versus lower energy intake within the same study.

Concepts of interaction were defined, effects of genotype by environment interactions on sire selection for dairy herds described, and methods for identifying genotype by environment interaction detailed. Strategies for addressing genotype by environment interaction in dairy populations are briefly discussed.

Relevant studies that compare the effects of genetic merit in dairy cows on milk yield, reproductive performance and/or survival between environments were identified by searching bibliographic databases, by reviewing lists of references in selected papers and from papers nominated by members of the Feeding the Genes Project Reference Group.

Genotype by environment interactions in dairy cows have been estimated using both cohort studies in controlled environments (in research herds) and large scale cohort studies in commercial herds. Details of the most relevant studies of each type were presented and effects of genetic merit in different environments summarised.

Comparisons of breeds or strains were not included. Comparisons between cross-bred and pure-bred cows were also not reviewed. Some examples of such studies are listed in Literature Review Appendix 1.

GENOTYPE BY ENVIRONMENT INTERACTIONS: DEFINITION AND IMPORTANCE

CONCEPTS OF INTERACTION

Biological interaction occurs when two or more variables in combination produce an effect that is greater or less than that expected due to the separate effects of each variable (Thrusfield 2005). Synergism occurs when the joint effect is greater than that expected; antagonism occurs when the joint effect is less than that expected.

Biological interaction may be reflected in quantitive analyses of data as statistical interaction. Statistical interaction occurs when the effects of two or more variables in combination differs from the sum of the individual effects on that scale (Dohoo *et al* 2009).

Genotype by environment interaction occurs when the same genotypes result in different phenotypes in different environments (Hammami *et al* 2009a). Thus, genotype by environment interaction is also called 'environmental sensitivity' (eg Calus and Veerkamp 2003; Bryant *et al* 2007a). Examples of genotype by environment interaction are shown in Figure 1. In example 1a, with low concentrate feeding, high genetic merit cows produced approximately 30 kg more milk solids than low genetic merit cows. In contrast, with high concentrate feeding, the difference was approximately 65 kg of milk solids. These differences equate to 10% and 17% increases with low and high concentrate feeding, respectively. It is possible to observe genotype by environment interaction based on differences in absolute effects between environments but where proportional effects are similar in both environments.

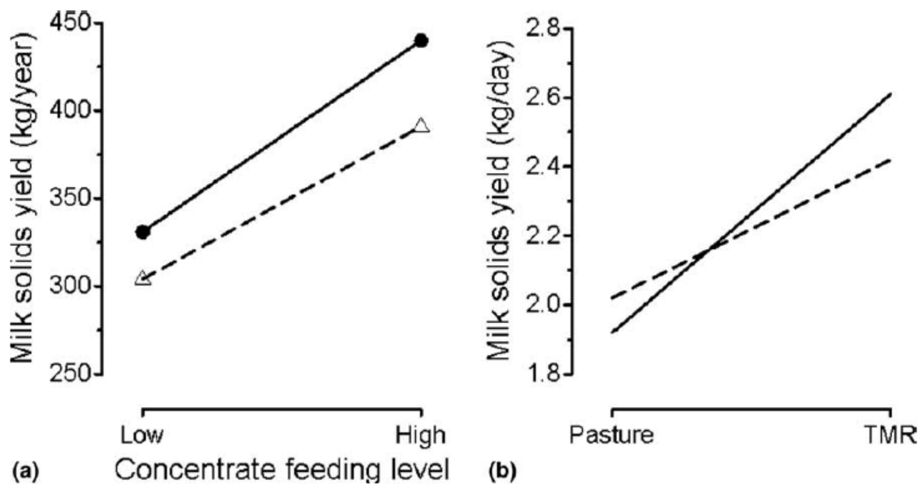


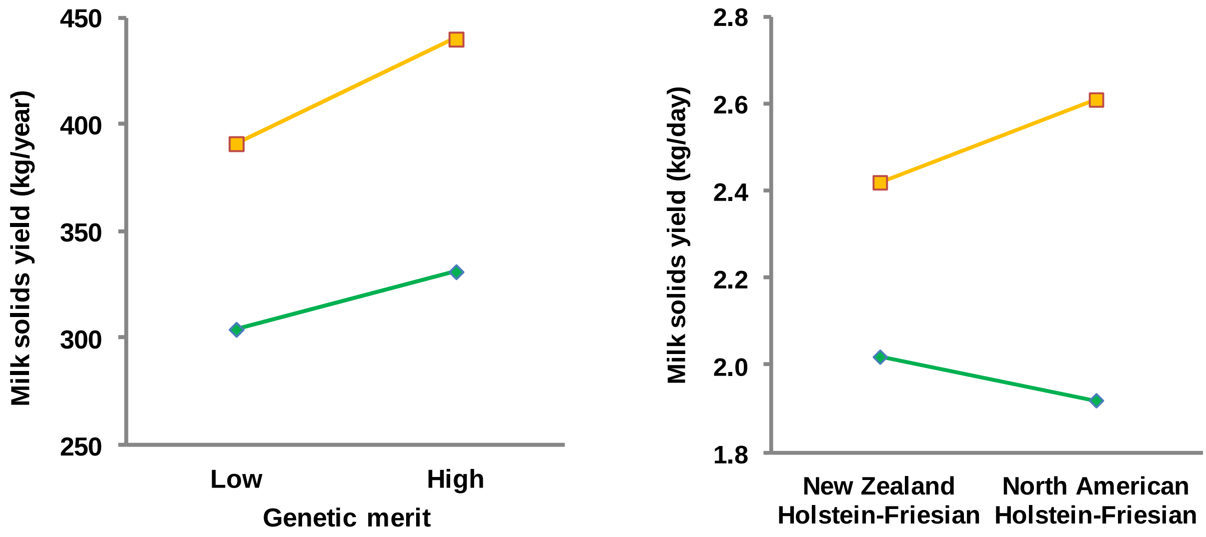
Fig. 1. Genotype × environment interactions. (a) Scaling effect for milk solids yield (kg/year) in high genetic merit (●–●) and low genetic merit (△–△) dairy cattle in systems with a low or high concentrate feeding level (Fulkerson et al., 2000). (b) Re-ranking for milk solids yield (kg/day) in New Zealand Holstein Friesian (– –) and North American Holstein Friesian (—) dairy cattle in a pasture-based or total mixed ration (TMR) system in early lactation (Kolver et al., 2002).

Figure 1 Examples of genotype by environment interactions, reproduced from Bryant *et al* 2005.

Genotype by environment interactions can cause reranking of genotypes in different environments. In example 1a in Figure 1, although genotype by environment interactions is present, the high genetic merit cows produced more than low merit cows in both environments. Thus, no reranking occurred. Genotype by environment interactions that do not cause reranking have been referred to as 'scaling effects' (Hammami *et al* 2009a). In contrast, in example 1b in Figure 1, New Zealand Holsteins had higher milk solids yields than

North American Holsteins in the pasture feeding system but lower milk solids yields in the total mixed ration system, so reranking of these genotypes occurred.

These same results can be depicted as comparisons of genetic merit or strain within feeding system (Figure 2). Differing slopes indicate genotype by environment interaction is occurring; a positive slope in one feeding system and negative slope in another corresponds to reranking of the genotypes between feeding systems.



a) b)

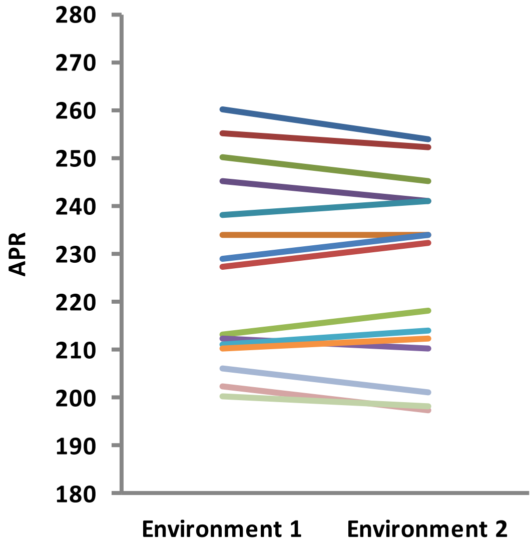
Figure 2 Examples of genotype by environment interactions, based on Bryant *et al* 2005 but instead depicted as comparisons of genetic merit or strain within feeding system (as distinct from comparisons of feeding system within genetic merit or strain). Green = low concentrate input (a) or pasture system (b); Gold = high concentrate input (a) or total mixed ration system (b).

Importantly the magnitude of genotype by environment interaction is specific to the genotypes and environments in which they are assessed. Greater interaction would generally be expected when assessed over wider ranges of genotypes and/or environments. Further, individual sires can rerank even though genetic merit groups or strains may not rerank between the same environments. The distinction between reranking and scaling is arbitrary in relation to sires, as, with moderate to large numbers of sires, some degree of reranking of sires would always be expected even across similar environments due to both weak genotype by environment interaction and sampling variability.

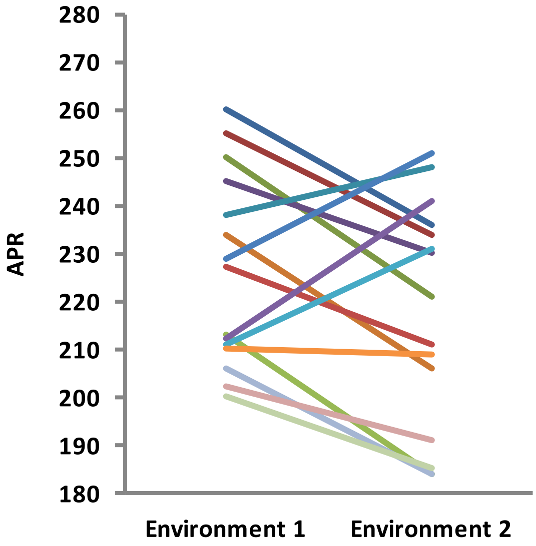
EFFECTS OF GENOTYPE BY ENVIRONMENT INTERACTIONS ON SIRE SELECTION FOR DAIRY HERDS

RERANKING

Genotype by environment interactions can be defined at breed or individual animal levels; gene by environment interactions can also be assessed in some circumstances (Lin and Togashi 2002). Effects of interactions on sire selection for dairy herds have been studied extensively. Reranking of individual sires is of greater practical importance than interaction without reranking. Without reranking, the same sires are best in all environments in which they were assessed. With substantial reranking, sire selection is more complex as the best sires differ depending on the environment in which they are used. Hypothetical examples of minor and substantial genotype by environment interactions are shown in Figure 3.



a)



b)

Figure 3 Hypothetical examples of minor (a) and substantial (b) genotype by environment interactions for Australian Profit Rankings for 15 sires between two environments; Spearman's correlation coefficients for thes examples are 0.98 and 0.57, respectively.

SCALING EFFECTS

Even in the absence of reranking of sires, genotype by environment interaction that is not accounted for can distort genetic investment decisions of herd managers. Scaling effects can mean that the economic effects of increases in genetic merit differ between herds in different environments. In the absence of accurate information about likely marginal effects of increases in genetic merit in their herd, some herd managers may underinvest in improving genetic merit as they underestimate the expected response in their herd, and others may overinvest as they overestimate the expected response in their herd. This lack of information may distort attempts by herd managers to maximise profitability through optimising marginal expenditures throughout their farm (Dijkhuizen and Morris 1997).

IDENTIFYING GENOTYPE BY ENVIRONMENT INTERACTION

The extent of genotype by environment is commonly assessed using genetic correlations between the same attribute measured in different environments (Falconer 1952; Lin and Togashi 2002). A correlation coefficient of 1 would indicate no genotype by environment interaction; lower correlation coefficients would occurr when there is greater genotype by environment interaction.

Genotype by environment is also assessed from correlations between breeding values of the same sires in different environments. Both rank- and product-moment correlation coefficients have been used. High correlation coefficients (ie very close to 1) indicate minimal reranking of sires overall.

Genotype interaction with herd-year-season has been estimated as the proportion of the phenotypic variance due to the sire*herd-year-season effect (Ramirez-Valverde *et al* 2010). Genetic variances of sires have also been used (for example, Calus and Veerkamp 2003), as differences in variances of sires' breeding values between environments may lead to scaling effects, especially between low and high production environments (Hammami *et al* 2009a). Falconer (1990) proposed using the difference between phenotypic values of a genotype or a population in two environments, divided by the difference between the means of all individuals in both environments. Namkoong (1985) noted that genotype by environment interaction can be present for a composite index despite no such interaction for the individual traits. Other measures of genotype by environment interaction have been proposed (Dickerson 1962; Yamada 1962).

ADDRESSING GENOTYPE BY ENVIRONMENT INTERACTION IN DAIRY POPULATIONS

If genotype by environment interaction is addressed by assessing sires in a range of environments, the costs and effects on the rate of genetic progress in all environments must be considered. An early suggestion was that genotype by environment interaction is not important unless the correlation coefficient for the genetic correlation is less than 0.8 (Robertson 1959). Even though no basis for this was presented, this value is often cited (eg Cromie *et al* 1998; Boettcher *et al* 2003; Bryant *et al* 2007a; Gernand *et al* 2007; Hammami *et al* 2009b; Ramirez-Valverde *et al* 2010).

Simulation modelling should allow exploration of the impact of various genotype by environment interaction on herd milk production and profitability. When both environments are of equal importance, Mulder *et al* (2006) suggested separate breeding schemes only when the genetic correlation is less than 0.6. However genotype by environment interactions are often considered important even where genetic correlations are much higher than 0.6.

The importance to herd managers of genotype by environment interaction in their particular herd will depend on:

- the extent of reranking over the range of genetic values used by herd managers when selecting sires,
- the differences in genetic merit of the sires in this range,
- the economic values of such differences to herd managers, and
- the differences in costs of semen from different sires in this range.

At a national level, the following must also be considered:

- the relative sizes of the different environments (and expected future sizes), and
- the increased costs of generating separate breeding values for various environments and/or the decreased rate of genetic gain.

Specific strategies have been identified to minimise the reduction in rate of genetic gain when genotype by environment interaction is present (Mulder and Bijma 2005). Genotype by country interactions may be addressed through reaction norms of sires estimated using random regression models with common measures of herd environment (Kolmodin *et al* 2002). Accuracy of sire estimates could be assessed using herds with, for example, similar milk production levels regardless of country (Hayes *et al* 2003).

COHORT STUDIES IN CONTROLLED ENVIRONMENTS

STUDY SELECTION CRITERIA

Cohort studies in controlled environments were selected if they met all of the following criteria:

- dairy cows selected because they had different genetic merit were used,
- high and lower energy intakes were achieved within the same study,
- cows of each genetic merit category were allocated to each energy intake,
- milk yield and/or reproductive performance were compared, and
- genetic merit by energy intake interactions were assessed.

RESULTS AND DISCUSSION

MILK PRODUCTION

Key methods and results relating to genetic merit by energy intake interactions on milk production are summarised in Table 1. Five studies were identified. In two of these studies (Buckley *et al* 2000; Fulkerson *et al* 2008), genetic merit was confounded by % Holstein genes.

In the two earliest studies (Veerkamp *et al* 1994; Buckley *et al* 2000), none of the interactions between genetic merit group and feeding system were significantly different from zero other than fat%, which declined more with genetic merit on the high energy density ration in Veerkamp *et al*'s study (Veerkamp *et al* 1994). In a later study (Kennedy *et al* 2003), significant interactions were detected for solids-corrected milk yield, fat yield and fat%. However the interactions were complex as effects of genetic merit on milk and fat yield were smallest in the medium concentrate intake group, with larger effects in the low concentrate intake group.

In the two most recent studies, genetic merit had larger effects on energy-corrected milk when cows were fed a high caloric density ration (Beerda *et al* 2007), and on protein yield when cows were fed larger amounts of concentrates (Fulkerson *et al* 2008).

These findings suggest that genetic merit by energy intake interactions are occurring, with effects of genetic merit larger when cows have higher energy intakes.

Table 1 Summary of cohort studies assessing interactions between genetic merit and feeding system on milk production in dairy cows in controlled environments

Definitions of genetic merit groups	Feeding system	No. of lactations*	Effects of increased genetic merit by feeding system**	Comments
Veerkamp *et al* (1994)				
Sires were average of UK fat plus protein PTA (low merit) and highest fat plus protein PTA bulls available (high merit)	Low density: Concentrates, brewers grains and silage of 20 :5 : 75 (low density) 1.0 t of concentrate per cow per annum High density: Concentrates, brewers grains and silage of 45 : 5 : 50 2.5 t of concentrate per cow per annum Both diets were fed *ad libitum*	Approx. 94	Fat + protein (kg/cow/lactation): Cows: + 57 kg (low density) +61 kg (high density) Heifers: + 46 kg (low density) +53 kg (high density) Fat % declined more with merit on high density ration Protein% increased with merit generally similarly on both rations None of the interactions between genetic merit group and feeding system were significantly different from zero.	Genetic merit groups were balanced for average % Holstein
Buckley *et al* (2000)				
Selected from the Moorepark herd (medium merit) or selected based on their superior pedigree index for milk production (high merit)	A: High stocking rate, high nitrogen fertilization rate and planned concentrate intake of 500 kg/cow/lactation Received 0.86 t, 0.65 t, and 0.34 t in years 1-3, respectively. As for A but planned to feed twice the level of concentrate input Received 1.45 t, 1.11 t, and 0.87 t in years 1-3, respectively. As for A but cows grazed to a higher postgrazing sward surface Received 0.86 t, 0.65 t, and 0.34 t in years 1-3, respectively.	Approx. 44	Only main effects (ie pooled effects across all three feeding systems) are reported. None of the interactions between genetic merit group and feeding system were significantly different from zero.	Genetic merit groups differed by % Holstein (higher in high merit group)

* per genetic merit-feeding group combination
** point estimates are shown only if these were reported for each genetic merit-feeding group combination

Table 1 (cont) Summary of cohort studies assessing interactions between genetic merit and feedin g system on milk production in dairy cows in controlled environments

Definitions of genetic merit groups	Feeding system	No. of lactations*	Effects of increased genetic merit by feeding system**	Comments
Kennedy *et al* (2003)				
Medium merit cows were selected on their lesser pedigree index for milk production. High merit cows were selected based on their superior pedigree index for milk production.	Pastue plus: 0 kg concentrate/cow/day (low concentrates) 3 kg concentrate/cow/day (early lactation); 0 kg (late lactation)(medium concentrates) 6 kg concentrate/cow/day (early lactation); 4 kg (late lactation)(high concentrates)	Approx. 46	Early lactation: (late lactation results were broadly similar) Milk yield (kg/cow/day): +4.5 kg (low concentrates) +3.7 kg (medium concentrates) +5.0 kg (high concentrates) Solids-corrected milk yield (kg/cow/day): +3.1 kg (low concentrates) +2.0 kg (medium concentrates) +3.8 kg (high concentrates) Fat yield (kg/cow/day): +0.11 kg (low concentrates) +0.05 kg (medium concentrates) +0.16 kg (high concentrates) Protein yield (kg/cow/day): +0.13 kg (low concentrates) +0.11 kg (medium concentrates) +0.15 kg (high concentrates) Fat%: -0.22% (low concentrates) -0.34% (medium concentrates) -0.03% (high concentrates) Protein %: -0.09% (low concentrates) -0.07% (medium concentrates) -0.08% (high concentrates) For solids-corrected milk yield, fat yield and fat%, interactions were significantly different from zero.	Genetic merit groups differed slightly by % Holstein (65% and 75% in medium and high merit groups, respectively)
Beerda *et al* (2007)				
Low and high selection index for milk, fat, and protein	Low and high caloric density rations, fed *ad libitum* as PMR	22-28	Energy-corrected milk (kg/cow/day): +0.2 kg (low density ration) + 3.6 kg (high density ration) Fat% increased with merit only on low density ration Protein% was higher in high merit group only on low density ration (but interaction not significant) For energy-corrected milk and fat%, interactions were significantly different from zero.	Most cows were 100 % North American Holstein

* per genetic merit-feeding group combination
** point estimates are shown only if these were reported for each genetic merit-feeding group combination

Table 1 (cont) Summary of cohort studies assessing interactions between genetic merit and feedin g system on milk production in dairy cows in controlled environments

Definitions of genetic merit groups	Feeding system	No. of lactations*	Effects of increased genetic merit by feeding system**	Comments
Fulkerson *et al* (2008)				
2.3 and 49.1 kg fat plus protein Australian Breeding Value	Pasture plus 0.34 t, 0.84 t, and1.71 t DM concentrates per cow per lactation	?72	Milk yield (l/cow/lactation): +443 l (0.34 t) +538 l (0.84t +675 l (1.17 t) Fat yield (kg/cow/lactation): +22 kg (0.34 t) +24 kg (0.84 t) +32 kg (1.17 t Protein yield (kg/cow/lactation): +6 kg (0.34 t) +17 kg (0.84 t) +17 kg (1.17 t Fat%: +0.12% (0.34 t) +0.11% (0.84 t) +0.17% (1.17 t) Protein %: -0.15% (0.34 t) -0.01% (0.84 t) -0.06% (1.17 t) For protein yield and protein%, interactions were significantly different from zero.	Genetic merit groups differed in % North American genes (higher in high merit group) Fat and protein yield results differ between Tables 2and 3 Also reported slopes per unit increase in Australian Breeding Value

* per genetic merit-feeding group combination
** Point estimates are shown only if these were reported for each genetic merit-feeding group combination

REPRODUCTION

Key methods and results relating to genetic merit by energy intake interactions on reproduction are summarised in Table 2. Four studies were identified.

A wide variety of measures of reproductive performance were reported. Significant genetic merit by energy intake interactions were reported in only one of these studies (Fulkerson *et al* 2001); reductions in pregnancy rates by 24 days and 6 weeks after mating start date with genetic merit were smaller amongst cows fed more concentrates. Unfortunately, in this study, the statistical methods did not account for clustering of lactation within cow so p-values may be too low. In addition, genetic merit was confounded by % Holstein genes. However, these findings suggest that adverse effects of genetic merit and/or % Holstein genes on reproductive performance are partly ameliorated by increased energy intake.

Table 2 Summary of cohort studies assessing interactions between genetic merit and feedin g system on reproductive performance in dairy cows in controlled environments

Definitions of genetic merit groups	Feeding system	No. of lactations*	Effects of increased genetic merit by feeding system**	Comments
Pryce *et al* 1999				
Sires were average of UK fat plus protein PTA (low merit) and highest fat plus protein PTA bulls available (high merit)	Low density: Concentrates, brewers grains and silage of 20 :5 : 75 (low density) 1.0 t of concentrate per cow per annum High density: Concentrates, brewers grains and silage of 45 : 5 : 50 2.5 t of concentrate per cow per annum Both diets were fed *ad libitum*	Approx. 311	None of the interactions between genetic merit group and feeding system were significantly different from zero but for calving interval, P<0.1. The following traits were assessed: Oestrus not observed Conception at first service Calving interval Days to first service Days to first heat Days open	% Holstein not described; may have been similar to that reported by Veerkamp *et al* (1994) as this study was conducted using the same herd some years before it was used for Pryce et al's study For Veerkamp *et al* (1994)'s study, genetic merit groups were balanced for average % Holstein
Buckley *et al* 2000				
Selected from the Moorepark herd (medium merit) or selected based on their superior pedigree index for milk production (high merit)	A: High stocking rate, high nitrogen fertilization rate and planned concentrate intake of 500 kg/cow/lactation Received 0.86 t, 0.65 t, and 0.34 t in years 1-3, respectively. As for A but planned to feed twice the level of concentrate input Received 1.45 t, 1.11 t, and 0.87 t in years 1-3, respectively. As for A but cows grazed to a higher postgrazing sward surface Received 0.86 t, 0.65 t, and 0.34 t in years 1-3, respectively.	Approx. 44	No interactions between genetic merit group and feeding system were significantly different from zero. The following traits were assessed: Serviced in first 3 wk Calving to first service interval No. of services Conception rate (first and second service) Pregnancy rate	Genetic merit groups differed by % Holstein (higher in high merit group)

* per genetic merit-feeding group combination
** Point estimates are shown only if these were reported for each genetic merit-feeding group combination

Table 2 (cont) Summary of cohort studies assessing interactions between genetic merit and feedin g system on reproductive performance in dairy cows in controlled environments

Definitions of genetic merit groups	Feeding system	No. of lactations*	Effects of increased genetic merit by feeding system**	Comments
Fulkerson *et al* (2001)				
2.3 and 49.1 kg fat plus protein Australian Breeding Value	Pasture plus 0.34, 0.84, and1.71 t DM concentrates per cow per lactation	?72	Other than as indicated below, no results for genetic merit by feedin g system interactions were reported; presumably these were non-significant. Calving to first luteal phase (days): +6 (0.34 t) +6 (0.84 t) +3 (1.17 t) Calving to first observed oestrus(days): +11 (0.34 t) +3 (0.84 t) +15 (1.17 t) 24-day submission rate: -28% (0.34 t) -5% (0.84 t) -3% (1.17 t) First service conception rate: +3% (0.34 t) -9% (0.84 t) -20% (1.17 t) Calving to conception (days): +6 (0.34 t) +8 (0.84 t) +11 (1.17 t) % pregnant by 24 days: -18 (0.34 t) -9 (0.84 t) -9 (1.17 t) Significant interaction (P<0.05) % pregnant by 6 weeks: -22 (0.34 t) -14 (0.84 t) -17 (1.17 t) Significant interaction (P<0.05) % pregnant by 9 weeks: -11 (0.34 t) -15 (0.84 t) -13 (1.17 t) Interaction not significant % pregnant by 12 weeks: -13 (0.34 t) -11 (0.84 t) -3 (1.17 t) Interaction not significant	Genetic merit groups differed by % North American genes (higher in high merit group) Did not account for clustering of lactation within cow so p-values may be too low Herds were split-calving so effects of reduced reproductive performance may have 'magnified' as the trial progressed due to later calving dates (and hence shorter intervals from calving to mating start date in the lower fertility groups

* per genetic merit-feeding group combination
** Point estimates are shown only if these were reported for each genetic merit-feeding group combination

Table 2 (cont) Summary of cohort studies assessing interactions between genetic merit and feedin g system on reproductive performance in dairy cows in controlled environments

Definitions of genetic merit groups	Feeding system	No. of lactations*	Effects of increased genetic merit by feeding system**	Comments
Fulkerson *et al* (2001) (cont.)				
			No. treatments per cow mated: +0.14(0.34 t) +0.15 (0.84 t) +0.07 (1.17 t) No. abnormal cycles per cow mated: +0.05(0.34 t) +0.29 (0.84 t) +0.16 (1.17 t) *Exact values in graphs were obtained from Fulkerson *et al* 2000	
Pollott and Coffey (2008)				
Sires were average of UK fat plus protein PTA (low merit) and highest fat plus protein PTA bulls available (high merit)	High forage system (including pasture in summer, TMR for rest of year) High concentrate system fed as TMR	Approx. 91	No results for genetic merit by feedin g system interactions were reported; presumably all were non-significant. The following traits were assessed: Start of luteal activity Day of first heat Day of first service Day of successful service Number of cycles Number of heats Number of services Gestation lengt Calving interval Traits >42 d Day of first heat >42 d No. of heats >42 d C-LA[1] to first heat C-LA[1] to first AI C-LA[1] to successful service First heat to first AI First heat to successful service First service to successful service Intervals >42 d First heat >42 d to first AI First heat >42 d to successful service Mean progesterone level Length of luteal phase Interovulatory period Interluteal period Incidence of silent heats [1]C-LA = interval from calving to the start of luteal activity	% Holstein not described; may have been similar to that reported by Veerkamp *et al* (1994) as this study was conducted using the same herd some years before it was used for Pollott and Coffey's study For Veerkamp *et al* (1994)'s study, genetic merit groups were balanced for average % Holstein

* per genetic merit-feeding group combination
** Point estimates are shown only if these were reported for each genetic merit-feeding group combination

LARGE SCALE COHORT STUDIES IN COMMERCIAL HERDS

STUDY SELECTION CRITERIA

Large scale cohort studies in commercial herds were selected if they met all of the following criteria:

- the study was conducted in dairy herds
- genetic merit of study cows was measured,
- milk yield, reproductive performance and/or survival were compared,
- environments were based on feeding system or herd mean milk production, and
- genetic merit by environment interactions were assessed.

Additional relevant references are cited.

RESULTS AND DISCUSSION

Environment was defined in many ways in large scale cohort studies in commercial herds. Numerous studies met the selection criteria, with environments based on feeding system (6 studies; Table 3) or mean milk production (15 studies; Table 4). Some examples of studies that used other definitions of environment are listed in Literature Review Appendix 2.

These results indicate that in studies assessing genotype by environment interactions in dairy cow populations, environments are rarely based on feeding system. Herd mean milk production variables are used much more commonly.

This is problematic because herd managers directly control feeding but not milk yield, and milk yields can vary widely within a given feeding system. Furthermore, milk yield is partly determined by genetic merit of the herd, and more accurate estimates of the extent of genotype by environment interaction would be obtained if feeding system was used (Hayes *et al* 2003). When the environments are defined based on herd mean milk yields, statistical analyses that account for genetic merit have been used (for example, Hayes *et al* 2003; Hammami *et al* 2009b). In some studies where various environmental definitions have been compared directly, environments based at least partly on milk yield (Calus and Veerkamp 2003; Zwald *et al* 2003; Bryant *et al* 2007a) or nutritional (Haskell *et al* 2007) variables were amongst the most important, suggesting that nutritional factors are important causes of genotype by environment interaction in dairy cow populations.

For comparisons by feeding system, genetic correlations for milk producton traits varied from 0.62 (Berry *et al* 2003) and 0.76 (Ramirez-Valverde *et al* 2010) to 0.94 (Boettcher *et al* 2003). Regression slopes for milk production on sire predicted transmitting abilities werere higher in housed cows (Boettcher *et al* 2003); Kearney *et al* 2004a). Genetic correlations for days open were 1.0 and 0.74 in two subsets of data in one study (Kearney *et al* 2004b). Boettcher *et al* (2003) reported a genetic correlation for calving interval of 0.64 but this estimate was imprecise.

For comparisons where the environment was based on herd milk production, genetic correlations for milk producton traits varied from 0.64 to 1.00. Highest estimates were from non-pasture-fed herds; most estimates were above 0.92. Estimates were generally lower (mostly 0.64 to 0.93) when various environments were compared across pasture-fed herds.

Correlations were lowest when environments were more different (Cromie et al 1998; Kolmodin *et al* 2002; Zwald *et al* 2003; Petersson *et al* 2005; Bryant et al 2007a).

Genetic correlations for reproducton traits were reported in four of the selected studies. Estimates for calving interval varied widely, from 0.58 to 0.92, and for calving to first service, from 0.47 to 0.84.

These results indicate that genotype by environment interaction for milk production is generally low to modest, but important reranking may be occurring in some circumstances. Genotype by environment interaction may be more important between feeding systems, and between pasture-fed herds with different feed intakes.

Evidence about genotype by environment interactions for reproductive traits is limited, but these results suggest that important reranking may be occurring in some circumstances. This should be investigated in various Australian environments in future. Genetic correlations for reproductive intervals may have been reduced due to incomplete data (eg from periods when bulls run with herds) errors in ascribing conception dates (commonly due to lack of early rectal pregnancy test data, selection bias due to exclusion of animals not experiencing the interval endpoint, and failure to account for right censoring in statistical models. Intervals from calving are very poor phenotypic descriptors of reproductive performance in seasonal and split calving herds. The impact of using these intervals in seasonal and split calving herds requires investigation. For each of calving to first service interval and calving interval, genetic correlations between seasonal and year-round calving systems were high but correlations involving split-calving herds were lower (Haile-Mariam *et al* 2008).

Although not directly related to the review objectives, genotype by environment interactions for heterosis have been reported. Heterosis between Holstein and Dutch Friesian animals was greatest in low production environments (Penasa *et al* 2010), but heterosis between Holstein and New Zealand Friesian animals was lowest in very low production environments (Bryant et al 2007b).

Environment has also been defined based solely on country of location of the cows and herds. Some examples of such studies are listed in Literature Review Appendix 3. In addition, Interbull (the International Bull Evaluation Service) routinely assesses genetic correlations between participating countries for numerous traits. For Holstein cows, genetic correlations for protein yield between Australian and North American sires were 0.75, between Australian and and European sires 0.75 to 0.79, between Australian and New Zealand sires 0.85, and between various European countries, USA and Canada 0.85 to 0.92 (http://www.interbull.org/web/static/mace_evaluations/1412r/proddoc1412r.pdf). These results are further evidence that interactions between genotype by environment (country in this case) are greatest when environments are more different. Interbull also assesses genetic correlations between participating countries for numerous reproductive traits (http://www.interbull.org/web/static/mace_evaluations/1412r/fertdoc1412r.pdf). Genetic correlations between Australian sires and those from other countries vary widely, from 0.26 to 0.88, with most between 0.65 and 0.80. For calving interval, the genetic correlation between Australian and USA sires was 0.85. Reproductive traits were not assessed in the same way in all countries; reduced genetic correlations would be expected where measurement methods are markedly different.

Table 3 Summary of large scale cohort studies assessing interactions between genetic merit and environment in dairy cows in commercial herds where environment was based on herd feeding system

Trait	Definition of environment	Genotype by environment estimates
Cromie *et al* (1998)		
305-day milk, fat, protein	High (1.5 t) and low concentrate (0.5 t) fed/cow/year*	Genetic correlations: Milk 0.92 Fat 0.89 Protein 0.91 Product moment correlation of sires based on estimated breeding values: Milk 0.65 Fat 0.67 Protein 0.62
Berry *et al* (2003)		
Cumulative milk yield to day 180 of lactation	Average amount of concentrate supplementation offered per cow annually**	Genetic correlation between the most extreme environments: 0.62
Boettcher *et al* (2003)		
305-d mature equivalent milk, fat, and protein Calving interval	Intensive rotational grazing for at least 6 months per year with pasture contributing at least 70% of forage versus housed cows fed stored feeds	Regression slopes for milk, fat, and protein on sire predicted transmitting abilities higher in housed cows Genetic correlations: Milk 0.93 Fat 0.88 Protein 0.94 Calving interval 0.64 (imprecise estimate)
Kearney *et al* (2004a)		
Mature equivalent milk, fat and protein	Intensive rotational grazing for at least 6 months per year versus housed cows fed stored feeds	Regression slopes for milk, fat, and protein on sire predicted transmitting abilities higher in housed cows Genetic correlations: Milk 0.89 Fat 0.88 Protein 0.91 Rank correlations of sires based on estimated breeding values: Milk 0.59 Fat 0.63 Protein 0.66
Kearney *et al* (2004b)		
Days open Calving to first service Number of services per conception	Intensive rotational grazing for at least 6 months per year versus housed cows fed stored feeds	Genetic correlations: Days open 1.0 and 0.74 (two subsets of data analysed) Calving to first service 1.0 Number of services per conception 1.0
Ramirez-Valverde et al (2010)		
305-day mature equivalent milk yield	Intensive rotational grazing for at least 6 months per year versus housed cows fed stored feeds	Genetic correlation: 0.76 Product-moment correlation (of cows?) based on estimated breeding values: 0.96

* Presumably all cows were under pasture-based feeding
** Cows were pasture-fed for at least some of year; environment treated as a continuous variable

Table 4 Summary of large scale cohort studies assessing interactions between genetic merit and environment in dairy cows in commercial herds where environment was based on herd milk production

Trait	Definition of environment (herd-year classification)	Genotype by enviroment estimates
Pasture-fed herds*		
Cromie *et al* (1998)**		
305-day milk, fat, and protein yields	High and low milk yield/cow/year	Genetic correlation between highest and lowest 10%: Milk 0.82 Fat 1.00 Protein 0.85
Berry *et al* (2003)		
Cumulative milk yield to day 180 of lactation	Average of cumulative milk yield per cow to day 180 of lactation	Genetic correlation between the upper and lower thirds: 0.83 Genetic correlation between the most extreme environments: 0.64
Hayes *et al* (2003)		
Test day milk, fat and protein yields	Herd average test day protein yield adjusted for age and stage of lactation	Genetic correlations between 5th and 95th percentiles of herd average test day protein yield Milk 0.83 Fat 0.70 Protein 0.78
Bryant *et al* (2007a)		
Milk, fat and protein yields for 270-day lactation	Average kg of MS/cow per year adjusted for cow age, breed and lactation length	Genetic correlations between most extreme environment groups: Milk 0.92 Fat 0.93 Protein 0.87
Haile-Mariam *et al* (2008)		
Calving interval, calving to first service interval, 25-day non-return to first service, recalved by 18 months	Herd average lactation milk volume adjusted for age and lactation duration	Genetic correlations between 5th and 95th percentiles of herd average lactation milk volume: Calving interval 0.58 Calving to first service interval 0.47 25-day non-return to first service 0.79 Recalved by 18 months 0.31
Other herds		
Castillo-Juarez *et al* (2000)		
Mature equivalent milk yield, conception to first service	Herd mean and herd standard deviation for mature equivalent milk yield both high or both low	Genetic correlations: Mature equivalent milk yield 0.98, Conception to first service 1.00
Castillo-Jaurex *et al* (2002)		
Mature equivalent milk, fat and protein yield for lactation	Mature equivalent milk volume herd mean and SD (kg): High: ≥9864 and ≥1621 Low: ≤9307 and ≤1479	Genetic correlations: all > 0.97

* The majoriity of (or all) cows in these studies were pasture-fed for at least some of each year
** Presumably pasture-fed cows

Table 4 (cont) Summary of large scale cohort studies assessing interactions between genetic merit and environment in dairy cows in commercial herds where environment was based on herd milk production

Trait	Definition of environment (herd-year classification)	Genotype by enviroment estimates
Other herds (cont)		
Kolmodin *et al* (2002)		
305 day protein production	Deviation from country average 305-day protein production	Genetic correlations between average and various percentiles of 305-day protein production: >0.92 except in low production, low fertility herds
Calus and Veerkamp (2003)		
Average of daily milk, fat, and protein yields within lactation	Average protein (kg/d)	Genetic correlations between 25% and 75% percentile: 0.99 or higher
Zwald *et al* (2003)		
Milk volume for lactations of 270 d (New Zealand), 290 d (South Africa, Australia, and Ireland), or 305 d (other countries)	Peak milk yield	Genetic correlations between quintiles Q1 vs Q5: 0.84 or 0.85 (Reported results differ between Figure 3 and the text)
Cerón-Muñoz *et al* (2004)		
305-day milk yield	Average milk yield for 305-day lactation	Genetic correlation: 0.97
Calus *et al* (2005)		
Calving to first service, calving to last service, interval from first to last service, calving interval, number of inseminations per service period, first-service conception, 56-day non-return to first insemination, survival (recalving recorded)	Average protein (kg/d)	Genetic correlations between 10th and 90th percentiles: Heifers None significant Cows Calving interval 0.92 Survival 0.97 Others not significant?
Petersson *et al* (2005)		
Productive life	Peak yield, protein yield	Genetic correlation between low and high quartile of: peak yield 0.93 and 0.95 protein yield 0.99 and 1.00 (Two models were used with different effects of herd, year and age at first calving)

* The majoriity of (or all) cows in these studies were pasture-fed for at least some of each year
** Presumably pasture-fed cows

Table 4 (cont) Summary of large scale cohort studies assessing interactions between genetic merit and environment in dairy cows in commercial herds where environment was based on herd milk production

Trait	Definition of environment (herd-year classification)	Genotype by enviroment estimates
Other herds (cont)		
Hammami *et al* (2009b)		
305-day milk volume	Clusters based on test day milk yields after accounting for: herd-test-date, age within season of calving and stage of lactation, stage of lactation, animal additive genetic effect, permanent environmental effects, and herd-year of calving	Correlations between low and high environments Genetic: within Tunisia 0.70 within Luxembourg 0.97 Rank correlation of sires based on estimated breeding values: Within Tunisia 0.33 Within Luxembourg 0.76 Correlations between countries lower than within countries
Strandberg *et al* (2009)		
Calving to first service, 56-day non-return, calving interval, number of inseminations	305-day milk, fat, and protein yields adjusted for age at calving, and year and month of calving	Genetic correlations between low and high quartiles: Calving to first service interval 0.77 and 0.84 Calving interval 0.74 and 0.77 (Two models were used)

* The majoriity of (or all) cows in these studies were pasture-fed for at least some of each year
** Presumably pasture-fed cows

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LITERATURE REVIEW APPENDIX 1

COMPARISONS BETWEEN BREEDS/CROSS-BREEDS

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INTERSTRAIN COMPARISONS

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LITERATURE REVIEW APPENDIX 2

Some examples of studies assessing genotype by environment interactions with environment defined as other than feeding system, herd mean milk production or country are listed below. Animal-level variables (eg sire predicted transmitting ability for milk yield), lactation-level variables (eg days to peak yield) and within-lactation variables (eg somatic cell count) were usually averaged to herd-year level before analyses.

Environments defined by herd

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Environments defined by region

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Sundberg T, Berglund B, Rydhmer L, Strandberg E. Fertility, somatic cell count and milk production in Swedish organic and conventional dairy herds. *Livestock Science* 2009;126:176-182.

Sundberg T, Rydhmer L, Fikse WF, Berglund B, Strandberg E. Genotype by environment interaction of Swedish dairy cows in organic and conventional production systems. *Acta Agriculturae Scandinavica Section a-Animal Science* 2010;60:65-73.

Refined nutitional variables

Dekleva MW, Dechow CD, Daubert JM *et al*. Short communication: Interactions of milk, fat, and protein yield genotypes with herd feeding characteristics. *Journal of Dairy Science* 2012;95:1559-1564.

Environments were defined variously based on amount of dry matter not eaten, diet crude protein percentage, and energy density of the diet (diet NE_L concentration)

Lactational persistency

Calus MPL, Veerkamp RF. Estimation of environmental sensitivity of genetic merit for milk production traits using a random regression model. *Journal of Dairy Science* 2003;86:3756-3764.

Calus MPL, Windig JJ, Veerkamp RF. Associations among descriptors of herd management and phenotypic and genetic levels of health and fertility. *Journal of Dairy Science* 2005;88:2178-2189.

Zwald NR, Weigel KA, Fikse WF, Rekaya R. Identification of factors that cause genotype by environment interaction between herds of Holstein cattle in seventeen countries. *Journal of Dairy Science* 2003;86:1009-1018.

Days to peak yield

Zwald NR, Weigel KA, Fikse WF, Rekaya R. Identification of factors that cause genotype by environment interaction between herds of Holstein cattle in seventeen countries. *Journal of Dairy Science* 2003;86:1009-1018.

Fat and/or protein percentage

Calus MPL, Veerkamp RF. Estimation of environmental sensitivity of genetic merit for milk production traits using a random regression model. *Journal of Dairy Science* 2003;86:3756-3764.

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Fat: protein ratio

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Change in fat percentage

Calus MPL, Veerkamp RF. Estimation of environmental sensitivity of genetic merit for milk production traits using a random regression model. *Journal of Dairy Science* 2003;86:3756-3764.

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Within herd variation in milk yield

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Somatic cell count

Calus MPL, Veerkamp RF. Estimation of environmental sensitivity of genetic merit for milk production traits using a random regression model. *Journal of Dairy Science* 2003;86:3756-3764.

Calus MPL, Windig JJ, Veerkamp RF. Associations among descriptors of herd management and phenotypic and genetic levels of health and fertility. *Journal of Dairy Science* 2005;88:2178-2189.

Body condition score

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Herd size

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Change in herd size

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Calving system (seasonal, split or year-round calving)

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Calving date distribution (average or peak)

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Various herd reproductive performance measures

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Kolmodin R, Strandberg E, Madsen P, Jensen J, Jorjani H. Genotype by environment interaction in Nordic dairy cattle studied using reaction norms. *Acta Agriculturae Scandinavica Section a-Animal Science* 2002;52:11-24.

Strandberg E, Brotherstone S, Wall E, Coffey MP. Genotype by environment interaction for first-lactation female fertility traits in UK dairy cattle. *Journal of Dairy Science* 2009;92:3437-3446.

Productive life

Petersson KJ, Kolmodin R, Strandberg E. Genotype by environment interaction for length of productive life in Swedish Red and White dairy cattle. *Acta Agriculturae Scandinavica Section a-Animal Science* 2005;55:9-15.

Number of first parity cows

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Age of cows

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Culling percentage

Zwald NR, Weigel KA, Fikse WF, Rekaya R. Identification of factors that cause genotype by environment interaction between herds of Holstein cattle in seventeen countries. *Journal of Dairy Science* 2003;86:1009-1018.

Percentage of first lactation animals culled

Zwald NR, Weigel KA, Fikse WF, Rekaya R. Identification of factors that cause genotype by environment interaction between herds of Holstein cattle in seventeen countries. *Journal of Dairy Science* 2003;86:1009-1018.

% North American Holstein

Zwald NR, Weigel KA, Fikse WF, Rekaya R. Identification of factors that cause genotype by environment interaction between herds of Holstein cattle in seventeen countries. *Journal of Dairy Science* 2003;86:1009-1018.

Sire predicted transmitting ability for milk yield

Zwald NR, Weigel KA, Fikse WF, Rekaya R. Identification of factors that cause genotype by environment interaction between herds of Holstein cattle in seventeen countries. Journal of Dairy Science 2003;86:1009-1018.

Body weight at first calving divided by age at first calving

Castillo-Juarez H, Oltenacu PA, Blake RW, McCulloch CE, Cienfuegos-Rivas EG. Effect of herd environment on the genetic and phenotypic relationships among milk yield, conception rate, and somatic cell score in Holstein cattle. *Journal of Dairy Science* 2000;83:807-814.

Heat load measures including temperature-humidity index

Brugemann K, Gernand E, von Borstel UU, Konig S. Genetic analyses of protein yield in dairy cows applying random regression models with time-dependent and temperature x humidity-dependent covariates. *Journal of Dairy Science* 2011;94:4129-4139.

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Rainfall

Maciel SMA, Amimo J, Martins M *et al*. Factors influencing reproductive performance of cows from different Nguni ecotypes in southern Mozambique. *Tropical Animal Health and Production* 2012;44:435-444.

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Climate

Sofla SS, Dezfuli BT, Mirzaei F. Interaction between genotype and climates for Holstein milk production traits in Iran. *African Journal of Biotechnology* 2011;10:11582-11587.

Altitude

Bryant JR, Lopez-Villalobos N, Pryce JE *et al*. Environmental sensitivity in New Zealand dairy cattle. *Journal of Dairy Science* 2007;90:1538-1547.

Complex definitions of environment based jointly on multiple variables

Ceron-Munoz MF, Tonhati H, Costa CN, Rojas-Sarmiento D, Echeverri DME. Factors that cause genotype by environment interaction and use of a multiple-trait herd-cluster model for milk yield of Holstein cattle from Brazil and Colombia. *Journal of Dairy Science* 2004;87:2687-2692.

Each herd was categorised into one of three groups based jointly on 8 variables: production level, phenotypic variability, age at first calving, calving interval, percentage of imported semen, lactation length, and herd size.

Gernand E, Waßmuth R, von Borstel UU, König S. Heterogeneity of variance components for production traits in large-scale dairy farms. *Livestock Science* 2007;112:78-89.

Each herd was categorised into one of three groups based jointly on herd size, test day protein yield, and average age at first calving.

Haskell MJ, Brotherstone S, Lawrence AB, White IMS. Characterization of the dairy farm environment in Great Britain and the effect of the farm environment on cow life span. *Journal of Dairy Science* 2007;90:5316-5323.

One environment classification was based on concentrate usage, number of veterinary visits, and number of cows that spend a lower than average time out at grass.

A second environment classification was based on temperature, rainfall, ages at first calving, and milk, fat and protein yields.

Strandberg E, Brotherstone S, Wall E, Coffey MP. Genotype by environment interaction for first-lactation female fertility traits in UK dairy cattle. *Journal of Dairy Science* 2009;92:3437-3446.

Herds were categorised based jointly on 305-d milk, fat, and protein yields, age at first calving, temperature, and rainfall.

Zwald NR, Weigel KA, Fikse WF, Rekaya R. Application of a multiple-trait herd cluster model for genetic evaluation of dairy sires from seventeen countries. *Journal of Dairy Science* 2003;86:376-382.

Each herd was allocated to one of seven clusters based on thirteen genetic, management, and climatic variables.

LITERATURE REVIEW APPENDIX 3

Some examples of studies assessing genotype by environment interactions with environment defined as country are listed below.

Fikse WF, Rekaya R, Weigel KA. Assessment of environmental descriptors for studying genotype by environment interaction. *Livestock Production Science* 2003;82:223-231.

Hammami H, Rekik B, Soyeurt H *et al*. Genotype x environment interaction for milk yield in Holsteins using Luxembourg and Tunisian populations. *Journal of Dairy Science* 2008;91:3661-3671.

Jamrozik J, Schaeffer LR, Weigel KA. Estimates of genetic parameters for single and multiple-country test-day models. *Journal of Dairy Science* 2002;85:3131-3141.

Ojango JMK, Pollott GE. The relationship between Holstein bull breeding values for milk yield derived in both the UK and Kenya. *Livestock Production Science* 2002;74:1-12.

Van der Linde, C., de Jong, G., 2003. *MACE for longevity traits. Bull.-INTERBULL* 30, 3– 9.

Weigel, K., Rekaya, R., Zwald, N., Fikse, W.F., 2001. International genetic evaluation of dairy sires using a multiple-trait model with individual animal performance records. *Journal of Dairy Science* 84, 2789–2795.

Zwald NR, Weigel KA, Fikse WF, Rekaya R. Characterization of dairy production systems in countries that participate in the International Bull Evaluation Service. *Journal of Dairy Science* 2001;84:2530-2534.

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The ADHIS is an Australian Dairy Farmers Ltd initiative that receives the majority of its funding from Dairy Australia through the Dairy Service Levy.

Australian Dairy Farmers