New Zealand Society of Animal Production online archive

This paper is from the New Zealand Society for Animal Production online archive. NZSAP holds a regular annual conference in June or July each year for the presentation of technical and applied topics in animal production. NZSAP plays an important role as a forum fostering research in all areas of animal production including production systems, nutrition, meat science, animal welfare, wool science, animal breeding and genetics.

An invitation is extended to all those involved in the field of animal production to apply for membership of the New Zealand Society of Animal Production at our website www.nzsap.org.nz

The New Zealand Society of Animal Production in publishing the conference proceedings is engaged in disseminating information, not rendering professional advice or services. The views expressed herein do not necessarily represent the views of the New Zealand Society of Animal Production and the New Zealand Society of Animal Production expressly disclaims any form of liability with respect to anything done or omitted to be done in reliance upon the contents of these proceedings.

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License.

You are free to:

   Share— copy and redistribute the material in any medium or format

Under the following terms:

   Attribution — You must give appropriate credit, provide a link to the license, and indicate if changes were made. You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.

   NonCommercial! — You may not use the material for commercial purposes.

   NoDerivatives — If you remix, transform, or build upon the material, you may not distribute the modified material.

http://creativecommons.org.nz/licences/licences-explained/
Profitability of rotational crossbreeding programmes in commercial dairy herds

N. LOPEZ-VILLALOBOS AND D.J. GARRICK

Department of Animal Science, Massey University, Palmerston North, New Zealand.

ABSTRACT

Dairy farm profitability can be increased through the use of superior cows in the lactating herd. Genetic superiority is determined by additive genetic effects and heterosis (present in crossbred animals). Profitability is the difference between income (sale of milk, bobby and salvage animals) and costs (related to the number of cows in the herd and the land area farmed). At comparable production, bigger cows consume more feed reducing their profitability per unit feed consumed. Previous studies have identified the high productivity of first-cross cows comprising Holstein-Friesian (F) and Jersey (J) breeds. In a self-replacing herd, first-cross (F1) animals will not be continuously available unless some straightbred animals are maintained. One approach for exploiting heterosis in a self-replacing herd, is to make use of rotational crossbreeding. This paper reports profitabilities of some rotational crossbreeding programs in comparison to farming straightbred dairy animals.

A model was used to estimate on an annual basis, the nutritional, biological and economic performance of whole herds consuming 12,000 kg dry matter per ha. Expected performances for straight- and cross-bred cows comprising F, J and Ayrshire (A) breeds, were obtained using estimates of breed and heterosis effects derived from Livestock Improvement’s animal evaluation system. Costs and prices were assumed to remain constant except for the market value of milkfat which had a (marginal) return of $0.44 per kg produced in excess of base year production.

In the base year, ignoring the sourcing of replacements, F1 FxJ herds had net income per ha of $1006. In self-replacing herds, rotational JxA had the highest income ($1008/ha) followed by straightbred J ($996/ha), rotational FxJ ($983/ha), rotational FxJxA ($958/ha), straightbred A ($915/ha), rotational FxA ($914/ha), and straightbred F ($869/ha). Genetic gain per year in each breed was taken into account using current estimates of trends. After 10 years, straightbred J herds had the highest net income ($1077/ha) followed by rotational JxA herds ($1070/ha). Results suggest that under New Zealand conditions, rotational crossbreeding programs could increase profitability of some commercial herds.

Keywords: rotational crossbreeding; heterosis; dairy cattle; profitability; simulation.

INTRODUCTION

Farm profit is the difference between income and expenditure and is strongly influenced by production per cow and stocking rate. Income arises from sale of milk, bobby calves and salvage animals. Milk pricing is determined by a formula \[ a \text{ fat} + b \text{ protein} - c \text{ milk} \], with values for \( a \), \( b \) and \( c \) equal to 1.98, 4.49 and 0.04, respectively for the season 1994/95 (Livestock Improvement Corporation, unpublished data).

Expenditure is related to the number of cows in the herd and the land area farmed and includes costs associated with provision of labour, fertiliser, health, breeding, repairs and maintenance. Many costs are related to provision of feed. The amount of feed required for maintenance increases with the size of the animal. Thus, larger cows require more maintenance energy than smaller cows. With fixed feed resources this extra feed requirement reduces the numbers of large cows that can be fed per hectare.

Previous studies in New Zealand (Quartermain and Carter, 1969; Ahlborn-Breier, 1989; Ahlborn-Breier and Hohenboken, 1991; Anonymous, 1994; Harris et al. 1994) have identified the high productivity of first-cross (F1) cows comprising Holstein-Friesian (F) and Jersey (J) breeds. These F1 FxJ cows produce more milkfat, similar protein, with less milk volume and they are smaller than straightbred Holstein-Friesians (Ahlborn-Breier, 1989). However, first-cross animals will not be available unless some straightbred animals are maintained.

One approach for exploiting heterosis in a self-replacing herd, is by way of rotational crossbreeding. For instance, in a Jersey herd, cows are artificially inseminated with semen of a straightbred F bull to produce F1 FxJ cows. Half of F1 cows are inseminated with Friesian semen to produce 3/4 F1/4 J cows and the other half are inseminated with J semen to produce 1/4 F3/4 J cows. Next, 3/4 F1/4 J cows are inseminated with J semen and 1/4 F3/4 J cows are inseminated with F semen. After three more generations, half of the herd will be 2/3 F1/3 J and the other half will be 1/3 F2/3 J. This paper reports profitabilities of some rotational crossbreeding programs in comparison to straightbreeding programs.

MATERIAL AND METHODS

A deterministic computer model was used to simulate average performance of Holstein-Friesian, Jersey, Ayrshire (A) and crossbred herds under grazing conditions. Three mating systems were modeled: straightbreeding, two- and three-breed rotational crossbreeding.

The nutritional requirements, biological and economic performances of a herd including replacements were simu-
lated on a yearly basis. The herd was grazed on ryegrass- 
clover pasture the whole year with supplementation as per 
normal farm practice. Stocking rates were adjusted on an 
annual basis according to the feed requirements of cows.

**Herd management**

Herd were self-replacing with industry average age 
structure. Ages and respective proportions were: 0-1 yr, 
0.22; 1-2 yr, 0.20; 2-3 yr, 0.12; 3-4 yr, 0.10; 4-5 yr, 0.09; 
5-6 yr, 0.08; 6-7 yr, 0.06; 7-8 yr, 0.05; 8-9 yr, 0.04; 9-10 
yr, 0.03; and 10-11 yr, 0.01. Mortality rates for rising 1-
year heifers, rising 2-year heifers and cows were 7, 6 and 
2%, respectively.

Cows and heifers were artificially inseminated using 
semen from proven straightbred sires. Calving rates in 
heifers and cows were assumed to be 85% with half the 
calves of each sex. Culling rates were variable such that 
the structure of the herd remained constant throughout the 
years. Causes of cow wastage (Holmes *et al.*, 1987) were 
categorised into: (1) reasons when culled animals are 
slaughtered and create income, and (2) reasons when the 
culled animals cannot be sold for income. Cows remaining 
in the herd after 11 years were culled.

Proportions of culled animals with respect to an 
average breeding cow were: male bobby calves, 0.44; 
surplus of female calves for rearing, 0.11; empty rising 2-
year heifers, 0.05; surplus of rising 2-year heifers, 0.06; 
and cows for slaughter, 0.16.

**Expected performance**

Expected annual performance (EP) for milk, milkfat, 
protein and liveweight of cows was simulated by each age 
class. In year t the expected performance for any trait was 
calculated as:

$$ EP_t = (q'o g_t + q's H_t q_d) f $$

where

- $q_o$, $q_d$ and $q_s$ are vectors of order 3 with elements 
  representing the composition of an individual in terms of 
  F, J and A fractions for sire, dam and offspring, respec-
  tively. The vector $q_o$ is determined from $1/2 (q_s + q_d)$;
- $g_t$ is a vector of order 3 of breed additive effects. 
  For the year t, the vector $g_t$ was obtained as $g_{t-1} + 
  D_g$,
- $H_t$ is a matrix of order 3x3 with diagonal elements 
  being zero and off diagonal elements being the $F_1$ 
  heterosis corresponding to the breeds represented by row 
  and column of the entry. The matrix $H$ can be constructed 
  from percentage heterosis figures as:

$$
\begin{bmatrix}
0 & \frac{h_{FJ}}{2} & \frac{h_{FA}}{2} \\
\frac{h_{FJ}}{2} & 0 & \frac{h_{JA}}{2} \\
\frac{h_{FA}}{2} & \frac{h_{JA}}{2} & 0
\end{bmatrix}
$$

$f$ is a multiplicative age adjustment factor. Age ad-
justment 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, 4-7, and 8-9, respectively.

Estimates of crossbreeding parameters for milk traits 
and liveweight used to predict the performance of cows are 
shown in Table 2. These estimates were obtained from 
analyses using an animal model (Anonymous, 1994).

Performance of an $F_1$ FxJ herd ignoring source of 
replacements was estimated for comparison. Herds using 
rotational crossing were assumed at equilibrium with re-
spect to breed composition.

**TABLE 1:** Genetic trends for milk traits and liveweight in New Zealand dairy breeds (Livestock Improvement Corporation, unpublished data).

<table>
<thead>
<tr>
<th>Breed</th>
<th>Milk (l/year)</th>
<th>Milkfat (kg/year)</th>
<th>Protein (kg/year)</th>
<th>Liveweight (kg/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holstein-Friesian</td>
<td>29.0</td>
<td>1.07</td>
<td>0.82</td>
<td>0.1</td>
</tr>
<tr>
<td>Jersey</td>
<td>26.4</td>
<td>1.93</td>
<td>0.94</td>
<td>0.1</td>
</tr>
<tr>
<td>Ayrshire</td>
<td>28.4</td>
<td>1.15</td>
<td>0.84</td>
<td>0.1</td>
</tr>
</tbody>
</table>

**TABLE 2:** Estimates of additive breed ($g$) and heterosis ($h$) effects for milk traits and liveweight of straightbred and crossbred Holstein-Friesian (F), Jersey (J) and Ayrshire (A) cows in New Zealand (Anonymous, 1994).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Milk yield (l)</th>
<th>Milkfat yield (kg)</th>
<th>Protein yield (kg)</th>
<th>Liveweight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$g^F$</td>
<td>3,503</td>
<td>154</td>
<td>121</td>
<td>450</td>
</tr>
<tr>
<td>$g^J$</td>
<td>2,640</td>
<td>149</td>
<td>109</td>
<td>350</td>
</tr>
<tr>
<td>$g^A$</td>
<td>3,368</td>
<td>146</td>
<td>121</td>
<td>390</td>
</tr>
</tbody>
</table>

**Heterosis effects**

| $h_{FJ}$ | 181 (5.9%) $^1$ | 10.4 (6.9%) | 7.3 (6.4%) |
| $h_{FA}$ | 106 (3.6%) | 4.2 (2.8%) | 3.6 (3.0%) |
| $h_{JA}$ | 172 (6.9%) | 9.4 (6.4%) | 7.0 (6.1%) |

$^1$ Values in brackets are percentages of heterosis

**TABLE 3:** Assumed liveweights (kg) at different ages for different breeds.

<table>
<thead>
<tr>
<th>Age (months)</th>
<th>Holstein-Friesian</th>
<th>Jersey</th>
<th>Ayrshire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth</td>
<td>35</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>6</td>
<td>120</td>
<td>90</td>
<td>110</td>
</tr>
<tr>
<td>18</td>
<td>310</td>
<td>240</td>
<td>290</td>
</tr>
<tr>
<td>30</td>
<td>450</td>
<td>350</td>
<td>390</td>
</tr>
<tr>
<td>Mature</td>
<td>465</td>
<td>365</td>
<td>405</td>
</tr>
</tbody>
</table>

Average values of liveweight for the three breeds are 
shown in Table 3. Liveweight gains were obtained as the 
difference between liveweight at different ages.

**Energy and dry matter requirements**

Dry matter intake (DMI) of dairy cows was calculated 
by dividing total requirement of metabolisable energy 
(ME) by an assumed energy density per kg pasture 
DM of 10.5 megajoules (MJ) ME. Total ME requirement
was determined by summing the component values:

\[ ME (MJ) = ME_m + ME_g + ME_l + ME_p \]

where

- **ME\_m** is the ME for maintenance estimated as 0.60 x LW\(^{0.75}\) x 365 (Holmes et al., 1987);
- **ME\_g** is the ME for liveweight gain estimated as 26.7 x kg LW gain for growing heifers and 38.5 x kg LW gain for growing cows (Holmes et al., 1987);
- **ME\_l** is the ME for lactation estimated as (1.2 x \(l_{milk}\)) + (55.4 x kg fat) + (38.5 x kg protein) (Holmes, 1995); and
- **ME\_p** is the ME for pregnancy estimated as 0.168 x LW\(^{0.75}\) x 73 (Moe and Tyrrell, 1972), and where LW is liveweight.

### Stocking Rate

Stocking rate (SR), defined as the number of mature cows grazing per ha, was calculated as the ratio of utilisable pasture per hectare to the total dry matter requirement (including replacements) per cow per year:

\[ SR = \frac{\text{Utilisable pasture per ha (kgDM)}}{\text{Pasture requirement per cow (kgDM)}} \]

It was assumed that 12,000 kg DM/ha were utilised for dairy production.

### Economic Analysis

The economic analysis was based on income obtained using average values of products marketed, less costs of an average New Zealand dairy farm. Profitability was expressed on a per hectare basis.

**Income.** Income from milk was determined as a fat + b protein - c milk. If the production volume of milkfat was increased in any year, that extra or marginal production was sold for low returns (Fenwick and Marshall, 1991). Marginal value per kg milkfat was $0.44 (LIC, unpublished data). The value of milkfat for the year \(t\) (\(v_f\)) was calculated as:

\[ v_f\_t = \frac{[z_t - z_0 \times 0.44] + [z_0 \times v_f\_0]}{z_t} \]

where, \(z_0\) is initial volume of milkfat produced, \(z_t\) is volume of milkfat in year \(t\) and \(v_f\_t\) is initial value of kg milkfat. In contrast, the marginal value of protein was assumed identical to the average value for protein.

Assumed values of stock sold are shown in Table 4.

The value of crossbred stock was equal to the value of the nearest straightbred. For example, the value of a \(3/4\) F \(1/4\) J bobby calf was taken as $60. The carcass yield was assumed on 55% for all animals. Income from other sources was taken as $96 per hectare.

**Production costs.** Average production costs were based on survey information (Bird, 1995) and included direct expenses and overheads. Direct expenses ($/cow) were: labour, 92; animal health, 42; breeding and herd testing, 23; farm dairy expenses, 16; and electricity, 19. Other direct expenses ($/ha) were: fertiliser, 287; weed and pest control, 21; freight, 14; and other costs, 27.

Overheads ($/ha) were: repairs and maintenance, 163; vehicle expenses, 111; administration, 111; and standing charges 122.

### RESULTS

#### Performance

Performances per cow and per hectare of different breeding programs are shown in Table 5. Rotational FxA and straightbred F herds ranked highest for milk yield per cow followed by rotational FxJxA and straightbred Ayshires. Herds using mating systems including Jersey genes had smaller cows producing higher milkfat yields.
and lower volumes of milk. Cows in the F, FxJ herd produced the highest milkfat yield and their liveweight was the average of straightbred Holstein-Friesian and Jersey. These rankings were almost the same after 10 years of simulation but more rapid increases in milkfat yield per cow were achieved in herds including the Jersey breed in the breeding system than in those herds including Holstein-Friesian and Ayrshire breeds.

Straightbred Jerseys ranked lowest for dry matter intake per cow and highest for stocking rate. Straightbred Holstein-Friesians ranked highest for dry matter intake and lowest for stocking rate.

Ayrshire herds ranked highest for milk production per hectare followed by rotational FxA, rotational FxJxA and straightbred Holstein-Friesian herds. Straightbred Jersey herds had the highest milkfat production per hectare followed by rotational FxJ herd. Rotational JxA herds ranked highest for protein production per hectare followed by straightbred Ayrshire and rotational FxJxA herds. These herds ranked similarly after 10 years of simulation.

**Economic Analysis**

Production costs and incomes per cow and per hectare of different breeding programs are shown in Table 6. Milk income per cow for crossbred herds was higher than that for straightbred herds. F₁ FxJ herds ranked highest ($740) followed by rotational FxJxA ($725) and rotational FxJ ($724). Value of milkfat was assumed to decrease because excess of production was paid in a marginal value of $0.44. The values per kg milkfat for the base year through year 10 decreased slightly and were 1.98, 1.97, 1.96, 1.95, 1.94, 1.93, 1.92, 1.91 and 1.90 respectively as a result of assuming a fixed area for milk production.

Production costs per cow were highest for straightbred Holstein-Friesian ($534) followed by rotational FxA ($524) and rotational FxJxA ($519).

In the base year, ignoring the source of replacements, F₁ FxJ herds had a net income of $1006/ha. In self-replacing herds, rotational JxA had the highest income ($1008) followed by straightbred Jersey ($996), rotational FxJ ($983), rotational FxJxA ($958), straightbred A ($915), rotational FxA ($914), and straightbred F ($869). After 10 years, straightbred Jersey herd had the highest net income ($1077) followed by rotational JxA herds ($1070).

Further economic analysis was not undertaken for first-cross F₁ FxJ herds as these are not self-replacing.

**TABLE 6:** Gross and net income and production costs per cow and per hectare for different breeding programs involving Holstein-Friesian (F), Jersey (J) and Ayrshire (A) breeds.

<table>
<thead>
<tr>
<th>Breeding system</th>
<th>Milk income $/cow/ha</th>
<th>Gross income $/cow/ha</th>
<th>Production Costs $/cow/ha</th>
<th>Net income $/cow/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straightbreeding</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>708</td>
<td>1724</td>
<td>891</td>
<td>1219</td>
</tr>
<tr>
<td>J</td>
<td>672</td>
<td>1949</td>
<td>830</td>
<td>2383</td>
</tr>
<tr>
<td>A</td>
<td>698</td>
<td>1833</td>
<td>858</td>
<td>2254</td>
</tr>
<tr>
<td>FxJ</td>
<td>740</td>
<td>1900</td>
<td>908</td>
<td>2333</td>
</tr>
<tr>
<td>FxA</td>
<td>724</td>
<td>1879</td>
<td>892</td>
<td>2315</td>
</tr>
<tr>
<td>JxA</td>
<td>717</td>
<td>1798</td>
<td>889</td>
<td>2230</td>
</tr>
<tr>
<td>FxJxA</td>
<td>725</td>
<td>1848</td>
<td>895</td>
<td>2281</td>
</tr>
<tr>
<td>Two-breed rotation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FxJ</td>
<td>738</td>
<td>1756</td>
<td>923</td>
<td>2195</td>
</tr>
<tr>
<td>J</td>
<td>731</td>
<td>2022</td>
<td>883</td>
<td>2444</td>
</tr>
<tr>
<td>A</td>
<td>731</td>
<td>1871</td>
<td>892</td>
<td>2284</td>
</tr>
<tr>
<td>FxJ</td>
<td>767</td>
<td>1931</td>
<td>936</td>
<td>2357</td>
</tr>
<tr>
<td>FxA</td>
<td>749</td>
<td>1833</td>
<td>922</td>
<td>2257</td>
</tr>
<tr>
<td>JxA</td>
<td>761</td>
<td>1994</td>
<td>919</td>
<td>2407</td>
</tr>
<tr>
<td>FxJxA</td>
<td>762</td>
<td>1890</td>
<td>933</td>
<td>2315</td>
</tr>
<tr>
<td>Three-breed rotation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FxJ</td>
<td>778</td>
<td>1872</td>
<td>943</td>
<td>2357</td>
</tr>
<tr>
<td>FxA</td>
<td>759</td>
<td>1789</td>
<td>912</td>
<td>2257</td>
</tr>
<tr>
<td>JxA</td>
<td>771</td>
<td>1954</td>
<td>921</td>
<td>2407</td>
</tr>
<tr>
<td>FxJxA</td>
<td>772</td>
<td>1890</td>
<td>933</td>
<td>2315</td>
</tr>
</tbody>
</table>

DISCUSSION

Caution must be taken when interpreting how crossbred cows perform when they are mixed in varying proportions with straightbred cows in the same herd (Glassey and McPherson, 1993).

Liveweight is of importance in the production system because it affects stocking rate and profitability of the dairy farm through its relation to feed requirements for maintenance. Requirements of dry matter for maintenance represented 48 - 53% of total annual requirements (data not shown). Liveweights of Jerseys were lower than that for Holstein-Friesians while that for crossbreed cows was of intermediate value (Table 5).

Production costs per cow of herds carrying bigger (Holstein-Friesian) animals were higher than those for carrying smaller (Jersey) animals. However, herds with higher stocking rates (Jersey) had higher production costs per hectare than those with lower stocking rate (Holstein-Friesian) because some production costs were proportional to stocking rate.

For the base year, crossbred herds had higher income per cow from milk sales than straightbred herds. F₁ FxJ cows showed an increase in the milk income per cow by $32 compared to Holstein-Friesian, $42 compared to Jersey and $61 compared to Ayrshire (Table 6). This was because F₁ FxJ cows produced higher milkfat and protein yields than the corresponding straightbreds and the volume produced was lower than that of Holstein-Friesians.

The real interest for the New Zealand dairy farmer, however, is overall output per unit of land. Given a fixed amount of feed per hectare, more milk was produced by Ayrshire and rotational FxA herds, more milkfat by Jersey and F₁ FxJ herds and more protein by rotational JxA herds (Table 5). In terms of economic efficiency per unit of land, the highest milk income corresponded to the Jersey herd followed by rotational JxA, F₁ FxJ and rotational FxA herds (Table 6). Milk incomes ($) per tonne DM.
for these four breeding systems were 162, 162, 158 and 157, respectively.

Annual genetic gain for milkfat production for the Jersey breed has been reported higher than that for Holstein-Friesian and Ayrshire breeds (Ahlborn-Breier et al. 1987). This higher genetic gain per year and a small reduction in the value of milkfat lead Jersey herds to be ranked highest for net income per hectare after 10 years of simulation.

There is considerable discussion of the reproductive performance and survival rate of crossbred cattle. Ahlborn-Breier (1989) reported that F₁ FxJ cows had higher calving rate than straightbred J or F cows. Survival from birth to first calving for crossbred cattle has been reported higher than for straightbreds (McAllister, 1986; Touchberry, 1992). In this study, however, no differences in reproductive performance and survival rate were considered. Inclusion of heterosis for fertility and survival would result in more animals for sale and more opportunity to cull based on performance, and as a consequence, profitability of crossbred herds compared to straightbred herds would be still higher.

Results in this simulation indicate that crossbred cows are more productive and could be more profitable than straightbred cows. Dairy herds with F₁ FxJ cows should be considered as a major option for breed resource utilisation. However, the real challenge is to establish breeding programs that retain merits of the first crosses. Rotational crossbreeding is a practical option for New Zealand commercial dairy farmers. This requires controlled mating which is possible given the present status of artificial insemination and recording in the dairy industry.

CONCLUSIONS

From this study based on New Zealand conditions, rotational crossbreeding programs can be shown to increase profitability in commercial herds.

ACKNOWLEDGMENTS

The senior author wishes to acknowledge financial support of Consejo Nacional de Ciencia y Tecnologia (CONACYT), México and Universidad Autonoma Chapingo, México.

REFERENCES