Crossbreeding in Australia – what have we learnt?

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Background

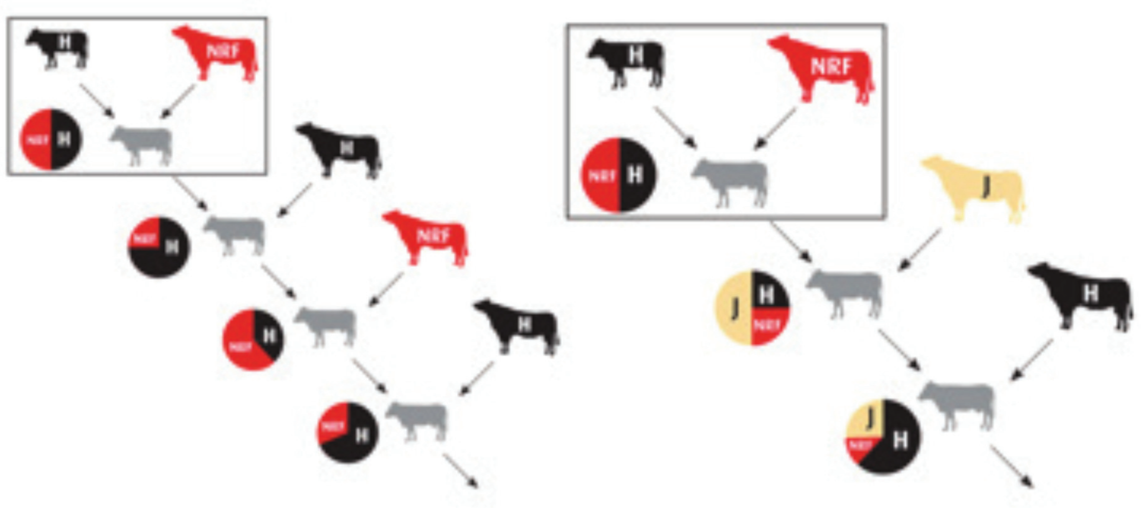
The use of crossbreeding has been suggested as a short-term solution for the decline in fertility in Australian dairy herds, which has been particularly evident in the Holstein Friesian (HF) breed in seasonal calving systems (Woolaston and Shephard, 2011). However, a 2006 survey of 255 Victorian and Tasmanian dairy farmers found that despite many respondents believing that crossbreeding could lead to potential gains in farm production, management, herd profitability and conception rates, very few intended increasing the proportion of crossbreds in their herds in the future (Pyman 2007). One of the main reasons given by these farmers was confusion over what step to take after breeding the first cross. This uncertainty led some farmers to revert back to the use of HF semen with mature HF cows. In fact a major conclusion from the study was that farmers needed more guidance on the management of a crossbreeding program. The review by Wollaston and Shephard (2011) reinforced this view by suggesting that "effective, clear and consistent extension material is needed to allow farmers to assess the benefits and implications of crossbreeding programs within their herds".

In 2015, Dairy Australia funded a two year research project which involved an analysis of the proportion of farmers utilising crossbreeding, including those employing a 3-breed rotational strategy. Additionally, Australian Dairy Herd Improvement Scheme (ADHIS[1]) data on production, cell count, reproduction and survival were used to answer the fundamental questions "where should we go after the first cross?" and "does a backcross or a 3-breed strategy perform better?" A survey of farmers' attitudes towards crossbreeding and an economic model was produced to compare the performance of a purebred herd with a 2-breed or 3-breed crossbreeding herd.

Are farmers utilising crossbreeding?

The breed structures in the Australian dairy industry were historically reported only by numbers of purebred cows or 2-breed (HF and Jersey(J)) crossbreed cows (DataGene, 2016). While these reports have shown a decrease in the use of HF/J cross animals over time (from 24,882 cows in 2008 to 21,964 cows in 2016), reports from reproductive advisers in the industry (S. Snowden; L. Bidevaate pers comm) suggest that an increasing number of farmers are employing crossbreeding, but many of these are now using a systematic 3-breed rotation (as depicted in Fig 1.), rather than 2-breeds (with alternate backcrossing to the parent breeds).

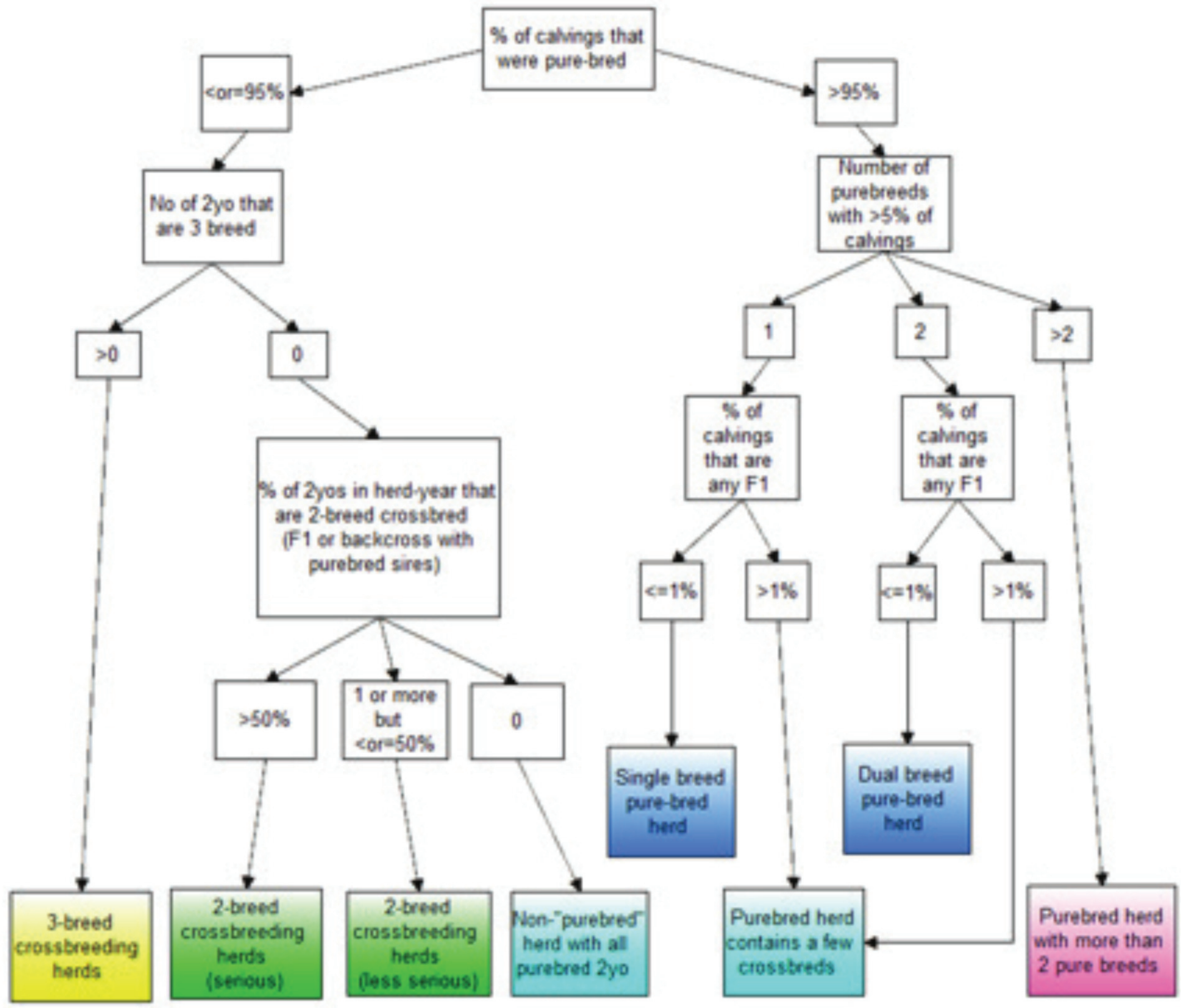
Figure 1 Example of two crossbreeding strategies – a 2-breed Holstein (H) x Norwegian Red (NRF) rotational cross on the left, and a 3-breed Holstein (H) x Norwegian Red (NRF) x Jersey (J) rotational cross on the right. Circles represent the breed makeup of each generation (Source: genoglobal.com/Start/why-crossbreeding/crossbreeding-programs2/3-plus/)



[1] ADHIS was restructured in 2016 is now part of DataGene

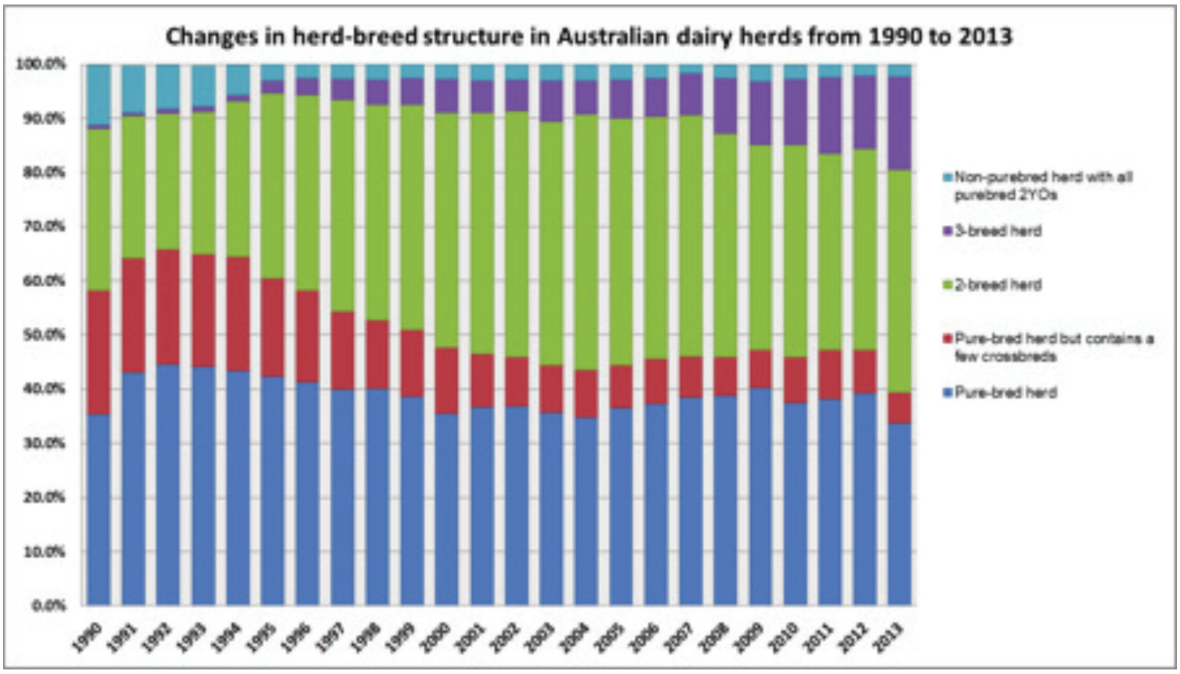
It was important to firstly establish how many farmers in Australia were employing crossbreeding, and of these, how many were choosing to use a 2-breed versus a 3-breed strategy. Additionally, changes over time in the use of the different strategies needed to be explored. Herd data was extracted from the ADHIS dataset (2001-2013) and herds were classified based on their herd-breed structure as shown in Figure 2.

Figure 2 Herd-breed classification system



The major findings were that across the industry, crossbreeding herds outnumbered purebred herds, and the proportion of crossbreeding herds had increased. Also, the proportion of herds employing a 3-breed strategy had increased over the years. The most common herd-breed structure in Australia between 2000 and 2013 was 2-breed crossbreeding herds (39% for less and more serious combined), with the most common breed combinations being the HF/J cross. The next most common type of herd was the purebred herd (35% for single and dual combined); with the most common breed being the HF. Over the period of time studied, the proportion of purebred herds decreased, while the proportion of crossbreeding herds (particularly 3-breed herds) increased. These trends varied with region and with calving system, but the findings indicate that more dairy farmers in Australia have begun to employ systematic crossbreeding strategies (Figure 3).

Figure 3 Changes in herd-breed structure in Australian dairy herds from 1990-2013



Evaluation of the performance, longevity and fertility of crossbred cows

The analysis of crossbred cows' performance in this study was a world first. While previous comparisons between purebred and crossbred cows have been made in various systems around the world, the F2 animal has not been widely studied, and in particular the comparison between a backcross (to one of the F1 parent breeds) with a 3-breed cross. Genetic theory predicts that more heterosis will be preserved with the addition of a third breed to the program but, (particularly in Australia) the gene pool for that third breed may be limited. The implication is that the F2 3-breed cross animal may not perform as well as a backcross that with a sire of good genetic merit.

The study evaluated all the data from the herd-breed classification study, along with NATSCAN[2] reproductive data. Where numbers of cows and lactations were available, comparisons were first made for milk production (and components), longevity, reproductive indices and cell count. The first part of the study made comparisons for these parameters between the F1 cross and the respective purebred parent breeds. The second section of the study made the comparisons at the F2 level between backcross and 3-breed combinations. For both sections, the comparisons were analysed from the actual values, and also with adjustment for sire and maternal grandsire ABV, allowing an evaluation of the potential of the particular cross, were the ABVs optimal.

The results for the F1 comparisons focused mainly on the most common F1 combinations; namely the J-HF cross cows and their performance compared with the parent purebred animals (however comparisons were made for all F1 animals who satisfied the section criteria). The results for production comparisons for the Jersey-HF cross cows are in Table 1.

[2] NATSCAN is the national fertility monitoring project where reproductive performance of herds on the national database providing sufficiently complete data to generate a Fertility Focus Report is monitored to identify national averages and trends

Table 1 Production comparisons between JJFF crossbred cows and their parent breeds

No. herds	No. cows	No. lactations JJJJ	No. lactations JJFF	No. lactations FFFF
136	64,496-64,497	34101 - 341021	17361	162551-1625592

	Breed	Mean	SD	Not adjusted for ABV: diff. between means	Not adjusted for ABV: 95% CI	Not adjusted for ABV: P	Adjusted for ABV: diff. between means	Adjusted for ABV: 95% CI	Adjusted for ABV: P
Milk						**<0.001**			**<0.001**
	JJJJ	4,724	1,403	Ref. group			Ref. group		
	JJFF	5,912	1,701	1,093	1,047 to 1,139	**<0.001**	911	854 to 967	**<0.001**
	FFFF	6,776	2,049	1,737	1,701 to 1,773	**<0.001**	836	781 to 892	**<0.001**
	JJFF F1: diff. from expected			224	188 to 260	**<0.001**	492	449 to 536	**<0.001**
	FFFF			Ref. group			Ref. group		
	JJFF			-644	-677 to -611	**<0.001**	74	28 to 120	0.002
Protein						**<0.001**			**<0.001**
	JJJJ	177.0	52.7	Ref. group			Ref. group		
	JJFF	209.1	59.0	29.5	28.1 to 30.9	**<0.001**	26.8	25.2 to 28.3	**<0.001**
	FFFF	220.9	66.5	35.7	34.6 to 36.9	**<0.001**	21.7	20.3 to 23.1	**<0.001**
	JJFF F1: diff. from expected			11.6	10.5 to 12.8	**<0.001**	15.9	14.7 to 17.1	**<0.001**
	FFFF			Ref. group			Ref. group		
	JJFF			-6.2	-7.2 to -5.2	**<0.001**	5.0	3.8 to 6.3	**<0.001**
Protein %						**<0.001**			**<0.001**
	JJJJ	3.75	0.27	Ref. group			Ref. group		
	JJFF	3.55	0.27	-0.19	-0.20 to -0.18	**<0.001**	-0.14	-0.15 to -0.13	**<0.001**
	FFFF	3.27	0.24	-0.45	-0.45 to -0.44	**<0.001**	-0.24	-0.25 to -0.23	**<0.001**
	JJFF F1: diff. from expected			0.03	0.02 to 0.04	**<0.001**	-0.02	-0.02 to -0.01	**<0.001**
	FFFF			Ref. group			Ref. group		
	JJFF			0.25	0.25 to 0.26	**<0.001**	0.10	0.10 to 0.11	**<0.001**
Fat						**<0.001**			**<0.001**
	JJJJ	233.6	67.2	Ref. group			Ref. group		
	JJFF	261.4	72.6	26.3	24.6 to 28.1	**<0.001**	23.1	21.2 to 24.9	**<0.001**
	FFFF	260.6	75.8	21.1	19.7 to 22.4	**<0.001**	10.2	8.7 to 11.8	**<0.001**
	JJFF F1: diff. from expected			15.8	14.4 to 17.2	**<0.001**	18.0	16.6 to 19.4	**<0.001**
	FFFF			Ref. group			Ref. group		
	JJFF			5.3	4.0 to 6.5	**<0.001**	12.9	11.5 to 14.2	**<0.001**
Fat %						**<0.001**			**<0.001**
	JJJJ	4.98	0.60	Ref. group			Ref. group		
	JJFF	4.46	0.58	-0.49	-0.51 to -0.47	**<0.001**	-0.21	-0.23 to -0.19	**<0.001**
	FFFF	3.89	0.54	-1.01	-1.02 to -0.99	**<0.001**	-0.14	-0.16 to -0.11	**<0.001**
	JJFF F1: diff. from expected			0.01	-0.01 to 0.03	0.288	-0.14	-0.16 to -0.12	**<0.001**
	FFFF			Ref. group			Ref. group		
	JJFF			0.51	0.50 to 0.53	**<0.001**	-0.07	-0.09 to -0.05	**<0.001**

For production, the purebred HF cows produced more milk and protein than the crossbred animals, but the crossbreds produced more fat and had higher milk composition (protein % and fat %) than HF cows. The Jersey-HF crossbred animals also had significantly longer survival than their parent breeds (Table 2), and were better than their parent breeds for some of the reproductive parameters (Table 3). There were no significant differences between the Jersey-HF crosses and their parent breeds in somatic cell counts. Although not shown here, the comparisons between the alternate F1 cross (namely HF-Jersey) and the parent breeds were similar.

Table 2 Survival comparisons between JJFF/FFJJ crossbred cows and their parent breeds

Breed	No. cows	Percent culled	Median time from 2yo calving (days)	Not adjusted for ABVs: Hazard ratio	Not adjusted for ABVs: 95% CI	Not adjusted for ABVs: P		Adjusted for ABVs: Hazard ratio	Adjusted for ABVs: 95% CI	Adjusted for ABVs: P
						<0.001				**<0.001**
JJJJ	8686	62%	1345	Ref. group				Ref. group		
JJFF	4012	69%	1396	0.8	0.7 to 0.8	**<0.001**		0.7	0.7 to 0.7	**<0.001**
FFFF	35963	66%	1251	0.8	0.8 to 0.9	**<0.001**		0.7	0.7 to 0.7	**<0.001**
JJFF: diff. from expected				0.9	0.9 to 1.0	**<0.001**		1.0	1.0 to 1.0	0.999
FFFF				Ref. group				Ref. group		
JJFF				0.8	0.8 to 0.9	**<0.001**		0.8	0.8 to 0.9	**<0.001**
No. herds	125									

Table 3 Reproduction comparisons for JJFF and FFJJ F1 cows compared with their parent breeds

	Breed	No. lactations	% submitted by week 3	Not adjusted for ABV: Odds ratio	Not adjusted for ABV: 95% CI	Not adjusted for ABV: P	Adjusted for ABV: Odds ratio	Adjusted for ABV: 95% CI	Adjusted for ABV: P	Breed	No. lactations	% submitted by week 3	Not adjusted for ABV: Odds ratio	Not adjusted for ABV: 95% CI	Not adjusted for ABV: P	Adjusted for ABV: Odds ratio	Adjusted for ABV: 95% CI	Adjusted for ABV: P
% submitted by week 3						**<0.001**			**<0.001**						**<0.001**			0.025
	JJJJ	3,289	70%	Ref. group			Ref. group			FFFF	14,038	55%	Ref. group			Ref. group		
	JJFF	3,156	77%	1.3	1.1 to 1.6	**<0.001**	1.5	1.3 to 1.9	**<0.001**	FFJJ	543	71%	1.6	1.2 to 2.1	**<0.001**	1.5	1.1 to 1.9	0.007
	FFFF	20,237	55%	0.7	0.6 to 0.8	**<0.001**	1.0	0.8 to 1.2	0.943	JJJJ	2,989	70%	1.4	1.2 to 1.7	**<0.001**	1.1	0.9 to 1.3	0.413
	JJFF: diff. from expected			1.8	1.6 to 2.1	**<0.001**	1.5	1.3 to 1.8	**<0.001**	FFJJ: diff. from expected			1.1	0.9 to 1.5	0.373	1.4	1.1 to 1.8	0.013
	FFFF			Ref. group			Ref. group			JJJJ			Ref. group			Ref. group		
	JJFF			4.8	3.9 to 6.2	**<0.001**	1.5	1.3 to 1.8	**<0.001**	FFJJ			1.3	1.0 to 1.7	0.024	1.3	1.0 to 1.8	0.047
			No. herds 88	No. cows	15,278							No. herds 55	No. cows	10,248				
% conceived to first service			**% conceived to first service**									**% conceived to first service**						
						<0.001			**<0.001**						0.034			0.035
	JJJJ	2,635	43%	Ref. group			Ref. group			FFFF	10,411	39%	Ref. group			Ref. group		
	JJFF	2,591	49%	1.2	1.0 to 1.5	0.017	1.4	1.2 to 1.7	**<0.001**	FFJJ	474	47%	1.3	1.0 to 1.6	0.034	1.1	0.9 to 1.4	0.393
	FFFF	14,850	39%	0.8	0.7 to 1.0	0.009	1.2	1.0 to 1.4	0.013	JJJJ	2,483	44%	1.2	1.0 to 1.3	0.060	0.8	0.7 to 1.0	0.035
	JJFF: diff. from expected			1.5	1.3 to 1.7	**<0.001**	1.3	1.1 to 1.5	**<0.001**	FFJJ: diff. from expected			1.1	0.9 to 1.4	0.421	1.2	1.0 to 1.5	0.086
	FFFF			Ref. group			Ref. group			JJJJ			Ref. group			Ref. group		
	JJFF			3.9	3.3 to 4.7	**<0.001**	1.2	1.0 to 1.3	0.030	FFJJ			1.2	0.9 to 1.5	0.131	1.4	1.0 to 1.8	0.022
			No. herds 93	No. cows	12,365							No. herds 60	No. cows	8,462				
% pregnant by week 6			**% pregnant by week 6**									**% pregnant by week 6**						
						<0.001			**<0.001**						**<0.001**			0.634
	JJJJ	3,086	62%	Ref. group			Ref. group			FFFF	13,450	47%	Ref. group			Ref. group		
	JJFF	3,066	66%	1.2	1.0 to 1.4	0.070	1.3	1.1 to 1.6	**<0.001**	FFJJ	538	60%	1.3	1.0 to 1.6	0.022	1.1	0.9 to 1.4	0.345
	FFFF	19,231	46%	0.7	0.6 to 0.8	**<0.001**	1.0	0.9 to 1.2	0.915	JJJJ	2,874	62%	1.5	1.3 to 1.8	**<0.001**	1.0	0.9 to 1.2	0.704
	JJFF: diff. from expected			1.7	1.6 to 2.0	**<0.001**	1.3	1.2 to 1.5	**<0.001**	FFJJ: diff. from expected			0.9	0.7 to 1.1	0.210	1.1	0.9 to 1.4	0.408
	FFFF			Ref. group			Ref. group			JJJJ			Ref. group			Ref. group		
	JJFF			4.2	3.5 to 5.0	**<0.001**	1.3	1.2 to 1.5	**<0.001**	FFJJ			1.1	0.8 to 1.3	0.641	1.1	0.8 to 1.4	0.539
			No. herds 93	No. cows	14,589							No. herds 60	No. cows	9,984				
% not pregnant by week 12			**% not pregnant by week 12**									**% not pregnant by week 12**						
						<0.001			0.296						**<0.001**			0.521
	JJJJ	3,101	6%	Ref. group			Ref. group			FFFF	13,001	15%	Ref. group			Ref. group		
	JJFF	3,021	8%	1.1	0.8 to 1.4	0.703	0.9	0.7 to 1.3	0.668	FFJJ	523	7%	0.7	0.5 to 1.1	0.122	0.8	0.5 to 1.2	0.356
	FFFF	18,589	16%	1.5	1.2 to 1.9	**<0.001**	1.1	0.8 to 1.4	0.493	JJJJ	2,848	6%	0.7	0.5 to 0.8	**<0.001**	0.9	0.7 to 1.2	0.398
	JJFF: diff. from expected			0.7	0.6 to 0.8	**<0.001**	0.9	0.7 to 1.1	0.325	FFJJ: diff. from expected			1.1	0.7 to 1.7	0.640	0.9	0.6 to 1.3	0.525
	FFFF			Ref. group			Ref. group			JJJJ			Ref. group			Ref. group		
	JJFF			2.4	2.0 to 2.9	0.153	0.9	0.7 to 1.0	0.133	FFJJ			0.9	0.6 to 1.3	0.610	0.9	0.6 to 1.5	0.760
			No. herds 93	No. cows	14301							No. herds 60	No. cows	9,747				

The results for the F2 comparisons varied, depending on the breeds used in the 3-breed cross, but for the most common 3-breed cross, the Australian Red (U) x J-HF, the results were conclusive (Table 4). For this cross, 3-breed cows performed significantly better than both the backcross cows (HF x J-HF or J x J-HF) for most of the parameters examined.

Table 4 Comparisons for HF/HF-J backcross versus U/HF-J 3-breed cross for all parameters

Parameter	FFFJ[1]		UUFJ		Not adjusted for sire and MGS ABVs			Adjusted for sire and MGS ABVs			No. cows	No. herds	No. lactations	
	Mean	SD	Mean	SD	Diff. between means	95% CI	P	Diff. between means	95% CI	P	6970	104	FFFJ	UUFJ
													23465	1736
Protein (kg)	204.9	61.5	210.1	53.0	7.2	3.4 to 11.1	**<0.001**	38.6	34.5 to 42.8	**<0.001**				
Milk (litres)	6010	1775	5950	1534	13	-99 to 125	0.817	888	755 to 1,020	**<0.001**				
Fat (kg)	252.4	73.0	257.7	65.5	9.00	4.5 to 13.5	**<0.001**	18.47	13.9 to 23.0	**<0.001**				
Protein %	3.41	0.26	3.54	0.25	0.13	0.11 to 0.15	**<0.001**	0.02	0.00 to 0.04	0.035				
Fat %	4.24	0.55	4.37	0.61	0.14	0.10 to 0.19	**<0.001**	-0.15	-0.20 to -0.10	**<0.001**				
					Odds ratio			Odds ratio			No. cows	No. herds	No. lactations FFFJ	No. lactations UUFJ
Submitted by week 3	75%		79%		1.2	0.9 to 1.6	0.192	0.8	0.6 to 1.1	0.200	2525	54	4783	595
Conceived to first service	47%		51%		1.3	1.0 to 1.6	0.027	1.1	0.9 to 1.5	0.421	2272	56	3981	543
Pregnant by week 6	63%		71%		1.5	1.2 to 1.8	0.001	1.0	0.8 to 1.3	0.921	2498	57	4720	611
Not pregnant by week 12	5%		3%		0.7	0.4 to 1.2	0.216	0.9	0.5 to 1.7	0.784	2269	36	4557	599
% with max. ICCC > 250,000	42%		33%		0.9	0.7 to 1.1	0.158	1.1	0.9 to 1.3	0.346	6348	93	19988	1423
	Mean	SD	Mean	SD	Ratio of means			Ratio of means						
No. ICCCs > 250,000	1.11	1.84	0.74	1.43	0.8	0.9 to 1.2	0.020	1.0	0.7 to 1.0	0.972	6353	48	19988	1423
					Hazard ratio			Hazard ratio					No. cows FFFJ	No. cows UUFJ
Percent culled	69%		25%		0.73	0.61 to 0.87	**<0.001**	0.94	0.77 to 1.14	0.525				
Median time from 2yo calving (days)	1407		703									100	5499	669

When the order of this 3-breed combination was changed (for example to J x HF-U or HF x J-U) although less results were significant, in most cases the 3-breed cows still outperformed the backcross animals. This indicates that the order of the cross may not matter, which could assist farmers in simplifying their breeding plans.

Survey of farmer attitudes to crossbreeding

A five-page survey was designed to collect qualitative and quantitative data about Australian dairy farmers' beliefs and attitudes about crossbred cows. Qualitative data was collected on farm composition, farmer demographics, previous or intended changes made to herd composition, comparisons between crossbred and purebred cows in terms of health, production and management parameters and interest in learning more about economic comparisons between purebred and crossbred cows. Quantitative data was collected about previous farmer experience with crossbred cows (including advantages and disadvantages of 3-breed and 2-breed crossbred cows), reasoning behind any changes made to herd composition and information that would be useful in order to make an informed decision on whether to change herd composition in relation to the number of crossbred cows.

The survey was distributed to clientele of the University of Melbourne Veterinary residents clinics. It was also sent to vets in Queensland and South Australia. As the response rate from these sources was very low, another strategy was devised: direct promotion to farmers via the AUSDAIRYL online forum. A total number of 94 responses were received, of which 20 (21.3%) were from pure breeding only herds, 9 (9.6%) were crossbreeding only and 65 (69.1%) had a combination of purebred and crossbred cows in their herd. Of the crossbreeding respondents, 75.5% (71 out of 74) employed a 2-breed strategy, and 39.4% (37 out of 74) had 3-breed crossbred cows.

Major differences between crossbreeding and pure breeding farmers were found in terms of demographics and farm management approaches. Pure breeding farmers tended to be older (38.9% were aged 50-59 years), compared with crossbreeding farmers (31.1% were aged 31-39 years). Farm size and herd size were lower for pure breeding farmers and their stocking rates were higher. Dry land farms were most commonly run by pure breeding farmers, whereas irrigated farms were most commonly run by crossbreeding farmers. Interestingly, 40.3% of crossbreeding farmers were very interested in learning more about economic comparisons between purebred and crossbred herds, whereas 44.4% of pure breeding respondents were not interested at all. Of all farmers surveyed, 67% were interested in learning more about economic, production, health and fertility comparisons between CB and purebred cows, as well as having access to reliable information. This is an increase, compared to the earlier survey (Pyman, 2007) which indicated that 58% of respondents were interested in further information.

The results indicated that most farmers believe that crossbred cows are better than purebred cows with regards to value of milk components, calving ease, fertility (getting back into calf) and general health problems. Factors which farmers rendered as disadvantageous when compared to purebred cows include selling value and access to export markets. No difference was believed to exist when considering milk production, temperament, cell count, availability of semen and cow appearance. Opinions were divided about size, lameness, effect on physical aspects of the farm, longevity in the herd and the simplicity of the breeding program.

Overall, the results indicated that the beliefs and attitudes of crossbreeding farmers are better aligned with the evidence in the literature about crossbreeding than those of pure breeding farmers. Crossbreeding farmers are also more interested in learning more about economic, production, reproductive and health comparisons.

Economic model of crossbred cows

The model used in the Improving Herds project to examine the impact of selection strategies on farm profitability was adapted to examine crossbreeding as a strategy. Three scenarios were compared: the persistence of a pure breed herd, crossbreeding to a 2-breed herd and crossbreeding to a 3-breed herd. This whole-farm simulation modelled individual cow's lives and the discrete but stochastic events in their lives. The model was developed in the R language and environment for statistical computing (R). The individual events were modelled as a combination of management rules overlaying previously-described physiological events (such as the probability of conception following service). The model was stochastic such that a random draw from the physiological event curve determined the result of any particular physiological event. Management rules defined the farming system, such as type of calving pattern, start of mating and calving, type of cow and breeding strategy. The physiological relationships, such as the risk of heat by days after calving, peak lactation milk production, risk of death or disease etc. were defined using mathematical equations obtained from industry data. This effectively means that there were no 'black box' relationships in model construction. Herd size was adjusted to meet pasture consumption targets that were in turn derived from the underlying pasture growth curve. Cow feed demand was estimates as a function of milk production and animal size and herd feed demand by collating individual cow feed demand across all cows. The herd was directed to grow (or shrink) by adjusting the duration the seasonal AI period to produce more (or fewer) replacement heifers according to the balance between total annual farm pasture production and total annual herd feed demand. This approach therefore adjusted stocking rate according to individual cow demand (with the stocking rate increasing as cow size and/or milk production decreased). The replacement rate (and therefore the duration of AI) was adjusted according to the desired herd size and the average longevity of cows.

The model accounts for all variable costs in the production cycle such as the cost of mating, herd health, and milking shed operation. Variable feed costs such as pasture, concentrates and conservation are included. All income streams are accounted for. These are milk, livestock sales, changes to the conserved fodder value and changes to herd inventory. The time line for accrual of costs and income are captured through the sequential progression of the model. This allows the future streams of income and costs to be collated and the net profit at each point in time to be estimated. These future income and expenditure streams are discounted using accepted economic principles and conservative discounting rates and the net present value of these discounted income and costs streams used to compare the gross margins of the three competing management scenarios. No interim product in the production cycle is valued; only saleable items and assumed of value. This avoids the need to estimate the final work of an intervention by multiplying the counts of items against their purported value at that time. The model has been designed to compare the short, medium and long term profitability of competing management strategies.

This model provides the most feasible, realistic and integrated representation of breeding program impacts within a modern Australian dairy farm. The model

[3] ImProving Herds project is a multi-disciplinary, collaborative research, development and extension program to provide better information to dairy farmers from herd-testing data on cow health, survival and profitability thereby supporting better decision making.

is in general suitable for studying impacts of change in management or composition such as exploring competing breeding objectives, changes to cow culling policy, variation in input and output prices and farming efficiency on overall farm profitability.

Overall the findings were that crossbreeding was consistently more profitable than persisting with a purebred herd in the pasture-based seasonally calving productior system that predominates in Australia. Gross margins improvements of between 4–8% pe annum is predicted within a ten-yea horizon (Table 5).

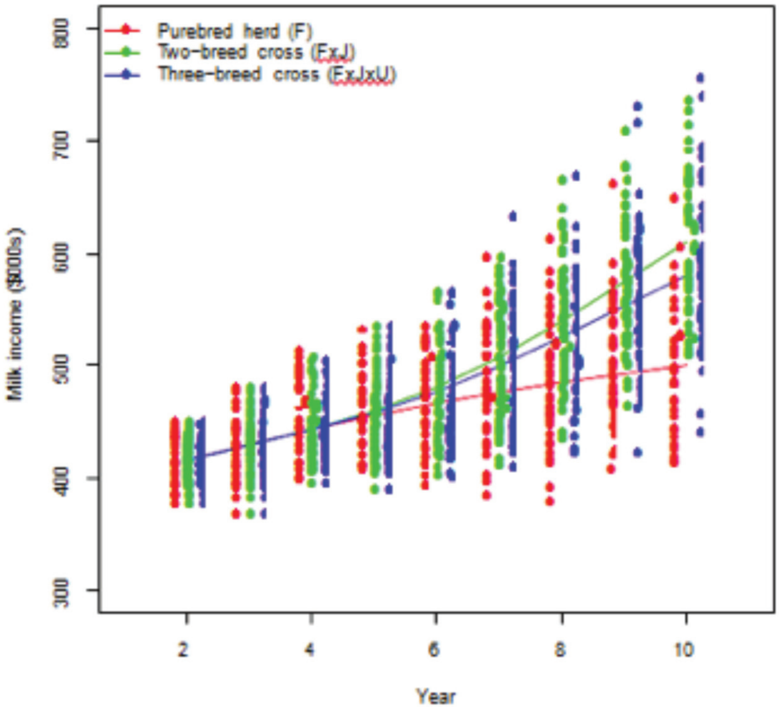
However, crossbreeding needs to be implemented for up to 6 years before differences between the strategies in farm profitability and performance become apparent (Figure 4). This is essentially the time required for the change in breeding strategy to be fully reflected in the milking herd. There is potential for a small reduction in milk production and profitability in the first few years of converting to a crossbreeding strategy. This arises when the bulk of the milking herd remains purebre and when the first few cohorts of crossbred replacements are smaller and less productive.

A key finding is that a crossbreeding strategy requires a concurrent increase in stocking rate. This is essential to ensure that farm pasture consumption is maintained as cow size and cow production decreases with the conversion from purebred to crossbred cows. The crossbreeding strategy resulted in a reduction in cow production per lactation but production per hectare is essentially maintained. This is the key to ensuring total farm milk production and profit is maintained through the transition. However, it should be noted, that the cow reduction in fat production is less than the reduction in protein and litres following the introduction of Jersey genetics.

Table 5 Predicted annual gross margin (discounted), difference from purebred ($ and %) by calving pattern and test scenario

Calving pattern	Test scenario	Net dollars	Difference ($)	Difference (%)
Seasonal	Pure Breed	257,074	0	0.00
Seasonal	Two-Breed Cross	278,152	21,078	7.60
Seasonal	Three-Breed Cross	268,204	11,129	4.10

Figure 4 Annual milk income distribution and trend by test scenario



Improved herd reproductive performance is the major driver of improved profitability. This operates via greater cow longevity providing for reduced annual herd depreciation costs. Cows live and produce for longer and fewer replacements need to be reared each year and these savings directly convert into extra profit. Enhancing reproductive performance is the primary way that crossbreeding improves farm profit in pasture-based dairying. Farms with inadequate reproductive performance can benefit from using sires within breeds that are above average for fertility (and are more fertile than the average cow in the herd). Using crossbreeding can further accelerate the rate of reproductive performance gain. Improved reproductive performance leads to longer cow survival. This not only allows for shorter and less expensive AI mating periods and lower replacement rearing costs but allows provides for an improved (more productive) milking herd age structure. More cows survive to their peak lactations between 5-7 years of age.

Supplementary feeding provides a gearing opportunity for well-managed crossbred herds. The ability to feed more grain to the (larger) herd can provide opportunity to generate even more profit when the milk price:grain price ratio is favourable. Conversely, there is opportunity for larger losses when this ratio is unfavourable. Careful evaluation of milk-to-grain prices and the expected marginal milk response to the feeding of additional grain is required – but this is the case for all grazing systems.

An effective crossbreeding strategy may provide capacity to maintain a true seasonally-calving herd with a short mating period. This strategy has reduced work demands and provides for a better match between farm pasture growth and herd feed demand. One of the benefits from an effective crossbreeding strategy is the provision of a herd more capable of responding to management change thereby providing better ability to manage season/price risks.

Summary

The retrospective analysis of herd-breed structures from 2000-2013 found that the proportion of Australian herds which have crossbred cows has increased over that time, and more farmers have employed systematic crossbreeding strategies, including utilising 3-breed cross systems. The proportions of purebred herds did not change dramatically over the period studied, but the number of purebred herds with some crossbreds declined, indicating that farmers have adopted more strategic crossbreeding systems.

The second part of the study showed that F1 Jersey-HF crossbred cows, although they produced less milk and protein than the HF cows, outperformed purebred HF cows for fat, fat %, protein %, survival and reproductive parameters. These results are supported by other similar studies (Heins et al., 2006; Auldist et al., 2007; Dechow et al., 2007; Prendiville et al., 2009; Heins et al., 2012 and Vance et al., 2013).

The comparisons between the F2 backcross (HF x J-HF or J x J-HF) and the most common 3-breed cross (U x J-HF) resulted in significantly better production, reproduction and survival parameters in favour of the 3-breed cross. This is an extremely important finding, as it will give herd reproductive advisers the ability to use evidence-based knowledge when developing a plan for farmers utilising crossbreeding.

The farmer survey clearly indicated that those farmers who are crossbreeding are seeking more evidence and guidance, and it will be important to disseminate the findings of this study in a targeted way. Interestingly, it appears that are demographic differences between crossbreeding versus pure breeding farmers, with crossbreeding farmers tending to be much younger. This could assist the industry with a targeted approach to educating those farmers most likely to benefit.

The final part of the study, the economic model, demonstrated that in the long term a crossbreeding strategy is likely to be more profitable in a seasonal calving system than pure breeding. However, it may be several years before the benefits are realised, another important message for farmers.

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