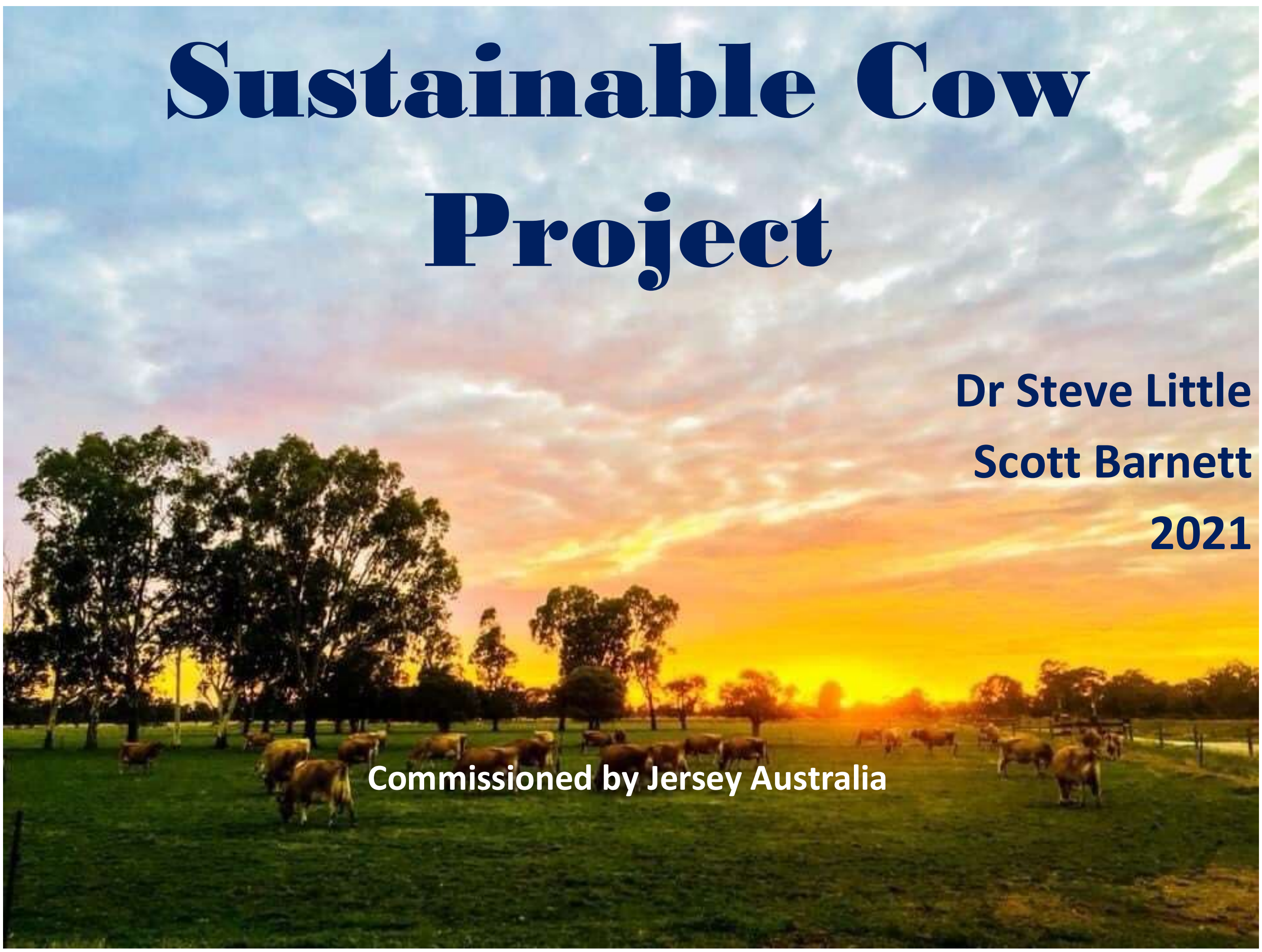
Australian Jerseys. Dairy's Finest Cows

JERSEY Australia

Jersey - The Most Profitable and Sustainable Cow Project



Dr Steve Little
Scott Barnett
2021

Commissioned by Jersey Australia

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Jersey – The Most Profitable and Sustainable Cow Project

Foreword:

When surveying farmers, profitability is always a key driver in their informed decision making. At Jersey Australia there has been many conversations around the board room or out in the paddock as to whether the Jersey cow is more profitable than other breeds. In 2021 Jersey Australia commissioned Dr Steve Little and Scott Barnett to undertake a detailed literature review and economic modelling on this topic,

The project was undertaken with an arm's length approach by Jersey Australia and with a strong expectation and demand by Dr Little and Mr Barnett that an evidence based non contrived investigation be undertaken. Jersey Australia could not agree more that this was an important requirement to undertake the project.

The results show a significant economic and sustainability advantage is available to farmers in milking Jersey cows.

Key Project Findings

- Milk Production. Jersey's
    - Produce 6-11% more energy corrected milk (ECM) produced per Kg of dry matter intake
    - Produce 26-31% more ECM per 100kg of liveweight
    - Are more efficient at utilising dietary nitrogen
    - Have higher NDF digestibility capacity
    - Spend more time grazing and ruminating per 24 hours providing a more stable food supply to rumen.
    - Have a 14-21% higher intake capacity per 100kg of liveweight
    - Jersey Milk provides superior nutrition to consumers
- Health. Jersey's.
    - Have less Health incidences to most illnesses reducing costs and time out of vat
    - Are more prone to Milk fever
        - the only key illness identified which jersey is more susceptible to.
- Management. Jerseys.
    - Have superior fertility reducing reproduction costs and calving intervals
    - have a greater longevity and productive life leading to reduced annual heifer replacements
    - Are more heat tolerant enabling cows to better sustain Australian climates and climate change
- Economically
    - Milking Jerseys is estimated to provide your business an additional $500,000 - $1,000,000 over 20 years of additional profit.

About the Authors

Dr Steve Little

Capacity⁺ Ag Consulting

Steve Little, of Capacity⁺ Ag Consulting, is an Australian veterinarian with additional qualifications in ruminant nutrition and agribusiness management. He is an honorary fellow and chief examiner of the *Australian Association of Ruminant Nutrition*. He is also a past president of the *Australian Association of Ruminant Nutrition* and the Cattle Chapter of the *Australian and New Zealand College of Veterinary Scientists*.

Steve has extensive experience as a farm advisor, providing herd nutrition, reproduction, health, and productivity advice, and as a consultant to animal nutrition and health companies, other commercial agribusinesses and public sector research and development organisations. He has led or contributed to many R & D projects and extension programs in Australia including *InCalf*, *feed.FIBRE.future*, *Feed2Milk*, *Cool Cows* and *Feeding the Genes*. Steve also developed the *Advanced Nutrition in Action* training program for dairy farmers and advisors now being delivered across Australia by Dairy Australia.

Scott Barnett

Director: Scott Barnett & Associates

Agricultural Production and Agribusiness Consultants

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Scott has over 25 years' experience working in and with the Australian dairy industry in both the government and private sectors. He is an experienced dairy management consultant with skills in all aspects of farm business management, forage production and utilisation, and nutrition. His experience covers grazing operations, PMR farms to fully housed TMR systems in dryland and irrigated dairying areas.

Scott holds a Bachelor of Science in Agriculture (University of Sydney), Master of Applied Science (Agriculture and Rural Development) (University of Western Sydney) and is a Graduate of the Company Directors Course (University of Sydney Graduate School of Management).

Scott has operated and been principal of Scott Barnett & Associates, a specialised dairy Management consultancy for over 25 years servicing family farms, industry bodies, corporate investors, and Government. Prior to establishing SBA, Scott work NSW Agriculture as a dairy advisory and extension officer.

Scott has authoring technical and farm focused publications on nutrition, forage management, cattle breeding, irrigation management and dairy farm investment and management. This is coupled with real on farm management experience, as well as being the lead shareholder in an 850-cow operation.

Scott currently services on the NSW Dairy Industry Advisory Panel.

Scott understands the human factors impacting dairy businesses and the external pressures faced by the dairy industry.

Capacity+ Ag Consulting

Helping build effectiveness, productivity and profit

Jersey – The Most Profitable and Sustainable Cow?

Literature Review for Jersey Australia

1st November 2021

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Abbreviations

ABV	Australian breeding value
BCFA	Branched chain fatty acid
BCS	Body condition score
BW	Bodyweight
$BW^{0.75}$	Metabolic bodyweight
CLA	Conjugated linoleic acid
CP	Crude Protein
DM	Dry Matter
ECM	Energy-corrected milk
FA	Fatty acid
DIM	Days in Milk
DM	Dry Matter
ECM	Energy-corrected milk
FCE	Feed Conversion Efficiency
GHG	Greenhouse gas
Ha	Hectare
ICCC	Individual Cow Cell Count
Kg	Kilogram
ME	Metabolisable Energy
MFD	Milk fat depression
Mg	Milligram
MJ	Megajoule
MUFA	Monounsaturated fatty acid
MS	Milksolids
NDF	Neutral Detergent Fibre
NEB	Negative energy balance
NEFA	Non-esterified fatty acids
OCFA	Odd chain fatty acid
PMR	Partial Mixed Ration
PUFA	Poly unsaturated fatty acid
SFA	Saturated fatty acid
THI	Temperature Humidity Index
TMR	Total Mixed Ration
Tn	Tonne

Executive Summary

This review has found that the Australian Jersey has several attributes compared with other breeds used in the Australian dairy industry that may contribute to the profitability and sustainability of Australian dairy farm businesses. These attributes include higher fertility, higher production efficiency, greater heat tolerance and longevity. The main findings are summarised in Table 1.

Table 1. Main findings of this review.

Aspect		Main findings
1	Milk yield, composition and market suitability	• Holsteins produce more milksolids per cow per year than Jerseys • The composition of milk differs between breeds, but many other factors also influence it • Fat and protein concentrations in milk of Jerseys are higher than those of Holsteins by about 1.1-1.4 g/100ml and 0.5-0.56 g/100ml respectively • The concentrations of fatty acids in milk fat differ between breeds but are small relative to those between different stages of lactation • Jersey milk fat contains a higher proportion of short and medium-chain fatty acids and a lower proportion of C16:1, C18:1, and conjugated linoleic acid • There is insufficient evidence to determine whether Jerseys are more or less susceptible to milk fat depression than Holsteins under the same feeding management and environmental conditions • The amino acid (AA) profile of Jersey milk does not differ significantly from other breeds • Jersey milk has higher concentrations of calcium, phosphorus and zinc than Holstein milk, and a lower concentration of potassium
2	Production efficiency	• Jerseys produce 6-11% more energy-corrected milk (ECM) than Holsteins per kilogram of dry matter intake, and 26-31% more ECM per 100 kg bodyweight than Holsteins. Jerseys are 8% more energetically efficient • Jersey cows' higher production efficiency is due to reduction and dilution of their daily maintenance energy requirement • Jerseys appear to be performing well in mixed breed herds. However, Jerseys in straight Jersey herds produce more milk solids per year than Jerseys in mixed-breed herds
3	Feed intake, eating behaviour and nutrient digestibility	• Jerseys have about 14-21% higher feed intake capacity than Holsteins per 100 kg bodyweight and 5% per unit metabolic bodyweight. This may be due to their larger gastrointestinal tract per kg body weight, higher rate of particle breakdown within the rumen and higher fractional outflow rate of digesta from the rumen • Jerseys spend more time grazing and ruminating per unit of ingested feed and distribute meals more evenly throughout each 24-hour period than Holsteins, providing a more regular supply of feed to the rumen • Several studies have found that Jerseys have higher NDF digestibility than Holsteins, despite their higher gut passage rate • A recent study indicates that Jersey cows are more efficient at utilising dietary nitrogen than Holsteins
4	Fertility	• Jerseys have higher fertility than Holsteins. This is likely to be due to genetic selection and energy metabolism, particularly in the transition period and early lactation, in which Jerseys remain in negative energy balance (NEB) for a shorter period of time relative to Holsteins and the magnitude of Jerseys' NEB is less than that of Helsteins • The mean daughter fertility breeding value for sires of Jersey cows has been flat or declining for four decades, whereas that of sires of Holstein cows is now increasing. If these trajectories continue, the fertility advantage of Jerseys over Holsteins may be reduced

5	Health	• Many Jersey breed associations claim that Jerseys suffer fewer health problems than Holsteins, including stillbirths, calving difficulties, metritis, mastitis, lameness. These claims are supported by several overseas surveys • However, Jersey cows are more predisposed to milk fever than Holsteins. (Milk fever risk is ≥ 2 times higher) • Australian herd data suggest that udder health of Jerseys is slightly better than that of Holsteins. Unfortunately, Australian herd data on specific health problems are not of sufficient quality to enable reliable analysis
6	Heat tolerance	• Jerseys are more heat tolerant than Holsteins, due to several factors related to their hair coat, skin structure, subcutaneous fat layer, and body surface area to volume ratio • Under heat stress, the rumen microbiome of Jersey cows is altered, thereby enhancing heat stress resistance, whereas in Holstein cows it is not • However, heat stressed Jersey cows may be potentially more susceptible to infections than Holsteins due to altered immune pathways
7	Longevity	• Cow longevity (survival) in a herd has an important influence on the herd's production efficiency, profitability and environmental footprint • Jerseys tend to live longer, producing for longer, and survive to later lactations more frequently than Holsteins in straight and mixed-breed herds • Increased longevity in a herd means the herd's mean milk production is higher and fewer non-productive replacement heifers are required
8	Lifetime production efficiency	• Many factors related to the milking herd and the replacement herd contribute to lifetime production efficiency of a whole herd • Jerseys have demonstrated advantages in grazing systems, longevity, productive life, calving ease, fertility, heat tolerance and hybrid vigour contribution. However, Holsteins offer different benefits in each production system. • A modelling approach may be more appropriate and useful when comparing lifetime efficiency of Jerseys and Holsteins within a given production system
9	Environmental footprint	• Several studies have suggested that the emission intensity of milk production is about 8-12% lower with a Jersey herd compared to a Holstein herd when the life cycle analysis (LCA) approach was used to calculate GHG emissions • However, there may be little difference between the breeds in emission intensity of milk production, as Jerseys emit more methane per kg DM intake compared to Holsteins
10	Suitability for different production / housing systems	• Jerseys are used successfully around the world in a diverse range of production systems (grazing and confinement) • Jerseys may perform at their best in grazing systems where their larger digestive tract per unit BW allows them a greater feed intake capacity. • Jerseys are better suited to walking longer distances associated with grazing systems than Holsteins, and to hot climatic conditions. • Jerseys' higher fertility and easier heat detection is also an advantage, particularly in grazing systems • The behaviours and performance of Jerseys in different housed production systems requires further research
11	Genetic trends	• The mean daughter fertility ABV for sires of Jersey cows has been flat or slowly declining for four decades, whereas that of sires of Holstein cows is now increasing • Cows' sire ABVs are highly variable for Jerseys and Holsteins, especially for cow's sire daughter fertility, Balanced Performance Index and Protein ABV

Project objectives

The objective of the project was to search for and document available evidence on the many attributes of the Australian Jersey compared with other breeds used in the Australian dairy industry that enable it to contribute to the profitability and sustainability of Australian dairy farm businesses.

Terms of reference

The project brief assigned to Capacity+ Ag Consulting by Jersey Australia was to conduct a comprehensive, objective review of published scientific literature and grey literature to find evidence currently available on each of the following eleven aspects for Jerseys vs. other breeds, be that evidence favourable or not to Jerseys:

1. Milk yield, composition and market suitability
2. Production efficiency
3. Feed intake, eating behaviour and feed digestibility
4. Fertility
5. Health
6. Heat tolerance
7. Longevity
8. Lifetime production efficiency
9. Environmental footprint
10. Suitability for different production / housing systems
11. Genetic trends

This literature review is not intended to compare Jerseys specifically with Holsteins. However, it is recognised that the majority of published research studies available which enable a comparison of Jerseys to one or more other breeds include Holsteins.

Based on this literature review, knowledge gaps that require future research to be undertaken to fill them will also be listed. Some of these may be potential R & D opportunities for Jersey Australia.

Should this project find evidence favourable to Jerseys, Jersey Australia's plan was to have desktop modelling conducted by Mr. Scott Barnett of Scott Barnett & Associates to assess the potential of Jersey cows to enhance the profitability of Australian dairy farm businesses under different conditions.

Statement of limitations

Due to the influence of many factors upon the performance of Jersey cows, this report is not a warranty, express or implied, of any particular biophysical or financial outcome.

This report is for information purposes only. It does not constitute stand-alone professional advice and should not be relied upon solely as a basis for decisions.

Introduction

To provide this literature review with an Australian context, two elements were added:

1. Findings from an online survey designed and offered to Jersey Australia members. Sixty two people responded in part or full.

   Respondents considered Jerseys' greatest advantages as a dairy breed to be:
   - Higher milk solids
   - More efficient (per kg feed, per kg bodyweight)
   - Greater calving ease
   - Less damage to paddocks
   - Easier to handle
   - More fertile

   Respondents considered Jerseys' greatest limitations as a dairy breed to be:
   - Lower values of calves, culls
   - Difficulty competing with larger cows in mixed herds
   - Milk fever prone
   - Fewer good quality cows available for purchase
   - Small gene pool

2. Analysis Australian herd recording data held by DataGene.

   Data relevant to the eleven aspects for Jerseys vs. other breeds were extracted and analysed by Dr. John Morton, veterinary epidemiological consultant. Summaries of these data may be found in relevant sections of this report and in the appendices.

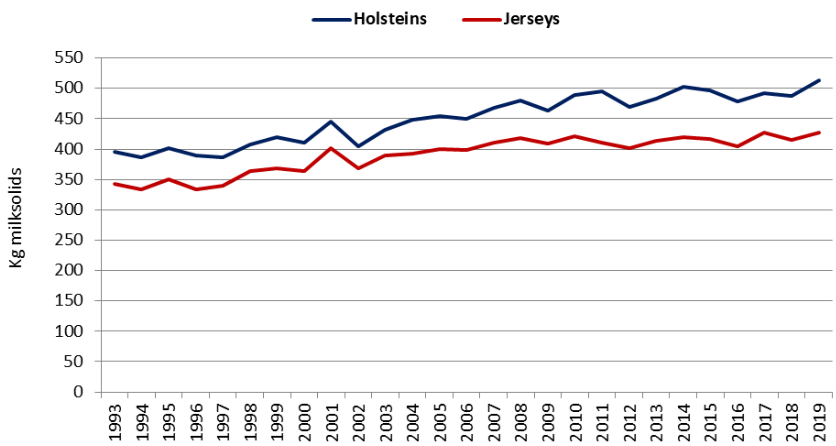
1. Milk yield, composition and market suitability

Key points:
- Holsteins produce more milksolids per cow per year than Jerseys
- The composition of milk differs between breeds, but many other factors also influence it
- Fat and protein concentrations in milk of Jerseys are higher than those of Holsteins by about 1.1-1.4 g/100ml and 0.5-0.56 g/100ml respectively
- The concentrations of fatty acids in milk fat differ between breeds but are small relative to those between different stages of lactation
- Jersey milk fat contains a higher proportion of short and medium-chain fatty acids and a lower proportion of C16:1, C18:1, and conjugated linoleic acid (CLA)
- Whether Jerseys are less susceptible to milk fat depression (MFD) than Holsteins under the same feeding management and environmental conditions is uncertain
- The amino acid (AA) profile of Jersey milk does not differ significantly from other breeds
- Jersey milk has higher concentrations of calcium, phosphorus and zinc than Holstein milk and a lower concentration of potassium

Milk yield

When respondents to the Jersey Australia survey were asked to give their level of agreement with the statement *'Jerseys produce more milk solids than other breeds*': 98% agreed or strongly agreed, and 2% disagreed or strongly disagreed.

Holsteins certainly produce more kilograms of milksolids per cow per year than Jerseys in seasonal/split calving herds and year-round calving herds, as shown by Australian herd recording data held by DataGene (Figure 1a,b). For further details, see Appendix A.



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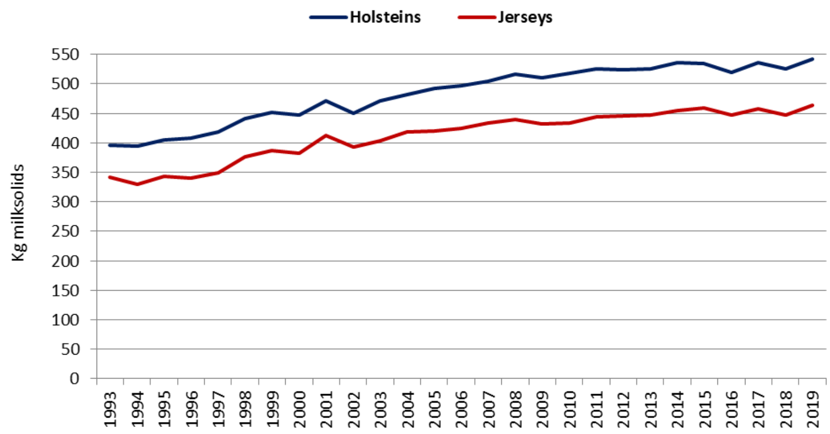


(b)

Figure 1. Average 305-day milksolids yield (kg) per cow by calving system, breed and year for **(a)** seasonal/split calving herds, and **(b)** year-round calving herds [DataGene, 2021].

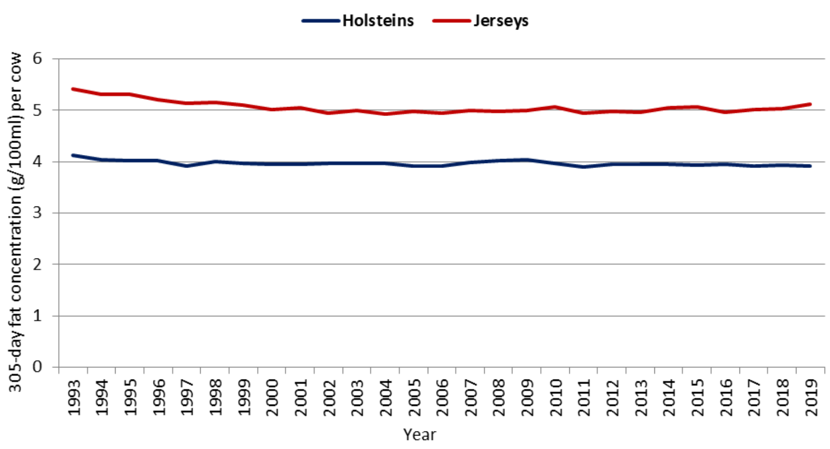
Milk composition

The composition of milk varies due to breed, physiological, husbandry and seasonal factors [Soyeurt *et al.,* 2006; Palladino *et al.,* 2010], lactation stage [Craninx *et al.*, 2008; Stoop *et al.*, 2009], age [Haile-Mariam and Pryce 2015], animal health [Goncalves et al. 2020], nutrition [Larsen *et al.*, 2010], milking interval [Quist *et al.*, 2008], on-farm storage [Forsback *et al.*, 2011] and seasonal changes [Heck *et al.*, 2009; Li *et al.,* 2019].

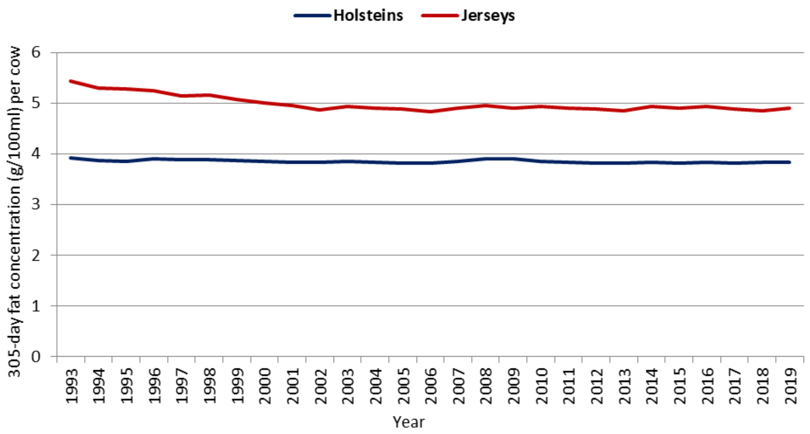
Fat and protein concentrations

Concentrations of fat and protein are higher in milk produced by Jersey cows than by Holstein-Jersey cross-bred cows and Holstein cows [Beaulieu and Palmquist, 1995; Rastani *et al.*, 2001; White *et al.*, 2001; Palladino *et al.*, 2010].

In Australia, based on herd recording data held by DataGene, the mean difference in the concentrations of fat in milk between Jersey cows and Holstein cows over a period of 27 years (1993 to 2019) was 1.1 g/100 ml in seasonal/split herds and 1.14 g/100 ml in year-round calving herds (Figure 2a,b).



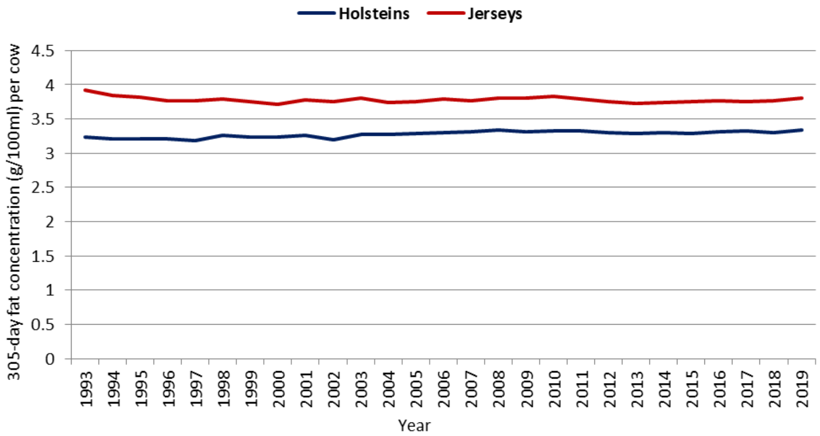
(a)



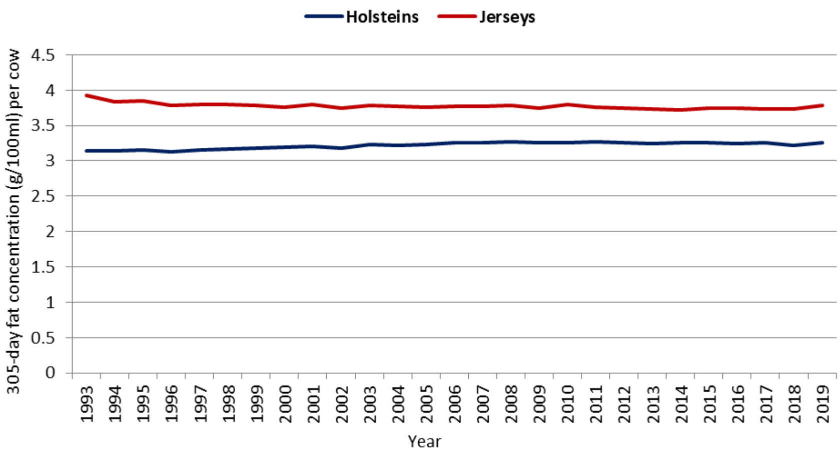
(b)

Figure 2. Average 305-day fat concentration (g/100 mL) per cow by calving system, breed and year for **(a)** seasonal/split calving herds, and **(b)** year-round calving herds [DataGene, 2021].

The mean difference in the concentrations of protein in milk between Jersey cows and Holstein cows over a period of 27 years (1993 to 2019) was about 0.5 g/100 ml in seasonal/split herds and 0.56 g/100 ml in year-round calving herds (Figure 3a,b).



(a)



(b)

Figure 3. Average 305-day protein concentration (g/100 mL) per cow by calving system, breed and year for **(a)** seasonal/split calving herds, and **(b)** year-round calving herds [DataGene, 2021].

Fatty acid profile of milk fat

Milk fat comprises a large number of individual fatty acids (FAs). About 70% of total milk FAs have no double bounds, i.e. saturated FAs (SFAs), 25% of FAs have one double bound, i.e., mono unsaturated FAs (MUFAs) and about 5% of FAs have multiple double bounds, i.e. poly unsaturated FAs (PUFAs). The groups of fatty acids and indices can be confusing. Table 2 is therefore provided [Van Eijndhoven, 2014].

Table 2. Groups of fatty acids and indices [from Van Eijndhoven, 2014].

Group	**Fatty acids**
Saturated fatty acids	C4:0; C5:0; C6:0; C7:0; C8:0; C9:0; C10:0; C11:0; C12:0; C14:0 *iso*; C14:0; C15:0 *iso*; C15:0 *ante iso*; C15:0; C16:0 *iso*; C16:0; C17:0 *iso*; C17:0 *ante iso*; C17:0; C18:0; C19:0; C20:0
Unsaturated fatty acids	C10:1; C12:1; C14:1; C16:1; C17:1; C20:3 *cis*-8-11-14; C18unsat
C6-12	C6:0; C8:0; C10:0; C12:0
C14-16	C14:0; C16:0
C18 unsaturated (unsat)	C18:1 *trans*-6; C18:1 *trans*-9; C18:1 *trans*-10; C18:1 *trans*-11; C18:1 *trans*-12; C18:1 *cis*-9; C18:1 *cis*-11; C18:1 *cis*-12; C18:2 *cis*-9-12; C18:3 *cis*-9-12-15; C18:2 *cis*-9; *trans*-11 (CLA)
C18 *trans*	C18:1 *trans*-6; C18:1 *trans*-9; C18:1 *trans*-10; C18:1 *trans*-11; C18:1 *trans*-12
n-3	All omega 3 fatty acids
n-6	All omega 6 fatty acids
Branched	C14:0 *iso*; C15:0 *iso*; C15:0 *ante iso*; C16:0 *iso*; C17:0 *iso*; C17:0 *ante iso*
Unsaturation index	(C10:1 + C12:1 + C14:1 + C16:1 + C17:1 + C18:1 cis-9 + C18:2 cis-9, trans-11) / (C10:0 + C10:1 + C12:0 + C12:1 + C14:0 + C14:1 + C16:0 + C16:1 + C17:0 + C17:1 + C18:0 + C18:1 cis-9 + C18:2 cis-9, trans-11)
Unsaturation index C12	C12:1 / (C12:0 + C12:1)
Unsaturation index C14	C14:1 / (C14:0 + C14:1)
Unsaturation index C16	C16:1 / (C16:0 + C16:1)
Unsaturation index C18	C18unsat / (C18:0 + C18unsat)

The concentrations of individual fatty acids in milk fat are influenced by cow breed [DePeters *et al.*, 1995; Croissant *et al.*, 2007], stage of lactation [Craninx *et al.*, 2008; Nantapo *et al.*, 2014], energy balance [Auldist *et al.*, 1998], genetics [Soyeurt *et al.*, 2007], diet and udder health. Diet is especially relevant when comparing concentrate-fed and pasture-based systems. Milk fatty acid composition in pasture-based systems is, additionally, subject to seasonal variations that influence the quantity and quality of available forages.

Differences have been found in the concentrations of fatty acids in the milk fat of Jersey vs. Holstein cows fed the same diet under the same environmental conditions. However, these differences between breeds are small relative to those between different stages of lactation. Furthermore, the range of values between individual cows for concentrations of all fatty acids in milk is greater than the variation across five selected breeds [Soyeurt *et al.*, 2006].

Jersey milk fat contains a higher proportion of short-chain fatty acids (C4:0, C6:0, and C8:0) and medium-chain fatty acids (C10:0, C12:0, and C14:0) than Holstein milk fat, and a lower proportion of C16:1, C18:1, and conjugated linoleic acid (CLA) (Table 3) [DePeters *et al.*, 1995; White *et al.*, 2001; Bainbridge *et al.*, 2016]. Jerseys have been found to produce slightly less CLAs than Holsteins in grazing and housed dairy production systems [White *et al.*, 2001; Palladino *et al.*, 2010].

Table 3. Content (g/kg milk) of major fatty acids in milk from three breeds of dairy cow over four time points; 5 days in milk (DIM), 95 DIM, 185 DIM, 275 DIM [Bainbridge *et al.,* 2016].

	Time Point													*P* Value		
	5 DIM			95 DIM			185 DIM			275 DIM			SE			
Fatty acid	HO	JE	CB	HO	JE	CB	HO	JE	CB	HO	JE	CB		B[g]	T[h]	B x T[i]
4:0	1.95	1.86	1.67	1.11	1.50	1.24	1.19	1.62	1.18	1.22	1.70	1.27	0.08	***	***	*
6:0	0.77	0.70	0.69	0.70	1.04	0.81	0.79	1.14	0.80	0.79	1.17	0.85	0.05	***	***	***
8:0	0.32	0.30	0.31	0.41	0.63	0.48	0.48	0.71	0.48	0.47	0.72	0.52	0.03	***	***	***
10:0	0.58	0.54	0.57	0.97	1.57	1.16	1.15	1.75	1.19	1.15	1.77	1.29	0.08	***	***	***
12:0	0.61	0.54	0.62	1.18	1.92	1.42	1.45	2.22	1.50	1.48	2.26	1.66	0.10	***	***	***
14:0	3.45	2.96	2.99	4.19	5.70	4.65	4.85	6.54	4.80	5.09	6.97	5.50	0.25	***	***	***
14:1 *c*9	0.14	0.09	0.12	0.30	0.34	0.35	0.39	0.51	0.42	0.42	0.52	0.49	0.03	NS	***	**
16:0	10.41	8.90	9.51	12.57	16.32	13.76	14.00	19.09	13.81	14.52	20.42	15.75	0.85	**	***	***
16:1 *c*9	0.64	0.45	0.56	0.61	0.58	0.63	0.61	0.83	0.66	0.68	0.89	0.80	0.07	NS	***	**
18:0	5.12	5.58	4.82	3.59	4.73	3.58	3.39	4.70	3.26	3.40	5.08	3.47	0.27	***	***	NS
18:1 *t*9	0.06	0.05	0.05	0.08	0.09	0.08	0.07	0.09	0.07	0.06	0.08	0.07	0.00	**	***	ƚ
18:1 *t*10	0.19	0.15	0.16	0.12	0.12	0.12	0.10	0.13	0.10	0.09	0.11	0.09	0.02	NS	***	NS
18:1 *t*11	0.57	0.47	0.63	0.39	0.44	0.37	0.34	0.41	0.29	0.35	0.44	0.31	0.04	NS	***	**
18:1 *t*12	0.10	0.08	0.09	0.13	0.14	0.12	0.11	0.14	0.11	0.10	0.13	0.10	0.01	*	***	*
18:1 *t*13/*t*14	3.90	3.86	3.32	0.16	0.24	0.18	0.16	0.23	0.16	0.17	0.22	0.15	0.28	NS	***	NS
18:1 *c*9	6.21	5.17	5.41	7.15	6.25	6.68	6.80	7.53	6.43	6.75	7.82	7.02	0.48	**	*	NS
18:2 *c*9,*c*12	0.59	0.65	0.58	0.60	0.64	0.60	0.61	0.72	0.59	0.56	0.71	0.61	0.05	*	NS	NS
18:3 *c*9,*c*12,*c*15	0.21	0.14	0.27	0.15	0.15	0.16	0.15	0.17	0.14	0.17	0.19	0.16	0.02	NS	**	*
18:2 *c*9,*t*11	0.21	0.14	0.21	0.19	0.16	0.18	0.17	0.17	0.15	0.18	0.18	0.17	0.02	NS	NS	NS
20:5 *c*5,*c*8,*c*11,*c*14,*c*17	0.03	0.02	0.04	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	ƚ	***	***
22:5 *c*7,*c*10,*c*13,*c*16,*c*19	0.06	0.04	0.06	0.03	0.03	0.04	0.03	0.02	0.03	0.02	0.02	0.02	0.00	NS	***	NS
22:6 *c*4,*c*7,*c*10,*c*13,*c*16,*c*19	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*	***	**
Unknown	0.22	0.15	0.21	0.26	0.27	0.24	0.18	0.23	0.19	0.21	0.28	0.20	0.02	NS	***	***
De novo	8.22	7.28	7.32	9.61	13.59	10.88	11.09	15.57	11.13	11.40	16.20	12.37	0.61	***	***	***
Mixed	11.23	9.49	10.22	13.28	17.00	14.49	14.71	20.02	14.55	15.29	21.42	16.65	0.89	**	***	***
Preformed	19.47	18.20	17.54	14.44	14.92	13.93	13.66	16.39	12.98	13.59	17.10	13.92	1.07	ƚ	***	NS
Total SFA[b]	24.09	22.08	21.94	25.85	34.76	28.26	28.47	39.36	28.15	29.29	41.71	31.52	1.48	***	***	***
Total MUFA[c]	13.03	11.35	11.36	9.94	9.16	9.48	9.44	10.87	9.06	9.45	11.20	9.88	0.83	NS	**	NS
Total PUFA	1.44	1.26	1.48	1.32	1.35	1.34	1.30	1.49	1.23	1.31	1.54	1.32	0.10	NS	NS	NS
Total 18:1 *trans*	1.01	0.83	1.02	0.82	0.91	0.80	0.72	0.89	0.67	0.69	0.86	0.66	0.06	NS	***	*
Total n-6 FA[d]	0.69	0.78	0.67	0.69	0.75	0.70	0.73	0.86	0.70	0.68	0.86	0.73	0.05	*	NS	NS
Total n-3 FA[e]	0.33	0.21	0.38	0.20	0.20	0.22	0.19	0.22	0.18	0.22	0.24	0.21	0.03	NS	***	**
n-6:n-3 ratio	2.19	3.75	1.98	3.51	3.69	3.23	3.78	4.03	3.79	3.15	3.74	3.47	0.19	***	***	*
Total CLA[f]	0.23	0.15	0.22	0.20	0.16	0.19	0.18	0.18	0.16	0.19	0.19	0.18	0.02	NS	NS	NS

[a]Least-sqaures (LS) means are based on n = 7 Holstein (HO), n = 8 Jersey (JE), and n = 7 HO x JE crossbreeds (CB).

[b]Total SFA: all saturated fatty acid (4:0 to 26:0).

[c]Total MUFA: all monounsaturated fatty acids (14:1 to 24:1).

[d]Total n-6 FA: all n-6 fatty acids; 18:2 *c*9,*c*12; 18:3 *c*6,*c*8,*c*12; 20:2 *c*11,*c*14; 20:3 *c*8,*c*11,*c*14; 20:4 *c*5,*c*8,*c*11,*c*14; and 22:4 *c*7,*c*10,*c*13,*c*16.

[e]Total n-3 FA: all n-3 fatty acids; 18:3 *c*9,*c*12,*c*15; 20:3 *c*11,*c*14,*c*17; 20:5 *c*5,*c*8,*c*11,*c*14,*c*17; 22:5 *c*7,*c*10,*c*13,*c*16,*c*19; and 22:6 *c*4,*c*7,*c*10,*c*13,*c*16,*c*19.

[f]Total CLA: all detected conjugated linoleic acid isomers: 18:2 *c*9,*t*11, 18:2 *t*11,*t*13, and 18:2 *t*7,*t*9/18:2 *t*10,*t*12.

[g]Breed effect.

[h]Time point effect.

[i]Breed x time point interaction.

ƚ $0.05 \leq P < 0.10$

*$P<0.05$

**$P<0.01$

***$P<0.001$, NS = Not significant

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Milk fat depression (MFD)

Milk fat depression (MFD) tends to occur in grazing systems when cows consume substantial quantities of fresh, high quality pasture rich in polyunsaturated fatty acids (PUFA). Incomplete bio-hydrogenation of excessive dietary PUFAs by rumen microbes leads to synthesis of many alternate CLA isomers, including trans-10, cis-12 CLA; trans-9, cis-11; and cis-10, trans-12, that are transported to the mammary gland where they impair the production of essential fat synthesis enzymes, inhibiting milk fat synthesis [Baumgard, 2001; Harvatine *et al.*, 2008; Jenkins *et al.*, 2014; Lock, 2010]. MFD is caused not only by the presence of significant levels of PUFAs in the rumen, but also by alterations in rumen fermentation involving both the microbial fermentation of dietary carbohydrates and the microbial bio-hydrogenation of fatty acids. Only a very small amount of trans-10, cis-12 CLA is required to reduce the milk fat concentration by 25%.

There is currently no definitive evidence available as to whether Jerseys are more or less susceptible to MFD than other breeds. Assessing any breed differences is difficult due to the high level of variation (threefold) in PUFAs and CLA between animals fed the same diet. The activity of the enzyme Δ^9-desaturase is key to understanding the differences in milk CLA between animals and breeds, as it converts vaccenic acid to CLA [Lock and Garnsworthy, 2003]. Kelly et al. (1998) found that between-animal variation in Δ^9-desaturase activity was higher in grazing and housed dairy production systems, meaning that any differences between breeds would be harder to detect in grazing systems. More research is required on the effect of heterosis on milk fatty acid (FA) concentration [Palladino *et al.*, 2010].

In the absence of any evidence on how different breeds respond to high MFD risk diets, it is worth considering how they respond to fat supplementation. Sears *et al.* (2020) conducted a study to understand how palmitic acid supplementation affected milk fat yield and composition in Holstein and Jersey cows. (Previous studies of responses to palmitic acid supplementation had only involved Holstein cows). They found that feeding palmitic acid consistently increased milk fat content and yield in both Holstein and Jersey cows. Jersey cows were more efficient at converting supplemental fat added into additional milk fat yield than Holsteins (36% vs. 21% respectively). Sears *et al.* (2020) concluded that this was due to differences in mammary gland extraction and incorporation of fatty acids into milk fat, as they did not observe any treatment or breed differences in fatty acid digestibility.

To understand if there are any breed differences in susceptibility to MFD it would be useful to conduct research studies in which lactating Jersey cows and Holstein cows managed under identical conditions were fed the same diets with low and high risk of MFD. Cows participating in each study would need to be at similar days in milk and milk yields. Given the large between-animal variability in susceptibility to MFD, these research studies would require large numbers of cows to enable any statistically significant breed difference to be identified. Another approach to understand if there are any breed differences in susceptibility to MFD would be to conduct a survey of commercial mixed-breed herds that had suffered periods of MFD. Herds recruited would need to be able to provide detailed, individual cow data on milk components, ideally recorded daily by an in-parlour milk metering system. Jersey cows and cows of other breeds within each of these herds that were at a similar stage of lactation and level of production would be selected, and their milk fat concentrations analysed to see if they are significantly different.

Casein

Casein is the predominate protein group in milk (about 80%), with whey protein making up the remaining 20%. Casein forms the building blocks of large colloidal particles called casein micelles that provide insoluble calcium phosphate to the suckling calf [Timlin *et al.*, 2021]. Beta-casein is the second most abundant protein in cows' milk, comprising 209 amino acids. The two main variants of beta-casein are A1 and A2, that differ at only one position in their amino acid sequence, position 67, which is histidine in A1 or proline in A2 milk. A1 beta-casein is a major form of beta-casein found in the milk of dairy breeds originating in northern European such as the Holstein, Friesian, Ayrshire and British Shorthorn. A2 beta-casein is found predominantly in the milk of Channel Island cows, Guernsey and Jersey, in Southern French breeds, Charolais and Limousin, and in the Zebu original cattle of Africa [Truswell, 2005]. Interest in 'A2' milk, produced by cows that only have alpha-2 casein and no alpha-1 casein, was generated in the early-mid 1990s when concerns were raised by researchers about a breakdown product of alpha-1 casein, beta-casomorphin-7 (BCM-7), could be associated with type I diabetes and may also be a risk factor for coronary heart disease [Truswell, 2005].

Amino acids

Csapo *et al.* (2011) and Lim *et al.* (2020) found that the amino acid (AA) profile of milk did not differ significantly between breeds, and that the higher concentrations of essential AA concentrations in Jersey milk compared to Holstein milk were a function of the higher protein level of Jersey milk.

Minerals

Differences between breeds in the mineral concentration of milk have been well studied. Lim *et al.* (2020) found that the concentrations of calcium, phosphorus and zinc were higher in Jersey milk than in Holstein milk, while the potassium concentration was lower. However, for cows of any particular breed, mineral concentrations in milk also vary widely between individual cows within a herd, and between herds [Cerbulis and Farrell, 1976; Rodriguez *et al.,* 2001].

Milk market suitability

When respondents to the Jersey Australia survey were asked to give their level of agreement with the statement *'Jerseys provide access to more milk markets than other breeds'*, 67% agreed or strongly agreed, 12% disagreed or strongly disagreed, and 21% were unsure.

Milk composition influences the processing attributes of milk i.e. casein micelle size, heat stability, buffering capacity, rennet coagulation time and ethanol stability [Chen *et al.*, 2016]. Studies are inconsistent as to whether Jersey milk has better heat stability than Holstein milk. The higher levels of protein and fat found in Jersey and Guernsey milks results in higher cheese yields and a deeper yellow colour. Jersey milk, with its lower ratio of casein to fat, may be more suitable for bloomy rind cheeses, while Brown Swiss milk, with its higher ratio of casein to fat, may be more suitable for aged hard cheese [Wendorrf and Paulus*,* 2011]. While Jersey milk is supplied around the world into liquid milk and powdered milk markets, there are also opportunities to differentiate Jersey milk in cheese, butter and other products.

Fatty acids from a human health perspective

There is increasing interest in the potential human health benefits that may be gained from consuming bioactive fatty acids such as α-linolenic acid (ALA; 18:3 c9,c12,c15), conjugated linoleic acids (CLAs), and vaccenic acid (VA; 18:1 t11), from milk and dairy products [Bainbridge *et al.*, 2016]. Higher dietary intakes of ALA has been associated with decreased inflammation, neurological disorders and cardiovascular disease, CLAs have been shown to have anti-carcinogenic effects and VA has been found to have anti-carcinogenic effects and reduce cardiovascular disease. Higher dietary intakes of several saturated fatty acids in milk have also been found to have human health benefits. Palmitic acid (16:0), Stearic acid (18:0) and very-long-chain saturated fatty acids (>22 carbon atoms) have been associated with decreased insulin sensitivity, reduced cardiovascular disease and lower the risk of diabetes respectively. However, a moderate-high dietary intakes of myristic acid (14:0) have been associated with higher plasma high-density lipoprotein level, a risk factor for cardiovascular disease. Branched-chain fatty acids (BCFA) have also been found to have anti-carcinogenic properties and help improve pancreatic function. BCFAs are unique in that they are only synthesised in the cell walls of rumen bacteria and protozoa. Their use as potential biomarkers for rumen function has therefore been suggested [Fievez *et al.,* 2012]. The content and profile of BCFA in milk fat depends on the activity and composition of the rumen microbial population, which is a function of diet and cow breed.

The bioactive fatty acid profile of milk is influenced by animal genetics, stage of lactation, diet and environment. Bainbridge *et al.* (2016) compared the fatty acid profile of milk (g/100g FA) and the concentration of fatty acids in milk (g/kg milk) by stage of lactation and breed in Holstein, Jersey and HJ crossbred cows fed the same diet. They found that stage of lactation was the predominant factor affecting the FA content of milk. However, there were also differences between breeds (Table 4). The content of OBCFA and BCFA in milk fat from Jersey cows increased at each time point, whereas the content of OBCFA in Holsteins did not differ across the lactation. Overall, milk from Jersey cows had a greater content of n-6 FA than Holsteins and crossbreds (0.81 vs. 0.70 and 0.70 g/kg milk, respectively) resulting in higher n-6:n-3 ratio when compared to Holsteins and crossbreds at 5 DIM.

Table 4. Content (g/kg milk) of odd and branched-chain fatty acids (OBCFA) in milk from three breeds of dairy cow over four time points; 5 days in milk (DIM), 95 DIM, 185 DIM, 275 DIM [Bainbridge *et al.,* 2016].

	Time Point													*P* Value		
	5 DIM			95 DIM			185 DIM			275 DIM			SE			
Fatty acid	**HO**	**JE**	**CB**	**HO**	**JE**	**CB**	**HO**	**JE**	**CB**	**HO**	**JE**	**CB**		**B**[f]	**T**[g]	**B x T**[h]
5:0	0.02	0.01	0.01	0.02	0.01	0.02	0.03	0.04	0.03	0.02	0.03	0.02	0.00	NS	***	*
7:0	0.01	0.00	0.01	0.01	0.02	0.02	0.01	0.02	0.01	0.01	0.02	0.01	0.00	NS	***	*
9:0	0.01	0.00	0.01	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.01	0.00	*	***	NS
11:0	0.03	0.02	0.03	0.09	0.12	0.10	0.11	0.16	0.12	0.12	0.17	0.13	0.01	***	***	**
13:0	0.03	0.02	0.02	0.08	0.11	0.09	0.09	0.13	0.09	0.09	0.13	0.10	0.01	**	***	**
***iso*-13:0**	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.00	NS	***	NS
***anteiso*-13:0**	0.01	0.01	0.01	0.02	0.04	0.03	0.04	0.05	0.04	0.04	0.06	0.05	0.00	**	***	*
***iso*-14:0**	0.03	0.03	0.03	0.03	0.06	0.05	0.04	0.07	0.05	0.06	0.08	0.07	0.00	***	***	***
15:0	0.32	0.25	0.28	0.52	0.59	0.52	0.52	0.68	0.50	0.53	0.72	0.53	0.03	**	***	**
***iso*-15:0**	0.09	0.07	0.07	0.08	0.09	0.08	0.08	0.10	0.08	0.10	0.13	0.10	0.00	**	***	***
***anteiso*-15:0**	0.13	0.11	0.12	0.18	0.18	0.17	0.18	0.21	0.17	0.20	0.25	0.21	0.00	ŧ	***	**
***iso*-16:0**	0.11	0.09	0.09	0.08	0.13	0.10	0.11	0.18	0.11	0.14	0.21	0.17	0.01	***	***	***
17:0	0.38	0.31	0.32	0.29	0.32	0.29	0.28	0.37	0.28	0.29	0.39	0.31	0.02	*	*	**
***iso*-17:0**	0.15	0.12	0.14	0.13	0.12	0.12	0.11	0.13	0.11	0.12	0.14	0.13	0.01	NS	**	*
***anteiso*-17:0**	0.17	0.15	0.13	0.04	0.05	0.04	0.06	0.06	0.04	0.03	0.04	0.04	0.01	NS	***	NS
17:1 c9	0.18	0.12	0.13	0.09	0.07	0.08	0.08	0.09	0.07	0.08	0.09	0.08	0.01	NS	***	*
***iso*-18:0**	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	NS	*	NS
Total OBCFA	2.28	1.82	1.92	2.19	2.50	2.24	2.32	2.96	2.22	2.42	3.21	2.55	0.11	**	***	***
Total BCFA[b]	0.70	0.58	0.59	0.57	0.69	0.61	0.65	0.82	0.62	0.71	0.94	0.78	0.03	**	***	***
Total OCFA[c]	1.59	1.24	1.33	1.62	1.81	1.63	1.67	2.14	1.60	1.71	2.27	1.77	0.09	**	***	***
Total *iso* BCFA[d]	0.39	0.32	0.34	0.33	0.42	0.37	0.36	0.50	0.37	0.43	0.59	0.48	0.02	**	***	***
Total *anteiso* BCFA[e]	0.31	0.26	0.25	0.24	0.27	0.24	0.29	0.32	0.26	0.28	0.35	0.30	0.02	*	***	**

[a]Least-sqaures (LS) means are based on n = 7 Holstein (HO), n = 8 Jersey (JE), and n = 7 HO x JE crossbreeds (CB).
[b]Total BCFA: all branched-chain fatty acids (*iso*-13:0 to *iso*-18:0 and *anteiso*-13:0 to *anteiso*-17:0).
[c]Total OCFA: all odd-chain fatty acids (5:0 to 17:0).
[d]Total *iso* BCFA: all *iso* branched-chain fatty acids (*iso*-13:0 to *iso*-18:0).
[e]Total *anteiso* BCFA: all *anteiso* branched-chain fatty acids (*anteiso*-13:0 to *anteiso*17:0).
[f]Breed effect.
[g]Time point effect.
[h]Breed x time point interaction.
ŧ 0.05≤*P*<0.10
**P*<0.05
***P*<0.01
****P*<0.001, NS = Not significant.

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2. Production efficiency

Key points:

- Studies have found that Jerseys produce 6-11% more energy-corrected milk (ECM) than Holsteins per kilogram of dry matter intake, and 26-31% more ECM per 100 kg bodyweight than Holsteins. Jerseys are also 8% more energetically efficiency
- Jersey cows' higher production efficiency is due to reduction and dilution of their daily maintenance energy requirement
- Jerseys are performing well in mixed breed herds

When respondents to the Jersey Australia survey were asked to give their level of agreement with the statement *'Jerseys convert feed into milk more efficiently than other breeds'*: 96% agreed or strongly agreed, 2% disagreed or strongly disagreed, and 2% were unsure.

Production efficiency may be expressed and measured in many different ways. Two of the most common measures are the amount of milk solids (MS) or energy corrected milk yield (ECM) per unit of dry matter (DM) intake, and the amount of milk solids (MS) or energy corrected milk yield (ECM) per 100kg bodyweight (BW).

Grainger and Goddard (2004) compiled the results of research studies described in eleven scientific papers and reported that feed conversion efficiency (g MS/kg DM) was generally higher (8 out of 11 comparisons) for the Jersey compared with the Holstein and Friesian cows, averaging about 6.4% higher. (For more details, see Appendix B, Table B.1).

More recent studies confirm the conclusions of Grainger and Goddard (2004) that Jerseys use feed more efficiently than Holsteins. Beecher *et al.* (2014) found that feed conversion efficiency (g MS/kg DM) of Jerseys on an entirely pasture diet was 16% higher than that of Holsteins. Milk solids yield (kilograms of fat and protein) per 100 kg BW was 0.27 kg for Holsteins but 0.35 kg for Jerseys with the crossbred being intermediate.

A Danish study by Kristensen *et al.* (2015) compared the efficiency of Holstein, Jersey and other breeds in herds where cows were fed either a total mixed ration or a partial mixed ration and housed in loose housing systems. Jerseys were found to have higher efficiency for six efficiency measures for energy and production, namely:

- Total energy requirement in percent of NEL intake (NELEFF)
- Residual feed intake (RFI)
- Kilograms of ECM per 10 MJ of NEL (ECMNEL)
- Kilograms of ECM per kilogram of DMI (ECMDMI)
- Kilograms of ECM per 100 kg of live weight (ECMBW)
- Kilograms of DM per 100 kg of live weight (DMIBW)

As shown in Table 5., Kristensen *et al.* (2015) found that Jerseys produced 8% more energy-corrected milk (ECM) than Holsteins per kilogram of dry matter intake, and 31% more ECM per 100 kg bodyweight than Holsteins. Jerseys were also 8% more energetically efficient, as measured in kg ECM per 10 MJ of net energy for lactation (NE_L).

Table 5. Efficiency measures for energy, production, and environmental load in the group of lactating cows in commercial herds of different breeds [Kristensen *et al.*, 2015].

	Holstein-Friesian		Jersey		Other	
Item[1]	Mean	SD	Mean	SD	Mean	SD
Energy						
NELEFF, %	95.6[b]	4.7	97.8[a]	4.4	95.8[b]	4.8
Residual feed intake, MJ of NE_L	6.4[a]	6.9	2.8[b]	5.4	6.0[a]	6.6
Production						
ECMNEL, kg of ECM per 10 MJ of NE_L	2.09[b]	0.15	2.25[a]	0.13	2.07[b]	0.16
ECMDMI, kg of ECM per kg of DMI	1.35[b]	0.11	1.46[a]	0.10	1.34[b]	0.12
ECMBW, kg of ECM per 100 kg of LW	5.06[b]	0.55	6.65[a]	0.63	4.97[b]	0.66
DMIBW, kg of DM per 100 kg of LW	3.76[b]	0.30	4.56[a]	0.36	3.72[b]	0.32
Environment						
N efficiency, %	27.5	2.3	27.3	2.5	27.4	2.4
ECMCH4, kg of ECM per MJ of CH_4	1.12[b]	0.10	1.26[a]	0.18	1.11[b]	0.11

[a,b]Means with identical superscripts are not significantly ($P > 0.05$) different.
[1]NELEFF = total energy requirement in percent of NE_L intake; LW = live weight.

An Irish, pasture-based study by Prendiville *et al.* (2009) found similar results to Kristensen *et al.* (2015). Jerseys produced 11% more energy-corrected milk (ECM) than Holsteins per kilogram of dry matter intake, and 29% more ECM per 100 kg bodyweight than Holsteins. (Table 6.).

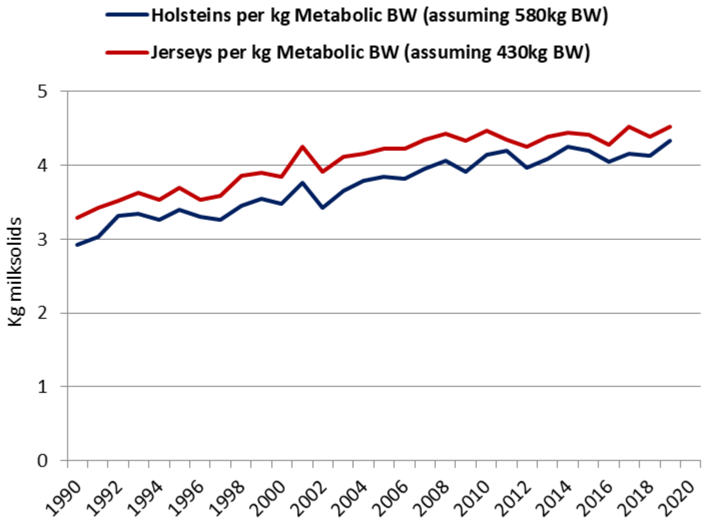
Table 6. Effect of dairy cow breed on total DMI, corresponding energy intake, and gross efficiency measures [Prendiville *et al.*, 2009].

	Breed group				
Trait	HF	J	F_1	SEM[2]	*P*-value
Total DMI (kg)	16.9[a]	14.7[b]	16.2[a]	0.23	<0.001
Energy intake (UFL[3])	17.8[a]	15.6[b]	17.1[a]	0.24	<0.001
TDMI[4]/100 kg of BW (kg)	3.39[a]	3.99[b]	3.63[c]	0.05	<0.01
SCM/100 kg of BW (kg)	3.41[a]	4.30[b]	3.95[c]	0.07	<0.01
Milk solids/100 kg of BW (kg)	0.27[a]	0.35[b]	0.32[c]	0.06	<0.001
Milk solids/TDMI (kg)	0.079[a]	0.088[b]	0.087[b]	0.0011	<0.001

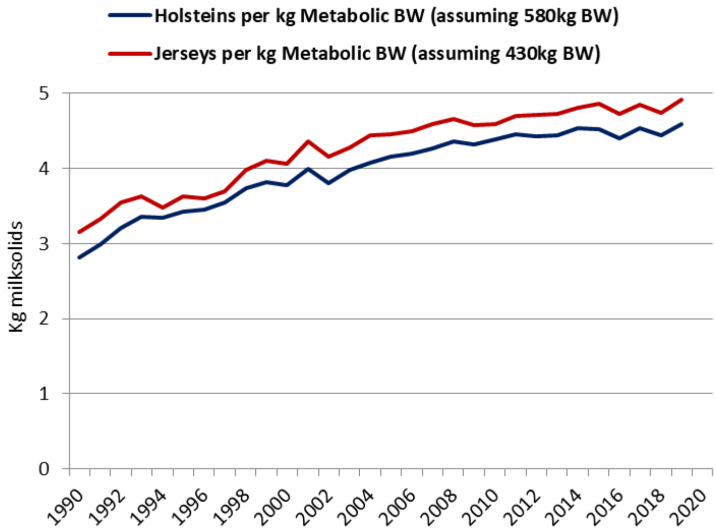
[a–c]Means within a row with different superscripts differ ($P < 0.05$).
[1]HF = Holstein-Friesian; J = Jersey; F_1 = Jersey × Holstein-Friesian.
[2]SEM = pooled SEM.
[3]One UFL is defined as the net energy content of 1 kg of standard barley for milk production (O'Mara, 2000).
[4]TDMI = total DMI.

Milk production per kg metabolic bodyweight (calculated as body weight to the power of 0.75 ($BW^{0.75}$) is more useful than milk production per 100 kg, as it is an estimation of the amount of metabolically active tissue in a cow's body upon which its energy expenditure and basal metabolic rate depend.

Analysis of Australian herd recording data held by DataGene shows that Jerseys produce approximately 9% more milksolids per unit metabolic bodyweight ($BW^{0.75}$) than Holsteins (Figure 4a,b).



(a)



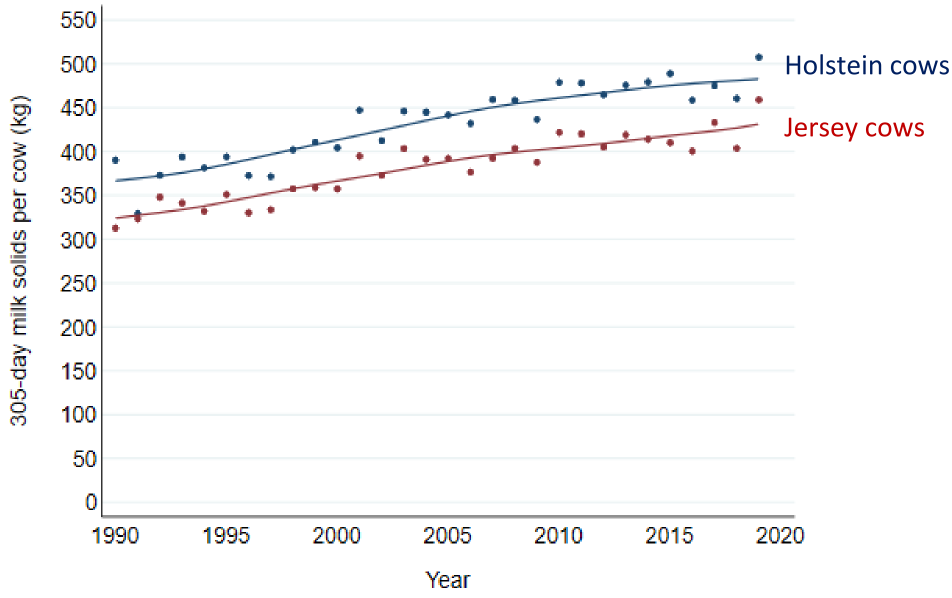
(b)

Figure 4. Average 305-day milk solids per kg metabolic bodyweight ($BW^{0.75}$) for cows by year in **(a)** seasonal and split calving herds, and **(b)** year-round calving herds [DataGene, 2021].

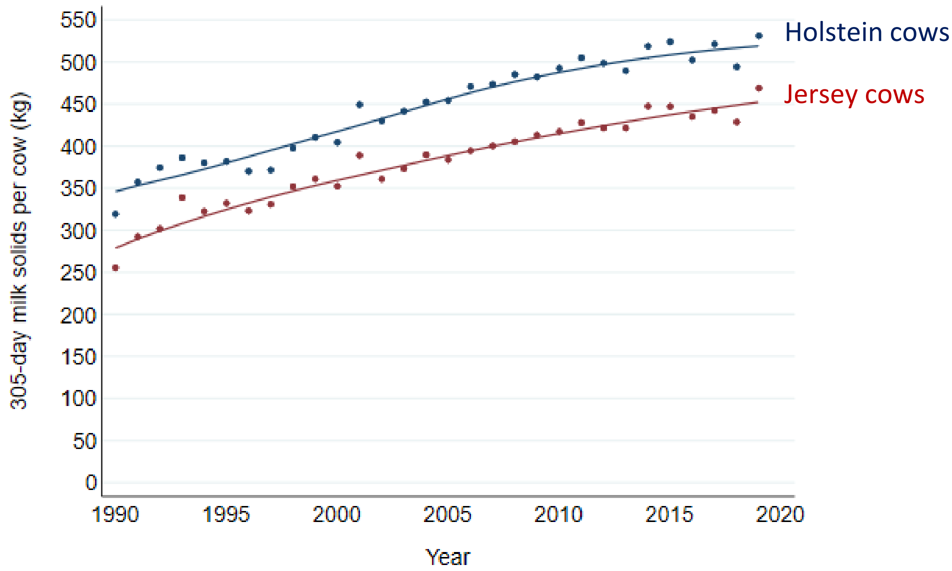
Energy balances provide a detailed measure of partitioning of energy within the cow, but energy metabolism studies comparing breeds are scarce. Grainger and Goddard (2004) reviewed three studies and found that in two of those studies, heat production was lower in Jerseys, but there were no differences between Jerseys and Holsteins in the more recent study conducted by Tyrrell *et al.* (1990). More recently, Dong *et al.* (2015) conducted a meta-analysis on 935 observations that were collated from 32 calorimetric chamber experiments undertaken between 1992 and 2010 at the Agri-Food and Biosciences Institute at Hillsborough, UK. Most of the observations were from Holstein cows, but in a comparison of Holstein versus non-Holstein (includes Norwegian, Jersey X Holstein and Norwegian X Holstein), there was no significant effect between the two different groups of dairy cows on the efficiencies of metabolisable energy use for maintenance or lactation.

Jersey cow performance in mixed-breed herds

Some respondents to the Jersey Australia survey expressed concern about how well Jersey cows competed with Holstein cows in mixed-breed herds. Australian herd recording data held by DataGene suggest that Jersey cows perform well alongside other cows in mixed-breed herds, as the difference between milk solids production per cow per year of Jersey cows and Holstein cows in mixed-breed herds from 1990 to 2019 has remained fairly constant over many years (Figure 5a,b).



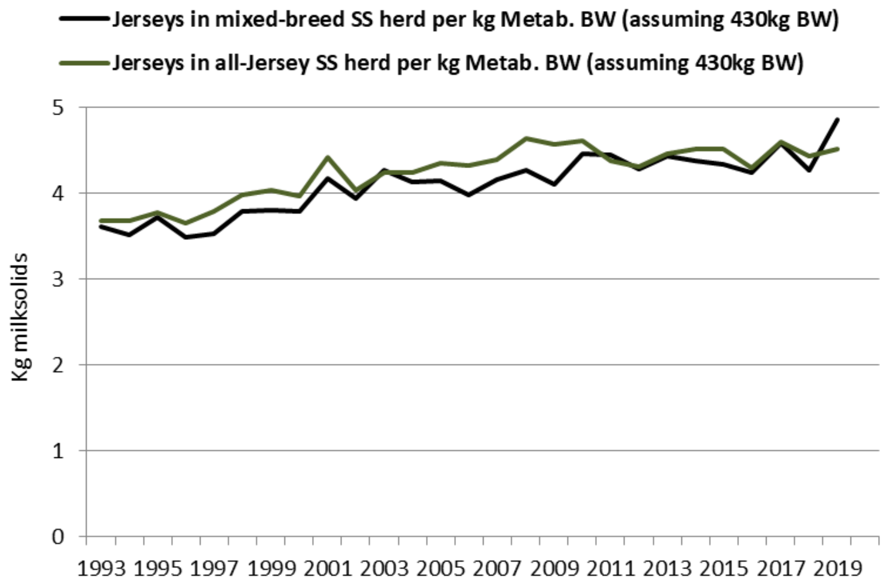
(a)



(b)

Figure 5. Average 305-day milk solids per cow for cows by year for **(a)** mixed-breed seasonal and split calving herds, and **(b)** mixed-breed year-round calving herds. Blue points and line of best fit represent Holstein cows in mixed-breed herds. Red points and line represent Jersey cows in mixed-breed herds [DataGene, 2021].

However, Australian herd recording data held by DataGene from 1993 to 2019 suggest that Jersey cows in straight Jersey herds tend to produce more milk solids per year than Jerseys in mixed-breed herds. There could be many factors contributing to this difference. (Figure 6a,b).



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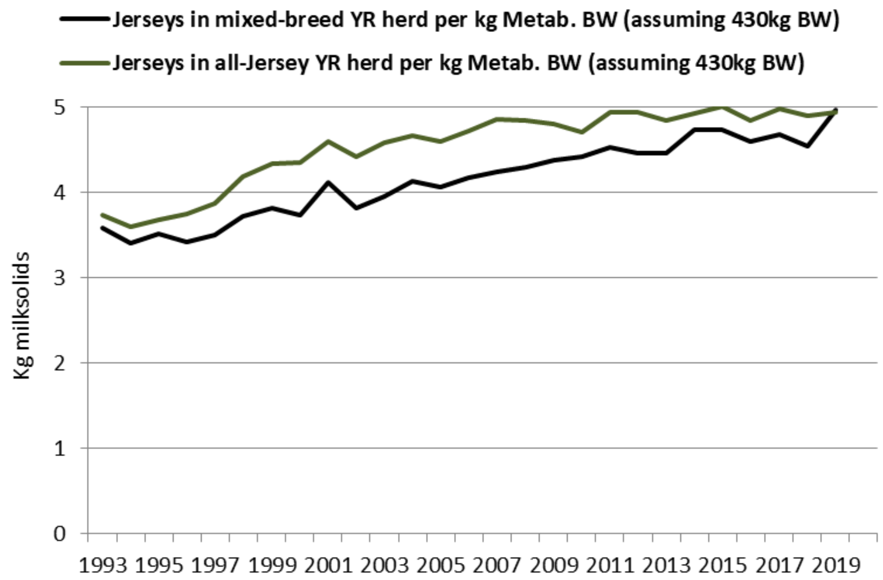


(b)

Figure 6. Average 305-day milk solids per kg metabolic bodyweight ($BW^{0.75}$) for cows per year for **(a)** Jersey cows in mixed-breed vs. all-Jersey seasonal and split calving herds, and **(b)** Jersey cows in mixed-breed vs. all-Jersey year-round calving herds [DataGene, 2021].

3. Feed intake, eating behaviour and feed digestibility

Key points:

- Jerseys have about 14-21% higher feed intake capacity than Holsteins per 100 kg bodyweight and 5% per unit metabolic bodyweight. This may be due to their larger gastrointestinal tract per kg body weight, higher rate of particle breakdown within the rumen and higher fractional outflow rate of digesta from the rumen
- Jerseys spend more time grazing and ruminating per unit of ingested feed and distribute meals more evenly throughout each 24-hour period, providing a more regular supply of feed to the rumen
- NDF digestibility is higher in Jerseys, despite their higher gut passage rate

Feed intake

Grainger and Goddard (2004) reviewed 11 part and whole lactation studies conducted between 1986 and 2001: five in the USA, three in Europe and five in New Zealand that compared the feed intake of Holsteins-Friesians and Jerseys. They found that in every one of these studies, Jerseys ate more total dry matter (DM) per 100kg bodyweight than Holstein-Friesian cows, ranging from 4.3% to 23.5% more, averaging about 14.2% more. When intake was expressed as DM per kg metabolic bodyweight, Jersey cows still ate 5.1% more than Holstein-Friesian cows. (For more details, see Appendix B, Table B.1). The differences between the breeds were smaller in New Zealand studies, probably because pasture diets were not offered *ad libitum*, whereas in European and USA studies, TMR diets would have been offered *ad libitum*, exaggerating the differences in DM intake. Kristensen *et al.* (2015) found that Jerseys ate 21% more total DM per 100 kg bodyweight than Holsteins. Prendiville *et al.* (2009) reported similar results: Jerseys ate 18% more total DM per 100 kg bodyweight than Holsteins. Sears *et al.* (2020) found in their study of multiparous, mid-lactation cows fed a TMR that the DM intake of Jersey cows was 4.90% of BW, while that of Holsteins was 3.37% of BW.

The higher feed intake capacity of Jersey cows may be explained by their greater weight of gastrointestinal tract per kg body weight compared with Holstein cows. Smith and Baldwin (1974) found that the total weight of gastro-intestinal tract of Holstein cows was only 0.88 or 0.95 that of Jersey cows, expressed per kg bodyweight or per kg metabolic bodyweight respectively. Several researchers have found that Jerseys have a larger gastrointestinal tract per unit bodyweight than Holsteins [Smith and Baldwin, 1974; Lewis, Thackaberry and Buckley, 2011]. Nagel and Piatkowski (1988) reported that the rumen/reticulum of Holstein cows weighed 0.8 that of Jersey cows per kg metabolic bodyweight. Beecher *et al.* (2014) found that the gastrointestinal tract weight, when expressed as a proportion of bodyweight, was 142.5 g/kg bodyweight in Jerseys and 128.8 g/kg bodyweight in Holsteins. (Jerseys also had heavier heart, lungs and pancreas than Holsteins per unit bodyweight). These findings suggest that Jersey cows have a greater capacity to consume roughage per unit bodyweight than Holsteins. Furthermore, Jersey cows often have a higher rate of particle breakdown within the rumen than Holstein cows and higher fractional outflow rate of digesta from the rumen [Aikman *et al.*, 2008]. This could facilitate the Jersey's higher relative intake capacity. In grazing systems, Jerseys have also demonstrated the capability to eat as much supplemental concentrate as Holsteins at three different feeding levels (6.8, 4.5, and 2.3 kg/cow per feeding) during measured feeding times of 2.5 to 15 min [White, 2000; White *et al.*, 2000].

Eating behaviour

Several studies have provided data on differences in the eating behaviour of different breeds that may be associated with DM intake capacity and production efficiency. Prendiville *et al.* (2009) investigated differences in grazing behaviour among Holstein, Jersey and Jersey X Holstein cows under an intensive seasonal grass-based environment. They reported little differences among breeds for grazing time, number of grazing bouts, grazing bout duration and total number of bites. In absolute terms, Holstein cows had higher grass DM intake per bite and rate of intake per minute but Jersey cows had more grazing mastications. However when the grazing behaviour parameters were expressed both as per 100kg of BW or per kg DM intake, Jerseys had longer grazing times, and higher total bites, bite rate, and amount DM per bite [Prendiville *et al.*, 2010].

It is clear from the results obtained by Prendiville *et al.* (2010) that inherent grazing and ruminating differences do exist between cows varying in intake capacity and production efficiency. Furthermore, their results imply that Jersey cows with higher intake capacities have increased grazing time and rate of DM intake per unit of BW. Increased production efficiency, on the other hand, would appear to be aided in particular by improvements in mastication behaviour during grazing. Similarly, Vance *et al.* (2012) found that, when expressed on a metabolic BW basis, Jersey X Holstein crossbred cows had a higher DM intake than Holsteins, with this being facilitated by a longer time spent grazing and a greater number of grazing bites per day. They suggested that the smaller cross-bred cows had a greater 'grazing drive' that enabled them to compete with larger, Holstein herd-mates, and may be more capable of maintaining normal grazing behaviour in adverse weather conditions.

Aikman et al. (2008) compared the eating and rumination behaviour, rate of passage and diet digestibility of Jersey and Holstein cows fed a total mixed ration (TMR). They found that Jerseys spent more time eating and ruminating per unit of ingested feed than Holsteins and distributed their meals more evenly throughout each 24-hour period, providing a more regular supply of feed to the rumen. This was despite finding that the two breeds did not differ in DM intake per unit of BW.

When eating a mixed ration, dairy cows sort feed particles, usually in favour of smaller particles (grain, protein meals) and against longer forage components (i.e. straw, hay, silage) [Miller-Cushon and DeVries, 2017]. Perceived palatability of individual ration ingredients is likely to be a main driver of feed sorting, and sorting in favour of smaller particles is consistent with a preference for sweet flavours [Nombekela *et al.,* 1994]. However, cows have been shown to alter their feed preferences in favour of more physically effective forage particles when induced with sub-acute ruminal acidosis (SARA) [Maulfair *et al.*, 2013; Kmicikewzcz and Heinrichs, 2015]. The extent to which cows do this impacts on their intakes of intake of highly-fermentable carbohydrates and effective fibre, and therefore on rumen pH, milk composition and the risk of ruminal acidosis While differences between Jerseys and other breeds in feed sorting behaviour and preference for different ingredients when offered mixed rations have been observed in practice, they have not been investigated in controlled research studies. Knowledge on differences between Jerseys and other breeds in their eating rate, sorting behaviour and ingredient preferences would be useful to guide the feeding management of Jersey herds and Jersey cows within mixed-breed herds housed in confinement systems (freestall barns, compost bedded pack barns, dry-lots) in which TMRs are fed.

A series of short-term experiments could be conducted using an approach similar to that used by Sporndly *et al.* (2006). A measured quantity of a mixed ration with measured proportions of long fibrous ingredients (hay, silage), grains, protein meals, wet and dry by-products would be prepared. The ration would be passed through a set of sieves (Penn. State shaker box) prior to offering this ration to cows. After the meal commenced, it would be briefly interrupted at pre-set intervals and the sieving process repeated. Differences in the weight of feed particles held on each screen at each sieving would indicate the extent to which Jersey cows sorted in favour of smaller or larger particles during a meal compared to other breeds. Analysis of video recordings of cows' eating behaviour may also be useful.

Nutrient digestibility

Studies by Blake *et al.* (1986) and Ingvartsen and Weisbjerg (1993) found no differences in nutrient digestibility between dairy breeds when offered corn silage and concentrate blends and a total mixed ration respectively. However, Aikman *et al.* (2008) found that although Jersey cows had a shorter rumen retention time than Holsteins, neutral detergent fibre (NDF) digestibility was significantly higher (p=0.008). No significant differences were found in dry matter digestibility, starch digestibility and N digestibility. (For details, see Appendix C, Table C.1). Beecher *et al.* (2014) reported that for all digestibility parameters (dry matter, organic matter, nitrogen, NDF and ADF), the apparent, total tract digestibility of fresh-cut perennial ryegrass pasture was higher for Jerseys than Holsteins. This was despite Jerseys having a faster gut passage rate, and may be at least partly explained by the Jersey's larger gastrointestinal tract, and therefore larger area for nutrient absorption. Jerseys' feeding behaviour may also contribute to higher digestibility. Firstly, Jerseys have more evenly distributed meals across each day and spend more time eating and ruminating per kilogram of dry matter eaten. This may help to maintain a more stable rumen and reduce the likelihood of ruminal acidosis. Secondly, chewing feed for longer (Prendiville *et al.*, 2010) reduces it to smaller sized particles, so rumen microbes are provided with greater feed surface area for attachment and digestion.

Beecher *et al.* (2014) compared the relative abundance of several rumen microbial populations potentially involved in fibre digestion in Jerseys and Holsteins, but was unable to find any differences that would explain Jersey's higher digestibility. King *et al.* (2011) reported that although many rumen methanogen library sequences were common to both breeds of dairy cattle, there were more individual sequences in the library specific to the Holstein and less found in the Jersey library, highlighting increased diversity in the Holstein library. The possible differences in rumen microbial populations are likely to contribute to the production efficiency differences between Jerseys and Holsteins.

Sears *et al.* (2020) found in their study of multiparous, mid-lactation cows fed a TMR that while Jerseys consumed more nitrogen than Holsteins as a percent of BW (0.15% vs. 0.09% respectively), their blood urea nitrogen (BUN) level was lower (12.6 mg/dL vs. 13.8 mg/dL), as was their urine total nitrogen (124.5 g/day vs. 145 g/day). This indicated that Jersey cows were more efficient at utilising dietary nitrogen. (For details, see Appendix C, Table C.2). Previous studies by Blake *et al.* (1986), Kauffman and St-Pierre (2001) and Knowlton *et al.* (2010) suggested that Jersey cows excreted about 30% less faecal and urinary nitrogen than Holstein cows, but that this was due largely to differences in BW and DM intake rather than differences in nitrogen utilisation efficiency.

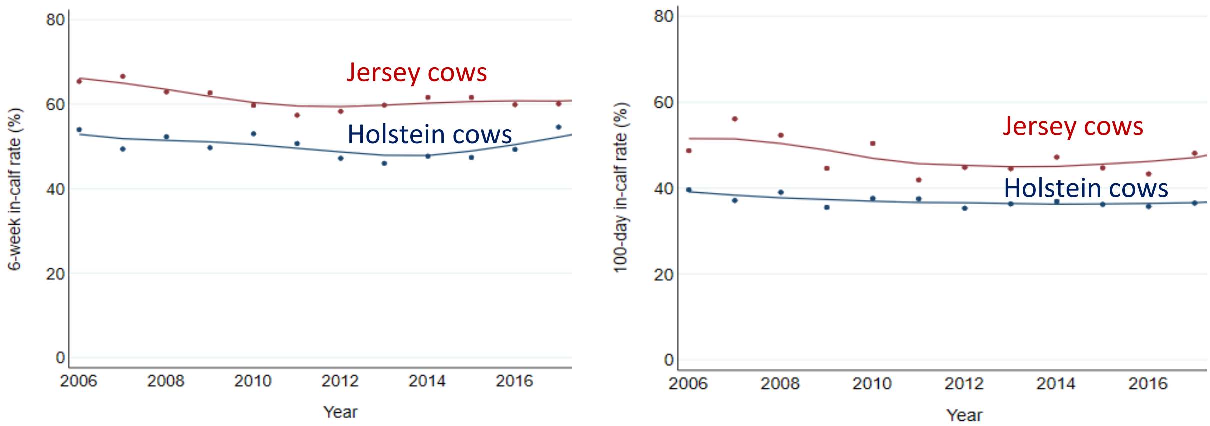
4. Fertility

Key points:

- Jerseys have higher fertility than Holsteins. This is likely to be due to genetic selection and energy metabolism, particularly in the transition period and early lactation
- The mean daughter fertility breeding value for sires of Jersey cows has been flat or declining for four decades, whereas that of sires of Holstein cows is now increasing. If these trajectories continue, the fertility advantage of Jerseys over Holsteins may be reduced
- Available evidence suggests that in the transition period and early lactation, Jerseys remain in negative energy balance (NEB) for a shorter period of time relative to Holsteins and that the magnitude of Jerseys’ NEB is less than that of Holsteins

When respondents were asked to give their level of agreement with the statement *‘Jerseys are more fertile than other breeds’*: 73% agreed or strongly agreed, 17% disagreed or strongly disagreed, and 10% were unsure.

It is well accepted globally that, generally, Jerseys have higher fertility than Holsteins. Analysis of Australian herd recording data held by DataGene shows that the reproductive performance of Jerseys has been consistently higher than that of Holsteins for many years (Figure 7a,b).



(a) **(b)**

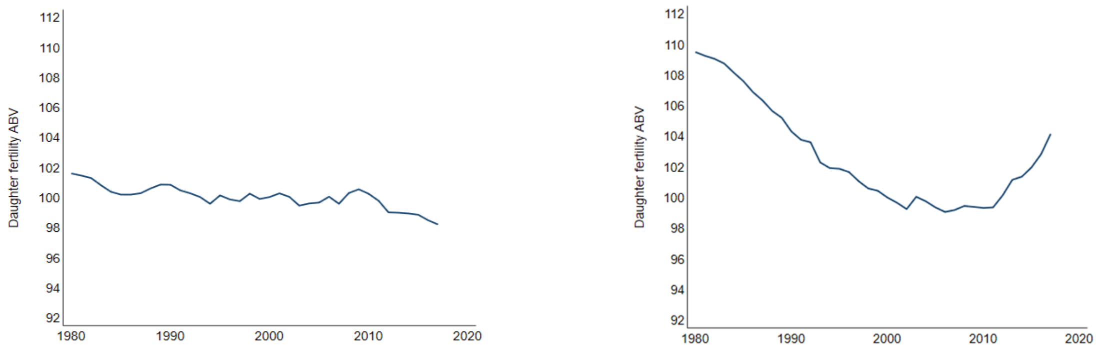
Figure 7. Reproductive performance of **(a)** seasonal/split calving herds in Australia, and **(b)** year-round calving herds. Blue points and line of best fit represent Holstein herds. Red points and line represent Jersey herds [DataGene, 2021].

Reproductive physiology

After calving, Jerseys return to oestrus sooner, often exhibit a stronger and better observed oestrus and remain in heat longer than Holsteins. They also breed back earlier with fewer services per conception and stay in the milking herd longer. There is very little available evidence of differences in the reproductive physiology between the two breeds that may contribute to these differences in fertility. The number of days to the involution of the cervix and uterus have been found to be similar in Holsteins and Jerseys [Fonseca *et al.*, 1983]. While Fonseca *et al.* (1983) found no significant difference in the progesterone profile of blood collected from the two breeds before or after insemination, a later study found that Holstein cows had a lower percentage of cows achieving >1 ng/ml progesterone in plasma by 30 days in milk than Jerseys, which is indicative of delayed return to oestrus and fewer successful pregnancies [Brown *et al.*, 2012]. Any differences in insulin, NEFA and IGF-1 levels in Jersey and Holstein cows observed by Brown *et al.* (2012) may have been more a reflection of the milk yield and energy balance in these animals.

Genetic selection

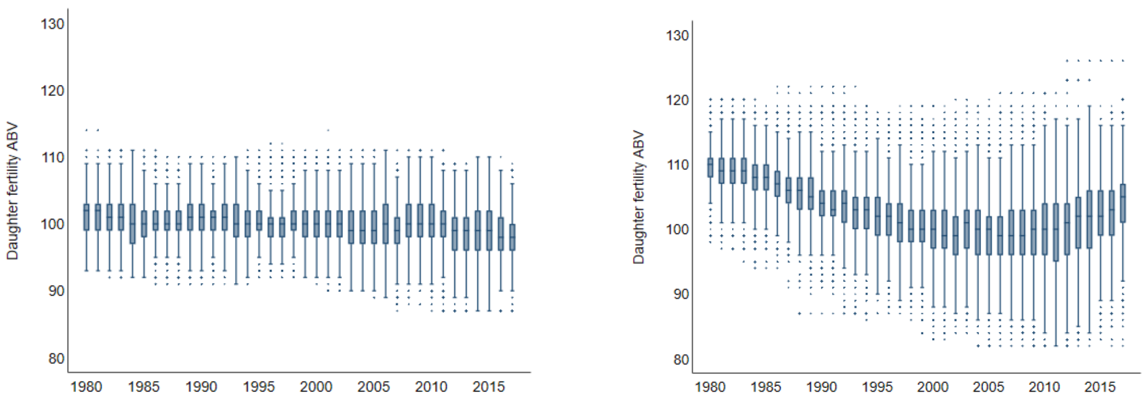
Rather than possible inherent differences between breeds in reproductive physiology, one of the main reasons why the fertility of Jerseys is superior to Holsteins is more likely be due to differences in genetic selection and energy metabolism, particularly in early lactation. Up until the 1970s the focus on selection in the dairy industry, particularly Holsteins, was solely on increasing milk production, followed later by selection for conformation. It is only within the past twenty years that the national selection indices of many countries, including several European countries, the United States, Canada, Australia and New Zealand, have become more balanced and fertility and health traits have been included [Miglior *et al.*, 2017]. The mean daughter fertility Australian breeding value for sires of Jersey cows has been on a flat to declining trajectory for the past four decades (Figure 8a). However, the Australian breeding value for sires of Holstein cows was adjusted in the early 2000s and the mean daughter fertility ABV is now on an upwards trajectory (Figure 8b). If these trajectories were to continue, it is possible that the fertility advantage of Jerseys over Holsteins may be reduced. The latest data from DataGene suggest that the mean daughter fertility Australian breeding value for sires of Jersey cows may have bottomed and be beginning to increase.



(a) **(b)**

Figure 8. Mean daughter fertility breeding value for sires of cows by cow's year of birth for **(a)** Jersey cows, and **(b)** Holstein cows, by cow's year of birth [DataGene, 2021].

The daughter fertility breeding values for sires of cows by cow's year of birth in both Holsteins and Jerseys are highly variable. However, they are become progressively more variable in Holsteins than in Jerseys (Figure 9a,b).



(a) **(b)**

Figure 9. Cow's sire daughter fertility breeding values for **(a)** Jersey cows, and **(b)** Holstein cows by cow's year of birth; boxes contain the central 50% of values for cows born in each year. [DataGene, 2021].

Energy balance

Energy balance during the transition period and early lactation is the major driver of reproductive success in dairy cows. When a freshly-calved cow has inadequate intake of metabolic fuels and is in negative energy balance (NEB), various hormonal signals from the pancreas, liver and fatty tissues such as insulin, IGF-1, leptin etc. are inhibited, leading to reduced secretion of gonadotropin in the brain, which leads to: no FSH and LH pulses & pre-ovulatory LH surge, reduced ovarian secretion of hormones (oestrogen, progesterone), inhibiting hormone-dependent reproductive behaviours, follicular development and ovulation. So NEB in early lactation, as exhibited by body condition loss post-calving, therefore manifests itself in more days to resumption of normal cycling activity, lower first service conception rate, and lower in-calf rates [Butler, 2003; LeRoy *et al.*, 2008]. The duration and the magnitude of negative energy balance in early lactation appear to both be important. As shown by Santos *et al.* (2010), the relationships between energy secreted in milk (i.e. milk yield) and energy balance, and between energy required for maintenance (body size) and energy balance, are very weak, whereas the relationship between energy intake (i.e. feed intake) and energy balance is fairly strong.

Few studies have been done that have compared energy balance in dairy cows of different breeds. Rastani *et al.* (2001) reported that in a confinement system Jerseys remained in NEB for a shorter period of time post-calving relative to Holsteins (8 weeks vs. 11 weeks) and that the magnitude of Jerseys' NEB was less than that of Holsteins. Jerseys had a greater EB for the first 7 weeks of lactation relative to Holsteins (Figure 10).

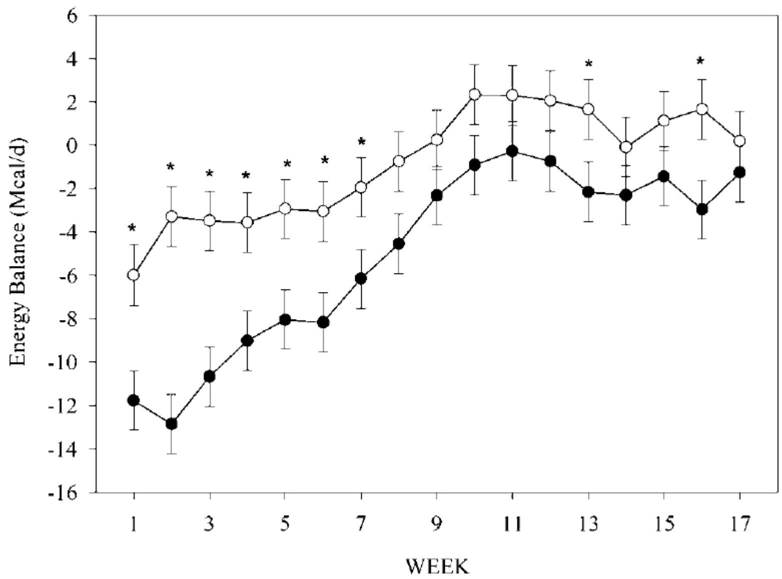


Figure 10. Estimated tissue energy balance of Jersey cows (○) and Holstein cows (●) from week 1 to week 17 of lactation. Tissue energy balances calculated according to NRC (1989). Asterisks indicate that the tissue energy balance differed ($P < 0.05$) between the two breeds at that time point [Rastani et al., 2001].

This is consistent with Brown *et al.* (2012), who found that plasma NEFA levels in second lactation cows were lower in Jerseys than in Holsteins. Washburn *et al*. (2002) conducted a multiple-year study in which groups of Jersey and Holstein cows were run in a pasture-based production system and a confinement system using a total mixed ration (TMR). They found that in each system, Jerseys had higher body condition scores (BCSs) than Holsteins cows throughout lactation, and that cows of both breeds in pasture-based system had lower BCSs than cows in the confinement system. They also found that the difference between the BCSs of Jerseys in the pasture-based system and the confinement system was less than that of Holsteins, indicating that Jerseys ate more than Holsteins relative to their body weight and milk production in the pasture-based system (Figure 11). However, in a study of first-calvers, Olson *et al.* (2010) found that Jerseys took 12.8 weeks post-calving to first enter positive energy balance whereas Holsteins took 9.8 weeks.

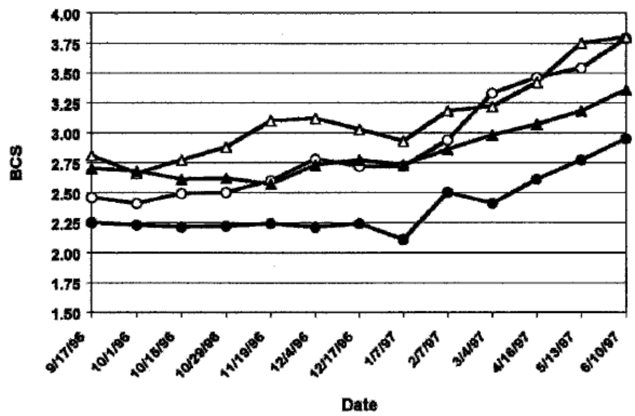


Figure 11. Mean BCS (5-point scale, Y-axis) across lactation for cows calving in fall, 1996. Four treatment and breed groups are identified as follows: Holsteins fed a TMR in confinement (○), Holsteins fed pasture plus supplement (●), Jerseys fed a TMR in confinement (Δ), and Jerseys fed pasture plus supplement (▲). In this example, treatment, breed, date, breed × date, treatment × date, and treatment × breed × date were all significant. (P < 0.05) [Washburn *et al.*, 2002].

The extent to which cows' appetites are depressed in the pre-calving transition period (last 3 weeks before calving) is important as it sets the trajectory for energy balance post-calving. French (2006) found that in a confinement system, while Holsteins' feed intake dropped 35% in the last 3 weeks before calving, Jerseys cows' feed intake only dropped 17%. NEFA concentrations in plasma were similar for the two breeds up to day 5 pre-calving, but greater for Holsteins compared with Jerseys thereafter. Energy balance was numerically greater for Holsteins at week 3 pre-calving, similar for breeds at week 2 pre-calving, and tended to be greater (P < 0.10) for Jerseys during the last 3 days pre-calving (Figure 12). (For charts of daily DM intake and plasma NEFA levels pre-calving from French *et al.*, see Appendix D, Figures D.1 and D.2).

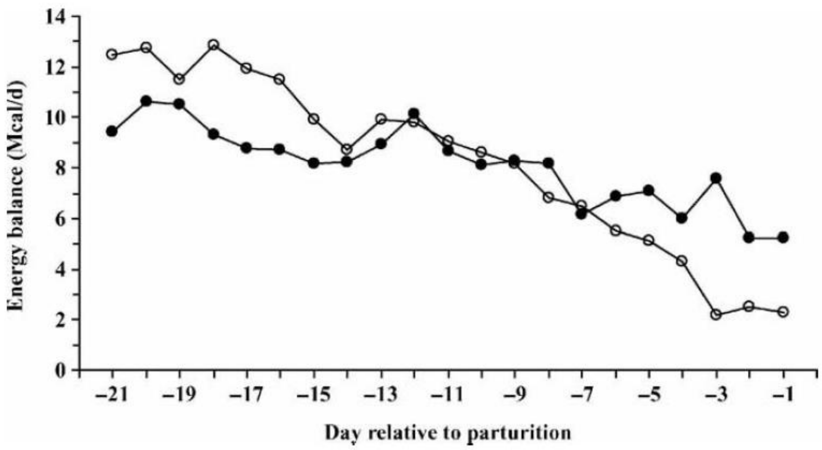


Figure 12. Least squares mean daily energy balance by day relative to parturition for Holsteins (○) and Jerseys (●). Interaction for breed by time was significant at the level of P < 0.01 (SE = 1.2, n = 14) [French, 2006].

Analysis of Australian herd recording data held by DataGene shows that post-calving, Jersey cows take more days to reach peak milk yield than Holstein cows of the same age. This is particularly so in cows aged between 4 to 9 years (Figure 13) (Table 7). This provides further indirect evidence to support the theory that Jerseys are less reliant on body tissue reserves than Holsteins to supply nutrients to support milk production in early lactation. More research is required to quantify and compare the feed intakes, milk yields and daily energy balances of Jerseys and Holsteins through the transition period and early lactation in grazing systems.

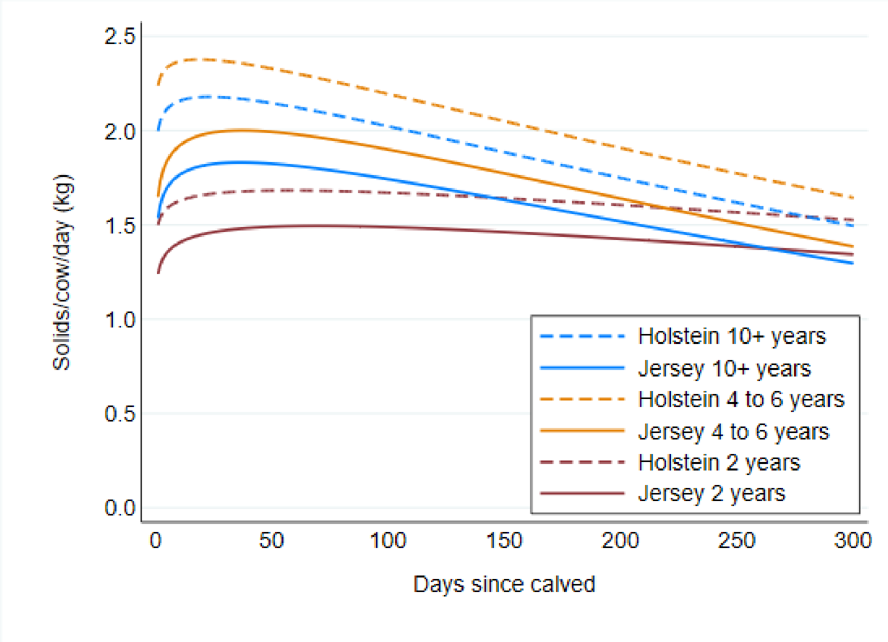


Figure 13. Lactation curves of Jersey and Holstein cows (kg milksolids/cow/day) of different age groups, based on test days up to 400 days in milk for cows calved from 2011 [DataGene, 2021].

Table 7. Summary data - peak solids yield and time to peak solids by breed and age group (DataGene, 2021)

Breed	Age at calving	No. test days	Day 1 milksolids yield (kg/cow/day)	Peak milksolids yield (kg/cow/day)	Time to peak yield (days)
JJJJ	2 years	158,375	1.24	1.49	69.7
FFFF	2 years	1,386,185	1.50	1.68	57.0
JJJJ	3 years	133,204	1.51	1.78	40.5
FFFF	3 years	1,134,749	1.92	2.06	25.1
JJJJ	4 to 6 years	282,395	1.65	2.00	37.1
FFFF	4 to 6 years	2,413,372	2.24	2.38	18.8
JJJJ	7 to 9 years	100,030	1.64	2.00	36.8
FFFF	7 to 9 years	891,265	2.22	2.38	19.9
JJJJ	10+ years	21,701	1.54	1.83	36.3
FFFF	10+ years	187,338	2.00	2.18	23.0

5. Health

Key points:
• Many Jersey breed associations claim that Jerseys suffer fewer health problems than Holsteins, including stillbirths, calving difficulties, metritis, mastitis, lameness. These claims are supported by several overseas surveys • However, Jersey cows are more predisposed to milk fever than Holsteins. (Milk fever risk is ≥ 2 times higher in Jerseys) • Australian herd data suggest that udder health of Jerseys is slightly better than that of Holsteins. Unfortunately, Australian herd data on specific health problems are not of sufficient quality to enable reliable analysis

When respondents to the Jersey Australia survey were asked to give their level of agreement with the statement 'Jerseys suffer fewer metabolic-related health problems around calving than other breeds', 49% agreed or strongly agreed, 42% disagreed or strongly disagreed, and 9% were unsure.

Many of the Jersey breed organisations report that Jerseys suffer fewer health problems than Holsteins. Jerseys have fewer stillbirths, lower calving difficulties and less metritis than other breeds (Jersey Australia, 2020). Jersey herds require fewer replacements because of less mastitis and lameness (JerseyNZ, 2020). USJersey (2016) also claim that Jerseys have a lower incidence of clinical mastitis, less disease and injury and fewer feet and leg problems which add up to a lower culling rate.

Several overseas surveys conducted since the late 1970s support many of these generalisations published by Jersey breed organisations: Erb and Martin, 1978; Morse *et al.*, 1987; Washburn *et al.*, 2002; Youngerman *et al.*, 2004; Berry *et al.*, 2007.

Calving difficulty, stillbirths and metritis

Jerseys are well-known for their ease of calving, which reduces labour and veterinary costs. For example, Dhakal *et al.* (2013) found that out of 139 multiparous Holstein cows, 7.2% needed assistance with a mean calf birthweight of 36.6 kg. Out of 89 multiparous Jersey cows, 3.4% needed assistance, with a mean calf birth weight of 25.0 kg. Several studies have also found decreased rates of calving difficulty with Jersey-sired cross-bred calves vs. Holstein calves, and with calves of cross-bred dams vs. purebred dams (Olsen *et al.*, 2009; Heins *et al.*, 2003; Heins *et al.*, 2006). Jersey heifers have fewer still births than Holstein heifers and subsequently less metritis (US Jersey, 2016).

Mastitis

In their relatively small study, Washburn *et al.* (2002) reported that Jerseys had half as many clinical cases of mastitis per cow as Holsteins. They also reported that Holsteins had higher culling rate and lower body condition scores than Jerseys. However in another study with small sample size, somatic cell score and incidence of mastitis were similar across the breeds, Jerseys and Holsteins [Prendiville *et al.,* 2010]. Berry *et al.* (2007) reported a much larger study involving over 2,500 lactations and found similar results to those of Washburn *et al.* (2002) in that Holsteins had a greater probability of clinical mastitis in mid or late lactation, compared to Jerseys. Bannerman *et al.* (2008) compared a number of innate immune parameters in Jersey and Holstein cows following intra-mammary infection by *Escherichia coli*, a leading cause of clinical mastitis. They were unable to find any differences between Jerseys and Holsteins in the innate immune response to intra-mammary infection. Olson *et al.* (2011) found that Jerseys were more likely to suffer mastitis than Holsteins but less likely to suffer ketosis, with odds ratios of 21.5 and 0.54 respectively).

Analysis of Australian herd recording data held by DataGene shows that individual cow cell counts (ICCC) of Jerseys are slightly lower than Holsteins, suggesting that udder health of Jerseys is slightly better than that of Holsteins (Figures 14, 15 and 16). (For further details see Appendix E, Tables E.1., E.2. and E.3).

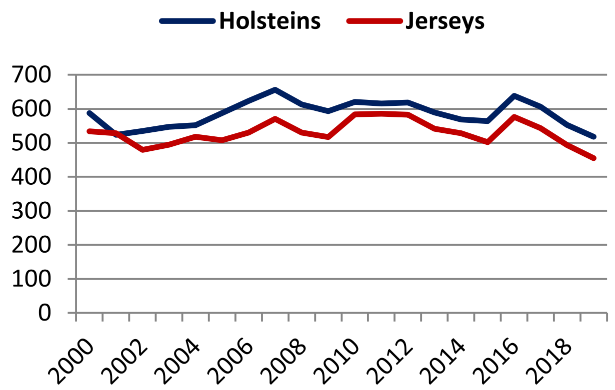


Figure 14. Averages of peak individual cow cell counts for lactations by 400 DIM. Blue line represents Holstein herds. Red line represents Jersey herds [DataGene, 2021].

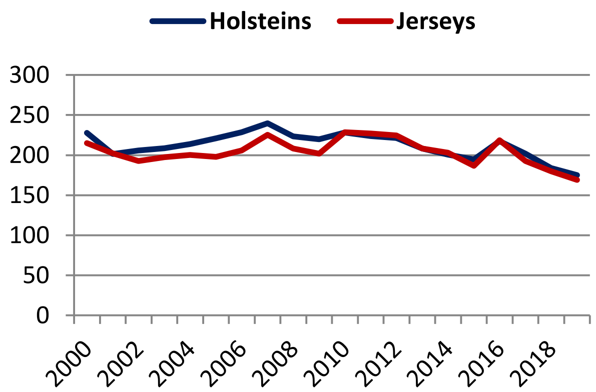


Figure 15. Averages of average individual cow cell counts for lactations by 400 DIM. Blue line represents Holstein herds. Red line represents Jersey herds [DataGene, 2021].

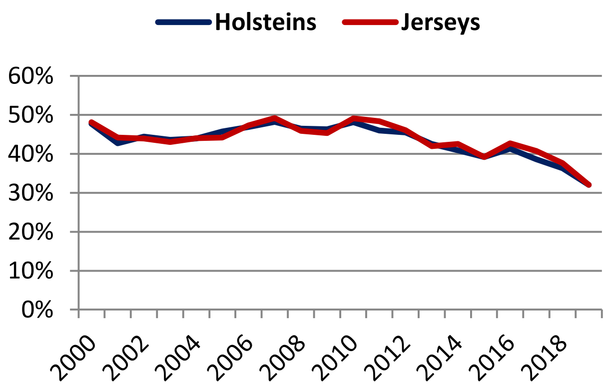


Figure 16. Percentages of lactations where the cow had at least one individual cow cell count >250,000 cells/mL by 400 DIM. Blue line represents Holstein herds. Red line represents Jersey herds [DataGene, 2021].

Ruminal acidosis

Jerseys may be less sensitive to ruminal acidosis than Holsteins. Further to a study by Luan *et al.* (2016), Xu *et al* (2017) measured changes in several systemic and molecular biomarkers of metabolism, inflammation, and oxidative stress in the hours following a grain challenge that induced sub-acute ruminal acidosis. Their findings suggest that Jerseys are better able to adapt than Holsteins following a grain challenge. As described previously, Jerseys' eating behaviour is different to that of Holsteins. Jerseys have more evenly distributed meals across each day and spend more time eating and ruminating per kilogram of dry matter eaten. This may help Jerseys to maintain a more stable rumen, reducing the likelihood of ruminal acidosis, and enable them to cope better with more highly fermentable diets than Holsteins.

Milk fever

Jerseys are more predisposed to milk fever than Holsteins. Clinical hypoglycaemia in dairy cattle, also known as milk fever, is a metabolic disease characterised by clinical symptoms due to a reduction of blood calcium concentration that usually affects high-yielding multiparous cows. The greater susceptibility of Jerseys to milk fever has been reported by many researchers. In a meta-analysis that involved a review of thirty five scientific papers that was conducted by Lean *et al.* (2006) to study dietary cation anion differences in hypocalcaemia, they found that Jersey cows were at 2.25 times higher risk of milk fever than Holstein cows. Likewise, Roche and Berry (2006) found that in grazing systems Jersey cows had 4.96 times the risk of suffering milk fever compared with Holstein cows. More recently, again in a grazing population, Saborio-Montero *et al.* (2017) reported that Jersey and Holstein cows had 3.04 and 1.61 times the risk of occurrence of milk fever compared with Brown Swiss breed cows. Furthermore, Santorio-Montero *et al.* (2018), in their study to estimate genetic effects for milk fever, reported that the observed incidence of milk fever was higher in Jerseys than in Holsteins. Jersey cows may be more predisposed to milk fever because they have fewer vitamin D3 receptors in their small intestine [Horst *et al.*, 1990; Goff, 2008]. There may also be other mechanisms that contribute [Prapong *et al.*, 2005]. Increased calcium concentrations in Jersey cow colostrum may be one [NRC, 2001].

Unfortunately, Australian herd recording data held by DataGene on the prevalence of specific health problems are not of sufficient quality to enable reliable analysis.

Acquisition of passive immunity by neonatal calves

Timely, adequate colostrum intake is the most important management factor affecting morbidity and mortality in pre-weaned calves. Quigley *et al.* (1998) raised the possibility that neonatal Jersey calves absorbed immunoglobulins at a slower rate than Holstein calves, but continued to absorb them for longer after birth. In a controlled experiment, Jones *et al.* (2004) administered the same quantities of colostrum of known quality to Jersey and Holstein calves per unit metabolic bodyweight using best management practices. They found that Jersey calves had higher 24-hour IgG concentrations than Holsteins (16.47 ± 0.71 and 11.12 ± 0.60 g/L), and absorbed IgG with 21.9 ± 0.9% efficiency compared with 17.0 ± 0.7% for Holsteins. Jersey calves also maintained greater plasma IgG concentrations than Holsteins from day 1 through day 15. A study by Ballou *et al.* (2012) in which 7-day old Jersey and Holstein calves were inoculated with Escherichia coli 0111:B4 LPS indicated that despite having greater passive transfer, after the neonatal period, Jersey calves have lower innate immune responses, with a lower rate of neutrophil oxidative burst and whole-blood killing capacity found. Ballou *et al.* (2012) concluded that Jersey calves may be at increased relative risk for morbidity during the immediate post-weaned period compared with Holstein calves. More research is required.

6. Heat tolerance

Key points:

- Jerseys are more heat tolerant than Holsteins, due to several factors related to their hair coat, skin structure, subcutaneous fat layer, and body surface area to volume ratio
- Under heat stress, the rumen microbiome of Jersey cows is altered, thereby enhancing heat stress resistance, whereas in Holstein cows it is not
- However, heat stressed Jersey cows may be potentially more susceptible to infections than Holsteins due to altered immune pathways

Ability to cope in hot conditions

When respondents to the Jersey Australia survey were asked to give their level of agreement with the statement 'Jerseys cope better in hot weather conditions than other breeds', 90% agreed or strongly agreed, 2% disagreed or strongly disagreed, and 8% were unsure.

Seath and Miller (1947) conducted one of the very early studies comparing Holsteins and Jerseys for heat tolerance and identified some significant differences. In their studies, the body temperature of Holsteins was about 0.4 °C higher than in Jerseys. In addition, the rate of increase of body temperature as the result of air temperature increase was greater for Holsteins than for Jerseys. There was little difference between the breeds on respiration or pulse rates. However, Harris et al. (1960) reported higher respiration rates and rectal temperatures in Holstein cows than in Jersey cows, under heat stress conditions.

Muller and Botha (1993) found that the rectal temperatures of Jersey cows were lower than those of the Friesian cows from 11:00 to 19:00, with the greatest difference (0.55°C) recorded at 15:00. The respiration rate of Jersey cows was lower than that of Friesian cows at 15:00, 17:00 and 19:00, with the greatest difference recorded at 15:00. (See Appendix F for further information).

West (2003) found that the rectal temperatures of Jerseys was 0.3°C lower under the same range of temperature humidity index (THI) than that of Holsteins. Similarly, *Liang et al.* (2013) found that in summer, mean daily reticulo-rumen temperature (DRT) of Jersey cows was lower than that of Holstein cows, adjusted for differences in milk yield.

Most recently, Kim *et al.* (2021) found that rectal temperatures increased significantly in Holstein cows under hot conditions but not in Jersey cows (Figure 17). Respiration rates of Holstein and Jersey cows increased significantly in hot conditions, but there was no significant difference between them.

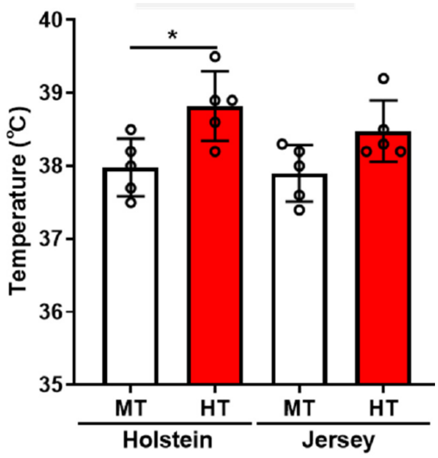


Figure 17. Physiological responses of Holstein and Jersey cows to differential seasonal environment. Measurements of rectal temperature for Holstein and Jersey cows in MT condition (THI = 69.6) and HT condition (THI = 87.5). Data are represented as mean ± SD; n = 5 animals/group. Values were statistically analysed by repeated measures two-way ANOVA with Tukey's multiple comparison test. * $p < 0.05$; MT = moderate THI season; HT = high THI season [Kim *et al.,* 2021].

Contributing factors

Many inherent factors have been identified that may contribute to different tolerances to heat stress between dairy breeds: body size and surface area, skin colour, sweating rate, respiration rate, and heat production [Finch, 1986; Kadzere *et al.*, 2002]. Muller and Botha (1993) reviewed the morphological differences between breeds related to coat colour, milk production levels and type and thickness of fatty layers under the skin that may account for tolerance levels to heat stress. They found that:

- Jersey cows generally have a lighter hair colour than Holstein cows and white or light-coloured hair affords some advantage in reflecting thermal radiation.
- Jersey cows have small, baggy sweat glands, resulting in a skin structure which is more characteristic of the *Bos indicus* breeds.
- Jersey cows seem to have shorter hair than Holstein cows and tolerance to heat stress increases when the hair coat is shorter.
- Holstein cows generally have more fat deposited beneath the skin which will impair heat loss.

Impacts on milk yield and composition

The air temperature/humidity level that triggers a drop in milk production and signs of animal distress is significantly higher for Jerseys that Holsteins. Smith *et al.* (2013) reported that Holstein milk yield declined during both moderate and severe heat stress whereas Jersey milk yield only declined during severe heat stress. Furthermore the Cool Cows document produced by Dairy Australia (2020) concluded that, of the European dairy breeds, the Brown Swiss and Jersey are least vulnerable to heat stress, followed by the Ayrshire and the Guernsey. The Holstein-Friesian was the most vulnerable dairy breed (Dairy Australia, 2020).

In a New Zealand study, reductions of greater than 10 g of milksolids day per unit increase in 3-day average temperature-humidity index (THI) were studied. In Holstein-Friesian cows, reductions started to occur at a 3-day average THI of 68, compared to 69 in HF x NZ Jersey cross-breeds, and 75 in NZ Jersey cattle [Bryant *et al.,* 2007]. Sharma *et al.* (1983) compared effects of heat stress on Jersey cow and Holstein cows. Jersey milk yields were less sensitive to high ambient temperatures than Holstein yields, but Jersey milk composition appeared more sensitive.

Impacts on ruminal microbiome and gene expression

Heat stress conditions alter the rumen microbiome of cows (Chen et al, 2018). More recently, detailed studies on the ruminal microbiome and gene expression of Holstein and Jersey cows may shed some light on further reasons for the greater heat tolerance of Jersey cows. Kim *et al.* (2020) determined the differences in the rumen microbiome of Holstein and Jersey cows on a mild spring day vs. a hot summer (maximum THI: 69.6 and 87.5 respectively). They found significant changes in rumen bacterial taxa and functional gene abundance in Jersey cows that may be associated with better adaptation ability of Jerseys to heat stress. In a later study to better understand the immune response of different dairy cattle breeds, Kim *et al.* (2021) found that there were breed-specific pathways in which gene expression was either increased by heat stress in Holsteins or down regulated by heat stress in Jersey cows. Collectively, there were both common and breed-specific altered genes and pathways in Holstein and Jersey cows [Kim *et al.,* 2021]. It is uncertain how much time a cow must be subjected to hot conditions before substantial changes to its rumen microbiome occur. However, it is likely to take several days.

Genetic selection for improved heat tolerance

Heat tolerance within each dairy breed is substantial [Garner *et al.*, 2016]. Genetic variation exists in the performance of dairy cows under heat stress conditions [Hayes *et al.*, 2003, Bohmanova *et al.,* 2007]. Heat tolerance in dairy cattle can be improved using genomic selection. Nguyen *et al.* (2016) derived genomic predictions for heat tolerance with an accuracy of 0.39 to 0.57 in Holsteins and 0.44 to 0.61 in Jerseys. Since then, a genomic breeding value for heat tolerance (HT GEBV) in Australian dairy cattle has been developed, validated and released [Nguyen *et al.*, 2016; Garner *et al.*, 2016; DataGene, 2017]. The reliability of the HT ABVg is moderate and comparable to that of other economically important traits such as Feed Saved.

Genetic trends for both Jerseys and Holsteins show a slight decline in heat tolerance over time. Between 1990 and 2011, the HT ABVg declined at a rate of 0.3% per year in both Jerseys and Holsteins. This is expected given that the correlation of heat tolerance with milk production is unfavourable [Nguyen *et al.*, 2018]. (See Appendix G for further information).

7. Longevity

Key points:

- Cow longevity (survival) in a herd has an important influence on the herd's production efficiency, profitability and environmental footprint
- Jerseys tend to live longer, producing longer, and survive to later lactations more frequent than Holsteins in single and mixed breed herds
- Increased longevity in a herd means the herd's mean milk production is higher and fewer non-productive replacement heifers are required

When respondents to the Jersey Australia survey were asked to give their level of agreement with the statement 'Jerseys remain productive for longer in the herd than other breeds': 66% agreed or strongly agreed, 19% disagreed or strongly disagreed, and 15% were unsure.

The length of a cow's productive life is determined by many inherent cow factors such as milk yield, health, reproductive status, and reproductive performance, and external factors such as milk price, salvage value, cost and availability of replacements. Ultimately, it is the farmer's culling strategy that determines how long a cow remains in the herd. Many different definitions and methods of measuring longevity have therefore been developed. These include age at last calving, number of lactations, length of life between first calving and culling, age at culling or removal, and survival to different ages [Van Doormaal *et al.*, 1985]. In their review, Schuster *et al.* (2020) recommended using the following terminology:

- Herd life (HL) - days from birth until culling
- Length of productive life (LPL) - days from first calving until culling
- Stayability or Survivability - the proportion of cows that survive to a specific age

In dairy production, cow longevity (survival) in a herd has an important influence on the herd's production efficiency, profitability and environmental footprint. Cows reach full maturity and produce the most milk in their fifth lactation [Grandl *et al.*, 2016]. With increased longevity in a herd, there is a greater proportion of mature cows in the herd and the herd's mean milk production is therefore higher. With increased longevity, a lower herd replacement rate is required, and therefore fewer non-productive replacement heifers are required, as illustrated in Table 8. [DeVries *et al.*, 2020].

Table 8. Number of replacement heifers a farm needs to rear per year (300 cow herd with 20% heifer non-completion rate) [Little, 2021].

Sensitivity Analysis:						
			Adult Cow Cull Rate			
	72	**22%**	**24%**	**26%**	**28%**	**30%**
	22	73	79	86	92	99
Age	**24**	79	86	94	101	108
First	**26**	86	94	101	109	117
Calving	**28**	92	101	109	118	126
	30	99	108	117	126	135

The length of productive life (years) of dairy cows differs between milk-producing countries, and this may be associated with the different production systems used, and the culling criteria applied in each production system in each country (Figure 18). Reproductive failure and health problems around calving are the most frequent reason for involuntary culling worldwide [DeVries *et al.*, 2020; Dallago *et al.*, 2021].

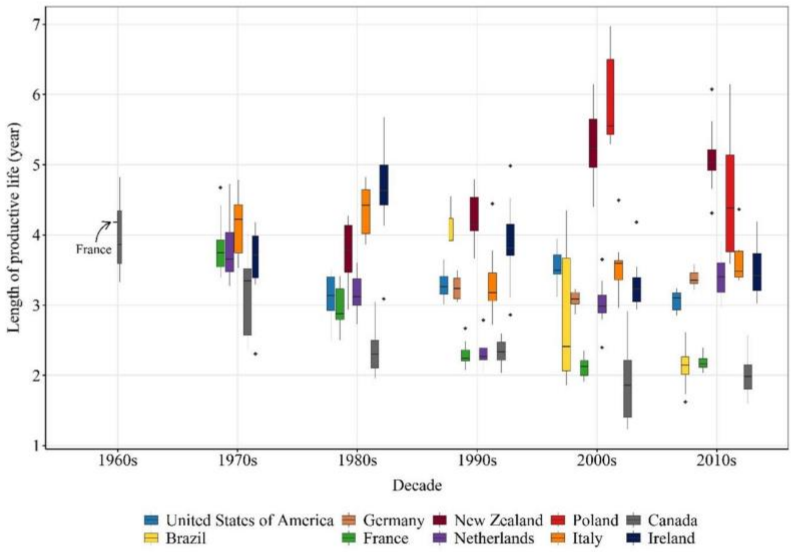


Figure 18. The length of productive life (years) of dairy cows from the top 10 high milk-producing countries by decade. The relative width of each box per country within decades represents the number of observations available to generate it. The wider the box, the more observations were available [Dallago *et al.*, 2021].

Many of the Jersey breed organisations report that Jersey cows have the highest rate of staying in production and the lowest rate of removal. For example, USJersey (2016) presented the annual National Dairy Herd Improvement Association Reports for 2015 and showed that the proportion of Jerseys continuing in production was 72.3%, whereas for all other breeds and crossbreds, the proportion was 66.9%. Differences in reproductive performance, lower incidence of mastitis, less disease and injury, and fewer feet and leg problems were identified as contributing to the lower rate of removal in Jerseys. However, the difference between Jerseys and the other breeds had been reduced from about 5.4% units to only 3.5% units by 2019 [Council on Dairy Cattle Breeding, 2020].

There have been relatively few reports in the scientific literature that have compared the longevity of Jerseys against that in Holsteins, particularly within herd. In a very early study, Parker *et al.* (1960) analysed the disposal records of Jersey and Holstein cows from USDA herds at Beltsville, Maryland, and their results indicated that, although 41% of the Holsteins and 21% of the Jerseys were removed from the herds as non-breeders, differences in longevity between individual cows were determined largely by non-genetic influences.

In their analyses across different herds in USA, Garcia-Peniche *et al.* (2006) found that the Jersey breed showed an advantage above Holstein cows for all the longevity-related traits studied. The survival of Holsteins to 5 years of age was lower than for Jerseys, both in herds with single breeds and when the two breeds were compared within herds. The Jerseys' greater longevity was attributed to younger ages at first calving and shorter calving intervals. Unfortunately there have been very few of these types of comparative studies where Jerseys and Holsteins are kept in the same herd under similar conditions.

In a more recent US study based on 5.9 million DHIA lactation records from 10 Midwest states from 2006 to 2010, Shahid *et al.* (2015) found that Holstein cows had a significantly higher mortality hazard than Jersey, Ayrshire, Brown Swiss, and crossbreds. Jerseys had a 21% lower mortality hazard ratio than Holsteins. However, a Danish study found that Jerseys had a greater mortality incidence risk than Holsteins (Maia *et al.*, 2013).

Analysis of Australian herd calving data from 1980 to mid-2020 held by DataGene shows that of the Jerseys enrolled at their first calving (100%), 84% went on to further calvings and so 16% had no further calvings in that herd. In contrast, for Holsteins, 81% went on to further calvings and so 19% had no further calvings. Up to 8 years from first calving, the percentages of cows still in the herd were slightly higher for Jerseys (Figure 19).

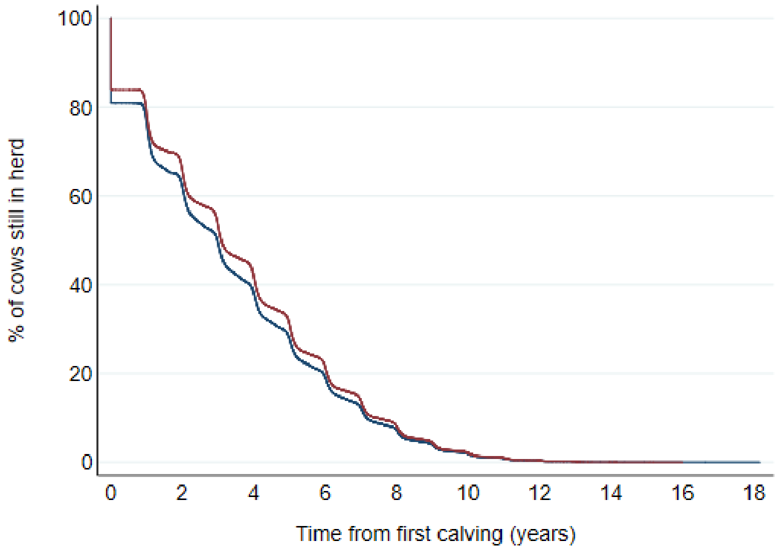


Figure 19. Percentages of cows still in herd by time from first calving for Jerseys (maroon; n=394,443 cows) and Holsteins (navy; n=2,366,820 cows), 1990 to 2020; cows first calved in any year included [DataGene, 2021].

These patterns were also assessed separately for cows first calved in 1990 to 1994, 1995 to 1999, 2000 to 2004, 2005 to 2009, 2010 to 2014, and 2015 to 2019. (Figure 20). In all these periods, the percentages of first calvers (aged 21 to 30 months at first calving) that had no further calvings was lower for Jerseys than Holsteins. For both Jerseys and Holsteins, percentages of first calvers that had no further calvings increased progressively from the period 1990 to 1994 to the period 2005 to 2009 before declining. (See Appendix H for further information).

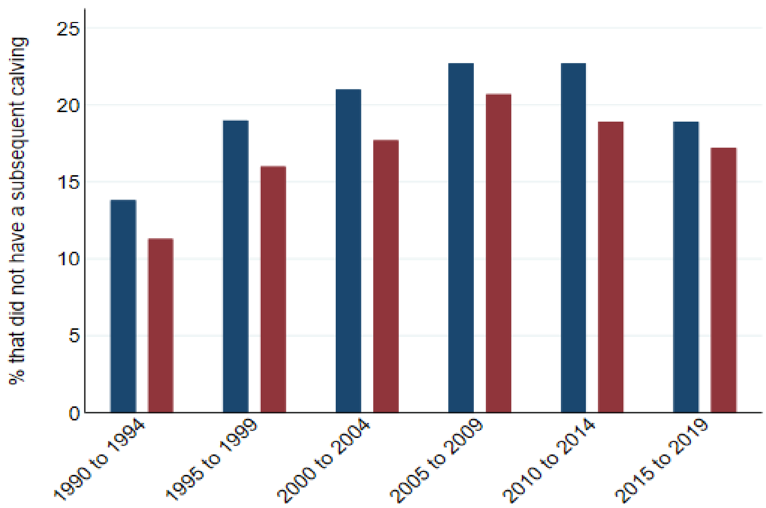


Figure 20. Percentages of first calvers (aged 21 to 30 months at first calving) that did not have a subsequent calving in the herd for Jersey (maroon) and Holstein (navy) cows by year of first calving [DataGene, 2021].

These differences in the longevity of Jerseys and Holsteins impact on the herd replacement rate required to maintain a herd and the milking herd's cow age profiles, with Jersey herds having slightly fewer younger (lower producing) cows and more (higher producing) older cows (Figure 21).

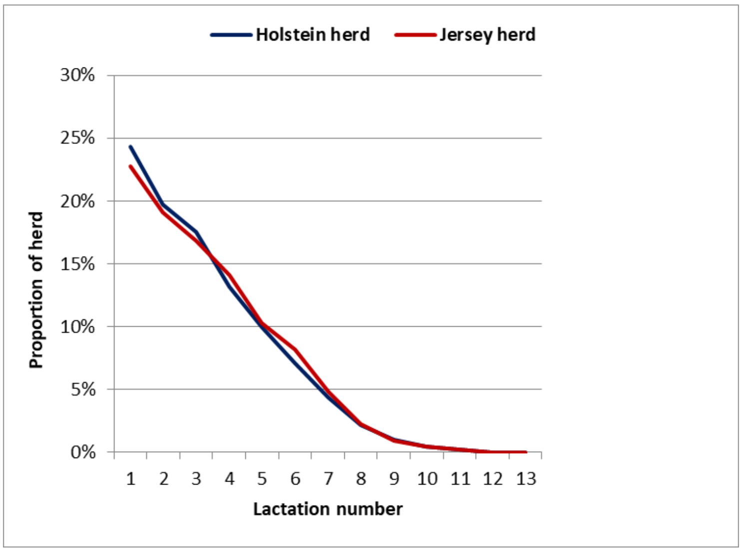


Figure 21. Jersey and Holstein milking herd profiles, across seasonal, split and year-round-calving systems, based on 25,703 and 138,792 calving records respectively for 2019 [DataGene, 2021].

8. Lifetime production efficiency

Key points:

- Many factors related to the milking herd and the replacement herd contribute to lifetime production efficiency of a whole herd
- Jerseys have demonstrated advantages in grazing systems, longevity, productive life, calving ease, reproduction, heat stress and hybrid vigour contribution. However, Holsteins offer different various benefits in each production system
- A modelling approach may therefore be more appropriate and useful when comparing lifetime efficiency of Jerseys and Holsteins within a given production system

At a herd level, considering all animals on a farm, there are many factors which contribute to lifetime production efficiency, as expressed as the percentage of total megajoules of metabolisable energy eaten that is used for productive purposes i.e. producing milk (Figure 22). Improved performance in any of these factors will therefore help to improve lifetime production efficiency. For example, considering the number of lactations per cow, Garnsworthy (2014) calculated that if a cow that had completed three lactations went on to complete a fourth lactation, its lifetime energetic efficiency (NE milk/ ME intake) was increased by 8%. Of course, improved performance in any of these factors will also help to reduce a herd's environmental footprint with respect to greenhouse gas (GHG) emissions (DeVries *et al.,* 2020). Reductions in water use and nitrogen use may also be realised.

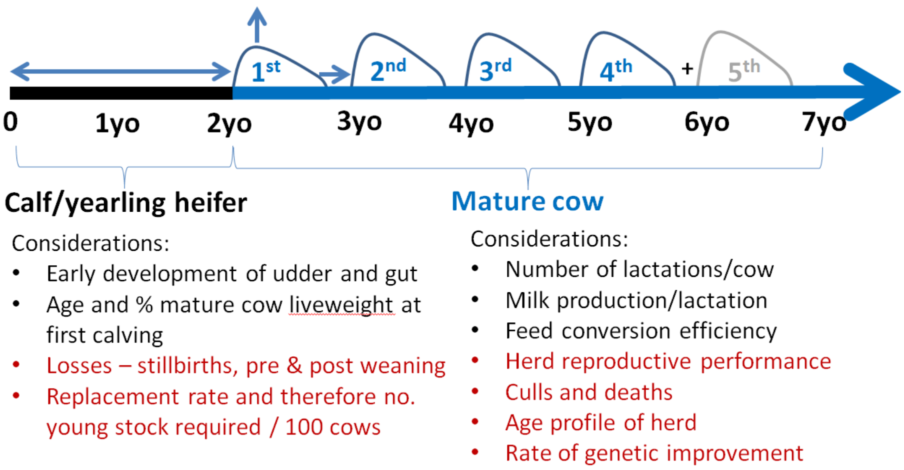


Figure 22. Lifetime production efficiency of the whole herd (inc. young stock). [Little, 2014].

One of the earliest farmlet studies that compared the performance of Holsteins and Jerseys conducted in New Zealand was reported by Grainger and Goddard (2004). First year results suggested that net income was greater for Jerseys, but in later years of the study the results showed that Holsteins were the more profitable breed. Numerous comparative breed studies in Ireland have been reported since and while each breed has its benefits, the lifetime efficiency and most profitable breed is often in dispute depending upon production system (confinement or grazing), stocking rate, season, milk prices, etc. [Prendiville *et al.,* 2009; Coffey *et al.,* 2016]. Nevertheless, many of these studies show the heterosis benefit of the Holstein X Jersey crossbred [Prendiville *et al.,* 2009; Coffey *et al.,* 2016].

The efficiency and profitability of Holstein and Jersey cows has been scrutinized, compared, and debated for many years. Carstensen (2013) reviewed the literature of numerous studies relating to Holstein and Jersey efficiency and profitability to determine if a breed advantage existed in any or all related areas. Jerseys were found to demonstrate breed advantages in grazing systems, longevity, productive life, calving ease, reproduction, heat stress under normal conditions, and hybrid vigour contribution [Carstensen, 2013]. Overall, breed differences and interactions were discovered in every area examined. While Jerseys excelled in a greater number of areas, Carstensen (2013) concluded that an overall advantage was difficult to discern due to the various benefits offered by both breeds.

Where there are diverse dairy production systems, the various breeds of dairy cows each have their own characteristics that may contribute to their lifetime productive efficiency in each system. The relative performance of various breed traits may differ depending upon the production system. It may therefore be more appropriate and useful when comparing Jerseys with Holsteins to use a modelling approach such as that used by Pyman *et al.* (2008) when they compared the performance of Holstein cows with Holstein X Jersey cross cows, so that all the different and various factors that contribute to lifetime efficiency can be taken into account for each breed. Of course, the outcomes of any modelling study are highly dependent on the assumptions used.

9. Environmental footprint

Key points:

- Several studies have suggested that the emission intensity of milk production is about 8-12% lower with a Jersey herd compared to a Holstein herd when the life cycle analysis (LCA) approach was used to calculate GHG emissions
- However, there may be little difference between the breeds in emission intensity of milk production, as Jerseys emit more methane per kg DM intake compared to Holsteins

When respondents to the Jersey Australia survey were asked to give their level of agreement with the statement 'Jerseys are more environmentally friendly than other breeds', 80% agreed or strongly agreed, and 20% were unsure.

The livestock sector is responsible for about 18% of the total global greenhouse gas (GHG) emissions. As methanogenesis is inevitable and essential for rumen functioning, methane (CH_4) emissions will account for a considerable amount of greenhouse gas emissions in the dairy industry.

One of the earliest greenhouse gas studies on the comparison between dairy breeds was conducted by Capper and Cady (2012) to investigate the environmental impact of milk from Jersey and Holstein cows for cheese production in USA. They found that for Jersey and Holstein herds to produce the same amount of protein, milkfat and other solids (500,000 t of cheese), the Jersey herd's total GHG emissions (carbon dioxide + methane + nitrous oxide emissions) were 21% lower than the Holstein herd's ($6,442 \times 10^3$ t vs. $8,104 \times 10^3$ t).

These observations are in agreement with other studies. Bangani *et al.* (2019) examined a kikuyu based pasture system in South Africa and found that despite Jersey's having higher carbon emissions when expressed as proportions of dry matter intake or body weight, Jerseys produced lower methane emissions/kg energy-corrected milk (ECM) across all parities and all stages of lactation. (See Appendix I for more information). Dalla Riva *et al.* (2014) found greater CO_2 equivalent emissions per unit ECM production in Holsteins compared to Jerseys, when examined in an intensive Italian dairy system; the results being 0.80 kg CO_2eq/kg ECM for Jerseys, and 0.96 kg CO_2eq/kg ECM for the Holstein herd (a 17% difference). Kristensen et al. (2014) found that Jerseys produced 1.26 kg of ECM per MJ of CH_4 compared to 1.12 kg of ECM per MJ of CH_4 for Holstein-Friesians (a 12.5% difference).

In contrast, the results of Olijhoek *et al.* (2018) suggested that there were little differences between Holstein and Jersey cows in methane production per kilogram ECM. However it must be noted that in the study by Olijhoek *et al.* (2018) respiration chambers were used to measure CH_4 production, as opposed to the national inventory approach used by Dalla Riva *et al.* (2014). Olijhoek *et al.* (2018) also found the Jersey cow had a higher CH_4 production, relative to dry matter intake, postulating a difference in microbial community structure between the two breeds.

There is little comparative data from Australia. In one of the early modelling studies conducted for the dairy industry in Australia, Bell *et al.* (2013) reported that the enteric CH_4 emissions were 340 g/day for Holsteins and only 281 g/day for the Jersey cow. However, when the enteric CH_4 emissions (which contribute about 77% of the total CO_2-eq emissions) were expressed on an ECM basis, there appeared to be little difference between the breeds.

The Australian Dairy Carbon Calculator (ADCC), which incorporates the International Panel on Climate Change and Australian inventory methodologies, algorithms and emission factors, has been used to estimate the total greenhouse gas emissions from dairy farms in Australia [Christie *et al.*, 2012, 2018]. Using the average production values reported by Bell *et al.* (2013) the total GHG emissions from a Jersey herd were compared to a Holstein herd, using the ADCC. Karen Christie (personal communication, 2021) calculated the total farm GHG emissions and expressed them as tonne CO_2 equiv/year (2,231 and 2,298, for Holstein and Jersey farms, respectively), or emission intensity in kg CO_2 equiv/kg fat and protein corrected milk (0.94 and 0.87, for Holstein and Jersey farms, respectively). This represents an 8% decline in emission intensity for the Jersey herd. The energy intensity of milk production results of this study was also similar to other published Australian studies, based on real-farm data (Christie *et al.,* 2018), confirming any assumptions made in the current study align with real farm data.

In summary, the results of several international studies suggest that the emission intensity of milk production is about 10% lower with the Jersey herd compared to a Holstein herd when the lifecycle analysis (LCA) approach is used to calculate GHG emissions. However, the Jerseys were only lower because the LCA approach assumed the same methane emission per kg dry matter intake. Several recent experimental studies measuring enteric CH_4 in respiration chambers such as those reported by Olijhoek *et al.* (2018) and Uddin *et al.* (2020) have found that this is not the case, and that Jerseys emit more CH_4 per kg DM intake compared to Friesians (Figure 23). Therefore, if the LCA methodology reflected this higher CH_4 emission per kg of DM intake for Jerseys, compared to Holsteins, there may have been little difference between the breeds. Further research is required.

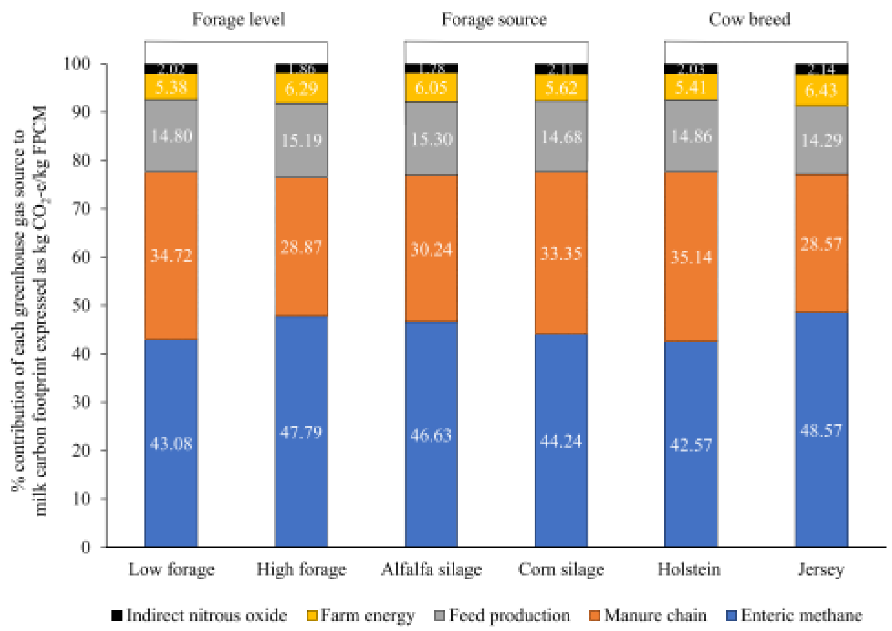


Figure 23. Percentage contribution of different greenhouse gas sources to cradle-to-farmgate carbon footprint [kg CO2-e/kg fat-and-protein corrected milk (FPCM)] for different dietary and breed scenarios [Uddin *et al.,* 2020].

10. Suitability for different production / housing systems

Key points:

- Jerseys are used successfully around the world in a diverse range of production systems (grazing and confinement)
- However, Jerseys express their dominance in grazing systems where their larger digestive tract per unit bodyweight allows them a greater feed intake capacity
- Jerseys are better suited to walking longer distances associated with grazing systems than Holsteins, and to hot climatic conditions

Definite breed differences do arise across various production systems. While Jerseys are used successfully around the world in a diverse range of production systems, they may perform at their best in grazing systems where the majority of their nutrients come from fresh pasture and conserved forages. A major advantage of the Jersey over the Holstein is their larger digestive tract per unit bodyweight which allows the Jersey cow a greater feed intake capacity (pasture and supplements) per unit bodyweight. This enhanced intake capacity and ability to consume often lower quality roughage is an advantage for Jerseys in grazing systems because they are forage based and often offer lower quality roughage than TMR diets.

In addition, because of their lighter weight and lower maintenance requirement, Jerseys are better suited to walking longer distances associated with grazing systems than Holsteins. In the grazing situation and under hot climatic conditions where strategies to mitigate heat stress (shade and evaporative cooling) are inadequate to help cows maintain a low heat load level, Jerseys will do better than Holsteins because of their greater heat tolerance. Because of their higher fertility and easier heat detection, Jerseys are well suited to a grazing system, where heat detection may be suboptimal. However, the fertility advantage of Jerseys over Holsteins has also been found in confinement systems.

Jerseys and Holsteins exhibit different lying and eating behaviours in confinement systems [Munksgaard *et al.*, 2020]. Further research is needed to understand how the behaviours and performance of Jerseys and Holsteins compare in different types of housed systems (freestall barn, compost-bedded pack barn) with or without automatic milking systems. This may have important implications for how Jerseys are fed and managed in these systems.

11. Genetic trends

Key points:

- The mean daughter fertility ABV for sires of Jersey cows has been flat or slowly declining for four decades, whereas that of sires of Holstein cows is now increasing
- Cows' sire ABVs are highly variable for Jerseys and Holsteins, especially for cow's sire daughter fertility, Balanced Performance Index and Protein ABV

Daughter fertility ABV

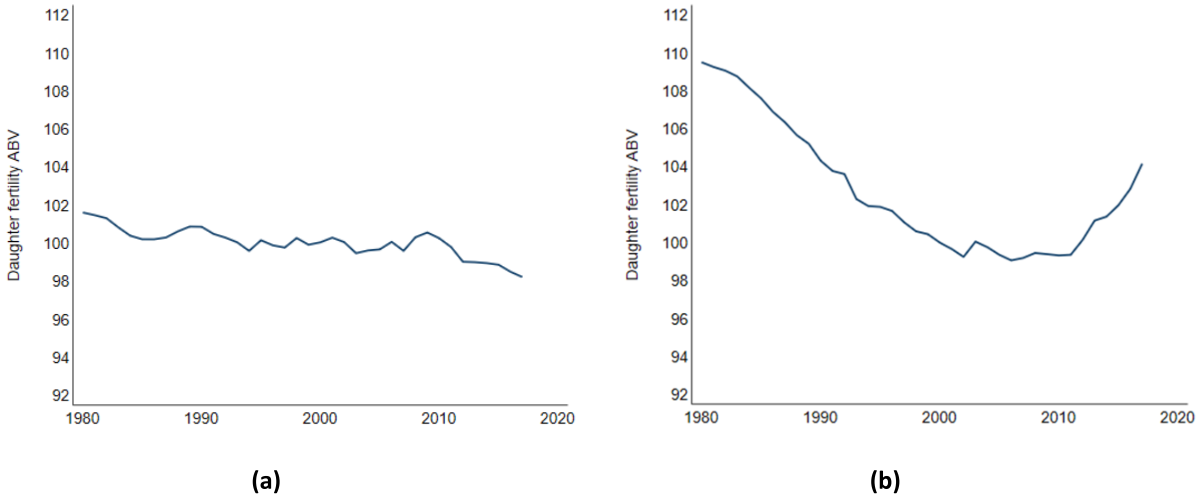


Figure 24. Mean daughter fertility ABV for sires of cows by cow's year of birth for **(a)** Jersey cows, and **(b)** Holstein cows (ABV estimates generated on 14th April 2020).

The daughter fertility breeding values for sires of cows by cow's year of birth in both Holsteins and Jerseys are highly variable. However, they are become progressively more variable in Holsteins than in Jerseys.

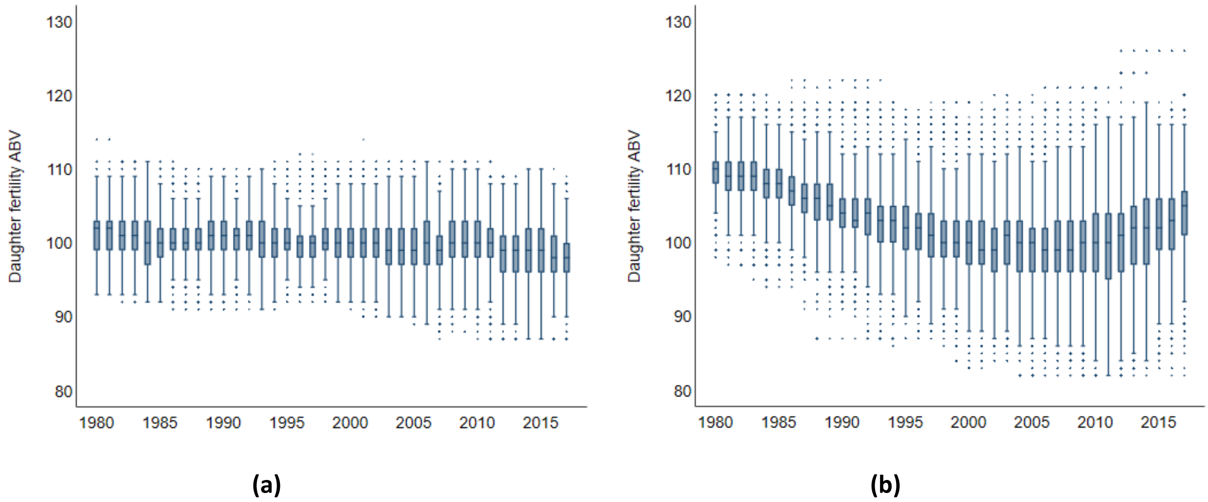
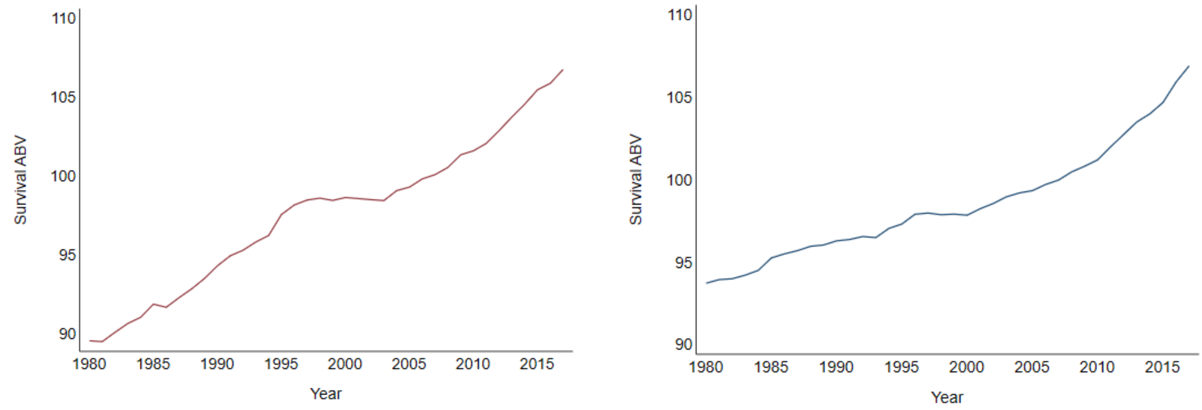


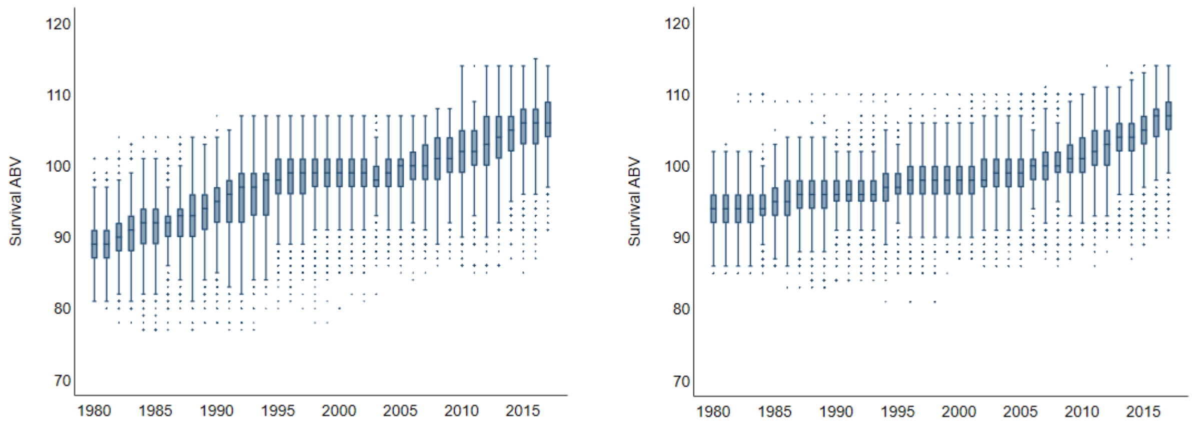
Figure 25. Cow's sire daughter fertility ABVs by cow's year of birth for **(a)** Jersey cows, and **(b)** Holstein cows; boxes contain the central 50% of values for cows born in each year (ABV estimates generated on 14th April 2020).

Survival ABV



(a) **(b)**

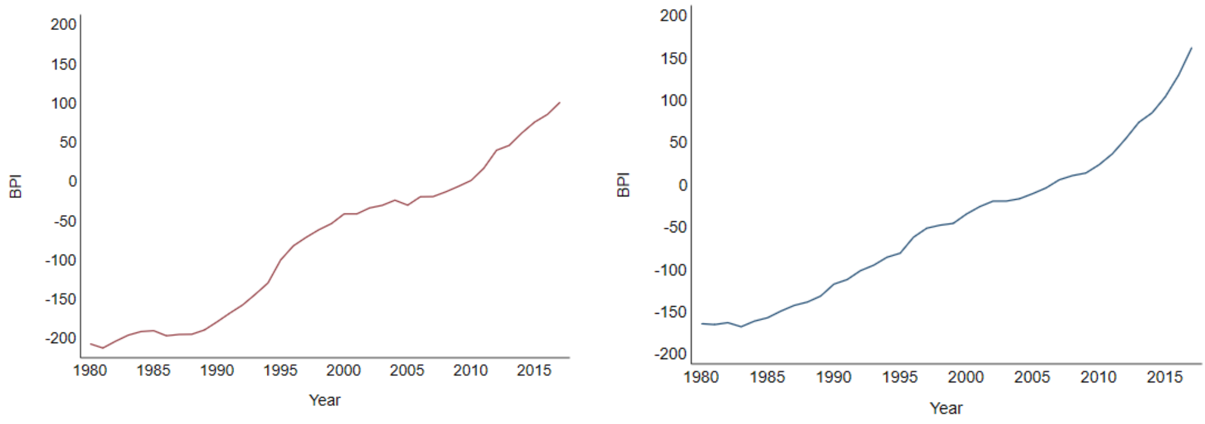
Figure 26. Mean cows' sire survival ABV by cow's year of birth for **(a)** Jersey cows, and **(b)** Holstein cows (ABV estimates generated on 14th April 2020).



(a) **(b)**

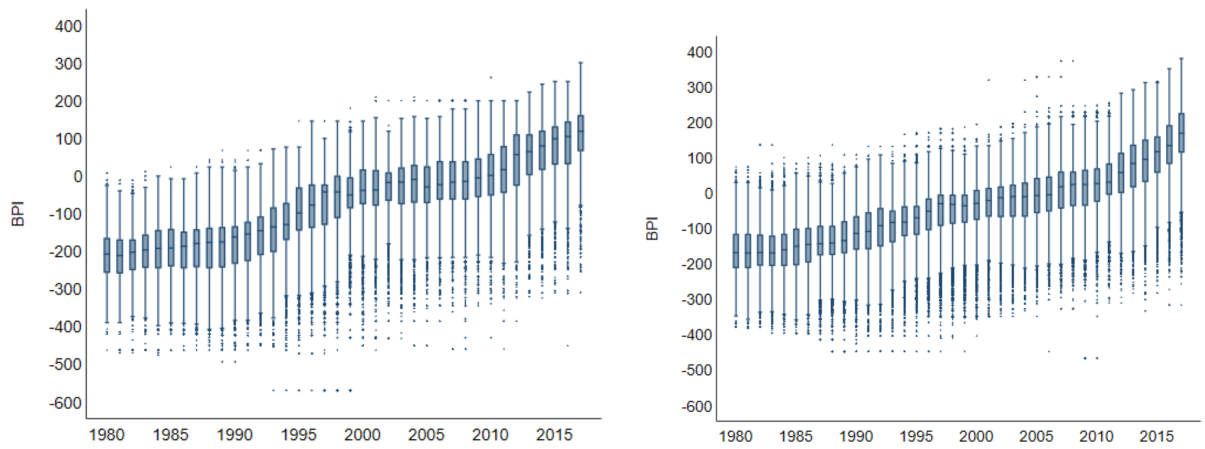
Figure 27. Cows' sire survival ABV by cow's year of birth for **(a)** Jersey cows, and **(b)** Holstein cows; boxes contain the central 50% of values for cows born in each year (ABV estimates generated on 14th April 2020).

Balanced Performance Index ABV



(a) (b)

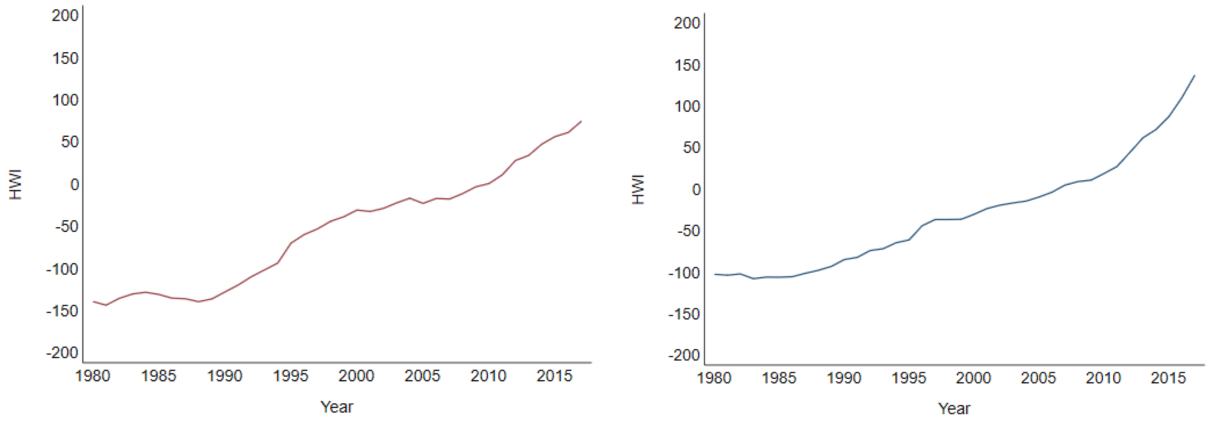
Figure 28. Mean cows' sire Balanced Performance Index by cow's year of birth for **(a)** Jersey cows, and **(b)** Holstein cows (ABV estimates generated on 14th April 2020).



(a) (b)

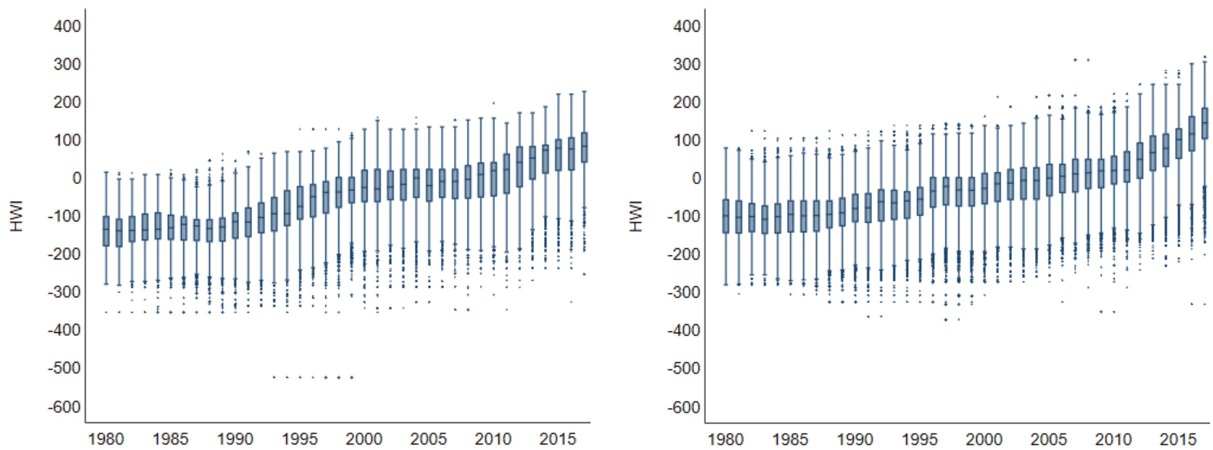
Figure 29. Cow's sire Balanced Performance Index values by cow's year of birth for **(a)** Jersey cows, and **(b)** Holstein cows; boxes contain the central 50% of values for cows born in each year (ABV estimates generated on 14th April 2020).

Health Weighted Index ABV



(a) **(b)**

Figure 30. Mean cows' sire Health Weighted Index by cow's year of birth for **(a)** Jersey cows, and **(b)** Holstein cows (ABV estimates generated on 14th April 2020).



(a) **(b)**

Figure 31. Cow's sire Health Weighted Index values by cow's year of birth for **(a)** Jersey cows, and **(b)** Holstein cows; boxes contain the central 50% of values for cows born in each year (ABV estimates generated on 14th April 2020).

Fat ABV

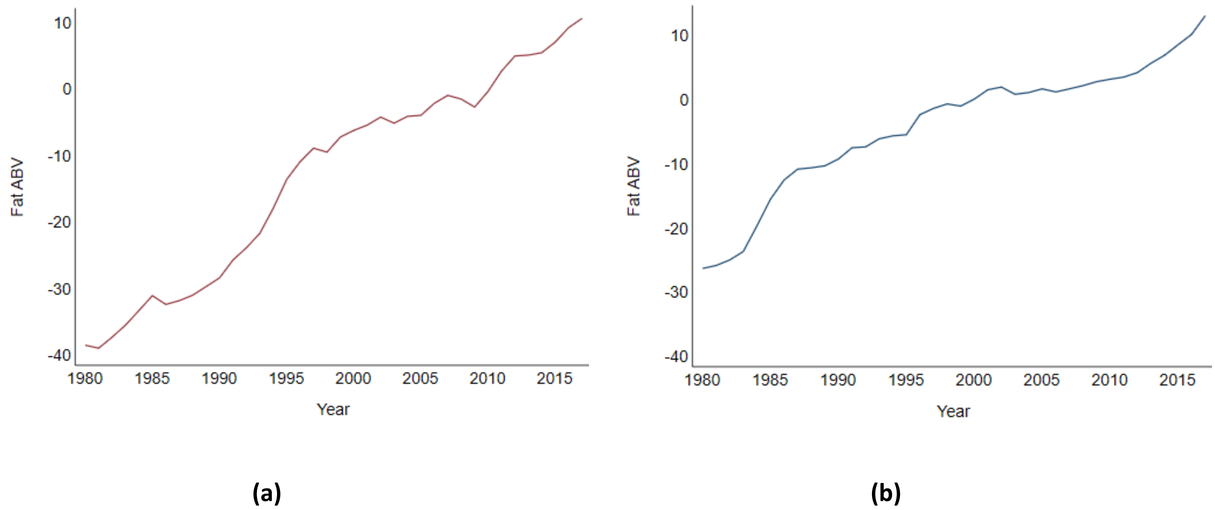


Figure 32. Mean cows' sire Fat ABV values by cow's year of birth for **(a)** Jersey cows, and **(b)** Holstein cows (ABV estimates generated on 14th April 2020).

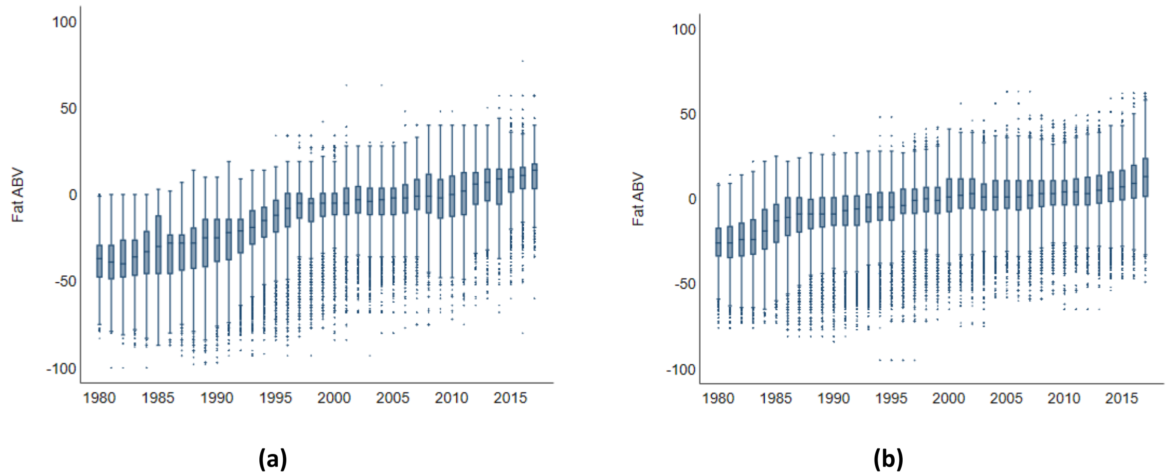
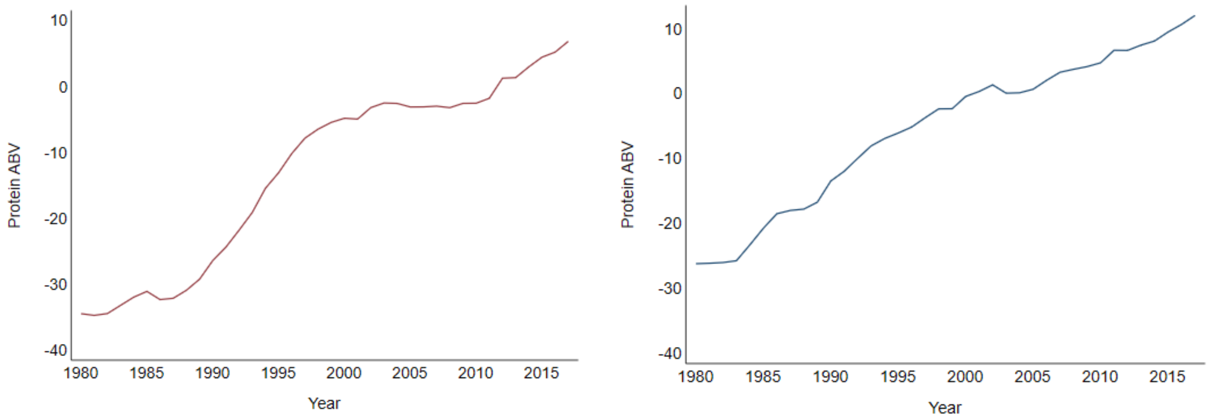


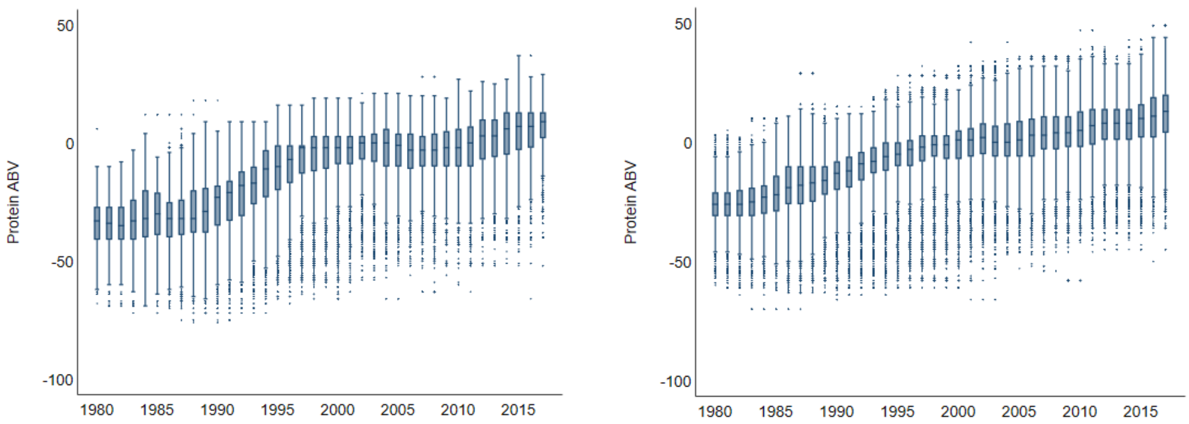
Figure 33. Cow's sire Fat ABV values by cow's year of birth for **(a)** Jersey cows, and **(b)** Holstein cows; boxes contain the central 50% of values for cows born in each year (ABV estimates generated on 14th April 2020).

Protein ABV



(a) (b)

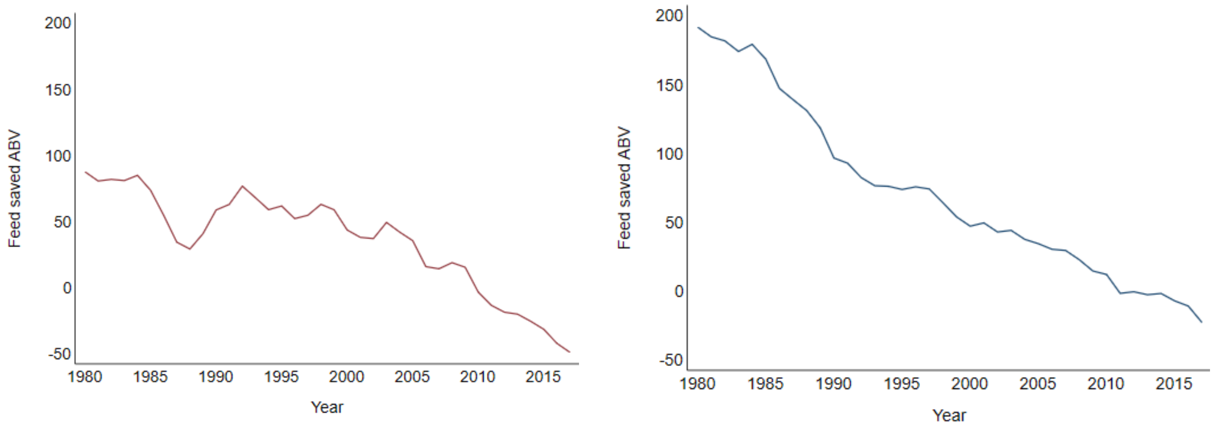
Figure 34. Mean cows' sire Protein ABV values by cow's year of birth for **(a)** Jersey cows, and **(b)** Holstein cows (ABV estimates generated on 14th April 2020).



(a) (b)

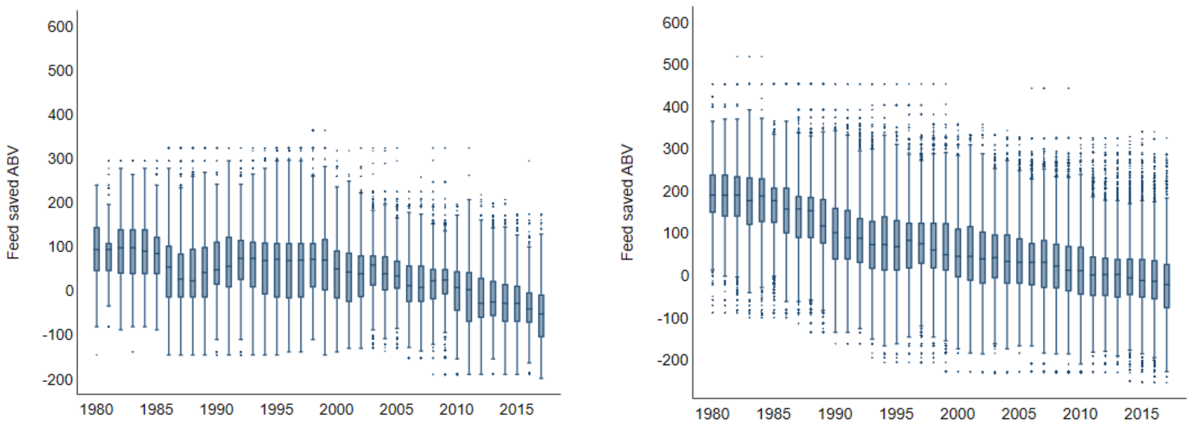
Figure 35. Cow's sire Protein ABV values by cow's year of birth for **(a)** Jersey cows, and **(b)** Holstein cows; boxes contain the central 50% of values for cows born in each year (ABV estimates generated on 14th April 2020).

Feed saved ABV



(a) (b)

Figure 36. Mean cows' sire Feed saved ABV values by cow's year of birth for **(a)** Jersey cows, and **(b)** Holstein cows (ABV estimates generated on 14th April 2020).



(a) (b)

Figure 37. Cow's sire Feed saved ABV values by cow's year of birth for **(a)** Jersey cows, and **(b)** Holstein cows; boxes contain the central 50% of values for cows born in each year (ABV estimates generated on 14th April 2020).

Knowledge gaps requiring further research

Based on this literature review, there are knowledge gaps that require future research to be undertaken to fill (Table 9). Some of these may be potential R & D opportunities for Jersey Australia.

Table 9. Knowledge gaps that require future research to be undertaken to fill.

Aspect	Knowledge gap
Milk yield, composition and market suitability	Whether there are significant breed differences in susceptible to milk fat depression (MFD) under the same feeding management and environmental conditions
	Better understanding of how breed influences the composition and quality of dairy products in food manufacturing
Production efficiency	Quantification and comparison of the production efficiencies of Jerseys and Holsteins in Australian production systems
Feed intake, eating behaviour and feed digestibility	Better understanding of differences in feed intake, eating behaviour (fresh pasture, conserved forages, concentrate supplements) and nutrient digestibility between Jerseys and Holsteins in Australian production systems Eating rate, sorting behaviour and preferences of Jerseys vs. other breeds for different ingredients when offered a mixed ration
Fertility	Feed intakes, milk yields and daily energy balances of Jerseys and Holsteins through the transition period and early lactation in Australian production systems
Health	Better understanding of differences between Jerseys and Holsteins in sensitivity to ruminal acidosis
	Understanding of mechanisms that make Jersey cows more predisposed to milk fever than Holsteins and how these may be addressed
	Prevalence of specific health problems in Australian Jersey herds compared to Holstein herds
	Better understanding of the differences between Jersey and Holstein neonatal calves re. acquisition of passive immunity
	Whether the lower innate immune responses found in Jersey calves do put them at increased relative risk for morbidity during the immediate post-weaned period compared with Holstein calves
Heat tolerance	Breed-specific temperature-humidity index (THI) thresholds for moderate, high and severe heat stress to assist farmers make herd management decisions in hot weather
	Better understanding of the effects of heat on the ruminal microbiome and gene expression in Holstein and Jersey cows
Longevity	Better understanding of the risk factors for culling in Australian Jersey herds compared to Holstein herds
Lifetime production efficiency	Quantification of each factor that contributes to the lifetime production efficiency of a Jersey herd vs. a Holstein herd in different production systems
Environmental footprint	Emission intensity of milk production for Australian Jersey and Holstein herds using the National Greenhouse Gas Inventory methodology, factoring in different rates of CH_4 emission per kg dry matter intake
Suitability for different production / housing systems	Behaviours and performance of Jerseys compared to Holsteins in different housed systems (freestall barn, compost-bedded pack barn) with or without automatic milking systems

Appendices

A. Milk production (Aust. herd recording data, 1980-2019)

All eligible lactations (1980 – 2019)

Table A.1 Average 305-day solids yield (kg) per cow by calving system, breed and year

Year	Seasonal or split calving				Year-round calving			
	FFFF		JJJJ		FFFF		JJJJ	
	No. lactations	Average	No. lactations	Average	No. lactations	Average	No. lactations	Average
1980	202	230.5	31	233.3	0		2	474.0
1981	489	237.4	57	258.3	4	323.3	0	
1982	852	269.1	103	274.9	94	290.5	4	289.5
1983	5,636	264.6	1,155	249.6	12,296	287.8	2,841	259.5
1984	7,888	307.8	1,447	291.8	23,654	312.2	4,736	298.1
1985	10,434	326.7	1,747	317.7	28,225	309.2	5,115	291.5
1986	13,644	336.5	2,091	328.1	34,262	310.5	5,309	295.0
1987	16,710	310.9	2,812	298.1	41,050	319.8	5,875	295.3
1988	17,267	334.3	2,656	310.7	49,675	322.7	6,755	298.1
1989	22,219	338.9	3,627	311.0	55,092	328.0	7,141	303.3
1990	24,253	345.2	3,846	310.8	61,075	332.4	7,647	297.7
1991	27,115	357.8	3,398	323.7	64,555	353.7	7,607	314.8
1992	33,245	391.4	4,381	331.8	73,504	379.9	7,998	334.8
1993	185,788	395.1	40,301	343.1	167,086	396.4	28,551	342.4
1994	235,905	386.3	48,178	333.8	260,591	394.7	37,806	328.9
1995	225,380	401.1	43,012	349.6	248,549	404.4	33,052	342.7
1996	242,599	389.8	44,256	334.1	273,103	408.3	35,327	340.5
1997	252,224	386.0	44,528	339.3	284,012	419.1	35,203	349.4
1998	255,688	408.3	44,626	363.8	290,097	441.2	34,395	376.4
1999	243,578	419.9	42,202	367.8	296,248	452.0	35,261	387.2
2000	223,598	410.8	38,486	363.5	303,070	447.0	36,281	383.0
2001	166,906	444.7	29,240	401.2	277,611	471.8	30,517	412.0
2002	133,346	405.2	24,887	369.0	285,092	450.1	31,758	392.3
2003	123,963	431.8	28,285	389.3	275,828	470.8	32,161	403.8
2004	113,801	448.7	25,357	392.2	283,592	481.5	37,822	419.0
2005	97,154	454.9	23,175	399.5	283,840	491.8	38,737	420.7
2006	92,778	450.5	22,271	398.5	251,702	496.5	33,645	424.9
2007	79,796	467.3	19,279	410.7	251,341	504.9	33,445	433.5
2008	71,622	479.4	15,622	418.4	243,607	516.1	35,568	439.9
2009	56,881	462.8	14,463	409.7	243,217	510.2	32,024	432.6
2010	59,257	489.4	13,205	421.7	230,036	518.6	33,584	433.4
2011	50,481	495.5	12,113	410.3	240,462	526.0	33,951	444.2
2012	46,478	469.0	11,128	401.2	227,687	524.0	32,723	445.3
2013	43,373	483.5	10,304	413.8	214,806	524.9	32,910	446.5
2014	44,292	502.1	10,679	419.8	205,502	536.8	31,331	454.5
2015	38,626	496.5	9,250	417.0	192,951	535.1	28,515	458.6
2016	33,752	479.0	7,936	404.5	166,812	519.6	25,224	446.9
2017	30,071	491.9	7,441	427.0	160,613	536.2	25,539	458.3
2018	25,372	487.9	7,575	414.7	150,918	525.0	23,593	447.4
2019	22,887	512.5	7,027	427.3	118,061	542.4	19,519	464.1

Table A.2. Average 305-day milk production (kg) per cow by calving system, breed and year

Year	Seasonal or split calving				Year-round calving			
	FFFF		JJJJ		FFFF		JJJJ	
	No. lactations	Average	No. lactations	Average	No. lactations	Average	No. lactations	Average
1980	202	3,210	31	2,722	0		2	5,625
1981	489	3,313	57	3,038	4	6,153	0	
1982	852	3,632	103	3,099	94	4,390	4	3,540
1983	5,636	4,281	1,155	3,512	12,296	4,635	2,841	3,517
1984	7,888	4,172	1,447	3,206	23,654	4,403	4,736	3,306
1985	10,434	4,400	1,747	3,469	28,225	4,375	5,115	3,273
1986	13,644	4,468	2,091	3,524	34,262	4,380	5,309	3,281
1987	16,710	4,262	2,812	3,285	41,050	4,519	5,875	3,275
1988	17,267	4,541	2,656	3,407	49,675	4,559	6,755	3,292
1989	22,219	4,609	3,627	3,469	55,092	4,630	7,141	3,356
1990	24,253	4,693	3,846	3,462	61,075	4,738	7,647	3,339
1991	27,115	4,850	3,398	3,565	64,555	5,085	7,607	3,525
1992	33,245	5,322	4,381	3,655	73,504	5,467	7,998	3,760
1993	185,788	5,357	40,301	3,774	167,086	5,601	28,551	3,755
1994	235,905	5,332	48,178	3,743	260,591	5,631	37,806	3,676
1995	225,380	5,543	43,012	3,923	248,549	5,783	33,052	3,836
1996	242,599	5,393	44,256	3,803	273,103	5,824	35,327	3,852
1997	252,224	5,428	44,528	3,911	284,012	6,000	35,203	3,986
1998	255,688	5,645	44,626	4,135	290,097	6,286	34,395	4,278
1999	243,578	5,847	42,202	4,217	296,248	6,441	35,261	4,452
2000	223,598	5,739	38,486	4,207	303,070	6,376	36,281	4,421
2001	166,906	6,206	29,240	4,602	277,611	6,743	30,517	4,756
2002	133,346	5,686	24,887	4,294	285,092	6,446	31,758	4,583
2003	123,963	5,981	28,285	4,461	275,828	6,693	32,161	4,683
2004	113,801	6,221	25,357	4,559	283,592	6,858	37,822	4,862
2005	97,154	6,329	23,175	4,601	283,840	7,019	38,737	4,901
2006	92,778	6,256	22,271	4,587	251,702	7,053	33,645	4,962
2007	79,796	6,445	19,279	4,732	251,341	7,133	33,445	5,038
2008	71,622	6,538	15,622	4,792	243,607	7,208	35,568	5,077
2009	56,881	6,309	14,463	4,724	243,217	7,150	32,024	5,025
2010	59,257	6,734	13,205	4,828	230,036	7,316	33,584	5,024
2011	50,481	6,892	12,113	4,762	240,462	7,454	33,951	5,167
2012	46,478	6,499	11,128	4,651	227,687	7,455	32,723	5,189
2013	43,373	6,716	10,304	4,817	214,806	7,488	32,910	5,241
2014	44,292	6,963	10,679	4,825	205,502	7,624	31,331	5,291
2015	38,626	6,894	9,250	4,810	192,951	7,625	28,515	5,320
2016	33,752	6,614	7,936	4,660	166,812	7,412	25,224	5,172
2017	30,071	6,807	7,441	4,916	160,613	7,631	25,539	5,333
2018	25,372	6,771	7,575	4,748	150,918	7,497	23,593	5,196
2019	22,887	7,086	7,027	4,825	118,061	7,704	19,519	5,360

Table A.3. Average 305-day fat yield (kg) per cow by calving system, breed and year

Year	Seasonal or split calving				Year-round calving			
	FFFF		JJJJ		FFFF		JJJJ	
	No. lactations	Average	No. lactations	Average	No. lactations	Average	No. lactations	Average
1980	202	129.6	31	135.2	0		2	251.0
1981	489	139.8	57	155.5	4	307.3	0	
1982	852	151.2	103	157.7	94	158.9	4	181.5
1983	5,636	176.4	1,155	185.3	12,296	184.7	2,841	184.3
1984	7,888	171.0	1,447	168.3	23,654	171.7	4,736	172.3
1985	10,434	180.9	1,747	183.4	28,225	171.1	5,115	169.9
1986	13,644	185.6	2,091	187.3	34,262	171.4	5,309	171.8
1987	16,710	175.4	2,812	172.8	41,050	178.2	5,875	172.9
1988	17,267	190.2	2,656	181.9	49,675	177.6	6,755	173.2
1989	22,219	191.7	3,627	181.4	55,092	179.6	7,141	175.5
1990	24,253	195.2	3,846	179.6	61,075	182.4	7,647	171.6
1991	27,115	201.7	3,398	187.5	64,555	195.2	7,607	182.4
1992	33,245	219.5	4,381	191.5	73,504	211.6	7,998	195.0
1993	185,788	221.2	40,301	199.0	167,086	219.9	28,551	198.4
1994	235,905	215.2	48,178	193.2	260,591	217.7	37,806	190.4
1995	225,380	223.0	43,012	202.6	248,549	222.5	33,052	197.9
1996	242,599	216.9	44,256	193.2	273,103	225.9	35,327	196.8
1997	252,224	213.0	44,528	195.3	284,012	231.0	35,203	200.6
1998	255,688	224.8	44,626	209.1	290,097	242.6	34,395	215.8
1999	243,578	230.9	42,202	211.2	296,248	247.7	35,261	221.3
2000	223,598	225.5	38,486	208.0	303,070	244.5	36,281	218.4
2001	166,906	242.8	29,240	228.4	277,611	256.1	30,517	233.4
2002	133,346	223.5	24,887	209.4	285,092	245.6	31,758	222.0
2003	123,963	235.9	28,285	220.8	275,828	255.2	32,161	228.3
2004	113,801	245.1	25,357	222.5	283,592	261.3	37,822	237.3
2005	97,154	247.0	23,175	227.5	283,840	265.7	38,737	237.8
2006	92,778	244.1	22,271	226.1	251,702	267.6	33,645	239.6
2007	79,796	254.4	19,279	233.9	251,341	273.3	33,445	245.0
2008	71,622	261.0	15,622	237.6	243,607	280.7	35,568	249.2
2009	56,881	253.3	14,463	232.4	243,217	277.5	32,024	244.6
2010	59,257	265.3	13,205	239.2	230,036	280.4	33,584	244.8
2011	50,481	266.8	12,113	232.2	240,462	282.8	33,951	250.6
2012	46,478	254.8	11,128	227.8	227,687	282.8	32,723	251.4
2013	43,373	262.4	10,304	235.3	214,806	283.0	32,910	252.0
2014	44,292	272.1	10,679	239.3	205,502	289.6	31,331	258.4
2015	38,626	269.4	9,250	237.5	192,951	288.2	28,515	260.5
2016	33,752	260.0	7,936	229.7	166,812	280.6	25,224	254.4
2017	30,071	265.1	7,441	242.8	160,613	288.3	25,539	259.7
2018	25,372	264.8	7,575	236.0	150,918	284.2	23,593	253.6
2019	22,887	276.1	7,027	243.6	118,061	292.4	19,519	262.0

Table A.4. Average 305-day fat concentration (g/100 mL) per cow by calving system, breed and year

Year	Seasonal or split calving				Year-round calving			
	FFFF		JJJJ		FFFF		JJJJ	
	No. lactations	Average	No. lactations	Average	No. lactations	Average	No. lactations	Average
1980	202	4.11	31	5.00	0		2	4.50
1981	489	4.27	57	5.17	4	4.84	0	
1982	852	4.19	103	5.15	94	3.62	4	5.18
1983	5,636	4.13	1,155	5.26	12,296	3.99	2,841	5.22
1984	7,888	4.12	1,447	5.25	23,654	3.90	4,736	5.18
1985	10,434	4.12	1,747	5.28	28,225	3.91	5,115	5.16
1986	13,644	4.17	2,091	5.31	34,262	3.92	5,309	5.20
1987	16,710	4.13	2,812	5.26	41,050	3.95	5,875	5.24
1988	17,267	4.21	2,656	5.35	49,675	3.90	6,755	5.24
1989	22,219	4.18	3,627	5.24	55,092	3.88	7,141	5.21
1990	24,253	4.18	3,846	5.18	61,075	3.86	7,647	5.12
1991	27,115	4.18	3,398	5.28	64,555	3.85	7,607	5.15
1992	33,245	4.15	4,381	5.22	73,504	3.88	7,998	5.16
1993	185,788	4.16	40,301	5.28	167,086	3.95	28,551	5.29
1994	235,905	4.06	48,178	5.17	260,591	3.89	37,806	5.18
1995	225,380	4.05	43,012	5.18	248,549	3.88	33,052	5.17
1996	242,599	4.05	44,256	5.09	273,103	3.91	35,327	5.12
1997	252,224	3.95	44,528	5.00	284,012	3.88	35,203	5.04
1998	255,688	4.02	44,626	5.07	290,097	3.89	34,395	5.06
1999	243,578	3.99	42,202	5.03	296,248	3.88	35,261	4.98
2000	223,598	3.96	38,486	4.96	303,070	3.87	36,281	4.95
2001	166,906	3.95	29,240	4.98	277,611	3.84	30,517	4.92
2002	133,346	3.96	24,887	4.88	285,092	3.85	31,758	4.85
2003	123,963	3.98	28,285	4.96	275,828	3.86	32,161	4.89
2004	113,801	3.98	25,357	4.89	283,592	3.86	37,822	4.89
2005	97,154	3.94	23,175	4.95	283,840	3.83	38,737	4.87
2006	92,778	3.94	22,271	4.93	251,702	3.84	33,645	4.85
2007	79,796	4.00	19,279	4.95	251,341	3.88	33,445	4.88
2008	71,622	4.04	15,622	4.98	243,607	3.94	35,568	4.92
2009	56,881	4.06	14,463	4.94	243,217	3.93	32,024	4.88
2010	59,257	3.99	13,205	4.98	230,036	3.88	33,584	4.90
2011	50,481	3.93	12,113	4.91	240,462	3.85	33,951	4.87
2012	46,478	3.97	11,128	4.92	227,687	3.85	32,723	4.86
2013	43,373	3.96	10,304	4.92	214,806	3.83	32,910	4.83
2014	44,292	3.97	10,679	4.98	205,502	3.85	31,331	4.91
2015	38,626	3.97	9,250	4.94	192,951	3.83	28,515	4.91
2016	33,752	3.99	7,936	4.94	166,812	3.84	25,224	4.93
2017	30,071	3.96	7,441	4.96	160,613	3.83	25,539	4.88
2018	25,372	3.96	7,575	4.97	150,918	3.84	23,593	4.89
2019	22,887	3.94	7,027	5.06	118,061	3.84	19,519	4.90

Table A.5. Average 305-day protein yield (kg) per cow by calving system, breed and year

Year	Seasonal or split calving				Year-round calving			
	FFFF		JJJJ		FFFF		JJJJ	
	No. lactations	Average	No. lactations	Average	No. lactations	Average	No. lactations	Average
1980	202	100.9	31	98.1	0		2	223.0
1981	489	97.7	57	102.9	4	16.0	0	
1982	852	117.9	103	117.1	94	131.6	4	108.0
1983	5,636	88.1	1,155	64.3	12,296	103.1	2,841	75.3
1984	7,888	136.8	1,447	123.4	23,654	140.5	4,736	125.8
1985	10,434	145.8	1,747	134.4	28,225	138.1	5,115	121.6
1986	13,644	150.9	2,091	140.8	34,262	139.1	5,309	123.2
1987	16,710	135.5	2,812	125.3	41,050	141.6	5,875	122.4
1988	17,267	144.2	2,656	128.7	49,675	145.1	6,755	124.9
1989	22,219	147.2	3,627	129.5	55,092	148.4	7,141	127.7
1990	24,253	149.9	3,846	131.2	61,075	150.0	7,647	126.2
1991	27,115	156.1	3,398	136.2	64,555	158.5	7,607	132.5
1992	33,245	171.9	4,381	140.3	73,504	168.3	7,998	139.8
1993	185,788	174.0	40,301	144.1	167,086	176.5	28,551	144.0
1994	235,905	171.1	48,178	140.6	260,591	177.0	37,806	138.5
1995	225,380	178.1	43,012	147.0	248,549	181.9	33,052	144.8
1996	242,599	172.9	44,256	140.9	273,103	182.4	35,327	143.7
1997	252,224	173.0	44,528	144.0	284,012	188.1	35,203	148.8
1998	255,688	183.6	44,626	154.8	290,097	198.5	34,395	160.6
1999	243,578	189.0	42,202	156.5	296,248	204.3	35,261	165.9
2000	223,598	185.4	38,486	155.4	303,070	202.5	36,281	164.6
2001	166,906	201.9	29,240	172.8	277,611	215.7	30,517	178.6
2002	133,346	181.6	24,887	159.6	285,092	204.4	31,758	170.3
2003	123,963	195.9	28,285	168.5	275,828	215.5	32,161	175.5
2004	113,801	203.6	25,357	169.8	283,592	220.2	37,822	181.7
2005	97,154	207.9	23,175	172.0	283,840	226.1	38,737	182.9
2006	92,778	206.4	22,271	172.4	251,702	228.9	33,645	185.3
2007	79,796	212.9	19,279	176.8	251,341	231.6	33,445	188.5
2008	71,622	218.4	15,622	180.8	243,607	235.4	35,568	190.7
2009	56,881	209.4	14,463	177.3	243,217	232.7	32,024	187.9
2010	59,257	224.1	13,205	182.5	230,036	238.2	33,584	188.6
2011	50,481	228.7	12,113	178.1	240,462	243.2	33,951	193.6
2012	46,478	214.2	11,128	173.4	227,687	241.2	32,723	193.8
2013	43,373	221.1	10,304	178.5	214,806	241.9	32,910	194.5
2014	44,292	229.9	10,679	180.5	205,502	247.1	31,331	196.1
2015	38,626	227.1	9,250	179.5	192,951	246.9	28,515	198.1
2016	33,752	219.0	7,936	174.7	166,812	239.0	25,224	192.5
2017	30,071	226.9	7,441	184.2	160,613	247.9	25,539	198.6
2018	25,372	223.1	7,575	178.7	150,918	240.8	23,593	193.8
2019	22,887	236.3	7,027	183.8	118,061	250.0	19,519	202.1

Table A.6. Average 305-day protein concentration (g/100 mL) per cow by calving system, breed and year

Year	Seasonal or split calving				Year-round calving			
	FFFF		JJJJ		FFFF		JJJJ	
	No. lactations	Average	No. lactations	Average	No. lactations	Average	No. lactations	Average
1980	202	3.16	31	3.61	0		2	3.97
1981	489	2.96	57	3.38	4	0.21	0	
1982	852	3.26	103	3.78	94	3.04	4	2.96
1983	5,636	2.24	1,155	1.96	12,296	2.34	2,841	2.31
1984	7,888	3.30	1,447	3.85	23,654	3.20	4,736	3.81
1985	10,434	3.32	1,747	3.87	28,225	3.17	5,115	3.71
1986	13,644	3.39	2,091	3.99	34,262	3.18	5,309	3.76
1987	16,710	3.19	2,812	3.82	41,050	3.15	5,875	3.73
1988	17,267	3.19	2,656	3.79	49,675	3.19	6,755	3.79
1989	22,219	3.21	3,627	3.74	55,092	3.21	7,141	3.81
1990	24,253	3.20	3,846	3.79	61,075	3.17	7,647	3.78
1991	27,115	3.23	3,398	3.83	64,555	3.12	7,607	3.75
1992	33,245	3.24	4,381	3.84	73,504	3.08	7,998	3.71
1993	185,788	3.26	40,301	3.82	167,086	3.16	28,551	3.84
1994	235,905	3.21	48,178	3.76	260,591	3.15	37,806	3.77
1995	225,380	3.22	43,012	3.75	248,549	3.15	33,052	3.78
1996	242,599	3.21	44,256	3.71	273,103	3.14	35,327	3.73
1997	252,224	3.19	44,528	3.68	284,012	3.15	35,203	3.74
1998	255,688	3.26	44,626	3.75	290,097	3.17	34,395	3.76
1999	243,578	3.24	42,202	3.72	296,248	3.18	35,261	3.73
2000	223,598	3.24	38,486	3.70	303,070	3.19	36,281	3.73
2001	166,906	3.26	29,240	3.76	277,611	3.21	30,517	3.76
2002	133,346	3.20	24,887	3.71	285,092	3.18	31,758	3.71
2003	123,963	3.28	28,285	3.78	275,828	3.23	32,161	3.75
2004	113,801	3.28	25,357	3.73	283,592	3.22	37,822	3.74
2005	97,154	3.29	23,175	3.74	283,840	3.23	38,737	3.74
2006	92,778	3.31	22,271	3.76	251,702	3.25	33,645	3.74
2007	79,796	3.31	19,279	3.74	251,341	3.26	33,445	3.75
2008	71,622	3.35	15,622	3.77	243,607	3.28	35,568	3.76
2009	56,881	3.33	14,463	3.76	243,217	3.27	32,024	3.75
2010	59,257	3.34	13,205	3.79	230,036	3.27	33,584	3.76
2011	50,481	3.33	12,113	3.76	240,462	3.28	33,951	3.75
2012	46,478	3.31	11,128	3.73	227,687	3.25	32,723	3.74
2013	43,373	3.31	10,304	3.71	214,806	3.25	32,910	3.72
2014	44,292	3.32	10,679	3.75	205,502	3.26	31,331	3.71
2015	38,626	3.30	9,250	3.73	192,951	3.25	28,515	3.73
2016	33,752	3.32	7,936	3.75	166,812	3.24	25,224	3.73
2017	30,071	3.34	7,441	3.75	160,613	3.26	25,539	3.73
2018	25,372	3.31	7,575	3.76	150,918	3.23	23,593	3.73
2019	22,887	3.35	7,027	3.81	118,061	3.26	19,519	3.77

Lactations from herds with both Holsteins and Jerseys in the same herd (1993 – 2019)

Lactations were included only from herds with at least 100 calvings in year of which at least 10% were by Holstein cows and at least 10% by Jersey cows.

Table A.7. Average 305-day solids yield (kg) per cow by calving system, breed and year

Year	Seasonal or split calving						Year-round calving					
	FFFF			JJJJ			FFFF			JJJJ		
	No. herds	No. lactations	Average	No. herds	No. lactations	Average	No. herds	No. lactations	Average	No. herds	No. lactations	Average
1993	257	17,319	393.9	257	12,973	341.4	119	7,832	386.1	119	6,125	338.9
1994	261	18,533	381.4	261	13,177	331.8	140	10,303	380.2	140	7,373	322.4
1995	241	16,053	394.0	241	11,406	351.0	135	9,040	382.0	135	7,081	332.1
1996	248	16,483	372.5	248	11,732	330.1	143	9,142	370.2	143	7,139	323.1
1997	215	14,603	371.5	215	10,521	333.7	125	8,595	371.6	125	6,827	330.8
1998	210	13,871	401.9	210	10,559	357.6	106	7,547	397.6	106	5,437	352.0
1999	185	12,179	410.5	185	9,606	358.9	115	8,195	410.4	115	6,067	360.9
2000	155	10,990	404.2	155	8,374	357.5	111	8,482	404.5	111	6,533	352.3
2001	114	7,701	447.2	114	6,932	394.8	92	7,162	449.2	92	5,336	389.0
2002	97	6,676	412.6	97	5,847	372.7	93	7,447	430.0	93	5,819	360.8
2003	88	5,544	446.0	88	5,695	403.3	104	9,258	441.5	104	6,376	373.2
2004	86	5,590	445.0	86	5,098	390.9	118	10,907	452.4	118	7,736	389.7
2005	76	5,409	441.8	76	4,521	392.1	112	9,912	454.2	112	7,203	383.8
2006	78	5,949	432.0	78	4,295	376.7	83	7,463	470.9	83	5,585	394.5
2007	56	4,005	459.3	56	2,852	392.3	96	9,311	473.5	96	6,161	400.2
2008	51	3,762	458.4	51	2,492	403.4	93	8,685	485.2	93	5,896	405.3
2009	50	3,627	436.6	50	2,563	387.8	89	8,337	482.2	89	5,827	413.1
2010	41	2,973	479.1	41	1,790	421.7	90	7,603	492.6	90	5,610	417.3
2011	40	3,027	478.2	40	2,044	420.2	84	7,507	505.0	84	5,478	427.8
2012	42	3,057	464.7	42	2,318	405.2	81	6,927	498.6	81	4,925	421.6
2013	42	2,719	475.7	42	2,067	419.1	77	7,027	489.6	77	4,729	421.6
2014	34	2,372	479.4	34	1,626	414.1	74	6,257	518.8	74	4,990	447.4
2015	32	1,969	488.9	32	1,456	410.0	59	5,688	524.0	59	3,967	447.1
2016	29	1,702	458.6	29	1,321	400.4	47	4,087	502.3	47	3,235	434.9
2017	20	1,304	474.9	20	965	432.9	50	4,354	521.3	50	3,262	442.4
2018	18	1,152	460.5	18	965	403.6	49	4,440	494.3	49	3,239	428.6
2019	17	1,352	507.6	17	871	459.0	37	3,913	531.2	37	2,108	469.0

Table A.8. Average 305-day milk yield (kg) per cow by calving system, breed and year

Year	Seasonal or split calving						Year-round calving					
	FFFF			JJJJ			FFFF			JJJJ		
	No. herds	No. lactations	Average	No. herds	No. lactations	Average	No. herds	No. lactations	Average	No. herds	No. lactations	Average
1993	257	17,319	5,211	257	12,973	3,798	119	7,832	5,220	119	6,125	3,743
1994	261	18,533	5,148	261	13,177	3,764	140	10,303	5,260	140	7,373	3,660
1995	241	16,053	5,322	241	11,406	3,974	135	9,040	5,280	135	7,081	3,771
1996	248	16,483	5,072	248	11,732	3,799	143	9,142	5,129	143	7,139	3,710
1997	215	14,603	5,094	215	10,521	3,876	125	8,595	5,197	125	6,827	3,826
1998	210	13,871	5,451	210	10,559	4,098	106	7,547	5,542	106	5,437	4,076
1999	185	12,179	5,633	185	9,606	4,161	115	8,195	5,709	115	6,067	4,205
2000	155	10,990	5,608	155	8,374	4,184	111	8,482	5,668	111	6,533	4,109
2001	114	7,701	6,165	114	6,932	4,574	92	7,162	6,306	92	5,336	4,536
2002	97	6,676	5,750	97	5,847	4,371	93	7,447	6,053	93	5,819	4,230
2003	88	5,544	6,071	88	5,695	4,671	104	9,258	6,111	104	6,376	4,357
2004	86	5,590	6,095	86	5,098	4,607	118	10,907	6,287	118	7,736	4,551
2005	76	5,409	6,025	76	4,521	4,594	112	9,912	6,349	112	7,203	4,499
2006	78	5,949	5,865	78	4,295	4,388	83	7,463	6,468	83	5,585	4,566
2007	56	4,005	6,257	56	2,852	4,587	96	9,311	6,461	96	6,161	4,603
2008	51	3,762	6,133	51	2,492	4,632	93	8,685	6,577	93	5,896	4,660
2009	50	3,627	5,890	50	2,563	4,568	89	8,337	6,568	89	5,827	4,769
2010	41	2,973	6,474	41	1,790	4,933	90	7,603	6,783	90	5,610	4,819
2011	40	3,027	6,585	40	2,044	5,000	84	7,507	6,982	84	5,478	4,946
2012	42	3,057	6,331	42	2,318	4,787	81	6,927	6,940	81	4,925	4,900
2013	42	2,719	6,483	42	2,067	4,929	77	7,027	6,823	77	4,729	4,914
2014	34	2,372	6,480	34	1,626	4,851	74	6,257	7,170	74	4,990	5,179
2015	32	1,969	6,655	32	1,456	4,768	59	5,688	7,277	59	3,967	5,196
2016	29	1,702	6,256	29	1,321	4,666	47	4,087	6,976	47	3,235	4,962
2017	20	1,304	6,451	20	965	5,074	50	4,354	7,215	50	3,262	5,122
2018	18	1,152	6,259	18	965	4,702	49	4,440	6,916	49	3,239	4,962
2019	17	1,352	6,901	17	871	5,234	37	3,913	7,403	37	2,108	5,437

Table A.9. Average 305-day fat yield (kg) per cow by calving system, breed and year

Year	Seasonal or split calving						Year-round calving					
	FFFF			JJJJ			FFFF			JJJJ		
	No. herds	No. lactations	Average	No. herds	No. lactations	Average	No. herds	No. lactations	Average	No. herds	No. lactations	Average
1993	257	17,319	221.6	257	12,973	197.5	119	7,832	216.3	119	6,125	196.4
1994	261	18,533	213.9	261	13,177	191.9	140	10,303	211.8	140	7,373	186.4
1995	241	16,053	221.0	241	11,406	203.6	135	9,040	212.1	135	7,081	191.5
1996	248	16,483	209.0	248	11,732	190.8	143	9,142	206.6	143	7,139	186.5
1997	215	14,603	207.2	215	10,521	192.3	125	8,595	205.6	125	6,827	189.6
1998	210	13,871	223.1	210	10,559	205.4	106	7,547	218.8	106	5,437	201.5
1999	185	12,179	227.7	185	9,606	205.9	115	8,195	227.3	115	6,067	206.6
2000	155	10,990	223.0	155	8,374	204.1	111	8,482	222.1	111	6,533	200.9
2001	114	7,701	245.5	114	6,932	224.4	92	7,162	246.3	92	5,336	221.0
2002	97	6,676	228.0	97	5,847	211.3	93	7,447	236.4	93	5,819	205.1
2003	88	5,544	245.4	88	5,695	228.7	104	9,258	242.7	104	6,376	211.7
2004	86	5,590	244.7	86	5,098	221.4	118	10,907	249.1	118	7,736	221.6
2005	76	5,409	243.7	76	4,521	222.8	112	9,912	248.4	112	7,203	217.5
2006	78	5,949	236.9	78	4,295	214.3	83	7,463	257.3	83	5,585	223.9
2007	56	4,005	251.9	56	2,852	222.3	96	9,311	260.5	96	6,161	227.8
2008	51	3,762	252.7	51	2,492	229.8	93	8,685	267.3	93	5,896	230.5
2009	50	3,627	242.0	50	2,563	219.8	89	8,337	265.7	89	5,827	234.3
2010	41	2,973	263.1	41	1,790	237.9	90	7,603	269.1	90	5,610	236.3
2011	40	3,027	261.1	40	2,044	236.5	84	7,507	275.5	84	5,478	241.8
2012	42	3,057	256.8	42	2,318	229.0	81	6,927	272.5	81	4,925	238.9
2013	42	2,719	261.3	42	2,067	238.1	77	7,027	267.9	77	4,729	239.8
2014	34	2,372	265.1	34	1,626	235.4	74	6,257	284.4	74	4,990	255.3
2015	32	1,969	268.9	32	1,456	232.8	59	5,688	287.3	59	3,967	255.2
2016	29	1,702	250.8	29	1,321	227.8	47	4,087	275.9	47	3,235	249.7
2017	20	1,304	259.3	20	965	245.7	50	4,354	285.7	50	3,262	251.4
2018	18	1,152	253.3	18	965	228.3	49	4,440	272.3	49	3,239	243.6
2019	17	1,352	277.7	17	871	261.0	37	3,913	290.6	37	2,108	265.5

Table A.10. Average 305-day fat concentration (g/100 mL) per cow by calving system, breed and year

Year	Seasonal or split calving						Year-round calving					
	FFFF			JJJJ			FFFF			JJJJ		
	No. herds	No. lactations	Average	No. herds	No. lactations	Average	No. herds	No. lactations	Average	No. herds	No. lactations	Average
1993	257	17,319	4.28	257	12,973	5.22	119	7,832	4.17	119	6,125	5.25
1994	261	18,533	4.18	261	13,177	5.10	140	10,303	4.05	140	7,373	5.10
1995	241	16,053	4.18	241	11,406	5.14	135	9,040	4.05	135	7,081	5.10
1996	248	16,483	4.14	248	11,732	5.04	143	9,142	4.06	143	7,139	5.03
1997	215	14,603	4.09	215	10,521	4.97	125	8,595	3.99	125	6,827	4.97
1998	210	13,871	4.12	210	10,559	5.03	106	7,547	3.98	106	5,437	4.96
1999	185	12,179	4.07	185	9,606	4.96	115	8,195	4.01	115	6,067	4.93
2000	155	10,990	4.01	155	8,374	4.89	111	8,482	3.97	111	6,533	4.91
2001	114	7,701	4.02	114	6,932	4.92	92	7,162	3.93	92	5,336	4.89
2002	97	6,676	3.99	97	5,847	4.83	93	7,447	3.93	93	5,819	4.85
2003	88	5,544	4.07	88	5,695	4.91	104	9,258	4.01	104	6,376	4.86
2004	86	5,590	4.04	86	5,098	4.81	118	10,907	4.00	118	7,736	4.88
2005	76	5,409	4.08	76	4,521	4.86	112	9,912	3.95	112	7,203	4.85
2006	78	5,949	4.07	78	4,295	4.89	83	7,463	4.02	83	5,585	4.91
2007	56	4,005	4.06	56	2,852	4.86	96	9,311	4.07	96	6,161	4.97
2008	51	3,762	4.15	51	2,492	4.97	93	8,685	4.10	93	5,896	4.95
2009	50	3,627	4.14	50	2,563	4.83	89	8,337	4.08	89	5,827	4.93
2010	41	2,973	4.10	41	1,790	4.87	90	7,603	4.02	90	5,610	4.93
2011	40	3,027	4.03	40	2,044	4.78	84	7,507	4.00	84	5,478	4.92
2012	42	3,057	4.09	42	2,318	4.81	81	6,927	3.97	81	4,925	4.88
2013	42	2,719	4.06	42	2,067	4.88	77	7,027	3.96	77	4,729	4.90
2014	34	2,372	4.14	34	1,626	4.88	74	6,257	4.01	74	4,990	4.95
2015	32	1,969	4.07	32	1,456	4.89	59	5,688	4.00	59	3,967	4.93
2016	29	1,702	4.05	29	1,321	4.89	47	4,087	4.01	47	3,235	5.06
2017	20	1,304	4.05	20	965	4.85	50	4,354	4.00	50	3,262	4.92
2018	18	1,152	4.06	18	965	4.84	49	4,440	3.98	49	3,239	4.93
2019	17	1,352	4.06	17	871	5.00	37	3,913	3.96	37	2,108	4.91

Table A.11. Average 305-day protein yield (kg) per cow by calving system, breed and year

Year	Seasonal or split calving						Year-round calving					
	FFFF			JJJJ			FFFF			JJJJ		
	No. herds	No. lactations	Average	No. herds	No. lactations	Average	No. herds	No. lactations	Average	No. herds	No. lactations	Average
1993	257	17,319	172.3	257	12,973	143.9	119	7,832	169.8	119	6,125	142.5
1994	261	18,533	167.5	261	13,177	139.9	140	10,303	168.4	140	7,373	136.0
1995	241	16,053	173.0	241	11,406	147.4	135	9,040	169.9	135	7,081	140.6
1996	248	16,483	163.5	248	11,732	139.4	143	9,142	163.6	143	7,139	136.6
1997	215	14,603	164.3	215	10,521	141.4	125	8,595	166.0	125	6,827	141.3
1998	210	13,871	178.8	210	10,559	152.2	106	7,547	178.8	106	5,437	150.5
1999	185	12,179	182.8	185	9,606	153.0	115	8,195	183.2	115	6,067	154.3
2000	155	10,990	181.2	155	8,374	153.3	111	8,482	182.4	111	6,533	151.4
2001	114	7,701	201.8	114	6,932	170.4	92	7,162	202.9	92	5,336	168.0
2002	97	6,676	184.7	97	5,847	161.4	93	7,447	193.6	93	5,819	155.7
2003	88	5,544	200.6	88	5,695	174.6	104	9,258	198.8	104	6,376	161.5
2004	86	5,590	200.4	86	5,098	169.5	118	10,907	203.4	118	7,736	168.0
2005	76	5,409	198.1	76	4,521	169.3	112	9,912	205.8	112	7,203	166.3
2006	78	5,949	195.1	78	4,295	162.4	83	7,463	213.6	83	5,585	170.6
2007	56	4,005	207.5	56	2,852	170.0	96	9,311	213.0	96	6,161	172.4
2008	51	3,762	205.7	51	2,492	173.6	93	8,685	217.9	93	5,896	174.8
2009	50	3,627	194.6	50	2,563	168.0	89	8,337	216.6	89	5,827	178.8
2010	41	2,973	216.0	41	1,790	183.8	90	7,603	223.5	90	5,610	181.0
2011	40	3,027	217.0	40	2,044	183.7	84	7,507	229.5	84	5,478	185.9
2012	42	3,057	207.8	42	2,318	176.2	81	6,927	226.0	81	4,925	182.7
2013	42	2,719	214.4	42	2,067	181.0	77	7,027	221.7	77	4,729	181.8
2014	34	2,372	214.4	34	1,626	178.7	74	6,257	234.4	74	4,990	192.1
2015	32	1,969	220.0	32	1,456	177.3	59	5,688	236.7	59	3,967	191.9
2016	29	1,702	207.7	29	1,321	172.6	47	4,087	226.4	47	3,235	185.2
2017	20	1,304	215.6	20	965	187.2	50	4,354	235.5	50	3,262	191.0
2018	18	1,152	207.3	18	965	175.3	49	4,440	222.0	49	3,239	185.1
2019	17	1,352	229.9	17	871	198.0	37	3,913	240.6	37	2,108	203.5

Table A.12. Average 305-day protein concentration (g/100mL) per cow by calving system, breed and year

Year	Seasonal or split calving						Year-round calving					
	FFFF			JJJJ			FFFF			JJJJ		
	No. herds	No. lactations	Average	No. herds	No. lactations	Average	No. herds	No. lactations	Average	No. herds	No. lactations	Average
1993	257	17,319	3.32	257	12,973	3.79	119	7,832	3.26	119	6,125	3.81
1994	261	18,533	3.26	261	13,177	3.72	140	10,303	3.21	140	7,373	3.72
1995	241	16,053	3.26	241	11,406	3.71	135	9,040	3.23	135	7,081	3.73
1996	248	16,483	3.23	248	11,732	3.67	143	9,142	3.20	143	7,139	3.68
1997	215	14,603	3.23	215	10,521	3.65	125	8,595	3.20	125	6,827	3.69
1998	210	13,871	3.29	210	10,559	3.71	106	7,547	3.24	106	5,437	3.70
1999	185	12,179	3.25	185	9,606	3.68	115	8,195	3.22	115	6,067	3.67
2000	155	10,990	3.24	155	8,374	3.67	111	8,482	3.24	111	6,533	3.70
2001	114	7,701	3.28	114	6,932	3.72	92	7,162	3.23	92	5,336	3.71
2002	97	6,676	3.21	97	5,847	3.69	93	7,447	3.20	93	5,819	3.68
2003	88	5,544	3.31	88	5,695	3.75	104	9,258	3.26	104	6,376	3.71
2004	86	5,590	3.29	86	5,098	3.68	118	10,907	3.25	118	7,736	3.70
2005	76	5,409	3.29	76	4,521	3.69	112	9,912	3.25	112	7,203	3.70
2006	78	5,949	3.34	78	4,295	3.71	83	7,463	3.31	83	5,585	3.74
2007	56	4,005	3.33	56	2,852	3.71	96	9,311	3.31	96	6,161	3.76
2008	51	3,762	3.36	51	2,492	3.75	93	8,685	3.32	93	5,896	3.76
2009	50	3,627	3.31	50	2,563	3.68	89	8,337	3.31	89	5,827	3.76
2010	41	2,973	3.35	41	1,790	3.74	90	7,603	3.31	90	5,610	3.77
2011	40	3,027	3.31	40	2,044	3.69	84	7,507	3.30	84	5,478	3.77
2012	42	3,057	3.29	42	2,318	3.69	81	6,927	3.27	81	4,925	3.74
2013	42	2,719	3.32	42	2,067	3.69	77	7,027	3.26	77	4,729	3.71
2014	34	2,372	3.32	34	1,626	3.69	74	6,257	3.28	74	4,990	3.72
2015	32	1,969	3.31	32	1,456	3.72	59	5,688	3.26	59	3,967	3.70
2016	29	1,702	3.33	29	1,321	3.70	47	4,087	3.26	47	3,235	3.75
2017	20	1,304	3.35	20	965	3.69	50	4,354	3.27	50	3,262	3.73
2018	18	1,152	3.31	18	965	3.72	49	4,440	3.22	49	3,239	3.73
2019	17	1,352	3.34	17	871	3.79	37	3,913	3.26	37	2,108	3.75

Lactations with Holsteins and Jerseys in separate herds (1993 – 2019)

Lactations were included only from herds with Holsteins and Jerseys in separate herds (i.e. herds with at least 100 calvings in year with Holsteins or Jerseys but no calvings by both breeds in year).

Table A.13. Average 305-day solids yield (kg) per cow by calving system, breed and year

Year	Seasonal or split calving						Year-round calving					
	FFFF			JJJJ			FFFF			JJJJ		
	No. herds	No. lactations	Average	No. herds	No. lactations	Average	No. herds	No. lactations	Average	No. herds	No. lactations	Average
1993	505	63,815	405.1	75	9,428	347.5	581	74,301	407.5	88	11,547	352.5
1994	633	84,464	400.7	86	12,132	347.5	915	122,393	410.8	111	15,635	340.1
1995	699	83,640	412.2	82	11,080	356.3	809	104,209	419.4	96	12,293	347.7
1996	848	99,900	401.0	102	12,556	345.1	1,071	132,358	420.5	109	13,703	354.1
1997	1023	125,155	396.2	120	15,989	357.8	1,205	152,597	435.6	108	14,601	366.2
1998	1068	130,683	413.7	131	17,462	375.8	1,281	166,888	455.5	111	14,702	395.6
1999	1058	131,149	427.5	117	16,301	380.9	1,348	173,350	462.7	115	15,712	409.6
2000	973	123,169	418.3	108	15,258	375.4	1,386	186,996	458.1	117	16,449	410.6
2001	745	93,753	449.3	78	11,257	417.3	1,263	175,953	481.2	97	14,261	434.3
2002	594	76,707	412.2	71	10,966	381.1	1,210	177,267	462.4	101	15,250	417.5
2003	572	72,063	437.5	79	12,849	401.2	1,194	175,613	481.6	95	14,757	432.5
2004	530	67,874	456.8	77	11,677	400.9	1,249	186,901	489.1	122	19,756	440.2
2005	426	57,850	464.4	72	11,477	410.8	1,182	182,050	499.5	118	19,587	434.4
2006	401	53,596	458.4	73	12,060	409.0	1,066	163,899	505.8	103	17,130	446.0
2007	328	44,770	476.4	66	10,447	415.0	1,046	165,844	512.1	105	17,910	459.1
2008	304	41,466	484.9	49	7,551	437.8	1,008	158,586	524.2	109	18,940	458.0
2009	240	31,851	464.8	47	7,250	432.0	978	160,425	518.5	97	16,412	453.1
2010	249	30,626	491.5	44	6,368	435.1	963	152,083	525.5	95	17,380	445.0
2011	210	25,795	503.1	37	4,911	413.9	1,002	162,930	533.7	92	17,649	466.3
2012	207	25,151	466.4	37	4,757	406.8	951	154,983	529.5	100	18,750	466.1
2013	208	25,108	483.2	37	4,502	421.8	922	145,269	529.5	96	17,761	457.1
2014	216	27,180	504.3	36	4,873	427.1	881	139,211	540.8	96	16,959	465.4
2015	180	22,250	502.0	30	3,775	427.0	840	130,563	539.0	87	16,000	473.1
2016	175	21,115	491.6	23	2,992	405.4	722	112,831	527.8	77	13,947	457.3
2017	161	17,453	498.6	29	3,464	434.8	691	105,709	539.9	81	14,320	470.3
2018	154	16,708	499.0	31	4,077	418.6	665	102,936	532.3	80	13,295	462.2
2019	147	15,875	523.5	30	3,863	426.7	526	78,679	553.4	71	11,562	466.0

Table A.14. Average 305-day milk yield (kg) per cow by calving system, breed and year

Year	Seasonal or split calving						Year-round calving					
	FFFF			JJJJ			FFFF			JJJJ		
	No. herds	No. lactations	Average	No. herds	No. lactations	Average	No. herds	No. lactations	Average	No. herds	No. lactations	Average
1993	505	63,815	5,528	75	9,428	3,721	581	74,301	5,784	88	11,547	3,776
1994	633	84,464	5,554	86	12,132	3,796	915	122,393	5,893	111	15,635	3,723
1995	699	83,640	5,726	82	11,080	3,911	809	104,209	6,021	96	12,293	3,818
1996	848	99,900	5,580	102	12,556	3,849	1,071	132,358	6,002	109	13,703	3,929
1997	1023	125,155	5,600	120	15,989	4,014	1,205	152,597	6,236	108	14,601	4,105
1998	1068	130,683	5,738	131	17,462	4,213	1,281	166,888	6,484	111	14,702	4,427
1999	1058	131,149	5,969	117	16,301	4,314	1,348	173,350	6,601	115	15,712	4,640
2000	973	123,169	5,857	108	15,258	4,304	1,386	186,996	6,546	117	16,449	4,702
2001	745	93,753	6,287	78	11,257	4,740	1,263	175,953	6,885	97	14,261	4,983
2002	594	76,707	5,782	71	10,966	4,387	1,210	177,267	6,633	101	15,250	4,849
2003	572	72,063	6,076	79	12,849	4,563	1,194	175,613	6,851	95	14,757	4,973
2004	530	67,874	6,353	77	11,677	4,636	1,249	186,901	6,979	122	19,756	5,084
2005	426	57,850	6,498	72	11,477	4,714	1,182	182,050	7,146	118	19,587	5,032
2006	401	53,596	6,393	73	12,060	4,686	1,066	163,899	7,206	103	17,130	5,191
2007	328	44,770	6,591	66	10,447	4,738	1,046	165,844	7,265	105	17,910	5,313
2008	304	41,466	6,645	49	7,551	5,002	1,008	158,586	7,360	109	18,940	5,258
2009	240	31,851	6,372	47	7,250	4,925	978	160,425	7,297	97	16,412	5,245
2010	249	30,626	6,796	44	6,368	4,910	963	152,083	7,450	95	17,380	5,123
2011	210	25,795	7,041	37	4,911	4,764	1,002	162,930	7,593	92	17,649	5,389
2012	207	25,151	6,485	37	4,757	4,663	951	154,983	7,560	100	18,750	5,403
2013	208	25,108	6,746	37	4,502	4,868	922	145,269	7,569	96	17,761	5,335
2014	216	27,180	7,032	36	4,873	4,869	881	139,211	7,701	96	16,959	5,401
2015	180	22,250	7,025	30	3,775	4,835	840	130,563	7,706	87	16,000	5,481
2016	175	21,115	6,839	23	2,992	4,658	722	112,831	7,545	77	13,947	5,281
2017	161	17,453	6,952	29	3,464	4,960	691	105,709	7,699	81	14,320	5,469
2018	154	16,708	6,961	31	4,077	4,758	665	102,936	7,607	80	13,295	5,391
2019	147	15,875	7,278	30	3,863	4,789	526	78,679	7,865	71	11,562	5,380

Table A.15. Average 305-day fat yield (kg) per cow by calving system, breed and year

Year	Seasonal or split calving						Year-round calving					
	FFFF			JJJJ			FFFF			JJJJ		
	No. herds	No. lactations	Average	No. herds	No. lactations	Average	No. herds	No. lactations	Average	No. herds	No. lactations	Average
1993	505	63,815	226.4	75	9,428	201.7	581	74,301	226.2	88	11,547	204.8
1994	633	84,464	222.8	86	12,132	201.5	915	122,393	226.4	111	15,635	197.1
1995	699	83,640	228.7	82	11,080	206.9	809	104,209	230.0	96	12,293	201.1
1996	848	99,900	222.4	102	12,556	200.1	1,071	132,358	232.9	109	13,703	205.4
1997	1023	125,155	218.1	120	15,989	206.3	1,205	152,597	240.1	108	14,601	210.7
1998	1068	130,683	227.3	131	17,462	216.5	1,281	166,888	250.4	111	14,702	227.5
1999	1058	131,149	234.6	117	16,301	219.3	1,348	173,350	253.4	115	15,712	234.6
2000	973	123,169	229.3	108	15,258	215.5	1,386	186,996	250.3	117	16,449	234.3
2001	745	93,753	245.1	78	11,257	238.1	1,263	175,953	261.0	97	14,261	245.6
2002	594	76,707	227.5	71	10,966	216.8	1,210	177,267	252.1	101	15,250	235.6
2003	572	72,063	238.7	79	12,849	227.6	1,194	175,613	260.8	95	14,757	244.7
2004	530	67,874	249.3	77	11,677	227.6	1,249	186,901	264.8	122	19,756	248.8
2005	426	57,850	251.4	72	11,477	234.0	1,182	182,050	269.3	118	19,587	245.4
2006	401	53,596	247.8	73	12,060	231.4	1,066	163,899	271.9	103	17,130	250.5
2007	328	44,770	259.0	66	10,447	236.6	1,046	165,844	276.5	105	17,910	259.4
2008	304	41,466	263.8	49	7,551	247.7	1,008	158,586	284.2	109	18,940	259.6
2009	240	31,851	254.2	47	7,250	244.9	978	160,425	281.4	97	16,412	256.7
2010	249	30,626	266.1	44	6,368	247.6	963	152,083	283.4	95	17,380	251.9
2011	210	25,795	269.8	37	4,911	234.3	1,002	162,930	286.6	92	17,649	263.6
2012	207	25,151	253.1	37	4,757	231.7	951	154,983	285.2	100	18,750	263.6
2013	208	25,108	262.1	37	4,502	240.6	922	145,269	285.2	96	17,761	258.3
2014	216	27,180	272.9	36	4,873	244.6	881	139,211	291.5	96	16,959	264.6
2015	180	22,250	271.6	30	3,775	245.3	840	130,563	289.7	87	16,000	268.3
2016	175	21,115	265.6	23	2,992	230.2	722	112,831	284.4	77	13,947	260.2
2017	161	17,453	267.8	29	3,464	248.6	691	105,709	290.2	81	14,320	266.5
2018	154	16,708	270.4	31	4,077	238.9	665	102,936	288.1	80	13,295	261.2
2019	147	15,875	281.0	30	3,863	244.3	526	78,679	298.3	71	11,562	262.9

Table A.16. Average 305-day fat concentration (g/100 mL) per cow by calving system, breed and year

Year	Seasonal or split calving						Year-round calving					
	FFFF			JJJJ			FFFF			JJJJ		
	No. herds	No. lactations	Average	No. herds	No. lactations	Average	No. herds	No. lactations	Average	No. herds	No. lactations	Average
1993	505	63,815	4.12	75	9,428	5.42	581	74,301	3.93	88	11,547	5.43
1994	633	84,464	4.03	86	12,132	5.31	915	122,393	3.87	111	15,635	5.30
1995	699	83,640	4.02	82	11,080	5.31	809	104,209	3.85	96	12,293	5.28
1996	848	99,900	4.02	102	12,556	5.21	1,071	132,358	3.91	109	13,703	5.24
1997	1023	125,155	3.92	120	15,989	5.14	1,205	152,597	3.88	108	14,601	5.15
1998	1068	130,683	4.00	131	17,462	5.15	1,281	166,888	3.89	111	14,702	5.16
1999	1058	131,149	3.97	117	16,301	5.10	1,348	173,350	3.87	115	15,712	5.07
2000	973	123,169	3.95	108	15,258	5.02	1,386	186,996	3.86	117	16,449	5.00
2001	745	93,753	3.94	78	11,257	5.05	1,263	175,953	3.83	97	14,261	4.95
2002	594	76,707	3.96	71	10,966	4.94	1,210	177,267	3.84	101	15,250	4.87
2003	572	72,063	3.97	79	12,849	5.00	1,194	175,613	3.85	95	14,757	4.94
2004	530	67,874	3.96	77	11,677	4.93	1,249	186,901	3.84	122	19,756	4.91
2005	426	57,850	3.91	72	11,477	4.97	1,182	182,050	3.82	118	19,587	4.89
2006	401	53,596	3.92	73	12,060	4.95	1,066	163,899	3.82	103	17,130	4.84
2007	328	44,770	3.98	66	10,447	4.99	1,046	165,844	3.85	105	17,910	4.90
2008	304	41,466	4.01	49	7,551	4.98	1,008	158,586	3.91	109	18,940	4.95
2009	240	31,851	4.03	47	7,250	4.99	978	160,425	3.90	97	16,412	4.91
2010	249	30,626	3.97	44	6,368	5.06	963	152,083	3.85	95	17,380	4.94
2011	210	25,795	3.89	37	4,911	4.95	1,002	162,930	3.83	92	17,649	4.91
2012	207	25,151	3.94	37	4,757	4.98	951	154,983	3.82	100	18,750	4.89
2013	208	25,108	3.94	37	4,502	4.96	922	145,269	3.82	96	17,761	4.86
2014	216	27,180	3.94	36	4,873	5.04	881	139,211	3.84	96	16,959	4.93
2015	180	22,250	3.93	30	3,775	5.06	840	130,563	3.82	87	16,000	4.91
2016	175	21,115	3.94	23	2,992	4.96	722	112,831	3.83	77	13,947	4.94
2017	161	17,453	3.91	29	3,464	5.02	691	105,709	3.82	81	14,320	4.88
2018	154	16,708	3.93	31	4,077	5.03	665	102,936	3.83	80	13,295	4.85
2019	147	15,875	3.91	30	3,863	5.11	526	78,679	3.84	71	11,562	4.90

Table A.17. Average 305-day protein yield (kg) per cow by calving system, breed and year

Year	Seasonal or split calving						Year-round calving					
	FFFF			JJJJ			FFFF			JJJJ		
	No. herds	No. lactations	Average	No. herds	No. lactations	Average	No. herds	No. lactations	Average	No. herds	No. lactations	Average
1993	505	63,815	178.7	75	9,428	145.8	581	74,301	181.2	88	11,547	147.7
1994	633	84,464	177.9	86	12,132	146.0	915	122,393	184.5	111	15,635	143.0
1995	699	83,640	183.5	82	11,080	149.4	809	104,209	189.3	96	12,293	146.7
1996	848	99,900	178.6	102	12,556	144.9	1,071	132,358	187.6	109	13,703	148.7
1997	1023	125,155	178.1	120	15,989	151.5	1,205	152,597	195.5	108	14,601	155.5
1998	1068	130,683	186.4	131	17,462	159.3	1,281	166,888	205.1	111	14,702	168.1
1999	1058	131,149	192.9	117	16,301	161.5	1,348	173,350	209.3	115	15,712	174.9
2000	973	123,169	189.0	108	15,258	159.8	1,386	186,996	207.8	117	16,449	176.2
2001	745	93,753	204.1	78	11,257	179.1	1,263	175,953	220.2	97	14,261	188.7
2002	594	76,707	184.6	71	10,966	164.4	1,210	177,267	210.4	101	15,250	181.9
2003	572	72,063	198.8	79	12,849	173.5	1,194	175,613	220.8	95	14,757	187.9
2004	530	67,874	207.4	77	11,677	173.3	1,249	186,901	224.2	122	19,756	191.3
2005	426	57,850	213.1	72	11,477	176.7	1,182	182,050	230.2	118	19,587	189.0
2006	401	53,596	210.5	73	12,060	177.5	1,066	163,899	234.0	103	17,130	195.5
2007	328	44,770	217.4	66	10,447	178.4	1,046	165,844	235.6	105	17,910	199.7
2008	304	41,466	221.2	49	7,551	190.1	1,008	158,586	240.0	109	18,940	198.4
2009	240	31,851	210.6	47	7,250	187.2	978	160,425	237.1	97	16,412	196.3
2010	249	30,626	225.4	44	6,368	187.4	963	152,083	242.1	95	17,380	193.2
2011	210	25,795	233.3	37	4,911	179.6	1,002	162,930	247.2	92	17,649	202.6
2012	207	25,151	213.3	37	4,757	175.1	951	154,983	244.3	100	18,750	202.5
2013	208	25,108	221.2	37	4,502	181.3	922	145,269	244.4	96	17,761	198.7
2014	216	27,180	231.4	36	4,873	182.5	881	139,211	249.3	96	16,959	200.7
2015	180	22,250	230.4	30	3,775	181.7	840	130,563	249.3	87	16,000	204.8
2016	175	21,115	226.0	23	2,992	175.2	722	112,831	243.3	77	13,947	197.1
2017	161	17,453	230.8	29	3,464	186.2	691	105,709	249.7	81	14,320	203.8
2018	154	16,708	228.7	31	4,077	179.6	665	102,936	244.3	80	13,295	201.0
2019	147	15,875	242.5	30	3,863	182.3	526	78,679	255.1	71	11,562	203.1

Table A.18. Average 305-day protein concentration (g/100 mL) per cow by calving system, breed and year

Year	Seasonal or split calving						Year-round calving					
	FFFF			JJJJ			FFFF			JJJJ		
	No. herds	No. lactations	Average	No. herds	No. lactations	Average	No. herds	No. lactations	Average	No. herds	No. lactations	Average
1993	505	63,815	3.24	75	9,428	3.92	581	74,301	3.14	88	11,547	3.92
1994	633	84,464	3.21	86	12,132	3.85	915	122,393	3.14	111	15,635	3.84
1995	699	83,640	3.21	82	11,080	3.82	809	104,209	3.15	96	12,293	3.85
1996	848	99,900	3.21	102	12,556	3.77	1,071	132,358	3.13	109	13,703	3.78
1997	1023	125,155	3.18	120	15,989	3.77	1,205	152,597	3.15	108	14,601	3.79
1998	1068	130,683	3.26	131	17,462	3.79	1,281	166,888	3.17	111	14,702	3.80
1999	1058	131,149	3.24	117	16,301	3.75	1,348	173,350	3.18	115	15,712	3.78
2000	973	123,169	3.24	108	15,258	3.72	1,386	186,996	3.19	117	16,449	3.76
2001	745	93,753	3.26	78	11,257	3.78	1,263	175,953	3.21	97	14,261	3.80
2002	594	76,707	3.20	71	10,966	3.75	1,210	177,267	3.18	101	15,250	3.75
2003	572	72,063	3.28	79	12,849	3.80	1,194	175,613	3.23	95	14,757	3.78
2004	530	67,874	3.28	77	11,677	3.74	1,249	186,901	3.22	122	19,756	3.77
2005	426	57,850	3.29	72	11,477	3.75	1,182	182,050	3.23	118	19,587	3.76
2006	401	53,596	3.30	73	12,060	3.79	1,066	163,899	3.26	103	17,130	3.77
2007	328	44,770	3.31	66	10,447	3.77	1,046	165,844	3.25	105	17,910	3.77
2008	304	41,466	3.34	49	7,551	3.80	1,008	158,586	3.27	109	18,940	3.78
2009	240	31,851	3.32	47	7,250	3.81	978	160,425	3.26	97	16,412	3.75
2010	249	30,626	3.33	44	6,368	3.83	963	152,083	3.26	95	17,380	3.79
2011	210	25,795	3.33	37	4,911	3.79	1,002	162,930	3.27	92	17,649	3.76
2012	207	25,151	3.30	37	4,757	3.76	951	154,983	3.25	100	18,750	3.75
2013	208	25,108	3.29	37	4,502	3.73	922	145,269	3.24	96	17,761	3.73
2014	216	27,180	3.30	36	4,873	3.74	881	139,211	3.25	96	16,959	3.72
2015	180	22,250	3.29	30	3,775	3.75	840	130,563	3.25	87	16,000	3.74
2016	175	21,115	3.32	23	2,992	3.77	722	112,831	3.24	77	13,947	3.74
2017	161	17,453	3.33	29	3,464	3.76	691	105,709	3.26	81	14,320	3.73
2018	154	16,708	3.30	31	4,077	3.77	665	102,936	3.22	80	13,295	3.73
2019	147	15,875	3.34	30	3,863	3.81	526	78,679	3.26	71	11,562	3.78

B. Feed conversion efficiency (studies reviewed by Grainger and Goddard, 2004)

Table B.1. Effects of breed on feed intake and feed conversion efficiency. [Grainger and Goddard, 2004].

Reference	Intake (kg DM/100 kg LW)			FCE (g MS/kg DM)		
	H-F	J	% diff.[A]	H-F	J	% diff.[A]
USA						
Rastani *et al.* (2001)	3.34	3.59	-7.5	134	130	3.0
West *et al.* (1990)	3.17	3.74	-18	78	86	-10.3
Beaulieu and Palmquist (1995)	3.3	3.84	-16.4	108	108	0
Blake *et al.* (1986)	3.2	3.65	-14.1	1.4[B]	1.3[B]	7.1
Tyrrell *et al.* (1990)	4.08	4.73	-15.9	110	125	-13.6
EUROPE						
Oldenbroek (1988)	3.29[C]	4.05	-23.1	87.5	95.1	-8.7
	3.11[D]	3.84	-23.5	88.6	105.2	-18.7
Gibson (1986)	2.68	3.09	-15.3	42.3	43.1	-1.9
NZ						
L'Huillier *et al.* (1988)	2.9	3.2	-10.3	105	108	-2.9
Mackle *et al.* (1996)	2.55	2.66	-4.3	115	128.5	-11.7
Thomson *et al.* (2001)	2.8	3.03	-8.2	99	109.8	-10.9

[A] Difference calculated as (H-F – J)/H-F expressed as a %; [B] FCE is kg 4%FCM/kg DM; [C] TMR diet; [D] Roughage diet

C. Nutrient digestibility data (Aikman et al., 2008; Sears et al., 2020)

Table C.1. Apparent total tract digestibility of dietary components by Holstein and Jersey cows measured at week 5 before expected calving date (−5) and week 6 and 14 of lactation. [Aikman *et al.*, 2008].

Item	Holsteins			Jerseys			SEM	$P <$		
	−5	6	14	−5	6	14		Breed	Week	Breed × week
DM										
Intake, kg/d	8.63	22.67	22.93	6.62	14.70	15.45	0.79	0.001	0.001	0.001
Digestibility, g/kg	695	710	716	707	725	720	11	0.266	0.224	0.843
OM										
Intake, kg/d	7.93	21.16	21.43	6.10	13.74	14.40	0.74	0.001	0.001	0.001
Digestibility, g/kg	716	730	737	726	747	743	10	0.192	0.128	0.821
Starch										
Intake, kg/d	0.22	4.37	4.14	0.15	2.76	2.67	0.10	0.001	0.001	0.001
Digestibility, g/kg	897	963	964	890	971	962	7	0.956	0.001	0.486
NDF										
Intake, kg/d	4.72	7.91	8.12	3.58	5.26	5.63	0.25	0.001	0.001	0.003
Digestibility, g/kg	693	547	565	709	584	595	19	0.008	0.001	0.750
ADF										
Intake, kg/d	2.97	4.67	4.91	2.23	3.17	3.43	0.16	0.001	0.001	0.008
Digestibility, g/kg	626	476	496	625	504	501	23	0.416	0.001	0.600
N										
Intake, g/d	194	585	594	146	375	405	21	0.001	0.001	0.001
Digestibility, g/kg	667	676	680	652	694	684	11	0.801	0.076	0.352

Table C.2. Nitrogen metabolism of mid-lactation Jersey and Holstein cows supplemented with or without a palmitic acid–enriched supplement. [Sears *et al.*, 2020].

Item	Jersey		Holstein		SEM	*P*-value		
	Control	Palmitic acid	Control	Palmitic acid		Treatment	Breed	Treatment × breed
Nitrogen intake, g/d	633	638	706	682	21.3	0.48	<0.01	0.33
Nitrogen intake, % of BW	0.13	0.14	0.09	0.09	0.01	0.45	<0.01	0.21
BUN, mg/dL	12.6	12.6	13.8	13.8	0.57	0.45	0.02	0.28
MUN, mg/dL	15.1	14.5	14.5	14.1	0.44	0.20	0.13	0.73
Milk protein nitrogen, g/d	165	173	166	170	7.89	0.24	0.69	0.69
Milk nitrogen efficiency, %	26.0	26.9	23.8	25.8	2.57	0.16	0.23	0.59
Urine total nitrogen, g/d	134	115	144	146	6.11	0.20	<0.01	0.12
Urine total nitrogen, % of nitrogen intake	21.0	17.9	20.5	21.7	1.15	0.18	0.04	0.55
Urine total nitrogen, % of BW	0.029	0.025	0.019	0.020	0.003	0.97	0.03	0.13

D. *Daily DM intake and plasma NEFA levels pre-calving* (French *et al.*, 2006)

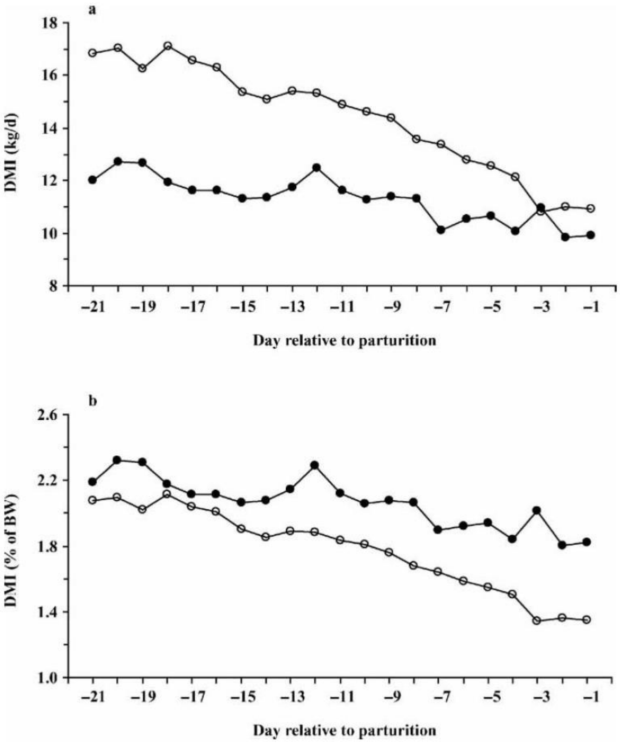


Figure D.1. Least squares mean daily DM intake expressed as kg/d (a) and percentage of BW (b) by day relative to parturition for Holsteins (○) and Jerseys (●). Interaction for breed by time was significant at the level of P < 0.001 (SE = 0.6, n = 14) and P < 0.05 (SE = 0.12, n = 14) for DMI expressed as kilograms/day and percentage of BW, respectively. [French, 2006].

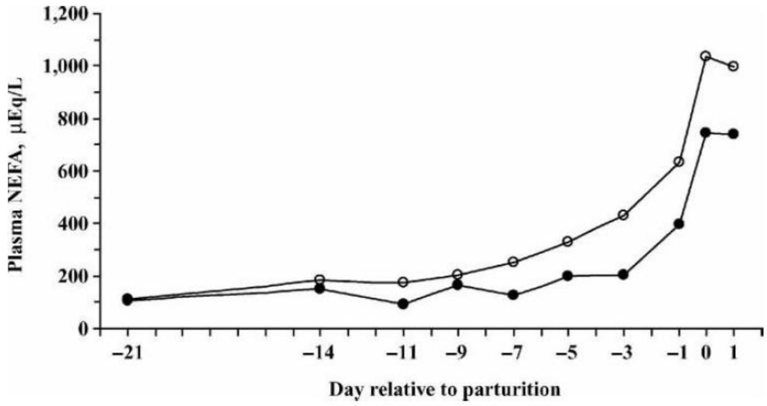


Figure D.2. Least squares mean plasma NEFA by day relative to parturition for Holsteins (○) and Jerseys (●). Interaction for breed by time was significant at the level of P < 0.01 (SE = 67, n = 14). Nonesterified fatty acids (NEFAs) were greater for Holsteins from 3 d prepartum to 1 d postpartum relative to Jerseys. [French, 2006].

E. Individual cow cell counts (Aust. herd recording data, 2000-2019)

Table E.1. Percentages of lactations where the cow had at least one individual cow cell count >250,000 cells/mL; only individual cow cell counts by 400 days in milk were included and only lactations with 4 to 10 such counts were used. [DataGene, 2021].

Year	FFFF		JJJJ	
	No. lactations	% of lactations where atleast one individual cow cell count was >250,000	No. lactations	% of lactations where atleast one individual cow cell count was >250,000
2000	83,889	47.7%	9,288	48.1%
2001	86,034	42.8%	8,747	44.1%
2002	84,234	44.4%	8,662	43.9%
2003	83,230	43.6%	8,508	43.2%
2004	85,669	43.7%	8,931	44.3%
2005	87,141	45.6%	8,660	44.4%
2006	83,649	46.7%	8,874	47.5%
2007	81,648	48.1%	9,588	49.2%
2008	83,441	46.3%	8,392	45.9%
2009	79,826	46.0%	8,025	45.3%
2010	80,546	47.9%	8,102	49.0%
2011	85,795	45.7%	9,012	48.5%
2012	82,300	45.1%	9,273	46.1%
2013	79,471	42.1%	9,112	42.3%
2014	77,661	40.5%	8,772	42.7%
2015	74,488	38.9%	9,158	39.9%
2016	56,588	41.2%	7,691	43.3%
2017	57,078	38.6%	8,395	41.3%
2018	53,740	36.6%	7,670	37.9%
2019	48,060	32.0%	6,458	32.0%

Table E.2. Averages of peak individual cow cell counts for lactations; only individual cow cell counts by 400 days in milk were included and only lactations with 4 to 10 such counts were used. [DataGene, 2021].

Year	FFFF		JJJJ	
	No. lactations	Average of peak individual cow cell counts for lactations	No. lactations	Average of peak individual cow cell counts for lactations
2000	83,889	587.5	9,288	533.6
2001	86,034	523.3	8,747	528.3
2002	84,234	534.4	8,662	479.5
2003	83,230	546.8	8,508	494.7
2004	85,669	552.2	8,931	518.1
2005	87,141	587.0	8,660	507.5
2006	83,649	622.8	8,874	529.9
2007	81,648	655.6	9,588	571.0
2008	83,441	612.8	8,392	530.0
2009	79,826	593.5	8,025	516.8
2010	80,546	620.2	8,102	583.8
2011	85,795	615.3	9,012	585.8
2012	82,300	618.6	9,273	583.1
2013	79,471	589.4	9,112	541.2
2014	77,661	568.5	8,772	528.0
2015	74,488	564.0	9,158	501.8
2016	56,588	638.3	7,691	576.5
2017	57,078	606.5	8,395	543.0
2018	53,740	552.5	7,670	493.7
2019	48,060	518.3	6,458	455.4

Table E.3. Averages of arithmetic average individual cow cell count for lactations; only individual cow cell counts by 400 days in milk were included and only lactations with 4 to 10 such counts were used. [DataGene, 2021].

Year	FFFF		JJJJ	
	No. lactations	Average of average individual cow cell count for lactations	No. lactations	Average of average individual cow cell count for lactations
2000	83,889	228.0	9,288	215.0
2001	86,034	201.6	8,747	202.2
2002	84,234	205.7	8,662	192.5
2003	83,230	208.6	8,508	197.5
2004	85,669	213.9	8,931	200.4
2005	87,141	221.0	8,660	197.9
2006	83,649	228.8	8,874	205.7
2007	81,648	239.9	9,588	225.6
2008	83,441	223.6	8,392	208.3
2009	79,826	220.0	8,025	201.8
2010	80,546	228.2	8,102	228.5
2011	85,795	223.9	9,012	227.2
2012	82,300	221.5	9,273	224.7
2013	79,471	208.2	9,112	208.3
2014	77,661	200.5	8,772	203.2
2015	74,488	194.6	9,158	186.6
2016	56,588	217.4	7,691	218.7
2017	57,078	202.0	8,395	192.7
2018	53,740	183.9	7,670	179.8
2019	48,060	175.0	6,458	169.1

F. Relationship between ambient temperature and rectal temperature (Muller and Botha, 1993)

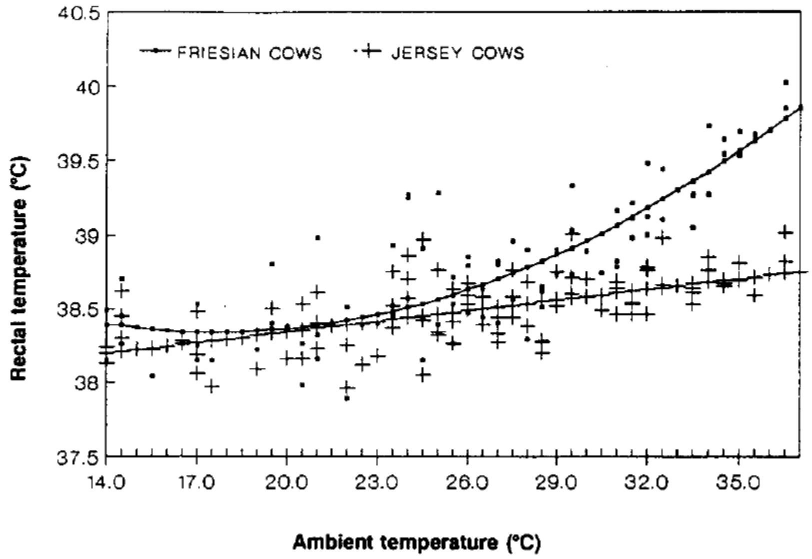


Figure F.1. The relationship between ambient temperature(x) and rectal temperature (y) of Friesian [y = 39.57 - 0.1403(SE = 0.0354)x+ 0.004(SE = 0.OOO7)xx^2; R^2 = 0.63] and Jersey cows [y = 37.86 - 0.02405(SE= 0.OO36)x;R^2 = 0.30]. [Muller and Botha, 1993].

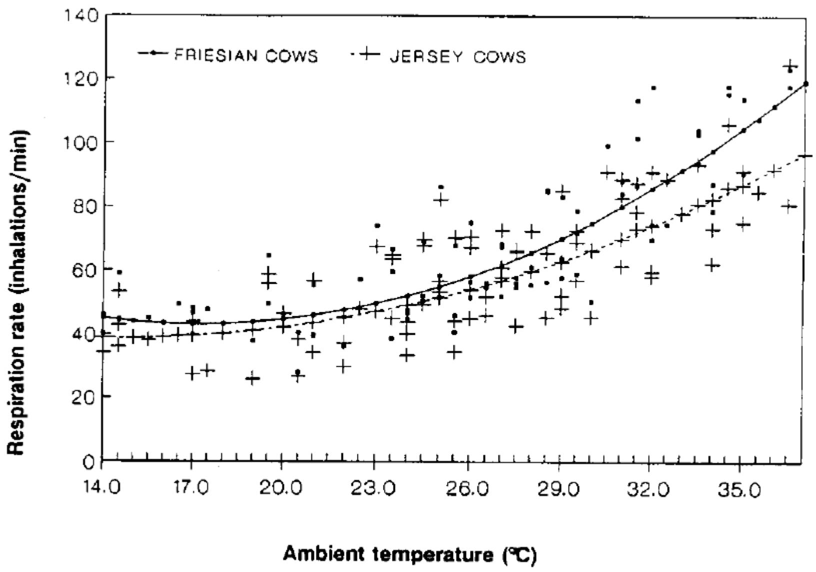


Figure F.2. The relationship between ambient temperature (x) and respiration rate (y) of Friesian [y = IOLl - 6.728(SE = 1.511)x + 0.195(SE = 0.030)x^2; R^2 = 0.708] and Jersey cows [y = 62.80 - 3.315(5£ = 1.614)x + 0.115(5£ = 0.032)x^2; R^2 = 0.556]. [Muller and Botha, 1993].

G. *Distribution and trend in ABVg for heat tolerance (Nguyen et al., 2018)*

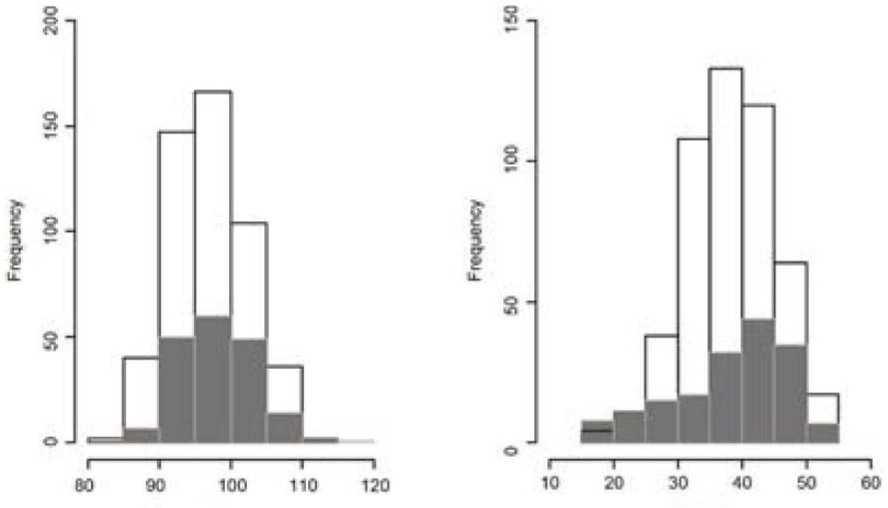


Figure G.1. (a) Distribution of Australian genomic breeding value for heat tolerance in 497 Holstein (white bars) and 183 Jersey (gray bars) bulls without daughters in the reference; **(b)** corresponding reliability. [Nguyen *et al.*, 2018].

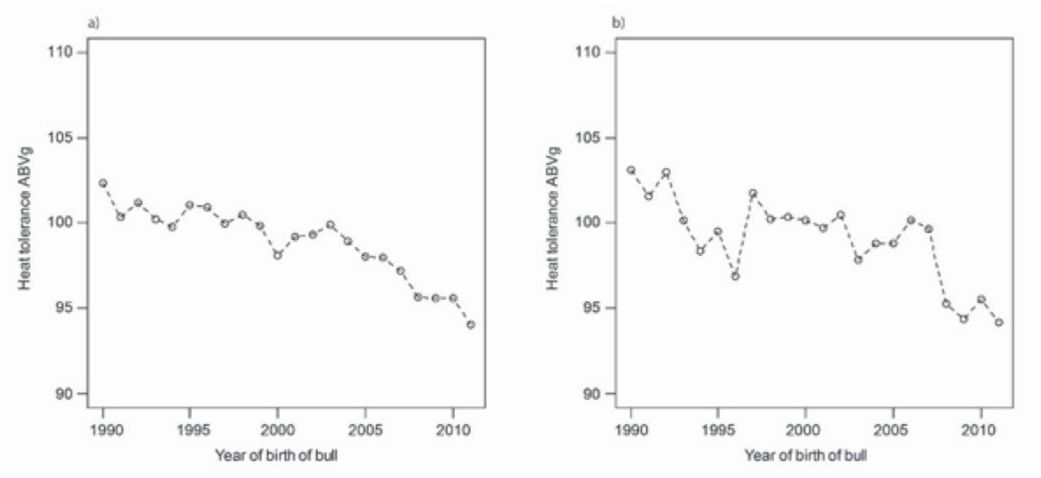


Figure G.2. Genetic trend of ABVg for heat tolerance in **(a)** 2,665 Holstein and **(b)** 641 Jersey bulls born in and after 1990 [Nguyen *et al.*, 2018].

H. Longevity (Aust. herd recording data, 1990-2019)

Calvings from 1980 to mid-2020 in Australian herd data held by DataGene were used to assess longevity i.e. time from first calving to last calving, using cows aged 21 to 30 months at their first recorded calving. Each cow's last recorded calving was classified as the cow's final calving in the herd if she had no further calvings recorded in the herd for at least 20 months. Where herds had ceased milk recording, cows whose last recorded calving was in the last 20 months before the herd's last recorded calving date were right-censored at their last recorded calving date. Where herds had temporarily stopped milk recording for periods of more than 365 days (ie no recorded calving dates for the herd for that time), cows whose last recorded calving was after the herd recommenced milk recording were right-censored at 20 months before the date the herd stopped milk recorded.

Table H.1. Percentages of first calvers (aged 21 to 30 months at first calving) that did not have a subsequent calving in the herd by breed and year of first calving

Year of first calving	FFFF		JJJJ	
	No. cows	**% that did not have a subsequent calving**	**No. cows**	**% that did not have a subsequent calving**
1990 to 1994	334,725	13.8%	60,522	11.3%
1995 to 1999	538,211	19.0%	83,932	16.0%
2000 to 2004	494,339	21.0%	75,660	17.7%
2005 to 2009	344,483	22.7%	55,485	20.7%
2010 to 2014	274,873	22.7%	47,363	18.9%
2015 to 2019	215,509	18.9%	36,721	17.2%

Table H.2. Median times from first calving at 21 to 30 months to last calving in the herd by breed and year of first calving

Year of first calving	FFFF		JJJJ	
	No. cows	**Median time from first to last calving (years (months))**	**No. cows**	**Median time from first to last calving (years (months))**
1990 to 1994	334,725	3.8 (45.2)	60,522	3.9 (47.3)
1995 to 1999	538,211	3.0 (35.9)	83,932	3.0 (36.6)
2000 to 2004	494,339	2.4 (28.2)	75,660	3.0 (35.9)
2005 to 2009	344,483	2.2 (26.1)	55,485	2.5 (30.5)
2010 to 2014	274,873	2.2 (26.0)	47,363	2.7 (32.5)
2015 to 2019	215,509	3.3 (39.8)	36,721	>3.3 (39.8)

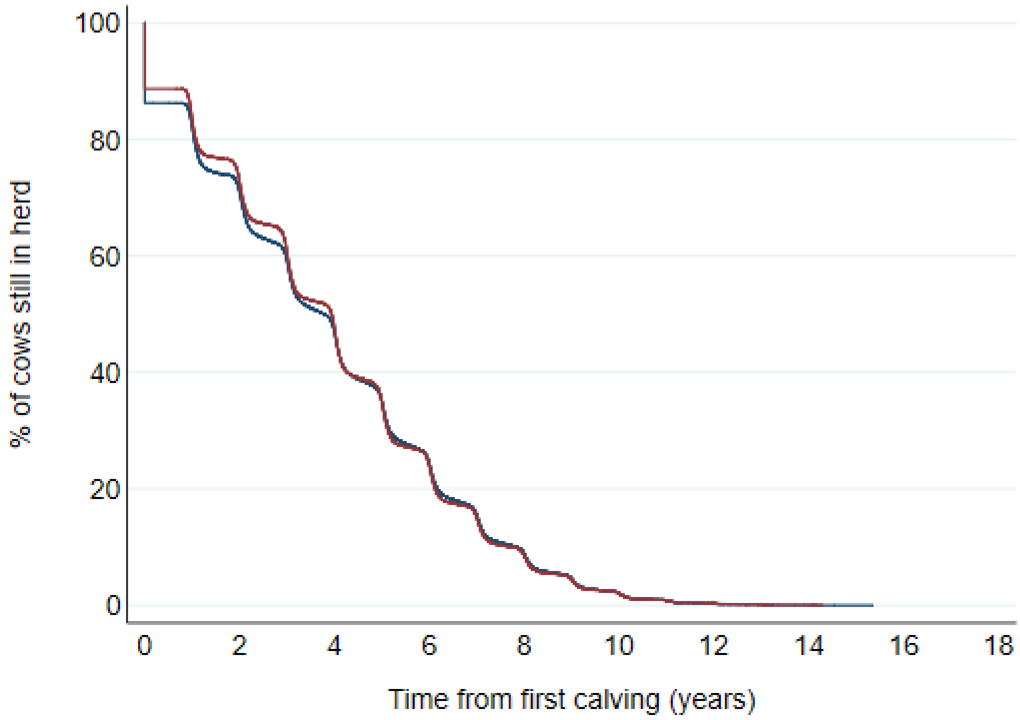


Figure H.1. Percentages of cows still in herd by time from first calving for Jerseys (maroon; n=60,522 cows) and Holsteins (navy; n=334,725 cows); cows first calved in 1990 to 1994

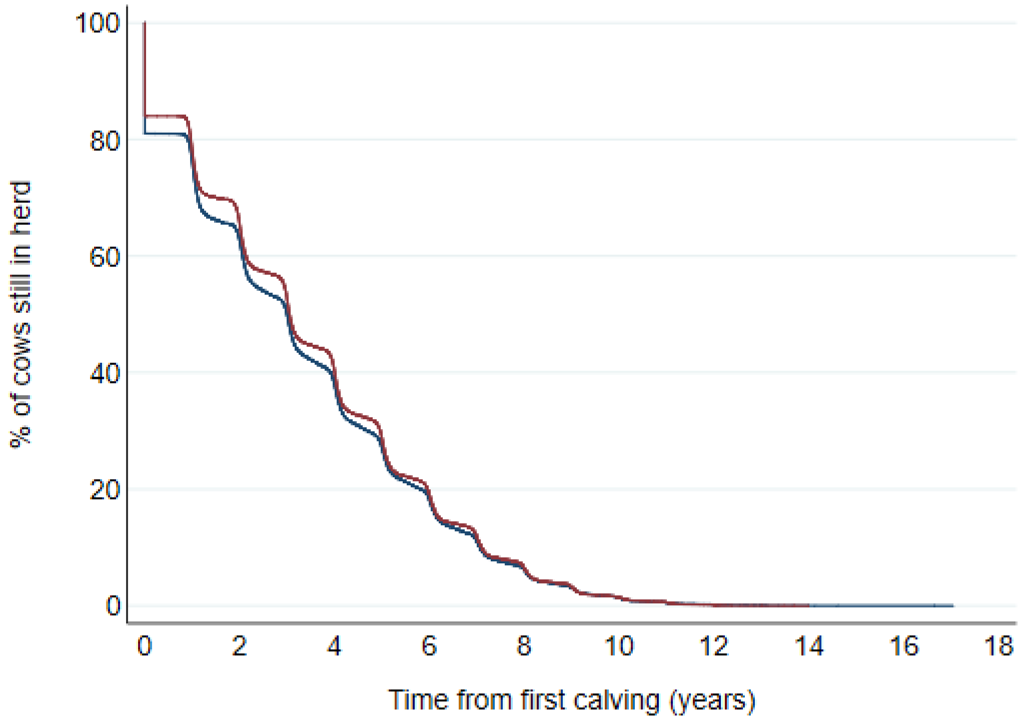


Figure H.2. Percentages of cows still in herd by time from first calving for Jerseys (maroon; n=83,932cows) and Holstein (navy; n=538,211cows); cows first calved in 1995 to 1999

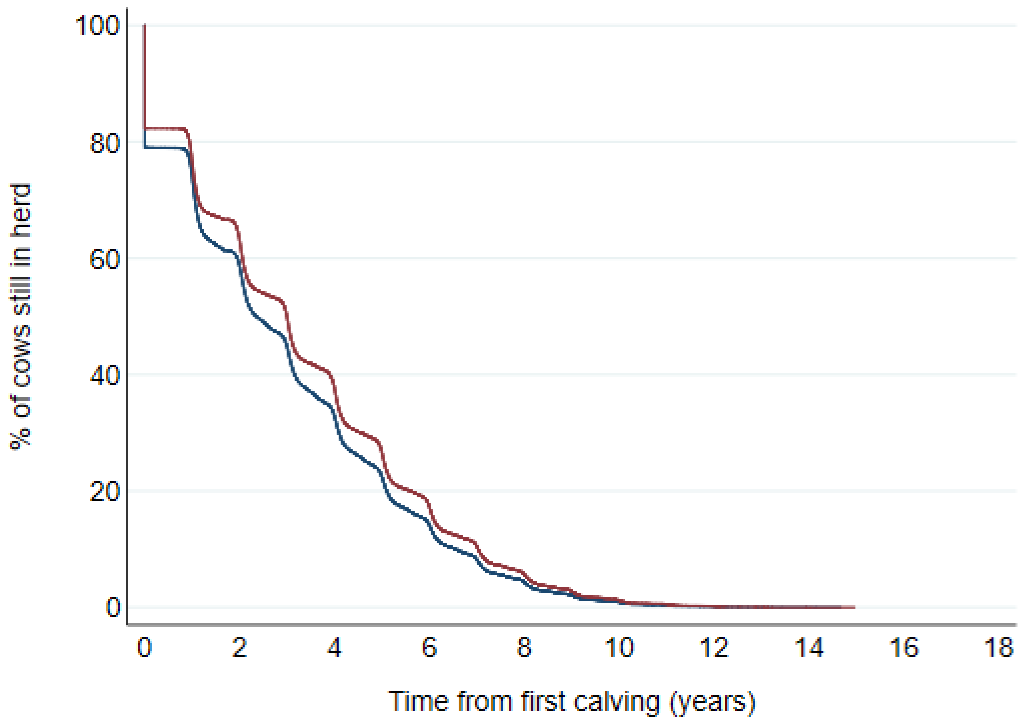


Figure H.3. Percentages of cows still in herd by time from first calving for Jerseys (maroon; n=75,660cows) and Holstein (navy; n=494,339cows); cows first calved in 2000 to 2004

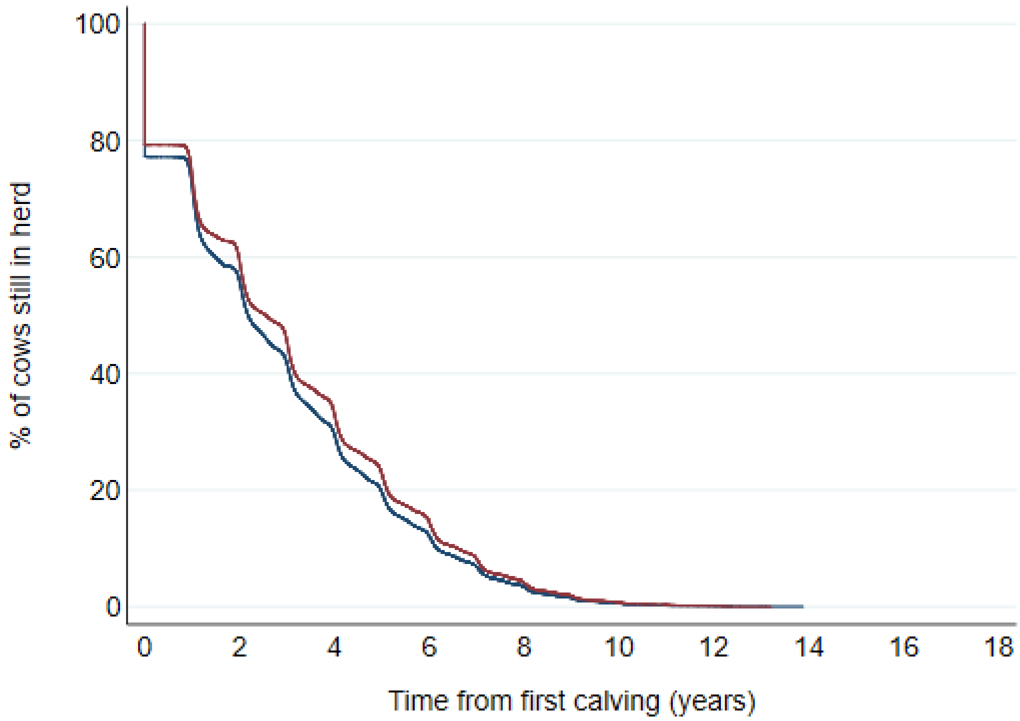


Figure H.4. Percentages of cows still in herd by time from first calving for Jerseys (maroon; n=55,485cows) and Holstein (navy; n=344,483cows); cows first calved in 2005 to 2009

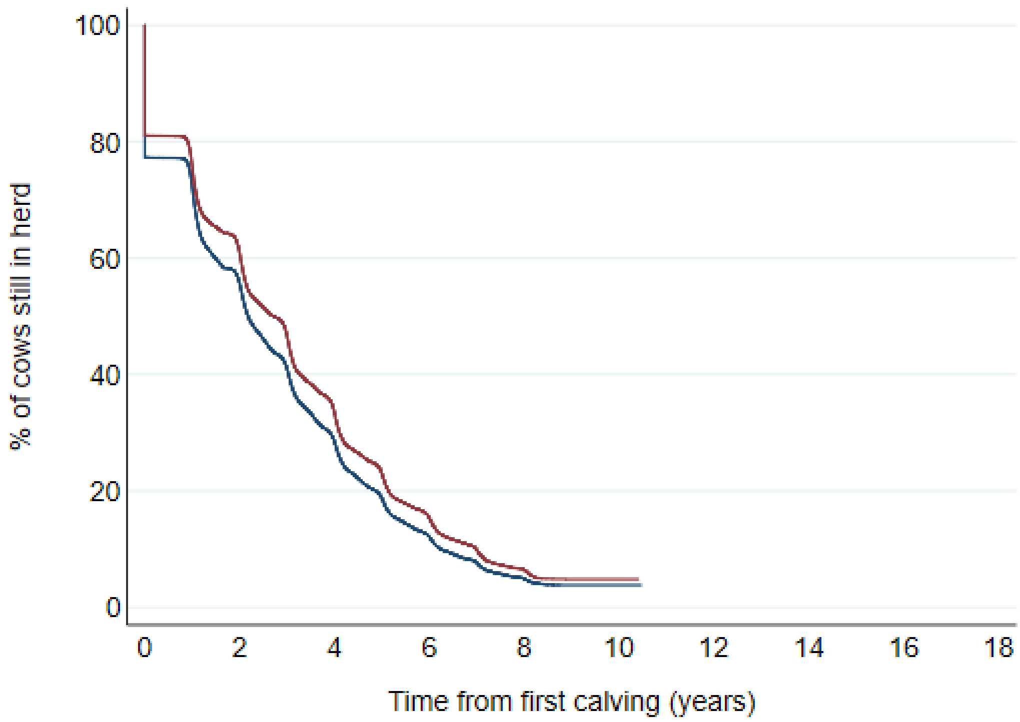


Figure H.5. Percentages of cows still in herd by time from first calving for Jerseys (maroon; n=47,363cows) and Holstein (navy; n=274,873 cows); cows first calved in 2010 to 2014

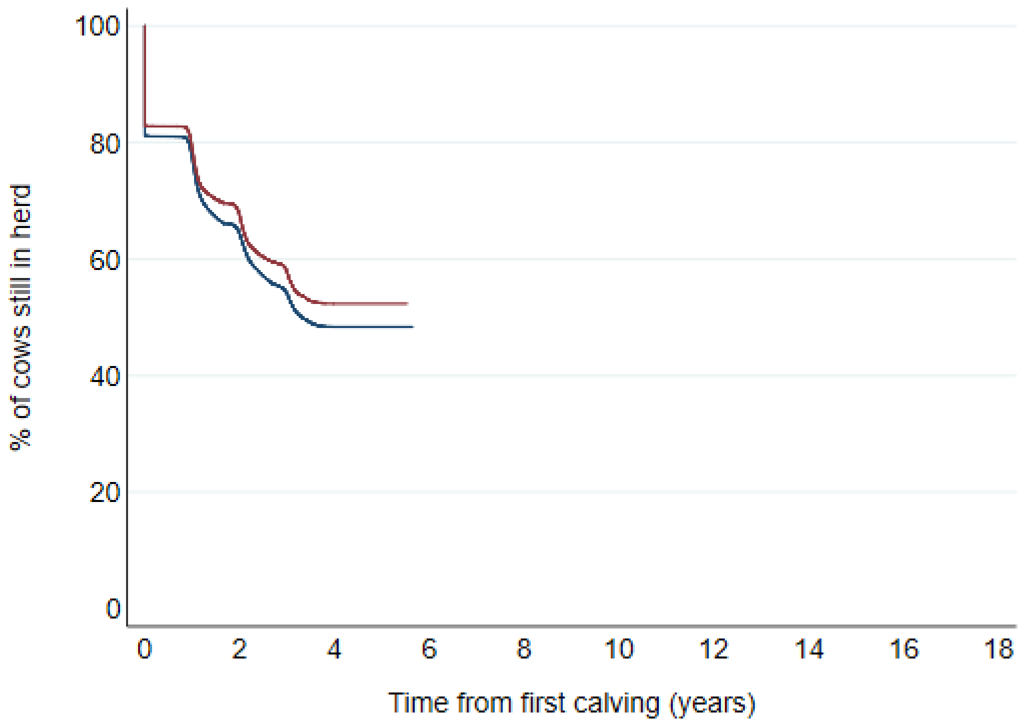


Figure H.6. Percentages of cows still in herd by time from first calving for Jerseys (maroon; n=36,721cows) and Holstein (navy; n=215,509cows); cows first calved in 2015 to 2019

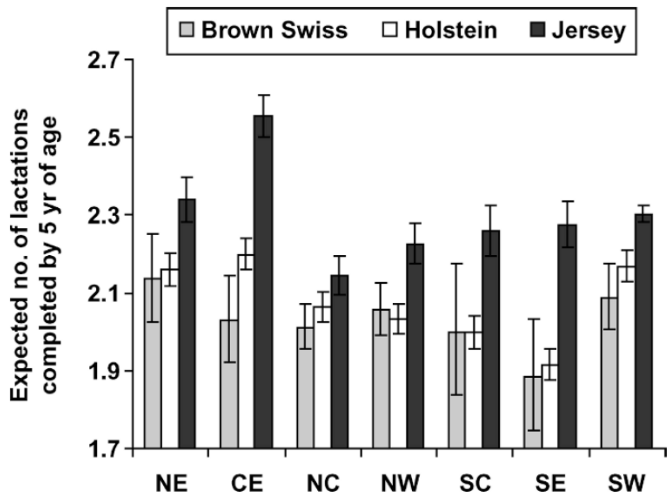


Figure H.7. Expected number of lactations completed by 5 years of age for Brown Swiss, Jerseys, and Holsteins in herds with one breed by region in USA (NE = Northeast, NC = North Central, NW = Northwest, CE =Central, SE = Southeast, SC = South Central, SW = Southwest). Vertical lines represent confidence interval ranges. Jerseys in Southwest were the reference with the overall mean of the poisson analysis. [Garcia-Peniche *et al.*, 2006].

I. *Mean enteric CO_2 and CH_4 emissions and their efficiencies (Bangani et al., 2018)*

Table I.1. Mean enteric CO_2 and CH_4 emissions and their efficiencies of Holstein and Jersey cows as affected by parity and lactation stage. [Bangani *et al.*, 2019].

	Parity										
	Parity 1		Parity 2		Parity 3		Parity 4+ (mature cows)		P-values		Intxn
	H	J	H	J	H	J	H	J	Breed	P	B×P
CO_2/day	$10.2^{d}\pm0.05$	$8.9^{g}\pm0.06$	$11.0^{c}\pm0.06$	$9.4^{g}\pm0.06$	$11.5^{b}\pm0.06$	$9.9^{e}\pm0.06$	$11.8^{a}\pm0.06$	$10.1^{d}\pm0.06$	<.01	<.01	<.01
CO_2/DMI	$0.65^{c}\pm0.001$	$0.69^{a}\pm0.001$	$0.63^{d}\pm0.002$	$0.68^{b}\pm0.002$	$0.62^{e}\pm0.002$	$0.66^{c}\pm0.002$	$0.62^{e}\pm0.002$	$0.66^{c}\pm0.002$	<.01	<.01	0.02
CO_2/BW	$2.01^{e}\pm0.01$	$2.42^{a}\pm0.01$	$1.97^{f}\pm0.01$	$2.34^{b}\pm0.01$	$1.95^{g}\pm0.01$	$2.32^{c}\pm0.02$	$1.92^{h}\pm0.01$	$2.31^{d}\pm0.02$	<.01	<.01	0.01
CO_2/ECM	$0.56^{a}\pm0.01$	$0.56^{a}\pm0.01$	$0.51^{b}\pm0.01$	$0.53^{b}\pm0.01$	$0.50^{c}\pm0.01$	$0.50^{c}\pm0.01$	$0.48^{d}\pm0.01$	$0.49^{d}\pm0.01$	0.38	<.01	0.08
MEF	$124.8^{d}\pm0.78$	$102.5^{g}\pm0.86$	$137.5^{c}\pm0.87$	$112.0^{f}\pm0.93$	$143.6^{b}\pm0.95$	$119.5^{e}\pm0.97$	$147.7^{a}\pm0.97$	$123.8^{d}\pm0.98$	<.01	<.01	<.01
CH_4/day	$342^{d}\pm2.1$	$281^{g}\pm2.4$	$377^{c}\pm2.4$	$307^{f}\pm2.5$	$393^{b}\pm2.6$	$327^{e}\pm2.7$	$405^{a}\pm2.7$	$339^{d}\pm2.7$	<.01	<.01	<.01
CH_4/kg DMI	$21.7^{a}\pm0.03$	$21.6^{b}\pm0.03$	$21.4^{c}\pm0.03$	$21.7^{a}\pm0.03$	$21.2^{d}\pm0.04$	$21.7^{a}\pm0.04$	$21.1^{e}\pm0.04$	$21.6^{b}\pm0.04$	<.01	<.01	<.01
CH_4/kg BW	$67.4^{b}\pm0.4$	$76.3^{a}\pm0.5$	$67.2^{b}\pm0.5$	$76.0^{a}\pm0.5$	$66.8^{bc}\pm0.5$	$76.6^{a}\pm0.5$	$66.0^{c}\pm0.5$	$76.7^{a}\pm0.5$	<.01	0.41	<.01
CH_4/ECM	$18.7^{a}\pm0.1$	$17.6^{b}\pm0.2$	$17.5^{b}\pm0.2$	$17.2^{bc}\pm0.2$	$17.0^{c}\pm0.2$	$16.4^{de}\pm0.2$	$16.6^{cd}\pm0.2$	$16.1^{e}\pm0.2$	0.01	0.01	<.01
	Lactation stage (days in milk)										
	Transition (<30)		Early lactation (31-100)		Mid-lactation (101-200)		Late lactation (201+)				
	H	J	H	J	H	J	H	J	Breed	LS	B×LS
CO_2/day	$9.4^{e}\pm0.07$	$8.3^{f}\pm0.07$	$11.4^{b}\pm0.05$	$9.8^{d}\pm0.06$	$11.9^{a}\pm0.05$	$10.2^{c}\pm0.06$	$11.8^{a}\pm0.05$	$10.1^{c}\pm0.06$	<.01	<.01	<.01
CO_2/DMI	$0.68^{b}\pm0.002$	$0.72^{a}\pm0.002$	$0.62^{e}\pm0.001$	$0.66^{c}\pm0.002$	$0.61^{e}\pm0.001$	$0.65^{d}\pm0.002$	$0.62^{e}\pm0.001$	$0.65^{d}\pm0.002$	<.01	<.01	0.03
CO_2/BW	$1.70^{h}\pm0.02$	$2.06^{f}\pm0.02$	$2.07^{e}\pm0.01$	$2.47^{b}\pm0.01$	$2.09^{d}\pm0.01$	$2.49^{a}\pm0.01$	$1.99^{g}\pm0.01$	$2.38^{c}\pm0.01$	<.01	<.01	0.06
CO_2/ECM	$0.40^{d}\pm0.01$	$0.40^{d}\pm0.01$	$0.48^{c}\pm0.01$	$0.49^{c}\pm0.01$	$0.56^{b}\pm0.01$	$0.56^{b}\pm0.01$	$0.61^{a}\pm0.01$	$0.62^{a}\pm0.01$	0.38	<.01	0.85
MEF	$111.1^{e}\pm1.0$	$89.2^{f}\pm1.1$	$143.5^{b}\pm0.9$	$118.9^{d}\pm0.9$	$150.3^{a}\pm0.8$	$125.4^{c}\pm0.9$	$148.8^{a}\pm0.9$	$124.3^{c}\pm0.9$	<.01	<.01	0.12
CH_4/day	$304^{e}\pm2.8$	$244^{f}\pm3.0$	$393^{b}\pm2.3$	$326^{d}\pm2.5$	$412^{a}\pm2.3$	$344^{c}\pm2.4$	$408^{a}\pm2.3$	$341^{c}\pm2.4$	<.01	<.01	0.12
CH_4/kg DMI	$21.5^{b}\pm0.04$	$20.7^{d}\pm0.05$	$21.5^{b}\pm0.03$	$22.0^{a}\pm0.03$	$21.2^{c}\pm0.03$	$22.0^{a}\pm0.03$	$21.3^{c}\pm0.03$	$22.0^{a}\pm0.03$	<.01	<.01	<.01
CH_4/kg BW	$54.5^{g}\pm0.6$	$59.8^{f}\pm0.6$	$71.4^{d}\pm0.5$	$81.9^{b}\pm0.5$	$72.5^{d}\pm0.4$	$84.0^{a}\pm0.$	$68.9^{e}\pm0.5$	$79.9^{c}\pm0.5$	<.01	<.01	<.01
CH_4/ECM	$12.7^{d}\pm0.2$	$11.4^{e}\pm0.2$	$16.7^{c}\pm0.2$	$16.3^{c}\pm0.2$	$19.4^{b}\pm0.2$	$19.0^{b}\pm0.2$	$21.1^{a}\pm0.2$	$20.7^{a}\pm0.2$	<.01	<.01	0.02

$^{a\text{-}h}$ Means within rows with different superscripts differ at $P<0.05$

CO_2: carbon dioxide (kg/day), **CH_4:** methane (g/day),**MEF:** methane emission factor (kg/head/year),**DMI:** dry matter intake (kg/day), **BW:** body weight (100 kg), **ECM:** energy corrected milk (kg/day), **Intxn:** interaction

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Economic modelling to assess potential of Jersey cows to enhance the profitability of Australian dairy farm businesses

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Introduction

Jersey Australia engaged Dr Steve Little of Capacity+ Ag Consulting to search for and document available evidence on the many attributes of the Australian Jersey compared with other breeds used in Australia dairy industry that enable it to contribute to the profitability and sustainability of Australian dairy farm businesses. Dr Little subsequently delivered to Jersey Australia his report entitled:

"*Jersey - The Most Profitable and Sustainable cow?" - Literature Review for Jersey Australia*

Following on from Dr Little's draft report, Jersey Australia engaged Scott Barnett of Scott Barnett & Associates to undertake desktop modelling of Jersey vs Holstein Friesians in Australian dairy production systems. These production systems involve direct grazing of pasture, feeding of home-grown conserved forage plus supplements fed in the bail and purchased forage.

The modelling undertaken drew on the findings of Dr Little's report for its base assumptions.

Two base models were developed. One represented a high proportion of directly grazed grass (HiGrass) based dairy farming systems of southern Victoria, Tasmania and south east South Australia. The other was representative of a higher proportion of conserved fodder being fed (HiCons) reflecting more the northern Victoria, NSW, WA, and Queensland systems. TMR systems were not assessed.

For each system a farm model was developed. The HiGrass system was based on Gippsland 2019-20 Dairy Farm Monitor Program data. The HiCons system was based on Northern Victoria 2019-20 Dairy Farm Monitor Program data.

The model farm was assumed to be running Holstein - Friesians. The Dairy Farm Monitor Program data was modified to only used herds whose individual production profiles (litres of milk, fat and protein test) when averaged reflected that of Data Gene production for Holstein - Friesian herds in Australia. The data was recalculated so that for each individual farm data set all key parameters were expressed on a per cow: per ha and per kilogram Milk solids (KgMS) was determined.

Farms were removed from inclusion in the data set based on high fat and protein test until the average production profile of the remaining farms approximated that of a Holstein - Friesian herd.

The results of all models are only as valid as the quality of assumptions used for model and the base data. The purpose of this report is not to make a definitive finding as to whether one breed is the only breed for a particular dairying system in Australia. This report is design to guide initial discussions about breed selection and provide economic parameters to the identified differences between biological attributes of Jersey cattle compare to Holstein Friesian cattle in a whole farm context.

Methodology

To model and compare the economic performance of a herd of Jersey cattle (JJJJ) vs Holstein Friesian cattle (FFFF) in for each of the two assumed production systems, results of the 2019/20 Victorian Dairy Farm Monitor Program (DFMP) (Agriculture Victoria 2020) were used. A typical FFFF herd would be modelled and then relative performance of JJJJ identified by Little would be applied to the base model. This would include biological performance impacting production.

The system representing a high proportion of the milking herd's energy coming from direct grazed grass (HiGrass) was modelled using the results of Gippsland DFMP.

The system representing higher proportion of conserved feed and purchased feed (HiCons) was modelled using the results of the Northern Victoria DFMP.

The data was recalculated so that for each individual farm data set all key parameters were expressed on a per cow: per ha and per kilogram Milk solids (KgMS) was determined.

The average milk production per cow and fat percentage and protein percentage for each data set was compared the average milk production and fat test and protein test for FFFF cattle from the 2019 DataGene data set (John Morton, *Pers. Com. 1 - supplied by S Little*). This was 7,282 litres at 3.91% fat and 3.34% protein (weight/volume). Individual herds from the relative DFMP herd were removed till the average of the remaining herds (Selected Herds) milk production system more closely reflected the FFFF results reported by Morton. The changes to average production are shown in Table 1 below.

Table 1: Data changes to reflect average milk production more aligned to FFFF herds.

	DataGene	Gippsland DFMP		Northern Victorian DFMP	
		Full data set	Selected Herds	Full data set	Selected Herds
Herds		25	12	30	16
Litres	7,278	6,104	7,177	7,201	8,161
Fat %	3.91%	4.39%	4.18%	4.34	4.09
Protein %	3.34%	3.57%	3.47%	3.52	3.41

For HiGrass selected herds 3.58 Tonnes dry matter per milker was directly grazed or 57% of total dry matter intake (6.32 TDM). Feed conversion efficiency (FCE - litres/kg dry matter intake) was 1.14.

For the HiCons selected herds 1.95 Tonnes dry matter per milker was directly grazed or 30% of total dry matter intake (6.65 TDM) - FCE 1.31.

John Morton (*Pers. Com. 2 supplied by S Little)* provided data calculated from DataGene for the years 1980 - 2020 the number of each age group of cows which failed to re calve again (from age of calving at 2-year-old to 20-year-old) across seasonal and split calving systems. This was split into FFFF and JJJJ The heifer replacement rate for FFFF and JJJJ was estimated using this data. The replacement rate calculated for FFFF herds was 24.3% and 22.8%.

It was assumed that using the calculated replacement rate utilising "fail to re calve" for each age group would capture the fertility, health, heat stress and longevity attributes of Jersey cattle relative to other breeds (in this case FFFF) even though quantitative variances were not cited by Dr Little.

Dr Little (Little 2021 - Figure 6) presented graphs of DataGene data of 6-week in-calf rate for seasonal and split calving herds (2006-2017) and 100-day in-calf rate for year-round herds (2006-2017). The author's reading of the seasonal/split calving graph suggests an approximate 20% superior performance in the 6-week in-calf rate for JJJJ over FFFF.

The major quantified differences between JJJJ and FFFF cited by Little related to feed intake, and feed efficiency in terms of both production per kilogram of feed intake and per body weight. These were:

- Jerseys produce 6-11% more energy-corrected milk (ECM) than Holsteins per kilogram of dry matter intake;
- Jerseys produce 26-31% more ECM per 100 kg bodyweight than Holsteins;

- Jerseys are 8% more energetically efficient;
- Jerseys have about 14-21% higher feed intake capacity than Holstein per 100kg bodyweight; and
- Jerseys have about 5% higher feed intake capacity than Holstein per unit of metabolic weight.

> ECM: Energy Corrected Milk determines the amount of energy in the milk based upon the milk, fat and protein. It allows for different quantities of milk (expressed as litres or kilograms of milk) of different fat and protein concentration to be compared on an energy basis. The ECM calculation used is that used is that defined by Sjaunja *et. al.* (1991) as used in the Rumen8 nutrition model:
>
> ECM= (Milk(kg)*(0.383*%fat+0.242*%protein+0.7832)/3.1138)

Calculating feed intake and milk production

To calculate and compare the biological performance of JJJJ relative to FFFF based on the DFMP data and Little's findings two methods were examined to determine JJJJ performance relative to the base FFFF model.

For both models it was assumed that the grazing/home grown feed platform was 125 ha. The total feed base (home grown and purchased) would be the same for both breeds (i.e. the same total feed harvested from the home grown feed platform would be applied to both herds as would be the total amount of purchased feed).

The first model is based on the relative efficiency of milk production per 100kgBW (i.e. JJJJ produced 28.5% more ECM/100kg BW than FFFF). The 28.5% percentage figure was chosen as it is the midpoint of the range quoted by Little.

Appendix 1 (Base Calculation Template 1) shows the methodology.

The second model is based on the combination of dry matter intake per kilogram of body weight (JJJJ have a 17.5% more feed intake per kg BW than FFFF) and then the efficiency of milk production per unit of feed intake (JJJJ produce 8.5% more ECM/kg Dry matter intake). Again, the midpoint figure cited by Little was chosen to be used.

Appendix 2 (Base Calculation Template 2) shows the methodology.

Livestock income assumptions

Livestock income was calculated based on the following assumptions:

Adult mortality: 3% for both FFFF and JJJJ

Number of cull cows sold: Herd size X (% replacement rate less cow mortality:)

All calves (bull and heifer calves) raised to 10 weeks (weaned)

Live calves weaned: 85% of cow herd

All bull calves and heifer calves not required to be kept for replacement herd sold at 10 weeks

R2 mortality: 3%

R1 mortality: 3%

Replacement heifers retained; Replacement rate plus R2 and R1 deaths

A phone survey of livestock agents who serviced the Shepparton and Leongatha Livestock Exchanges was undertaken to determine indicative prices for each breed (FFFF and JJJJ):

Cull cow price	$/kg Liveweight	FFFF: $2.80	JJJJ: $2.30
10 week bull calf	$/head	FFFF: $500	JJJJ: $275
10 week heifer calf:	$/head	FFFF: $450	JJJJ: $275

Milk income and operating cost assumptions

The milk income and operating cost assumptions are as per those for the DFMP are applied as per Dairy Australia's dairy chart of accounts.

Milk income is applied on a $/kg MS net of all charges, levies, bonuses and penalties. It is the average milk received by the farms by the farms included in the model herd calculations.

As it is assumed that total feed resource is used for both farms all feed costs making up purchased and homegrown feed are the same for both areas. This means that the total expenditure for homegrown feed and purchased feed the herd is the same be it FFFF or JJJJ. within the same feed system (HiGrass or HiCons). Home grown applied on a per hectare basis. Purchased feed are expressed on a per cow basis.

Below is set out how costs are allocated, be it on a Kg/MS, per cow or per Ha basis.

AI and Herd costs including semen, AI consumables, heat synchronisation, herd recording, cattle identification among other herd costs. It would be expected that the superior reproductive performance exhibited by JJJJ would be seen in lower costs spent on AI and breeding, other herd costs would apply on more of a per head cost. As stated above from the data presented by Dr Little there appears to be a 20% advantage in reproductive performance of JJJJ over FFFF. To calculate the AI and herd costs of JJJJ compared to FFFF on a per head basis the following formula was used:

JJJJCost/hd = *FFFFCost/hd* X *%Fixed/hd* + *FFFFCost/hd* X (1-*%Fixed/hd*)/(1+*JJJJReproAdvantage*)

where:

JJJJCost/hd:	is the JJJJ cost of AI and herd costs applied on a per head basis
FFFFCost/hd:	is the AI and herd costs from DFMP data
%Fixed/hd:	is the % of FFFFCost/hd that is assumed not to be breed related
JJJJReproAdvantage:	is the % reproductive advantage JJJJ exhibit over FFFF.

Assuming a 20% JJJJ reproductive advantage and 50% Fixed/hd cost the JJJJ cost/hd is 91.7% of the FFFF cost/hd. For each 10 percentage point decrease in assumed %Fixed/hd cost the JJJJ cost/hd decreases by 1.7 percentage points of the FFFF cost/hd:

50% fixed cost/hd	JJJJ/hd cost is 91.7% of FFFF/hd cost
40% fixed cost/hd	JJJJ/hd cost is 90.0% of FFFF/hd cost

30% fixed cost/hd JJJJ/hd cost is 88.7% of FFFF/hd cost

In the model used it was assumed that the fixed percentage costs applied on a per head basis is 40% and therefore the AI and herd costs for JJJJ would be 90% of that of FFFF AI and herd cost.

In the base models labour is allocated on a per cow basis. No creditable information was able to be found in the literature (Little *Pers. Com)* to indicate that the labour requirements on a time basis (hours per animal) was lower or higher for Jersey cows. The impact of changing the assumption for labour from a per cow basis to both a per area and per Kg milk solids is covered in the Discussion section.

Asset assumptions

Asset costs are applied the same for each herd within the feed system group except livestock. This assumes that the infrastructure and mobile plant is used independent of breed but reflects the feed base within the same production system. Land value and value of plant and machinery are calculated based on DFMP data.

It is noted that though both the HiGrass model and the HiCons model assume a milking area of 125Ha, the total land asset water asset is not the same for the HiGrass Model and the HiCons model. Based on the selected herds for HiGrass model, for every hectare of milking area there was a further 1.6 Ha of non-milking area land used. For the Hi Cons model for every hectare of milking area there was a further 2.4 Ha of non-milking area land used. This results in the total investment in land and water divided by the milking area being $24,341/Ha milking area for the HiGrass model and $37,363/Ha of milking area for the HiCons model.

As the non-livestock asset base (including plant and machinery) is assumed to be the same for each herd within each feed system the R&M costs are allocated on a per hectare basis.

Livestock values are based on values in Dairy Australia's Dairy Base (2021). The values are increase proportionally to reflect the higher demand for dairy livestock and beef cattle over recent years, as illustrated in the cull cow kg/liveweight value. The DairyBase value for a Holstein Friesian is $1,800/hd when the market is more reflected at $2,400/hd an increase of 33.3% (rounded to the nearest $10) was applied to DairyBase values. This outlined in the Table 2 below.

Table 2: Livestock values

	DairyBase Holstein Friesian	FFFF value applied	DairyBase Jersey	JJJJ value applied
Milkers	$1,800	$2,400	$1,400	$1,870
Rising R2	$1,400	$1,870	$1,050	$1,400
Rising R1	$675	$900	$525	$700

Appendix 3 Chart of Accounts shows the chart of accounts used and the parameter used to calculate the value.

Livestock Income can be found in Appendix 4 for the HiGrass farm system and HiCons farm system.

Results

JJJJ milk production

Shown on the next page is the relative physical parameters of the HiGrass FFFF and JJJJ herds based on the two methodologies for calculating feed intake and milk production for the HiGrass feed system.

Both models calculated very similar results for the production and herd weight of the JJJJ herd based on the assumptions and the based FFFF herd parameters. Based on a FFFF herd (575kg/cow) producing 7, 392 kgECM per head, the first model predicts a JJJJ (425kg/cow) would produce of 7,021 KgECM/head. The second models predict the JJJJ production would be 6,966 kgECM/head.

Similarly, shown on the page after next is the relative physical parameters of the HiCons FFFF and JJJJ herds based on the two methodologies for calculating feed intake and milk production for the HiGrass feed system.

Again, both models calculated very similar results for the production and herd weight of the JJJJ herd based on the assumptions and the based FFFF herd parameters. Based on a FFFF herd (575kg/cow) producing 8,371 kgECM per head, the first model predicts a JJJJ (425kg/cow) would produce of 7,950 KgECM/head. The second models predict the JJJJ production would be 7,888 kgECM/head.

The author believes this reflects the accuracy of the two modelling methods.

For economic modelling purposes it was decided to use the second model based on the combination of dry matter intake per kilogram of body weight (JJJJ have a 17.5% more feed intake per kg BW than FFFF) and then the efficiency of milk production per unit of feed intake (JJJJ produce 8.5% more ECM/kg Dry matter intake) for both the HiGrass and HiCons feed systems. This is because this model expressly accounts for dry matter intake per kg of BW and it is assumed that the same feed base is used for both FFFF and JJJJ herds for the same production system.

Expressing the ECM for each herd in each production system in production parameters of litres and % fat and % protein (as well as fat and protein yields) is shown in Table 4.

Table 4: Milk Production by Breed and production system.

	HiGrass		HiCons	
	FFFF	JJJJ	FFFF	JJJJ
ECM (Kg)	7, 486	6,973	8,371	7,888
Litres	7,177	5,893	8,161	6,664
Fat % (Kg)	4.18% (300)	5.11% (301)	4.08% (333)	5.11% (340)
Protein % (Kg)	3.47% (249)	3.81% (225)	3.41% (278)	3.81% (254)

HiGrass

Assumptions and calculations

Cells are base model assumptions

Cells are based on DFMP

Cells based on liteature review by Little

Calculated cells

		ECM/100kgBW Basis		
			Unit	
FFFF BW		575	kg	A
FFFF ECM		7,392	kg ECM	B
FFFF ECM/100kg BW	B/(A/100)	1,286	kgECM/100kgBW	C
JJJJ ECM Coefficient		28.5%		D
JJJJ ECM/100kg BW	C*(1+D)	1,652	kgECM/100kgBW	E
JJJJ BW		425	kg	F
JJJJ ECM	E*(F/100)	7,021	Kg ECM	G
Milking Area		125	Ha	H
FFFF Stocing rate		2.43	cows/Ha	I
Number FFFF cows	H*I	304	Cows	J
FFFF DMI/cow		6.32	TDM/cow	K
Herd Total DMI	J*K	1,918	TDM	L
FFFF DMI/100kg BW	(K*1,000)/(A/100)	1,099	kgDMI/100kg BW	M
JJJJ DMI Coefficient		17.5%		N
JJJJ DMI/100kg BW	M*(1+N)	1,291	kgDMI/100kg BW	P
JJJJ DMI/cow	(P*(F/100))/*1,000	5.49	TDM/cow	Q
Number JJJJ cows	L/Q	350	Cows	R
FFFF herd production	B*J	2,245,014	kg ECM	S
JJJJ herd production	G*R	2,455,185	kg ECM	T
FFFF ECM/100kg BW	C	1,286	kgECM/100kgBW	U
JJJJ ECM/100kg BW	E	1,652	kgECM/100kgBW	V
FFFF FCE	B/(K*1,000)	1.17	kgECM/kgDMI	
JJJJ FCE	G/(Q*1,000)	1.28	kgECM/kgDMI	
FFFF kgBW/ha	A*J/H	1,397	Kg/Ha	
JJJJ Kg BW/ha	F*R/H	1,189	Kg/Ha	
FFFF Herd BW		174,625		
JJJJ Herd BW		148,617		

		DMI/KgBW & FCE/KgDMI		
			Unit	
FFFF BW		575	kg	A
JJJJ BW		425	Kg	B
Milking Area		125	Ha	C
FFFF Stocing rate		2.43	cows/Ha	D
Number FFFF cows	D*E	304	Cows	E
FFFF DMI/cow		6.32	TDM/cow	F
JJJJ DMI Coefficient		17.5%		G
Herd Total DMI	E*F	1,918	TDM	H
FFFF DMI/100kg BW	(D*1,000)/(A/100)	1,099	kgDMI/100kg BW	I
JJJJ DMI/100kg BW	I*(1+G)	1,291	kgDMI/100kg BW	J
JJJJ DMI/cow	(J*(B/100))/1,000	5.49	TDM/cow	K
Number JJJJ cows	H/K	350	Cows	L
FFFF ECM		7,392	kg ECM	M
FFFF ECM/kgDMI	M/(F*1000)	1.17	kgECM/kgDMI	N
JJJJ FCE/kgDMI Coefficient		8.5%		P
JJJJ FCE ECM/kgDMI	N*(1+P)	1.27	kgECM/kgDMI	Q
JJJJ ECM	K*1000*Q	6,966	kg ECM	R
FFFF herd production	M*E	2,245,014	kg ECM	S
JJJJ herd production	R*L	2,435,840	kg ECM	T
FFFF ECM/100kg BW	M/(A/100)	1,286	kgECM/100kgBW	U
JJJJ ECM/100kg BW	R/(B/100)	1,639	kgECM/100kgBW	V
FFFF FCE	M/(F*1,000)	1.17	kgECM/kgDMI	
JJJJ FCE	R/(K*1,000)	1.27	kgECM/kgDMI	
FFFF kgBW/ha	A*E/C	1,397	Kg/Ha	
JJJJ Kg BW/ha	B*L/C	1,189	Kg/Ha	
FFFF Herd BW		174,625		
JJJJ Herd BW		148,617		

Northern Vic

Assumptions and calculations

Cells are base model assumptions

Cells are based on DFMP

Cells based on liteature review by Little

Calculated cells

		ECM/100kgBW Basis	Unit	
FFFF BW		575	kg	A
FFFF ECM		8,371	kg ECM	B
FFFF ECM/100kg BW	B/(A/100)	1,456	kgECM/100kgBW	C
JJJJ ECM Coefficient		28.5%		D
JJJJ ECM/100kg BW	C*(1+D)	1,871	kgECM/100kgBW	E
JJJJ BW		425	kg	F
JJJJ ECM	E*(F/100)	7,950	Kg ECM	G
Milking Area		125	Ha	H
FFFF Stocing rate		3.17	cows/Ha	I
Number FFFF cows	H*I	396	Cows	J
FFFF DMI/cow		6.55	TDM/cow	K
Herd Total DMI	J*K	2,595	TDM	L
FFFF DMI/100kg BW	(K*1,000)/(A/100)	1,139	kgDMI/100kg BW	M
JJJJ DMI Coefficient		17.5%		N
JJJJ DMI/100kg BW	M*(1+N)	1,338	kgDMI/100kg BW	P
JJJJ DMI/cow	(P*(F/100))/*1,000	5.69	TDM/cow	Q
Number JJJJ cows	L/Q	456	Cows	R
FFFF herd production	B*J	3,316,923	kg ECM	S
JJJJ herd production	G*R	3,627,443	kg ECM	T
FFFF ECM/100kg BW	C	1,456	kgECM/100kgBW	U
JJJJ ECM/100kg BW	E	1,871	kgECM/100kgBW	V
FFFF FCE	B/(K*1,000)	1.28	kgECM/kgDMI	
JJJJ FCE	G/(Q*1,000)	1.40	kgECM/kgDMI	
FFFF kgBW/ha	A*J/H	1,823	Kg/Ha	
JJJJ Kg BW/ha	F*R/H	1,551	Kg/Ha	
FFFF Herd BW		227,844		
JJJJ Herd BW		193,910		

		DMI/KgBW & FCE/KgDMI	Unit	
FFFF BW		575	kg	A
JJJJ BW		425	Kg	B
Milking Area		125	Ha	C
FFFF Stocing rate		3.17	cows/Ha	D
Number FFFF cows	D*E	396	Cows	E
FFFF DMI/cow		6.55	TDM/cow	F
JJJJ DMI Coefficient		17.5%		G
Herd Total DMI	C*D*F	2,595	TDM	H
FFFF DMI/100kg BW	(D*1,000)/(A/100)	1,139	kgDMI/100kg BW	I
JJJJ DMI/100kg BW	I*(1+G)	1,338	kgDMI/100kg BW	J
JJJJ DMI/cow	(J*(B/100))/*1,000	5.69	TDM/cow	K
Number JJJJ cows	H/K	456	Cows	L
FFFF ECM		8,371	kg ECM	M
FFFF ECM/kgDMI	L/(F*1000)	1.28	kgECM/kgDMI	N
JJJJ FCE/kgDMI Coefficient		8.5%		P
JJJJ FCE ECM/kgDMI	N*(1+P)	1.39	kgECM/kgDMI	Q
JJJJ ECM	K*1000*Q	7,888	kg ECM	R
FFFF herd production	M*E	3,316,923	kg ECM	S
JJJJ herd production	R*L	3,598,861	kg ECM	T
FFFF ECM/100kg BW	M/(A/100)	1,456	kgECM/100kgBW	U
JJJJ ECM/100kg BW	R/(B/100)	1,856	kgECM/100kgBW	V
FFFF FCE	M/(F*1,000)	1.28	kgECM/kgDMI	
JJJJ FCE	R/(K*1,000)	1.39	kgECM/kgDMI	
FFFF kgBW/ha	A*E/C	1,823	Kg/Ha	
JJJJ Kg BW/ha	B*L/C	1,551	Kg/Ha	
FFFF Herd BW		227,844		
JJJJ Herd BW		193,910		

Economic Modelling Results

Income and expenditure

HiGrass

The summary of the Statement of Expenditure and Expenses for the HiGrass model is shown in Table 5 below.

Table 5: HiGrass Statement of Income and Expenses

Physical			FFFF		JJJJ
Area	Ha		125		125
Cows	Number		304		350
Stocking rate	cows/ha		2.43		2.80
Milk Production					
Milk Production (Litres)	Per Cow	7,177	2,179,625	5,892	2,060,196
Milk Production - milk solids (KG)	Per Cow	549	166,808	526	183,765
Butterfat %	%	4.18%		5.11%	
Protein %	%	3.47%		3.81%	
Milk payment	$/kgMS	$ 6.99			
	Unit of calculation				
Milk income - current	Per KgMS	$ 6.99	1,165,365		1,283,831
Livestock sales			$182,640		$120,158
TOTAL CASH INCOME			1,348,005		1,403,988
AI and herd costs	Per Cow	$ 67.30	20,439	$ 60.57	21,181
Animal health	Per Cow	$ 70.49	21,406		24,648
Calf rearing	Per Cow	$ 31.58	9,590		11,042
Total herd cost		$ 169.36	51,435		56,871
Shed power	Per KgMS	$ 0.12	20,745		22,853
Dairy supplies	Per KgMS	$ 0.07	11,734		12,927
Total shed costs	Per KgMS	$ 0.19	32,478	-	35,780
Fodder purchases	Per Cow	$ 171.72	52,150	$ 149.13	52,150
Grains/concnetrates/Other	Per Cow	$ 891.70	270,806	$ 774.42	270,806
Agistment	Per Cow	$ 34.57	10,499	$ 30.02	10,499
Total purchased feeds costs		$ 1,097.99	333,455	$ 953.58	333,455
Fertiliser	Per Ha	$ 747.72	93,465		93,465
Irrigation	Per Ha	$ 302.95	37,868		37,868
Hay & Silage making	Per Ha	$ 208.86	26,107		26,107
Fuel & OIl	Per Ha	$ 102.35	12,794		12,794
Pasture & cropping	Per Ha	$ 182.95	22,869		22,869
Other feed costs	Per Ha	$ 53.44	6,680		6,680
Total home grown feed costs	Per Ha	$ 1,598.27	199,783		199,783
VARIABLE COSTS			617,152		625,889
GROSS MARGIN			**730,853**		**778,099**
Total labour costs	Per Cow	$ 746.21	226,622		260,942
Depreciation	Per Ha	$ 272.82	34,103		34,103
Repairs & Maintence	Per Ha	$ 430.63	53,829		53,829
Vehicles (Rego & insurance)	Per Ha	$ 41.08	5,135		5,135
Farm insurance	Per Ha	$ 64.84	8,105		8,105
Rates	Per Ha	$ 64.14	8,018		8,018
Other overheads (Rates/accounting/etc.)	Per Ha	$ 64.42	8,052		8,052
Total OverheadsCosts			343,864		378,184
EBIT			386,989		399,915

HiCons

The summary of the Statement of Expenditure and Expenses for the HiCons model is shown in Table 6 below.

Table 6: HiCons Statement of Income and Expenses

Physical			FFFF		JJJJ
Area	Ha		125		125
Cows	Number		396		456
Stocking rate	cows/ha		3.17		3.65
Milk Production					
Milk Production (Litres)	Per Cow	8,161	3,233,796	6,664	3,040,580
Milk Production - milk solids (KG)	Per Cow	611	242,109	594	271,214
Butterfat %	%	4.08%		5.11%	
Protein %	%	3.41%		3.81%	
Milk payment	$/kgMS	$ 7.22			
	Unit of calculation				
Milk income - current	Per KgMS	$ 7.22	1,747,230		1,957,272
Livestock sales			$236,760		$155,903
TOTAL CASH INCOME			1,983,990		2,113,174
AI and herd costs	Per Cow	$ 86.77	34,381	$ 78.09	35,629
Animal health	Per Cow	$ 112.86	44,723		51,495
Calf rearing	Per Cow	$ 21.39	8,475		9,758
Total herd cost		$ 221.02	87,578		96,882
Shed power	Per KgMS	$ 0.11	25,648		28,731
Dairy supplies	Per KgMS	$ 0.08	18,555		20,785
Total shed costs	Per KgMS	$ 0.18	44,203	-	49,517
Fodder purchases	Per Cow	$ 662.47	262,502	575.34	262,502
Grains/concnetrates/Other	Per Cow	$ 1,097.73	434,976	953.36	434,976
Agistment	Per Cow	$ 76.25	30,216	66.23	30,216
Total purchased feeds costs		$ 1,836.45	727,694		727,694
Fertiliser	Per Ha	$ 549.46	68,683		68,683
Irrigation	Per Ha	$ 778.61	97,326		97,326
Hay & Silage making	Per Ha	$ 614.93	76,867		76,867
Fuel & OIl	Per Ha	$ 160.43	20,054		20,054
Pasture & cropping	Per Ha	$ 512.86	64,107		64,107
Other feed costs	Per Ha	$ 19.49	2,436		2,436
Total home grown feed costs	Per Ha	$ 2,635.79	329,473		329,473
VARIABLE COSTS			1,188,948		1,203,566
GROSS MARGIN			**795,042**		**909,608**
Total labour costs	Per Cow	$ 836.51	331,468		381,665
Depreciation	Per Ha	$ 428.66	53,582		53,582
Repairs & Maintence	Per Ha	$ 599.54	74,943		74,943
Vehicles (Rego & insurance)	Per Ha	$ 41.33	5,166		5,166
Farm insurance	Per Ha	$ 118.97	14,871		14,871
Rates	Per Ha	$ 83.75	10,469		10,469
Other overheads (Rates/accounting/etc.)	Per Ha	$ 264.34	33,043		33,043
OVERHEAD COSTS			523,541		573,738
EBIT			271,501		335,870

Return on Assets

For each production system and for each herd an indicative Asset schedule was developed based on the DFMP values for Land and water on a per Hectare basis, Plant and equipment on a per hectare basis and other assets on a per hectare basis. The livestock asset value was established based on the herd profile using the modified DairyBase results. The Land and water per hectare value includes the value of non milking area land but expressed on a per hectare of milking area basis.

HiGrass

The asset schedule for model HiGrass feed system for both FFFF and JJJJ is shown below Table 7.

Table 7: Asset Schedule- HiGrass Farms

Asset	Milking Area FFFF	Value/unit	FFFF	Milking Area JJJJ	Value/unit	JJJJ
Land & water	125ha	@$24,341/ha*	$3,042,666	125ha	@$24,341/ha*	$3,042,666
Plant & Equipment			$165,277			$165,277
Other assets			$101,065			$101,065
Milkers	304	@ $2,400	$728,871	350	$1,870	$653,917
R2	74	@ $1,870	$138,380	79	$1,400	$110,600
R1	76	@ $900	$68,400	81	$700	$56,700
Total Assets			$4,244,660			$4,130,225

* *Total investment in all land (milking area and non milking area) plus water divided by milking area*

HiCons

The asset schedule for model HiGrass feed system for both FFFF and JJJJ is shown below Table 8.

Table 8: Asset Schedule- HiCons Farms

Asset	Unit FFFF	Value/unit	FFFF	Unit JJJJ	Value/unit	JJJJ
Land & water	125ha	@$37,363/ha*	$4,670,413	125ha	@$37,363/ha*	$4,670,413
Plant & Equipment			$159,139			$159,139
Other assets			$61,702			$61,702
Milkers	396	@ $2,400	$951,000	456	$1,870	$853,202
R2	95	@ $1,870	$177,650	103	$1,400	$144,200
R1	98	@ $900	$88,200	106	$700	$74,200
Total Assets			$6,108,104			$5,962,856

* *Total investment in all land (milking area and non milking area) plus water divided by milking area*

Pulling it together

In discussing and applying these results it is important to remember that this desktop modelling exercise is only as good as the assumptions made on base data to apply to the model. As such this document prime use is for informing discussion. The questions it raises will be more important than any "answers" it provides.

It is the authors observation that the making and application of management decisions is paramount in determining farm performance.

The model is also using figures from physical and financial results from one year of DFMP.

Caution is recommended in use of this material.

HiGrass

Based on the assumptions applied the comparison between the modelling for FFFF and JJJJ herds on the HiGrass system the main comparisons drawn are:

	FFFF	JJJJ	Comment
Herd size	304	350	Driven by JJJJ lower body weight but ability to eat more per kg of body weight
KgMS/cow	549	526	Driven by JJJJ ability to produce more milk per kg feed intake
KgMS per assume Kg Body weight	95%	124%	Aligns with reported FCE advantage of JJJJ over FFFF.
Kg Liveweight carried per Ha	1,397	1,189	Is there an advantage of decreasing JJJJ stocking rate and allowing its genetic potential to be expressed? Same for FFFF?
FCE (kgECM/kgDMI)	1.17	1.27	As feed is the major input a dairy system, this is an inherent advantage of JJJJ to be utilised
Milk income	$1,165,365	$1,283,831	A significant higher income per Ha and feed utilised
Livestock income	$182,640	$120,000	Lower body weight and lower value per kg BW in the market diminishes JJJJ economic advantage
Herd and shed cost	$83,913	$92,651	Increase related for the same feed base there is more milk to cool and more cows in the system. Relative minor difference compared it difference in milk and livestock income.

Feed costs			Same for both herds as the utilisation of the same feed base is a base assumption of the modelling
Labour costs	$226,622	$260,942	Based on more cows been milked. Assumption of the same cost per cow may penalised JJJJ. See discussion.
EBIT	$386,989	$399,915	3.3% advantage for Jersey cattle
Assets employed	$4,244,651	$4,130,225	Reflective of the lower market value of Jersey cows even though more are owned.
ROA	9.1%	9.7%	Both significantly higher than those published for the DFMP. Advantage for Jersey breed.

HiCons

Based on the assumptions applied the comparison between the modelling for FFFF and JJJJ herds on the HiCons system the main comparisons drawn are:

	FFFF	**JJJJ**	**Comment**
Herd size	396	456	Driven by JJJJ lower body weight but ability to eat more per kg of body weight
KgMS/cow	611	594	Driven by JJJJ ability to produce more milk per kg feed intake, figure a limit of cow efficiency, very high figure for Jersey cow?
KgMS per assume KG Body weight	106%	139%	Aligns with report FCE advantage of JJJJ over FFFF. JJJJ figure on limit of cow efficiency. Are assumed cow weights correct.
Kg Liveweight carried per Ha	1,823	1,551	Is there an advantage of decreasing JJJJ stocking rate and allowing its genetic potential to be expressed?
FCE (kgECM/kgDMI)	1.28	1.39	As feed is the major input a dairy system is inherent advantage of JJJJ to be utilised
Milk income	$1,983,990	$2,113,174	A significant higher income per Ha and feed utilised
Livestock income	$236,760	$155,903	Lower body weight and lower value per kg BW in the market diminishes JJJJ economic advantage, bigger herd size magnifies FFFF advantage
Herd and shed cost	$131,781	$146,399	Increase related for the same feed base there is more milk to cool and more cows in

			the system. Relative minor difference compared it difference in milk and livestock income.
Feed costs			Same for both herds as the utilisation of the same feed base is a base assumption of the modelling
Labour costs	$331,469	$381,665	Based on more cows been milked. Assumption of the same cost per cow may penalised JJJJ. See discussion.
EBIT	$271,659	$355,870	The higher the feed intake in the system, the more the FCE and intake efficiency of the JJJJ applies, livestock sales not sufficient to pull down JJJJJ feed efficiency. Are cow weights correct and therefore feed efficiency rate correct?
Assets employed	$6,108,104	$5,962,856	Reflective of the lower market value of Jersey cows even though more are owned.
ROA	4.4%	5.6%	Significant advantage for JJJJ herd

Discussion

The above models suggest that the Jersey breed is well placed to deliver a profitable outcome over the major pure bred cattle breed in Australia, the Holstein Friesian. In what may be surprising the comparative economic advantage of the JJJJ is more apparent in the lower grazing intake system than the high grazed grass model. Caution must be exhibited here as whether the base assumptions in the models are correct.

Despite the caution expressed above, based on the Jersey's reported higher dry matter intake per unit of body weight coupled with the Jersey's reported higher conversion of dry matter intake into ECM it would be expected that under a higher feed intake model the Jersey would be able to exhibit these advantages more readily. As feed is the major cost per variable cost on a dairy operation, the closer the Jersey is fed to being able to express her genetic ability the further the feed efficiency of the Jersey will be seen in the profit and loss statement of the farm.

The major relative disadvantage the breed seems to suffer is the sale value of surplus stock (cull cows, bull calves and surplus heifers). This disadvantage may be overcome with current work being carried out on improving the dairy beef supply chain and educating the market (buyers) on advantages of dairy beef stock. The relative performance of the Jersey breed to other dairy breeds, especially the larger body framed animals, is yet to be seen.

Labour is the next operating major cost (after feed costs) on a dairy farm. Consequently assumptions based on labour costs can be expected to impact the EBIT performance comparison between breeds. As mentioned, the models used labour cost expressed on a per cow basis. Alternative methods that could be used are:

- Expressing labour on a per Kg milk solid (KgMS) basis, or
- Assume the labour input is the same as the farm is the same size and time spent milking the extra Jersey cows is minimal with modern dairy equipment and milk out time of Jersey is expected to be less due to lower milk volume of the Jersey cow (litres of milk harvested per hour is similar).

To assess the impact of these assumptions labour costs, EBIT and ROA was calculated for the alternative options. The impact of changing these assumptions are shown in Table 9 (HiGrass) and Table 10 (HiCons) below.

Table 9: Impact labour assumption - HiGrass Farms

	FFFF	JJJJ per cow	JJJJ per KgMS	JJJJ per Ha
$/unit		$746	$1.36	$1,813
Labour costs	$226,622	$260,942	$249,659	$226,622
EBIT	$386,989	$399,915	$411,197	$434,235
ROA	9.1%	9.7%	10.0%	10.5%

Table 10: Impact labour assumption - HiCons Farms

	FFFF	JJJJ per cow	JJJJ per KgMS	JJJJ per Ha
$/unit		$837	$1.37	$2,652
Labour costs	$331,468	$381,665	$371,315	$331,468
EBIT	$271,501	$335,870	$346,220	$386,067
ROA	4.4%	5.6%	5.8%	6.5%

As can be seen the basis of the labour cost assumption has a major impact on the comparative calculated profitability of the Jersey farm. As mentioned models are only as good as assumptions used in the model. The model presented has the least favourable assumptions to the Jersey breed. The modelled profitability as measured by return on assets can vary by as much 9% for the HiGrass system and 15% for the HiCons system.

Any advantage the Jersey breed enjoys in EBIT performance is further enhanced when measured against ROA. This is time the lower market value of Jersey cattle is reflected in the asset value of the Jersey herd.

Based on the assumptions used in the models in this statement where the same feed base and non livestock base is utilised for both herds under each production system, such low livestock values will be a natural advantage. In fact, the dollar invest per unit of income (kgMS) is:

- HiGrass: $22.48/kgMS for the Jersey herd compared to $25.45 for the Holstein Friesian herd (11% advantage)
- HiCons: $21.99/khMS for the Jersey herd compared to $25.23 for Holstein Friesian herd (13% advantage).

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APPENDIX 1

Base Calculation Template 1: ECM per 100kg Body weight

FFFF *c.f.* JJJJ

Assumed — From DFMP — Literature

FFFF BW:		575kg	(A)
FFFF ECM:		7,200kg ECM	(B)
FFFF ECM/kg BW:	A/B		
	7,200/575 =	12.5 kgECM/kgBW	(C)
JJJJ ECM efficiency coefficient:		28.5%	(D)
JJJJ ECM/kg BW:	C * (1+D)		
	12.5 *(1+28.5%) =	16.1ECM/kgBW	(E)
JJJJ BW:		425Kg ECM	(F)
JJJJ ECM:	E*F		
	16.1*425 =	6,843 kg ECM	(G)
Milking Area:		125 Ha	(H)
FFFF SR		2.6 cows/Ha	(I)
Number FFFF	H*J		
	125*2.6=	325 cows	(J)
FFFF DMI/cow		6.23TDM/cow	(K)
Total Farm DMI	J*K		
	325*6.23	2,048 TDM	(L)
FFFF DMI/100kg BW	(K*1000)/(A/100)		
	(6.23*1000)/(575/100) =	1,083	(M)
JJJJ DMI coefficient		17.7%	(N)
JJJJ DMI/100kg BW	M*(1+N)		
	1,083*(1+17.5%) =	1,272 kgDMI/100kgBW	(P)
JJJJ DMI/cow	(P*(F/100))/1,000		
	(1,272*(425/100))/1,000=	5.41TDM/cow	(Q)
Number JJJJ	L/Q		
	2,048/5.41=	379 cows	(R)
FCE FFFF	B/(K*1000)		
	7,200/(6.23*1000) =	1.16 kgECM/kgDMI	
FCE JJJJ	G/(Q*1000)		
	6,853/(5.41*1000) =	1.27 kgECM/kgDMI	

Appendix 2

Base Calculation Template 2: Feed intake and ECM per kg dry matter intake

FFFF *c.f.* JJJJ

Assumed	From DFMP	Literature	
FFFF BW:		575kg	(A)
JJJJ BW:		425kg	(B)
Milking Area		125 ha	(C)
FFFF SR		2.43 cows/ha	(D)
Number FFFF cows	D*E		
	125 * 2.43 =	304 cows	(E)
FFFF DMI/cow		6.32 TDM/cow	(F)
JJJJ DMI Coefficient		17.5%	(G)
Herd total DMI	E*F		
	304*6.32 =	1,918 TDM	(H)
FFFF DMI/100KgDMI	(D*1,000)/(A/100)		
	(2.43*1,000)/(575/100) =	1,099kgDM/100kgBW	(I)
JJJJ DMI/100kgDMI	I*(1+G)		
	1,099*(1+17.5%) =	1,291kgDM/100kgBW	(J)
JJJJ DMI/cow	(J*(B/100))/1,000		
	1,291*(425/100))/1,000 =	5.49 TDM/cow	(K)
Number JJJJ cows	H/K		
	1,918/5.49 =	350 cows	(L)
FFFF ECM		7,200 kg ECM	(M)
FFFF ECM/kgDMI	M/(F*1,000)		
	7,2000/(6.32*1,000) =	1.14 Kg ECM/kgDMI	(N)
JJJJ FCE/kgDMI Coefficient		8.5%	(P)
JJJJ FCE ECM/kgDMI	N*(1+P)		
	1.14*(1+8.5%) =	1.24 kgECM/kgDMI	(Q)
JJJJ ECM	K*1000*Q		
	5.49*1,000*1.24 =	6,785 kgECM	(R)
FCE FFFF	N	1.14 kgECM/kgDMI	
FCE JJJJ	Q	1.24 kgECM/kgDMI	

APPENDIX 3

Chart of Accounts

Income	
Milk income	$/kgMS
Livestock income	$
Total Income	
COSTS	
AI and herd costs	$/cow (modified)
Animal health costs	$/cow
Calf rearing	$/cow
Total herd costs	$/cow
Shed Power	$/kgMS
Dairy supplies	$/kgMS
Total shed costs	$/kgMS
Fodder purchased	$/cow
Grains, concentrates/Other	$/cow
Agistment	$/cow
Total purchased feed costs	$/cow
Fertiliser	$/ha
Irrigation	$/ha
Hay & silage making	$/ha
Fuel & oil	$/ha
Pasture & cropping	$/ha
Other feed costs	$/ha
Total home grown feed costs	$/ha
Total Variable Costs	
GROSS MARGIN	
Total labour costs	$/cow
Depreciation	$/ha
Repairs & maintenance	$/ha
Vehicles (Rego & insurance)	$/ha
Farm insurance	$/ha
Rates	$/ha
Other overheads	$/ha
TOTAL COSTS	
EBIT	

APPENDIX 4

Livestock Income for HiGrass and HiCons Farm Systems

		HiGrass			HiCons	
		FFFF	JJJJ		FFFF	JJJJ
Herd Size		304	350		396	456
Weaned calf Rate		85%	85%		85%	85%
Heifer percentage		48.50%	48.50%		48.50%	48.50%
Heifers weaned		125	144		163	188
Bull calves weaned		133	153		173	200
Replacement rate		24%	23%		24%	23%
R2 death rate		2%	2%		2%	2%
R1 death rate		3%	3%		3%	3%
Heifer calves kept		78	84		101	109
Heifers for sale		47	60		62	79
Bull calves for sale		133	153		173	200
Adult herd death rate		5%	5%		5%	5%
Deaths per year		15	17		20	23
Culls per yer		59	63		76	81
Cull Liveweight		575	425		575	425
Cull cow price	$/kg	$2.80	$2.30		$2.80	$2.30
Weaned heifer calf	$/hd	450	275		450	275
Weaned bull calf	$/hd	500	275		500	275
Cull cows		$94,990	$61,583		$122,360	$79,178
Heifers		$21,150	$16,500		$27,900	$21,725
Bull calves		$66,500	$42,075		$86,500	$55,000
Livestock Income		$182,640	$120,158		$236,760	$155,903

Contact Jersey Australia to find out more on how the Australian Jersey can support your business profit objectives

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