
VOLUME 62 2002

Potential benefits of low replacement rate for dairy herd production and profit

N. LOPEZ-VILLALOBOS* and C. W. HOLMES

Institute of Veterinary, Animal and Biomedical Sciences, Massey University, Private Bag 11-222, Palmerston North 4442, New Zealand
*Corresponding author: n.lopez-villalobos@massey.ac.nz

ABSTRACT

The effects of different replacement rates on the genetic gain for lactation yields of milk and milksolids (fat + protein) per cow and farm profit per hectare were evaluated using a simulation model. Three levels of replacement rate were simulated 15, 19 and 27%, by varying the levels of involuntary culling, such as with low fertility, and voluntary culling based on production worth. The effect of selection of replacements based on breeding worth was also evaluated. In the base year, farm profit was higher for lower replacement rates. Annual genetic gain in average herd breeding values for milksolids after 20 years of using bulls of high breeding worth was higher at higher replacement rates. However, farm profit at Year 20 was still higher for a herd with a low replacement rate than for a herd with a high replacement rate. A herd with a 15% replacement rate in combination with selection of replacement heifers based on breeding worth, achieved the highest gain in breeding values for milksolids and achieved the highest farm profit at Year 20. These results demonstrate that low replacement rate in combination with selection of high breeding worth heifers can achieve high genetic gain in both milksolids and farm profit.

Keywords: replacement rate; farm profit; genetic gain.

INTRODUCTION

Replacement rate affects the age structure and the genetic merit of the dairy herd, and the productivity and profitability of the dairy farm, especially where heifers are competing with cows for feed resources. Jackson (1984) concluded that replacement rates around 20% are likely to maximise the profitability of the farm, a value that Simmonds (1998) agreed with. However, Vollebregt and Vollebregt (1998), two dairy farmers, concluded that a replacement rate of 15% ensured good genetic gain, with maximum production of milksolids (fat + protein) and minimum replacement costs, but they did not show how this level of replacement rate was calculated.

As a result of many interacting and conflicting factors, it is difficult to quantitatively evaluate the effect of different replacement rates on dairy farm productivity and profitability, and dairy herd improvement. Gartner and Herbert (1981) constructed a model to evaluate the effects of different replacement rates on grazing farms, where heifers competed with cows for feed. The model estimated the profitability of the total herd assuming that a fixed amount of feed was available for the whole herd, including the replacements. The results suggested that under these circumstances, a low replacement rate is desired because (i) more cows can be carried as fewer heifers need to be reared, (ii) there will be a higher proportion of mature cows with higher yields in the herd, (iii) the best cows can be selected for breeding the future cow replacements, and (iv) the total replacement cost of the herd will be lower.

Dynamic programming models have been developed in New Zealand to determine the optimum time that a cow should be culled to maximise profit (McArthur, 1973; Harris, 1988). Dynamic programming is based on the general principle that a cow of a particular age should be kept in the herd as long as her marginal profit is greater than the expected average profit of a young replacement cow (Van Arendonk, 1984; Lehenbauer & Oltjen, 1998). These dynamic programming models are focused on culling individual cows based on individual performance and assume no restrictions on feed supply for the whole herd.

Genetic merit of a dairy herd can be improved by three practices, breeding of replacements by sires of high genetic merit, culling cows of low genetic merit and selection of replacement heifers of the highest genetic merit (Holmes *et al*., 2002). However the productive merit of the herd will be determined not only by its genetic merit but also by its age structure; the lower yields expected from younger cows must be taken into account. Searle (1961) illustrated the likely genetic improvement in a dairy herd due to culling low producers, together with the use of above average sires by artificial insemination. Searle (1961) also showed that the genetic merit of the herd is affected by the level of voluntary culling of cows that a famer can apply on the herd. The average culling rate of cows in herds in the Bay of Plenty region of New Zealand was 22.6% over two seasons (Anderson, 1985). Main reasons for culling were infertility (6.3%), low production (3.7%), type (1.3%), sold (5.2%), mastitis (2.3%), facial eczema (1.1%) and other reasons (2.7%). The voluntary culling in these herds was about 10%. Currently the percentage culled for infertility is probably higher than 6%.

The present study used a simulation computer model to evaluate the effects of different replacement rates on the genetic merit and age structure of the herd and milksolids yield per cow and hectare and on farm profit per hectare.

MATERIALS AND METHODS

A deterministic model developed by Lopez-Villalobos *et al.* (2000) was used to simulate, on an annual basis, production and economic performance of dairy herds with eight different combinations of replacement rate, voluntary and involuntary culling rates and selection of heifers as shown in Table 3. Causes of wastage among young replacements and cows were sorted into voluntary culling, being their suitability for dairying including low production, type and temperament, and involuntary culling, being deaths, diseases including mastitis, bloat, metabolic problems and facial eczema, poor fertility and age. Cows were culled when they reached 11-years-old.

All herds were operated within a fixed feed supply, determined by the farm's area and pasture production per hectare. The herds, including replacements, were grazed on pasture during the whole year. The cows calved in early spring, produced milk for 270 days during the period of rapid pasture growth, and were dried off before winter, the period of slow pasture growth. Heifers calved at 24 months of age and thereafter maintained an average calving interval of 12 months. Artificial insemination was used in 80% of the cows and 30% of the heifers for a period of eight weeks, using semen from purebred sires. After this period, a bull was used for natural service of non-pregnant cows and heifers for a further four week period. Female progeny from non-artificial-insemination bulls and infertile heifers were sold for beef within the first week after calving. Numbers of animals were updated each year using a herd-growth model (Azzam *et al.*, 1990) according to the replacement rate imposed in the simulation.

The herd's total requirements for feed, including requirements for the maintenance and growing of the replacements, were calculated using the formulae proposed by AFRC (1993) assuming an energy density of 10.5 MJ of metabolisable energy (ME) per kg pasture dry matter (DM). It was assumed that 15,000 kg DM/ha was produced by ryegrass-clover pastures growing on fertile soils, and that 80%, or 12,000 kg DM/ha, was harvested by the animals. Herd size was adjusted to an area of 140 ha available for pasture production. This calculation assumes that the number of animals grazed per hectare was adjusted to meet their DM requirements, which in turn are determined by their production levels. Herd averages for live weight per cow and milk production per cow and per hectare were calculated each year by weighting the averages of age class by the number of animals.

Voluntary culling of cows was based on the genetic index called production worth (PW) calculated as the sum of the producing values for live weight and lactation yields of milk, fat and protein, each weighted by an economic value. Culling was across age classes following Ducrocq and Quaas (1988). Selection of heifers was based on the genetic index called breeding worth (BW) calculated as the sum of the breeding values for live weight and lactation yields of milk, fat and protein, each weighted by an economic value. Reliability of estimated BW of heifers was low because heifer's estimated breeding values were based only on parental information.

Each year the model calculated the genetic merit of new progeny as the average of the genetic superiority of the selected dams and sires as parents and also as each "age class" became 1 year older. For each of the age classes, expected phenotypic performances per cow for live weight and lactation yields of milk, fat and protein were calculated as the sum of the values considered as the genetic base plus the genetic merit of the cows. Age adjustment factors for milk and milk component yields per cow were 0.75, 0.88, 0.95, 1.0, and 0.90 for Lactations 1, 2, 3, 4 to 7, and 8 to 9, respectively. These factors were calculated from age production averages reported by Livestock Improvement Corporation (2009). Annual rates of genetic gain in the bull team were assumed at 45 L milk, 2.3 kg fat, 1.8 kg protein and 0.5 kg live weight.

Annual farm profit was measured as net income per hectare calculated from gross income minus production costs. Income was derived from the sale of milk and disposed animals. Milk income was calculated as: ($3.262 × kg fat) + ($8.816 × kg protein) – ($0.039 × litre milk). Beef income was derived from the sale of male calves, surplus female calves and culled rising 2-year-old and older cows. Average farm production costs included both direct expenses and overheads. Direct expenses per cow were: labour, $228; animal health, $55; breeding and herd testing, $34; farm dairy expenses, $20; electricity, $25; freight, $10; and others, $7. Direct expenses per hectare were: pasture renovation, $24; fertiliser, $360; weed and pest control, $19. Overheads per hectare were: repairs and maintenance, $182; vehicle expenses, $142;

TABLE 1: Lactation yields of milk, fat and protein and average live weight and age structure of the base herds. Herd size was adjusted to a 140 ha farm growing 15,000 kg DM/ha with 12,000 kg DM/ha eaten annually.

Parameter		Age class											Total dairy cows
		Calves	1	2	3	4	5	6	7	8	9	10	
Production													
Milk (kg)				3,050	3,499	3,778	3,932	3,887	3,842	3,797	3,639	3,410	
Fat (kg)				149	171	184	192	189	187	185	177	166	
Protein (kg)				116	133	143	149	147	146	144	138	129	
Live weight (kg)		137	315	406	440	452	456	457	457	456	456	455	
Replacement rate													
Low (15%)	Num	63	58	54	50	46	42	39	36	33	31	28	358
	%			15.0	13.9	12.8	11.8	10.9	10.0	9.3	8.5	7.8	100
Medium (19%)	Num	81	75	65	56	48	42	36	31	26	22	19	345
	%			18.8	16.2	14.0	12.1	10.4	8.9	7.6	6.5	5.5	100
High (27%)	Num	123	113	85	64	48	36	27	20	15	11	8	315
	%			27.1	20.4	15.3	11.4	8.6	6.4	4.8	3.5	2.6	100

TABLE 2: Averages of dry matter requirements, stocking rates, production of milk and milk components per cow and per hectare and farm profit for different replacement rates.

Component	Replacement rate		
	15%	19%	27%
Live weight (kg)	446	443	439
Production per cow			
Milk (L/yr)	3,627	3,602	3,541
Fat (kg/yr)	177	176	173
Protein (kg/yr)	138	137	135
DM requirements per cow (kg/yr/hd)	4,158	4,164	4,158
DM requirements per replacement (kg/yr/hd)	560	690	991
Stocking rate (cows/ha)	2.560	2.472	2.331
Production per hectare			
Milk (L/yr)	9,288	8,908	8,254
Fat (kg/yr)	453	434	402
Protein (kg/yr)	353	338	313
Incomes and costs per hectare			
Milk income ($/yr)	4,223	4,051	3,756
Beef income ($/yr)	308	354	434
Gross income ($/yr)	4,531	4,405	4,190
Production costs ($/yr)	2,256	2,223	2,169
Replacement costs ($/yr)	172	212	287
Net income ($/yr)	2,104	1,970	1,734

administration, $83; standing charges, $211; and depreciation, $265. Additional costs involving meal, labour, animal health and breeding, for rising one-year and rising two-year-olds were $210 and $200 per animal, respectively. No feed or grazing, was purchased except calf meal. The values quoted above are updated from values used by Lopez-Villalobos *et al.* (2000).

RESULTS AND DISCUSSION

The age structures generated for each level of replacement rate are detailed in Table 1. As replacement rate increased, the percentages of calves and yearlings also increased to allow for the increased rate of replacement but the number of lactating cows in the herd had to be decreased as more feed was required to meet the increased requirements of larger number of replacements. The number of calves reared for a 15% replacement rate was 63 with 54 cows entering the herd, whereas 123 were reared with 85 entering the herd for a 27% replacement rate, reflecting the higher involuntary culling in the latter herd. This means that the percentage of calves that became first calving cows were 86% and 69% respectively for the 15% and 27% replacement rate herds. A higher replacement rate increased the financial and feed costs of replacements and increased the percentage of younger cows with their relatively lower expected milksolids yields.

The production of milksolids per hectare was 806 kg for 15% replacement rate and 715 kg for 27% replacement rate (Table 2). Farm profit increased as replacement rate decreased; $1,734/ha for 27% replacement rate, $1,970/ha for 19% replacement rate and $2,104/ha for 15% replacement rate (Table 2). Therefore a change in replacement rate affected the herd's milk production and profit, per cow and per hectare.

The benefits of low replacement rate on the herd's production and profit have already been discussed by Vollebregt and Vollebregt (1998) from a famer's point of view. They set a target of 15% replacement rate to maximize the proportion of the four to eight-year-old groups in the herd, which are the cows that produced the highest level of milksolids, and minimized the rearing cost because

TABLE 3: Effect of replacement rate, level of voluntary and involuntary culling and selection of heifers on genetic gain and milksolids and farm profit per hectare.

Strategy	Replacement rate (%)	Involuntary culling (%)	Voluntary culling (%)	Selection on heifer	Herd genetic merit (kg MS/cow)			Milksolids (kg/ha)			Farm profit ($/ha)		
					Year		Gain	Year		Gain	Year		Gain
					0	20		0	20		0	20	
1	15	15	0	No	34.6	78.2	43.6	805	850	45	2,104	2,398	295
2	15	15	0	Yes	34.6	90.5	55.9	805	864	58	2,104	2,488	384
3	19	19	0	No	36.5	80.6	44.1	772	817	45	1,970	2,261	291
4	19	15	4	No	36.5	83.5	47.0	772	820	48	1,970	2,283	312
5	19	15	4	Yes	36.5	91.0	54.5	772	828	56	1,970	2,336	366
6	27	27	0	No	39.6	84.8	45.2	716	760	44	1,734	2,018	284
7	27	17	10	No	39.5	90.0	50.5	716	767	51	1,734	2,061	328
8	27	17	10	Yes	39.6	94.4	54.7	716	770	55	1,734	2,086	352

the number of heifers required for replacement was minimized.

Over a period of 20 years, breeding the herd to high BW sires had a large effect on genetic merit of the herd (Table 3). Rates of genetic gain for individual herds can be affected by level of replacement even when the herds are using the same sires to breed the young stock. For a replacement rate of 15% with no voluntary culling and selection of heifers (Strategy 1) the average milksolids breeding values of the herd increased from 34.6 to 78.2 kg/cow resulting in an annual genetic gain of 2.18 kg/cow, while a replacement rate of 27% with no voluntary culling and selection of heifers (Strategy 6) increased the herd average from 39.6 to 84.8 kg/cow resulting in an annual genetic gain of 2.26 kg. Opportunities for voluntary culling of low PW cows offer an opportunity to increase the genetic merit of the herd. A herd with 19% of replacement rate and 4% of voluntary culling and non-selection of best heifers (Strategy 4) increased the genetic merit of the herd from 36.5 to 83.5 kg milksolids/cow resulting in an annual gain of 2.35 kg/cow, compared with the herd with 19% of replacement rate, nil voluntary culling and non-selection of best heifers (Strategy 3) that increased the genetic merit of the herd from 36.5 to 80.6 kg milksolids/cow for an annual genetic of 2.21 kg milksolids/cow.

Selection of replacements based on BW can improve the genetic merit of the herd. At the three levels of replacement rates, opportunities for best heifers (Strategies 2, 5 and 8) resulted in higher annual genetic gains. A herd with 15% replacement rate in combination with selection of best BW replacement achieved the highest annual genetic gain in breeding values for milksolids (2.80 kg/cow).

Gains in phenotypic average production of milksolids per hectare for all strategies simulated are shown in Table 3. Even though the herd with 27% replacement rate with no heifer selection achieved higher gains in milksolids breeding values than the herd with 15% replacement rate with no heifer selection, the actual production of milksolids per hectare at year 20 was higher for the 15% replacement herd. This effect is due to the low replacement rate herd having a higher proportion of mature cows between four and eight years of age, with higher yields per cow than the high replacement rate herd. As indicated by Vollebregt and Vollebregt (1998) a herd with low replacement rate enables a larger proportion of feed to be used for milk production and less for supporting the growth of young cows.

The effects of breeding the herd to sires of high BW under different levels of replacement rate, voluntary culling rate of cows and selection of heifers on production of milksolids and farm profit per hectare is shown in Table 3. After 20 years, a herd with 15% replacement rate and no voluntary culling achieved a higher production of milksolids and farm profit per hectare than a herd with 27% replacement rate and no voluntary culling. Vollebregt and Vollebregt (1998) identified that a low replacement rate of 15% in combination with a larger proportion of the herd in calf to artificial insemination bulls each year resulted in more calves from which to select replacements. The present study confirmed this result that the production of milksolids and farm profit (Table 3) can be increased by increased selection intensity on heifers available for replacement. A herd with 15% replacement rate in combination with selection of replacement heifers based on BW achieved the highest production of milksolids (864 kg) and farm profit per hectare ($2,488) at year 20.

These results demonstrate that with a fixed amount of total feed as assumed here, profitability increased as replacement rate decreased because the number of cows able to be milked is increased and replacement costs are reduced. Similar results were found in the study of Gartner and Herbert (1981), profitability falls as replacement rate increases because the number of cows able to be milked and the maturity of the herd override the gains in milk yield per cow due to genetic improvement by yield culling and the greater use of a sire of high genetic merit.

Many of the benefits of low replacement rate apply also in situations where the supply of feed is not limited as although replacements are commonly grazed off-farm in New Zealand, this depends on the cost of the feed required and the value of milksolids. Replacement rates of 15% and lower are not physically possible in herds which must cull large numbers of cows especially for infertility and also for ill health, as is relatively common in New Zealand.

A sensitivity analysis will be required to evaluate the changes in milk and beef price and costs on farm profit under the different replacement rates and culling policies considered in this study. Van Arendonk (1985) from a simulation study concluded that a reduction in the difference between the carcass value of culled cows and the replacement costs resulted in a higher rate of voluntary replacement but changes in the price of milk, calves or feed, the production level of the herd or the rate of genetic improvement did not greatly affect the optimum replacement policy.

A conclusion from our study was that a low replacement rate of the order of 15%, in combination with culling of low PW cows and selection of high BW heifers, can be alternatives to achieve both genetic gain in milksolids and farm profit. However, such a low replacement rate is feasible only in herds that achieve high pregnancy rate, with excellent health in cows; once-a-day milking systems can achieve these conditions.

REFERENCES

AFRC. 1993. Energy and Protein Requirements of Ruminants. An Advisory Manual Prepared by the AFRC Technical Committee on Response to Nutrients. CAB Inc., Wallingford, Oxfordshire, U.K.

Anderson, D.C. 1985: Wastage and disease in Bay of Plenty dairy herds. *New Zealand Veterinary Journal* **33:** 61-65.

Azzam, S.M.; Azzam, A.M.; Nielsen, M.K.; Kinder, J.E. 1990: Markov chains as a shortcut method to estimate age distributions in herds of beef cattle under different culling strategies. *Journal of Animal Science* **68:** 5-14.

Ducrocq, V.; Quaas. R. L. 1988: Prediction of genetic response to truncation selection across generations. *Journal of Dairy Science* **71:** 2543-2553.

Gartner, J.A.; Herbert, W. A. 1981: A preliminary model to investigate culling and replacement policy in dairy herds. *Agricultural Systems* **4:** 189-215.

Harris, B.L. 1988: Optimal cow replacement on New Zealand seasonal supply dairy farms. *Proceedings of the New Zealand Society of Animal Production* **48:** 243-246.

Jackson, R.G. 1984: What is an optimum replacement rate? *Massey Dairy Farming Annual* **35:** 97-103.

Holmes, C. W.; Brookes, I. M.; Garrick, D. J.; MacKenzie, D. D. S.; Parkinson, T. J.; Wilson, G. F. 2002: Milk Production from Pasture: Principles and Practices. Swain, D. ed. Massey University, Palmerston North, New Zealand.

Livestock Improvement Corporation. 2009. Dairy Statistics 2008-2009. Livestock Improvement Corporation Ltd., Hamilton, New Zealand. 48 pp. www.lic.co.nz/pdf/dairy_stats/DAIRY_STATISTICS_08-09.pdf

Lehenbauer, T.; Oltjen, J.W. 1998: Dairy cow culling strategies: making economical culling decisions. *Journal of Dairy Science* **81:** 264–271.

Lopez-Villalobos, N.; Garrick, D.J.; Holmes, C.W.; Blair, H.T.; Spelman, R.J. 2000: Profitabilities of some mating systems for dairy herds in New Zealand. *Journal of Dairy Science* **83:** 144-153.

McArthur, A.T.G. 1973: Application of dynamic programming to the culling decision in dairy cattle. *Proceedings of the New Zealand Society of Animal Production* **33:** 141-147.

Searle, S.R. 1961: Estimating herd improvement from selection programs. *Journal of Dairy Science* **44:** 1103-1112.

Simmonds, J. 1998: What is a profitable sustainable replacement rate? *Proceedings of the Ruakura Farmers' Conference* **50:** 66-69.

Van Arendonk, J.A.M. 1984: Studies on replacement policies in dairy cattle. 1. Evaluation of techniques to determine the optimum time for replacement and to rank cows on future profitability. *Zeitschrift für Tierzüchtung und Züchtungsbiologie* **101:** 330-340.

Van Arendonk, J.A.M. 1985: Studies on the replacement policies in dairy cattle. II. Optimum policy and influence of changes in production and prices. *Livestock Production Science* **13:** 101-121.

Vollebregt, L., Vollebregt, R. 1998: Low replacement rates for profit. *Proceedings of the Ruakura Farmers' Conference* **50:** 70-72.