

Impact of rearing practices on modelled economic outcomes for pasture-based dairy heifer and dairy-beef production systems

David R. STEVENS^{1*} and Susan A. MCCOARD²

¹Bioeconomy Science Institute, Mosgiel, New Zealand

²Bioeconomy Science Institute, Palmerston North, New Zealand

*Corresponding author: david.stevens@agresearch.co.nz

Highlights

The application of economic modelling to the effects of high milk inputs and failure of passive transfer of immunity (FPT) in both dairy heifer and dairy-beef calf rearing systems demonstrated the greater effect of milk input on production parameters than FPT. However, high FPT had greater effects on mortality and morbidity, resulting in increased input costs and financial impacts. Increasing milk volumes reduced the overall cost of rearing dairy heifers by increasing first year milk production. Reducing the incidence of FPT had a similar positive effect on both dairy heifer and dairy-beef calf rearing enterprises, reducing total costs by approximately 19%.

Keywords: Calves, colostrum, growth, health, milk, management, modelling

Background

Calf rearing is an integral underpinning part of both the dairy and beef industries. Most of the calves reared from the New Zealand dairy herd are separated from their mothers shortly after birth and artificially reared to maximise harvested milk yields from the cow. On average, 28% of dairy calves are retained as replacements (1–1.2 million), 12% are reared on dairy farms, 15% are sold for beef rearing (1.05 million), and 35% are sold as ‘bobby’ calves (Edwards et al. 2021; Corkran and Higgins 2025). The New Zealand dairy sector is at a strategic crossroads with an opportunity to build a scalable, profitable dairy-beef system to utilise more of the non-replacement dairy calves that is estimated to be worth over NZD 1.2 billion (Corkran and Higgins, 2025). While genetics is a major driver for lifting dairy-beef productivity, calf rearing is the system’s pressure point. Not only do the first weeks of life carry the greatest mortality and morbidity risks, but there is also a disproportionate financial risk. Calf rearers carry the greatest risk as calf rearing is capital intensive and time sensitive, and thus rearing systems need to be both profitable and meet consumer expectations for animal welfare to lift rearing rates and support long-term beef supply.

Good calf rearing practices are intrinsic to both dairy heifer and dairy-beef enterprises. Highly productive

heifers entering the dairy herd are fundamental to long-term profitability and sustainability of the dairy sector. A move towards rearing more dairy-beef calves in New Zealand requires superior calf rearing management to avoid disease and health issues if large volumes of calves are reared in a short span of time. Therefore, a greater awareness of the impact of calf rearing practices on whole-of-life calf performance and economics of calf rearing is required to help mitigate the risks involved.

Each rearing system works slightly differently. Calves born on dairy farms enter the rearing facility at 1 day of age (Cuttance et al. 2017a), after being with the cow for up to 24 hours with colostrum management to support passive transfer of immunity to the calf, and transition onto whole milk or milk replacer occurring within the first week of life. Many calves reared for dairy-beef systems enter specialised rearing facilities associated with dairy farms. Calves are sold to these calf rearers at between 4 and 7 days of age. Thus, the starting point of replacement or dairy-beef rearing systems are often slightly different, being 1- or 7 days-of-age respectively. This makes a difference as any calf losses before 7 days of age are not associated with the dairy-beef rearers’ losses or profits.

It is well established that good colostrum management to avoid failure of passive transfer of immunity (FPT) and feeding more good quality whole milk or milk replacer per day are key nutritional levers to promote calf survival, growth, health, welfare and lifetime performance (e.g. Khan et al. 2011; Burggraaf et al. 2020; van Keulen et al. 2021; Ockenden et al. 2023). However, despite these evidence-based recommendations and recognition of the importance of calf health and growth by calf rearers (Sneddon et al. 2025), the incidence of FPT remains high, averaging 33% (Cuttance et al. 2017a), and restricted milk feeding systems remain commonplace in both dairy heifer and dairy-beef calf rearing systems. Reductions in liveweight gain increase the time to reach target liveweights in both dairy heifer replacement and dairy-beef rearing systems, thus increasing costs and influencing final productive outcomes.

Failure of passive transfer has been recorded in between 5 and 83% in dairy heifers (Cuttance et al. 2017a). Reasons can vary from the assumption that

calves have received colostrum from the cow prior to collection, feeding poor-quality colostrum (van Keulen et al. 2021) or feeding colostrum too late, and missing the critical early time window prior to gut closure (Hammon et al. 2020). The impact of FPT on both mortality and morbidity in the calves, and on pre- and post-weaning growth potential is highlighted in the literature, including several meta-analyses (Raboisson et al. 2016; Thomson et al. 2018; van Keulen et al. 2021; Abdelfattah et al. 2025).

A higher milk allowance supports higher pre-weaning growth rates in both heifers and bull calves (Khan et al. 2011; Ockenden et al. 2023; McCoard et al. 2024). For example, feeding dairy heifers 8 L of whole milk per day for 10 weeks resulted in weaning liveweights which were 19 kg greater than when fed 4 L of whole milk per day (Ockenden et al. 2023). A higher milk allowance has also been reported to improve immune function (Hammon et al. 2018, Ockenden et al. 2023). However, the milk volumes fed to calves in both dairy heifer and dairy-beef systems differ considerably between farms. This variation, when calculated as dry matter intake, has been reported as calves for dairy heifer replacements being fed 45.8 kg DM (high) over 68 days (Thomson et al. 2018) or 22 kg DM (low) over 90 days (Cuttance et al. 2017b). Compared to dairy heifers, calves reared for dairy-beef on average were fed a low milk volume of either 27.5 kg DM over 56 days or 19.7 kg DM over 43 days (Thomson et al. 2018).

Increased understanding of the economic benefits of adopting current best practice colostrum and milk feeding management recommendations to produce quality dairy heifer replacements and dairy-beef calves for beef production value chains may support practice-change within the industry. Our objective was to model the economic benefits or trade-offs of adopting best practice colostrum and milk feeding management to entry to the milking herd for dairy heifer replacements or point of sale from the calf rearer for dairy-beef calves. We incorporated current knowledge of the influences of milk volume and FPT on changes in liveweight gain, mortality and morbidity to estimate farm-scale outcomes.

Approach

Overall design

The effects of target enterprise, milk volume fed and FPT in calf rearing systems were investigated in a 2x2x2 factorial design (Figure 1). Target enterprise included rearing for dairy heifer replacements or dairy-beef production. Milk volume was fed as a high or low quantity of milk/milk replacer. Failure of passive transfer of immunity was high (near industry average) or low (best practice).

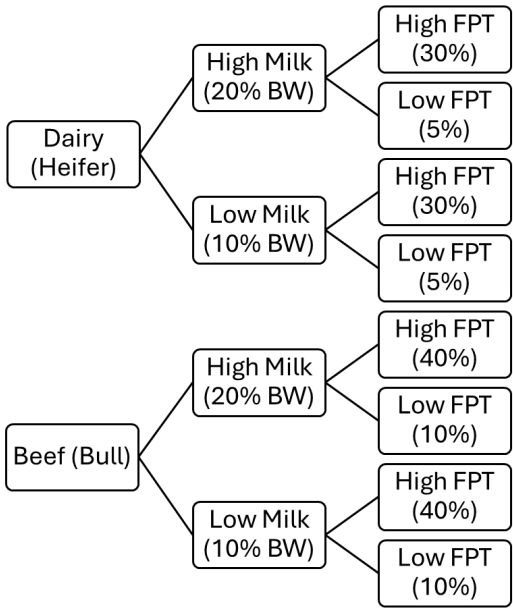


Figure 1 Scenario design for economic evaluation of the impacts of calf rearing practices on dairy heifer replacement and dairy-beef enterprises.

Data used to model the economic outcomes were based on current literature and assumptions as described below.

Target enterprise:

Calves reared for dairy heifer replacements were assumed to enter the rearing facility at 1 day of age (Cuttance et al. 2017a), while calves for beef were bulls which entered the rearing facility at point of sale at an average of 7 days of age.

Failure of passive transfer:

In dairy heifer replacements, high FPT of 30% was based on current industry statistics, while a low rate associated with best practice was assumed to be 5% to mimic the lowest reported FPT rate (Cuttance et al. 2017a). The rates of FPT in calves reared for dairy-beef were assumed to be 40% (high) and 10% (low) as no literature was available to determine this for New Zealand conditions. The assumed difference reflects potential differences in colostrum provision to calves destined for different target enterprises. The impacts of FPT on both mortality and morbidity in the calves, and on pre- and post-weaning growth potential were sourced from the literature, including several meta-analyses (Raboisson et al. 2016; Abdelfattah et al. 2025; van Keulen et al. 2021). Odds ratios are used to express potential changes in mortality and morbidity, relating final outcomes to estimates of the occurrence of death and disease when transfer of passive immunity is achieved. The Odds Ratios (OR) of mortality and

morbidity reported were converted into probabilities of incidence within the model based on estimates of baseline death rate and scours if passive immunity transfer was successful. The baseline death rate was estimated at 3% (Cuttance et al. 2017b; Raboisson et al. 2016), excluding deaths before entry to the rearing facility (approximately 1.1-1.8%). Morbidity, represented as scours, with passive transfer of immunity, was estimated to be 11% (Thomson et al. 2018).

Conversion of Odds Ratios to probabilities:

Odds ratios depend on the underlying prevalence of a condition in the unaffected population, thus the actual probability of the occurrence of a condition is calculated from the odds ratio and the original prevalence as follows:

$$\text{Probability of increased mortality (Prob}_{\text{INCRMORT}}) = 100 * (((\text{Prev}_{\text{MORTNoFPT}}) / (1 - (\text{Prev}_{\text{MORTNoFPT}}))) * \text{Prev}_{\text{MORTFPT}}) / (1 + ((\text{Prev}_{\text{MORTNoFPT}}) / (1 - (\text{Prev}_{\text{MORTNoFPT}}))) * \text{Prev}_{\text{MORTFPT}}))$$

Where $\text{Prev}_{\text{MORTNoFPT}}$ = prevalence in a population with no FPT = 3.0% (Cuttance et al. 2017; Raboisson et al. 2016)

And $\text{Prev}_{\text{MORTFPT}}$ = prevalence in a population with FPT

And $\text{Prev}_{\text{MORTFPT}} = 4.21$ (Abdelfattah et al. 2025; Raboisson et al. 2016)

$$\text{Probability of increased scouring (Prob}_{\text{INCRScour}}) = 100 * (((\text{Prev}_{\text{ScourNoFPT}}) / (1 - (\text{Prev}_{\text{ScourNoFPT}}))) * \text{Prev}_{\text{ScourFPT}}) / (1 + ((\text{Prev}_{\text{ScourNoFPT}}) / (1 - (\text{Prev}_{\text{ScourNoFPT}}))) * \text{Prev}_{\text{ScourFPT}}))$$

Where $\text{Prev}_{\text{ScourNoFPT}}$ = prevalence in a population with no FPT = 11% (Thomson et al. 2018)

And $\text{Prev}_{\text{ScourFPT}}$ = prevalence in a population with FPT

And $\text{Prev}_{\text{ScourFPT}} = 2.11$ (Abdelfattah et al. 2025; Raboisson et al. 2016)

These probabilities were then applied depending on the level of FPT assigned to each scenario as:

$$\text{Mortality}_{\text{TOTAL}} \% = (1 - \text{Prev}_{\text{MORTNoFPT}}) + ((1 - \text{Prev}_{\text{MORTNoFPT}}) * \text{Prob}_{\text{INCRMORT}})$$

$$\text{Morbidity}_{\text{TOTAL}} \% = (1 - \text{Prev}_{\text{ScourNoFPT}}) + ((1 - \text{Prev}_{\text{ScourNoFPT}}) * \text{Prob}_{\text{INCRScour}})$$

Odds ratios from a meta-analysis of Raboisson et al. (2016) and Abdelfattah et al. (2025) indicated that mortality in the FPT population of calves would increase to 11.5%, while scours would increase to 20.7% when translated into probabilities. These changes increase the capital and direct costs in calf rearing systems. Final outcomes of predicted mortality and morbidity are reported in Table 2.

Impacts on average daily gain (ADG) are also noted when FPT occurs. Both meta-analysis data (Raboisson

et al. 2016) and New Zealand data (van Keulen et al. 2021) were used and applied to animals which had suffered scours, as a representation of FPT in the herd. Before weaning, a reduction in liveweight gain of 69 g/d was applied to calves which had FPT which was the average change reported in the literature (Raboisson et al. 2016, Sutter et al. 2022; van Keulen et al. 2021). After weaning a reduction in ADG of 54 g/d was applied to those animals with FPT (Raboisson et al. 2016). Impact on average growth was calculated as:

$$\text{ADG}_{\text{PreWean}} = (\text{ADG}_{\text{POTPreWean}} * (1 - \text{Morbidity}_{\text{TOTAL}})) + ((\text{ADG}_{\text{POTPreWean}} - 69) * \text{Morbidity}_{\text{TOTAL}})$$

$$\text{ADG}_{\text{PostWean}} = \text{ADG}_{\text{POTPostWean}} - (54 * \text{Morbidity}_{\text{TOTAL}})$$

Where ADG is expressed in g/d

Milk/milk replacer volume:

Milk or milk replacer quantity offered was either 4 or 8 L/head per day, at 15% milk solids. It was assumed for the purpose of modelling economic and production outcomes that growth and health of calves reared on milk or milk replacer (henceforth termed “milk”) did not differ. Concentrate intake was reduced by 200 g/d when offering high milk volumes as per the meta-analysis by Xiao et al. (2025).

Applying the design

A spreadsheet model was used to determine the impacts of the three factors on a range of production and profitability metrics related to the final target enterprises of dairy heifer replacements or dairy-beef rearing. Target enterprise created differences in the starting liveweight due to sex and age at the start of the calculation period (Table 1), and ADG both before and after weaning, as heifers have a lower potential ADG than bulls. Feeding either high or low quantities of milk also resulted in differences in potential ADG. These potentials for dairy heifers were sourced from Ockenden et al. (2023). Bull liveweight gain was assumed to be 6.5% greater than heifers (McCoard et al. 2024).

Actual milk and concentrate intake

Average daily gain adjustments (Table 2) were then used to calculate the impacts on weaning date to meet the liveweight target, milk and concentrate used and entry to the milking herd (heifers) or sale as a 100 kg calf (beef). It was assumed that target liveweights at weaning were adhered to, thus requiring a change in the rearing period as time to weaning would change. This change would then impact on the amount of milk and concentrate that was required and calculated as below:

$$\text{Milk intake}_{\text{TOTAL}} = \text{Milk Allowance/d} * \text{Actual days to weaning}$$

Table 1 Base input parameters when calculating the impacts of high or low milk intake, and high or low failure of passive transfer of immunity (FPT) when rearing dairy heifers or dairy-beef bull calves.

		Target enterprise	
		Dairy	Beef
Gender		Heifer	Bull
Liveweight (kg)		35	45
Entry date		3-Aug	10-Aug
Entry age (d)		1	7
Base risks	Death		1.7
	Morbidity		2.0
Milk fed (kg DM/d)	High	1.2	1.2
	Low	0.6	0.6
FPT	High	30%	40%
	Low	5%	10%
Potential ADG (g/d)	to weaning (high milk)	830	880
	to weaning (low milk)	560	595
	post weaning	620	760
Target weaning liveweight (kg)	to weaning (high milk)	80	80
	to weaning (low milk)	80	80
Target days to weaning ¹	High milk	90	43
	Low milk	90	43
Feed costs (\$ per kg)	Milk	\$8.00	\$8.00
	Concentrate (first period)	\$1.28	\$1.28
Treatment costs per dose ²	Scours ^a		\$7.25
	Pneumonia ^b		\$1.30
	Anti-inflammatory ^c		\$0.75
	Labour (\$/hour)		\$31.10
	Time/treatment		12 minutes
Calf Value (\$) ³		\$788.9	\$282.5

¹ Target days to weaning are kept constant with an assumption that concentrate feeding will substitute for the change in milk fed
² Treatment costs are for ^aRevive Electrolyte, ^bPharmacillin 300 and ^cMetacam 20 anti-inflammatory treatments sourced from an internet search, 15 March 2026.
³ Values are National Standard Tax valuations for purchased bobby calves and rising 1-year heifers (IRD 2026).

Where Actual days to weaning (ADW) = (Target LW – entry weight)/ ADG_{PreWean}
Concentrate_{TOTAL} = Concentrate allowance/ * Actual days to weaning).

Post-weaning impacts

Post-weaning changes to ADG were applied in two ways to test the flow-on effects of FPT to an economic endpoint. For dairy heifer calves, the chosen endpoint was entry into the herd at first lactation. The economic indicator was the influence of timing of breeding on the length of first lactation and hence potential milk production. Xiao et al. (2025) found, in a meta-analysis, that lactation length was reduced by 0.5 months when low milk intakes were used, along with reductions

in milk fat and protein by 14.5 and 3.7 kg/lactation, respectively. It was assumed that the target liveweight of 300 kg for successful breeding, assumed to be 60% of mature liveweight, would be attained at 15 months of age (Handcock et al. 2018). Any changes in time to weaning and post-weaning ADG were then used to calculate the age of the heifer when it was first bred at 300 kg LW. This variance from 15 months was used to adjust the potential milk yield for the first lactation. First lactation milk yield was assumed to be 310 kg milk solids (MS)/cow over 270 days (Handcock et al. 2019).
The following equations were used to calculate first lactation milk production:
AB = Age at weaning + (300 - LW at weaning (kg)/

Table 2 Calf health and input parameters when calculating the impacts of high or low milk intake, and high or low failure of passive transfer of immunity (FPT) when rearing dairy heifers or dairy-beef bull calves.

Enterprise	Dairy		Beef	
FPT	5%	30%	10%	40%
Scours ¹	4	6	4	8
Anti-inflammatory ¹	1	2	1	3
Pneumonia and other related bacterial infections ¹	3	4	3	5
Treatment costs per animal treated	\$34.40	\$51.70	\$34.40	\$69.00
Labour cost per calf reared ²	\$5.72	\$10.38	\$8.93	\$14.81
Mortality	3.4%	5.6%	3.9%	6.4%
Morbidity	11.5%	13.9%	12.0%	14.9%
Pre-weaning ADG adjustment (g/d)	-3	-16	-5	-22
Post-weaning ADG adjustment (g/d)	-6	-8	-6	-15

¹ Number of treatments required per animal

² Cost of the time required to administer animal health treatments of 12 minutes per treatment at \$31.10/hr

$ADG_{PostWean}$)

Where AB = Age at breeding

$CD_{change} = AP - 15$ months

Where CD_{change} = calving date change (months)

$FYMP = 310 \text{ kg MS} - ((310\text{kg}/270\text{d}) * CD_{change} * 30)$

Where FYMP = first year milk production

The potential impact of weaning date and post-weaning ADG changes for the dairy-beef enterprise were applied using the assumption that changes in ADG would influence the days of grazing until sale.

$Grazing \text{ days}_{PostWean} = ((TW - WW) / ADG_{PostWean}) / 7$

Economic analysis

Cost of variables related to enterprise, FPT and milk feeding were calculated for each scenario. These included actual milk consumption, actual concentrate consumption, animal health costs, loss of capital, and costs associated with entry into the herd or point of sale. All values were calculated on a per head basis.

Animal health costs:

Current prices for diarrhoea treatment, anti-inflammatory and antibiotics use were sourced (Table 1). Treatment periods were applied depending on the potential severity of the disease (Table 2), within the ranges recommended by product manufacturers. This created a range of potential animal health costs depending on FPT (Table 2). A labour component was also added with an average treatment time of 12 minutes and a per hour labour cost of \$31.10. The labour cost was the per hour rate using the current annual average salary for dairy workers (\$72,778; Salary for Industry 2026) working 45 hours/week.

$Animal \text{ Health}_{Cost} = (\sum(Tmt \text{ number} * Tmt \text{ cost}) + (Tmt \text{ Number} * Labour \text{ Cost})) * Mortality_{TOTAL} \%$

Variable direct rearing costs

Variable direct costs were summed as follows, using a price of \$8/kg MS for milk powder, \$1.28/kg as fed for concentrate.

$Variable \text{ direct costs (VDC)} = (Milk \text{ intake}_{TOTAL} * \$8) + (High \text{ Conc (kg)} * \$1.28) + Animal \text{ Health}_{Cost}$

Loss of capital:

Capital costs of losses were calculated using the 2026 Inland Revenue Department Standard livestock values (IRD 2026) as follows:

$Capital \text{ loss (\$)} = Capital \text{ cost} * Mortality_{TOTAL} \%$
Where Capital cost for heifers as R1 replacements = \$788.90

And Capital cost for dairy-beef as a bobby calf = \$282.50

Also included in the cost of the dairy heifer enterprise was the extra rearing cost and capital cost of extra heifers reared to account for calf deaths assuming the farmer did not rear extra calves above the required replacement rate, calculated as follows:

$Replacement \text{ calf cost} = (Mortality_{TOTAL} \% * VDC) + (Mortality_{TOTAL} \% * Capital \text{ cost}_{BobbyCalf})$

Costs associated with entry to herd or point of sale:

The impact of calf rearing does not end at weaning. To account for flow-on effects further estimates of cost were calculated. For dairy heifer replacements it was the change in potential milk production in their first lactation, while in dairy-beef it was an estimate of the value of grazing from weaning until sale at 100 kg LW.

First lactation milk production (FYMP) was used to calculate the difference in milk production from the different scenarios. The base milk production for the first lactation was applied as 310 kg MS. Variation from this was then used to calculate the relative gain or loss

of first year milk revenue as

First milk value = (310-FYMP)*\$9.25.

To provide a financial metric for changes in attaining a sales weight of 100 kg for dairy-beef calves, the number of days required to meet a 100kg LW target were calculated. A combination of the cost of grazing post-weaning and savings compared to the latest sales date were calculated, costed at the present price of heifer grazing as an alternative grazing enterprise. This applies the logic that saved grazing days may be sold on to another enterprise.

Cost of grazing post-weaning = ((Grazing days_{PostWean})/7 * \$8/week) - ((Grazing days_{Worst} - Grazing days_{PostWean})/7 * \$8/week)

Where \$8 = cost of heifer grazing per week

Total variable costs:

Total variable costs to entry into the herd or point of sale were then calculated as follows:

Total Variable Costs_{Dairy} = VDC + Capital loss + Replacement calf cost + Milk reduction

Total Variable Costs_{Beef} = VDC + Capital loss + Value of grazing post-weaning

Other costs

Other rearing costs, including dehorning, bedding, housing, straw, power and fuel, ear tags were excluded from the analysis, though currently sum to approximately \$60/calf entering the rearing facility (SMS 2023). Costs of straw and bedding will rise when scours increase, though there is no definitive data in the literature to provide guidance on cost inclusion. The costs also exclude the costs of engaging with a veterinarian regarding animal health problems and treatment. With high incidence of disease, these costs may be significant.

Results and Discussion

The current liveweight at 15 months of age across the New Zealand dairy industry is 297 kg (Handcock et al. 2018) thus, estimates used here appear to align well. Sales dates of 100 kg dairy-beef calves ranged from 15 October to 6 November from an entry date of 10 August, aligning with industry practice (McRae 2003). The results presented here are specifically for changes in milk input and FPT, with all other parameters of good rearing practice being met. A range of other outcomes may be associated with changes in animal health and hygiene practices within a rearing facility.

Production outcomes

Changing milk inputs has been tested both at individual experiments (Burggraaf et al. 2020; Ockenden et al. 2023) and meta-analysis level (Xiao et al. 2025). Average increases in liveweight gain to weaning were 124 g/d (Xiao et al. 2025), with an average increase in liquid milk intake of 243 g/d, coinciding with a reduction in

concentrate DM intake of 197 g/d. Changing to a high milk input approach saw an increase in ADG, which then resulted in a reduction in time to weaning (Table 3) of 27 days in the dairy heifer replacement enterprise and 20 days in the dairy-beef enterprise.

In the dairy heifer scenario, effects continue until at least entry into the herd as a first-calver. This influence is seen in the time of attainment of puberty, translating into an increase in milk production of approximately 31 kg MS in the first lactation due to earlier calving (Table 3). The first season's milk production of the Low milk, high FPT scenario of 318 kg MS/cow was similar to the current estimated heifer production (310 kg MS/cow). The overall outcomes compare well to current reported figures (Cuttance et al. 2017b, Handcock et al. 2019) providing some assurance that the estimated effects represent the current situation. High milk inputs in the dairy-beef rearing system reduced days to sale by 20 compared to low milk inputs (Table 3).

Failure of passive transfer of immunity increased death rates by 2.1 and 2.6% in the dairy heifer and dairy-beef scenarios respectively (Table 3) and morbidity by 2.4 and 2.9%. The milk production of heifers was not increased by changing FPT. Sale date was brought forward 7 days when FPT was reduced in dairy-beef calves (Table 3).

Input outcomes

Changes in ADG when FPT increased meant that higher amounts of feed were required (Table 4) to meet target weaning weights (Table 1). Dairy farm practices saw a greater increase in calf milk replacer (CMR) equivalents (13.5 kg) than the dairy-beef calf rearing (9.4 kg). Savings in concentrate feeding with high milk allowance were again greater in the heifer rearing systems due to later weaning dates than in dairy-beef calf rearing (29.0 and 20.1 kg). Increases in both number of treatments and labour required for animal health treatments were increased when FPT increased (Table 4).

Financial outcomes

Financial outcomes presented here are for direct costs which vary when changing milk inputs or FPT.

The outcomes reported here have endeavoured to assess the impact of the rearing approach beyond the milk weaning endpoint. These future outcomes are often affected by other farm practices and unforeseen influences. If costs and benefits beyond milk weaning are removed, the direct cost of rearing is increased by \$87.85 and \$62.69, or approximately 17%, for heifer replacement and dairy-beef calf rearing, respectively (Table 5), when high milk inputs are used. The increase in FPT increases costs by approximately 19% or \$33.13 and \$17.78 for heifer replacement and dairy-beef calf

Table 3 Production outcomes of rearing dairy heifer replacements or dairy-beef when calculating the impacts of high or low milk intake, and high or low failure of passive transfer of immunity (FPT).

Enterprise	Milk	FPT	Mortality	Morbidity	ADG (g)	Days to weaning	ADG post-weaning (g)	LW at 15 Month (kg)	Proportion <300kg	First season milk production ¹
Dairy Heifers	Low	5%	3.4%	11%	554	81	614	306	0.31	321
Dairy Heifers	High	5%	3.4%	11%	826	54	614	323	0.06	351
Dairy Heifers	Low	30%	5.6%	14%	541	83	612	305	0.34	318
Dairy Heifers	High	30%	5.6%	14%	812	55	612	322	0.06	350
Milk	High vs Low				271	-27		16.7	-0.27	31.3
FPT	30% vs 5%		2.1%	2.4%	-14	1	-1	-1	0.02	-3

Enterprise	Milk	FPT	Mortality	Morbidity	ADG (g)	Days to weaning	ADG post-weaning (g)	Days to 100 kg	Sales date
Dairy-beef	Low	10%	3.9%	12%	588	60	754	86	4-Nov-25
Dairy-beef	High	10%	3.9%	12%	877	40	754	66	15-Oct-25
Dairy-beef	Low	40%	6.4%	15%	572	61	745	88	6-Nov-25
Dairy-beef	High	40%	6.4%	15%	861	41	745	68	16-Oct-25
Milk	High vs Low				289	-20		-20	20.1
FPT	40% vs 10%		2.6%	2.9%	-16	1	-9	2	1.5

¹Milk production expressed as kg MS/heifer**Table 4** Inputs used when rearing dairy heifers or dairy-beef when milk intake and failure of passive transfer of immunity (FPT) are altered per calf weaned.

Enterprise	Milk	FPT	CMR ¹ (kg)	Conc ² (kg)	Scours tmt ³ (n)	Antiinflam ⁴	Antibac ⁵	Labour ⁶ (hr)
Dairy Heifers	Low	5%	47.2	73.0	4	1	3	0.18
Dairy Heifers	High	5%	63.6	38.1	4	1	3	0.18
Dairy Heifers	Low	30%	47.5	74.9	6	2	4	0.33
Dairy Heifers	High	30%	63.4	38.8	6	2	4	0.33
Milk	High vs Low		16.1	-35.5				
FPT	30% vs 5%		0.1	1.2	2.0	1.0	1.0	0.15

Enterprise	Milk	FPT	CMR ¹ (kg)	Conc ² (kg)	Scours tmt ³ (n)	Antiinflam ⁴	Antibac ⁵	Labour ⁶ (hr)
Dairy-beef	Low	10%	34.6	53.6	6	2	4	0.29
Dairy-beef	High	10%	46.5	27.9	6	2	4	0.29
Dairy-beef	Low	40%	34.8	55.1	8	3	5	0.48
Dairy-beef	High	40%	46.4	28.5	8	3	5	0.48
Milk	High vs Low		11.8	-26.1				
FPT	40% vs 10%		0.1	1.0	2.0	1.0	1.0	0.19

¹ Calf milk replacer or fresh milk DM equivalent² Total concentrate fed³ Electrolyte treatments for scours as per manufacturer recommendations⁴ Anti-inflammatory treatments to accompany scours treatment as per manufacturer recommendations⁵ Antibacterial treatments to treat associated bacterial infections as co-morbidities as per manufacturer recommendations.⁶ Labour per calf reared estimated at 12 minutes per treatment administration.

rearing, respectively (Table 5).

The application of FPT as a guiding metric for quantifying the economic costs of calf rearing has been previously used internationally (Raboisson et al. 2016). That study resulted in an estimated cost of FPT of approximately €60 and €80/head for dairy and beef respectively. The current study applies these relationships between FPT and productivity as an average value per calf reared, rather than an individual calf affected. The relative differences in direct cost between the high and low FPT for dairy heifer replacements was \$33 at a shift in FPT from 5 to 30% (Table 5). This translates into a 6% increase in cost to rear a heifer until weaning. A potential total cost difference of \$56.83 was estimated until inclusion in the herd, or 18% increase in the cost of rearing a heifer. In dairy-beef, the impact of FPT (10 vs 40%) had a relative extra total cost of \$19.87/head, or 5%. Direct animal health costs ranged from \$3.95-\$10.27 across the range of FPT from 5% to 40%. This range sits around industry average estimates of \$10/head (SMS 2023), thus providing some assurance that the estimates are plausible.

Variable direct costs ranged from \$517-638/head in dairy heifers and \$369-449/head in dairy-beef (Table 5). Milk feeding ranged from \$378-508/head in dairy heifers with virtually no change between low and high FPT, and \$129 between low and high milk. Concentrate feeding was reduced by \$32-43/head with higher milk use and increased very little with the increase in FPT.

When rearing heifers, 40% of a self-selected group of dairy farmers responded that they did not know how much milk they fed to calves, while 20% did not know the cost of calf rearing (Thomson et al. 2018). This may imply that the rearers in these cohorts recognise the value of providing high milk inputs to achieve calves which will perform well in the future.

Overall, high milk inputs added costs to dairy heifer rearing, which were rewarded in higher first lactation milk production, reducing potential rearing costs by \$201/calf (Table 5). A 25 kg increase of liveweight at 21 months of age has been shown to increase milk production by 509 kg of milk over the first three lactations in New Zealand dairy cows (Handcock et al. 2018), justifying dairy farmers investment in high milk feeding. However, ensuring excellent colostrum feeding practices to reduce FPT also added benefits, reducing direct rearing costs to weaning by \$33/calf reared, and potential rearing costs by \$57/calf when first lactation milk production was considered.

In dairy-beef rearing to a 100 kg sales weight, increased milk costs of \$94 were partially offset by reductions in concentrate (-\$32) and pasture feeding costs (-\$23) with a net \$39.73/calf increase in total cost for high compared with low milk inputs (Table 5).

Farmers application of this knowledge will depend on how they value or can capture any further economic gains from surplus spring feed. Colostrum feeding to ensure low levels of FPT was an important factor in reduced calf rearing costs by \$20/calf. These results reinforce current recommended practices regarding colostrum management practices on the dairy farm to avoid FPT in calves that are then sold for dairy-beef rearing. Furthermore, these results highlight the value of dairy-beef rearers sourcing calves from suppliers with high standards of colostrum management and proven low incidence of FPT (via veterinary testing) even if there is a marginal cost of testing.

Best-case/worst-case

A selected set of metrics were compared for potential best- and worst-case scenarios. These were chosen to highlight potential benefits and problems when recommended industry practices are implemented (Table 6). The probability of impact of FPT varies depending on the management practices in place. Increased risk of death ranges from 5%-36%, and increased risk of disease ranges from 16-49% (Abdelfattah et al. 2025), compared to the 11% and 21% for death and disease risk used in the main scenarios. The best- and worst-case scenarios have applied these probabilities to the main scenarios to demonstrate the potential impacts of changes in management and hygiene practices. Milk intakes were the same as the high and low milk scenarios. Some cost variables have been pooled to create a feed cost, and animal health cost (including labour) and other production costs (including capital costs, grazing costs and first milk value).

Failure of passive transfer of immunity has the greatest effect, with total costs increasing by approximately \$409 per head in dairy heifers between best practice and worst outcomes (Table 6). Most significant contributors to that change were capital cost and other production costs, including extra calf replacement rearing and change of milk production in the first milking season. Attention to ensuring management and hygiene practices are optimal will have an impact on preventing death and disease. The impact of poor management practices is much greater when FPT is high (Table 6). Thus, it is important that calves get timely colostrum intake of recommended amounts (2L immediately and 2L later in the day of birth) and quality (22% or higher on a Brix refractometer) to keep rearing costs down and preventing longer term production impacts. Increases in all categories of cost except feed were a result of high FPT in the dairy-beef scenario. The reduction in costs of using a lower milk intake was still not enough to lower overall cost of rearing a calf when FPT was high.

Table 5 Financial outcomes when feeding high or low milk volumes and when failure of passive transfer of immunity (FPT) occurs when rearing dairy heifers or dairy-beef expressed per calf weaned.

Enterprise	Milk ¹	FPT ²	CRM ³ (\$)	Conc ⁴ (\$)	Animal Health (\$)	Ah (time)	Capital cost ⁵ (\$)	Repl cost ⁶ (\$)	Direct costs (\$)	First milk value ⁷ (\$)	Total rearing cost (\$)
Dairy Heifers	Low	5%	377.88	90.34	3.95	5.72	27.03	11.69	516.60	-99.97	416.63
Dairy Heifers	High	5%	508.45	47.27	3.95	5.72	27.03	13.23	605.65	-383.27	222.38
Dairy Heifers	Low	30%	379.79	90.79	7.19	10.38	43.82	18.95	550.93	-70.32	480.60
Dairy Heifers	High	30%	507.57	47.19	7.19	10.38	43.82	21.43	637.58	-365.51	272.07
Milk	High vs Low		129.18	-43.34				2.01	87.85	-289.24	-201.39
FPT	30% vs 5%		0.52	0.19	3.24	4.67	16.79	7.73	33.13	23.70	56.83

Enterprise	Milk	FPT	CRM (\$) ³	Conc (\$) ⁴	Animal Health (\$)	Ah (time)	Capital cost ⁵ (\$)	Direct costs (\$)	Grazing cost (\$)	Total cost (\$)
Dairy-Beef	Low	10%	276.58	66.12	6.19	8.93	10.88	368.70	28.06	396.76
Dairy-beef	High	10%	372.05	34.59	6.19	8.93	10.88	432.65	5.63	438.28
Dairy-beef	Low	40%	278.08	66.48	10.27	14.81	18.10	387.74	30.68	418.42
Dairy-beef	High	40%	371.47	34.53	10.27	14.81	18.10	449.18	7.19	456.36
Milk	High vs Low		94.43	-31.74				62.69	-22.96	39.73
FPT	40% vs 10%		0.46	0.15	4.08	5.87	7.22	17.78	2.09	19.87

¹ Milk inputs as per Figure 1

² FPT = failure of passive transfer of immunity caused by poor colostrum intake

³ CRM – calf milk replacer cost

⁴ Conc. – concentrate feed costs

⁵ Capital cost = cost of capital losses due to deaths as per IRD Standard values (IRD 2026).

⁶ Repl cost – cost of rearing an extra calf to replace those which die

⁷ First milk value – change in income during the first lactation due to variation in time to breeding. A negative value represents a higher milk production, and therefore an offset to rearing costs

Table 6 Production and financial outcomes when rearing dairy heifers and dairy-beef at extremes of inputs of milk intake and failure of passive transfer of immunity (FPT) through lack of adequate colostrum intake expressed per calf weaned.

Enterprise	Case ¹	FPT	Mortality ²	Morbidity ³	Feed Costs	AH costs ⁴	Capital costs	Other production costs ⁵	Total costs	Direct costs
Dairy Heifers	Best	5%	3.1%	11.2%	\$557	\$9	\$24	-\$382	\$208	591
Dairy Heifers	Worst	30%	13.0%	22.5%	\$450	\$38	\$103	\$27	\$617	590
Dairy-beef	Best	10%	3.2%	11.5%	\$408	\$10	\$9	\$7	\$434	427
Dairy-beef	Worst	40%	16.4%	26.4%	\$325	\$44	\$46	\$32	\$447	415

¹ Best = high milk + low FPT + low mortality/low morbidity risk and;

Worst = low milk + high FPT + high mortality/morbidity risk.

² Probability of death Best = 4.7%; Worst = 36.3% (Abdelfattah et al. 2025)

³ Probability of disease Best = 15.6%; Worst = 49.4% (Abdelfattah et al. 2025)

⁴ AH costs = animal health costs, including the labour required for treatment

⁵ Other production costs include changes in first year milk production and extra replacement rearing in dairy heifers, and cost of grazing to sale for dairy-beef.

Practical implications

The two drivers of effective calf rearing, milk intake and colostrum management, were modelled in this exercise to define the costs of changing each of those drivers in either dairy heifer or dairy-beef calf rearing. Reducing FPT incidence had a moderate effect on both calf rearing enterprises, reducing direct rearing costs by 6% and 4% for dairy heifer and dairy-beef calf rearing, respectively. Changes in outcomes post-weaning due to first lactation milk production increased the advantage in dairy heifers to a reduction in rearing costs of approximately 18%. Thus, attention to colostrum quality and feeding needs to be a focus of all rearers.

Increasing milk volumes fed increased direct costs in dairy heifer rearing by approximately 16%. This increase was offset by a higher return in first lactation, resulting in a net reduction in rearing costs of 45%. These gains may be influenced by farm practice and unforeseen circumstances, such as changes in feed supply, animal health or animal stress, and should be viewed with caution. However, regular achievement of the targets set in this analysis may provide on-going improvements in first lactation milk production. The cost of increasing milk volume in dairy-beef rearing systems was partially offset by reductions in concentrate feed and the time on pasture before sale at 100 kg, with a net increase in cost of 10%. The potential to capture the value of saved spring pasture will vary from farm to farm, though early sales of high-quality calves may attract a premium.

Increasing milk and maximising passive immunity transfer provided small reductions in mortality and morbidity, though the extra milk required increased direct costs significantly. Increasing the risk of mortality and morbidity in response to poor management and hygiene practices further eroded economic calf rearing outcomes, regardless of milk input or enterprise (dairy heifer vs dairy-beef).

As with all modelling studies, the results become a reflection of the assumptions made. The use of meta-analysis from local and international data provides some confidence of the robustness of the result. However, the physical and profitability outcomes from on-farm situations will vary from the values calculated here. The results presented are a guide to the potential outcomes of varying milk inputs and colostrum management to help guide farmer practice.

Cost-effective rearing systems to improve sustainable calf rearing systems for both dairy heifer and dairy-beef value chains, and to capture the opportunity of rearing more dairy-beef calves, will depend on colostrum management and ensuring the transfer of passive immunity to calves destined for rearing.

ACKNOWLEDGEMENTS

Many thanks to the Bioeconomy Science Institute, AgResearch Group Strategic Science Investment Fund for funding the research.

REFERENCES

- Abdelfattah E, Fausak E, Maier G. 2025. Failure of passive immune transfer in neonatal beef calves: A scoping review. *Animals* 15: 2072. <https://doi.org/10.3390/ani15142072>
- Burggraaf VT, Craigie CR, Khan MA, Muir PD, Thomson BC, Lowe KA, Leath SR, Taukiri KR, Staincliffe M, McCoard SA. 2020. Effect of feeding forage or concentrate starter diets in early life on life-time growth, carcass traits and meat quality of Wagyu × Friesian cattle. *Animal Production Science* 60: 1850-1860. <https://doi.org/10.1071/AN19486>
- Corkran J, Higgins E. 2025 The strategic moment for dairy-beef in New Zealand. RaboResearch, Food and Agribusiness. https://www.pamunewzealand.com/pamunewzealand-pmu3/images/RaboResearch_The-strategic-moment-for-dairy-beef-in-New-Zealand_Corkran-Higgins_Oct2025.pdf
- Cuttance EL, Mason WA, Laven RA, McDermott J, Phyn C. 2017. Prevalence and calf-level risk factors for failure of passive transfer in dairy calves in New Zealand. *New Zealand Veterinary Journal*. 65(6): 297-304. <https://doi.org/10.1080/00480169.2017.1361876>
- Cuttance E, Mason W, McDermott J, Laven RA, McDougall S, Phyn CVC. 2017. Calf and replacement heifer mortality from birth until weaning in pasture-based dairy herds in New Zealand. *Journal of Dairy Science* 100: 8347-8357. <https://doi.org/10.3168/jds.2017-12793>
- Edwards JP, Cuthbert S, Pinxterhuis JB, McDermott A. 2021. The fate of calves born on New Zealand dairy farms and dairy farmer attitudes towards producing dairy-beef calves. *New Zealand Journal of Animal Science and Production* 81: 179-185.
- Hammon HM, Frieten D, Gerbert C, Koch C, Dusel G, Weikard R, Kuhn C. 2018. Different milk diets have substantial effects on the jejunal mucosal immune system of pre-weaning calves, as demonstrated by whole transcriptome sequencing. *Scientific Reports* 8: 1693. <https://doi.org/10.1038/s41598-018-19954-2>
- Hammon HM, Liermann W, Frieten D, Koch C. 2020. Review: Importance of colostrum supply and milk feeding intensity on gastrointestinal and systemic development in calves. *Animal* 14: s133-s143. <https://doi.org/10.1017/S1751731119003148>
- Handcock RC, Lopez-Villalobos N, McNaughton LR,

- Back PJ, Edwards GR, Hickson RE. 2018. Live weight and growth of Holstein-Friesian, Jersey and crossbred dairy heifers in New Zealand. *New Zealand Journal of Agricultural Research*. <https://doi.org/10.1010/00288233.2018.1465984>
- Handcock RC, Lopez-Villalobos N, McNaughton LR, Back PJ, Edwards GR, Hickson RE. 2019. Positive relationships between body weight of dairy heifers and their first-lactation and accumulated three-parity lactation production. *Journal of Dairy Science* 102: 4577-4589. <https://doi.org/10.3168/jds.2018-15229>
- IRD 2026. National standard costs for specified livestock determination 2026 <https://www.taxtechnical.ird.govt.nz/determinations/livestock/standard-costs/nsc-2026>
- Khan MA, Weary DM, von Keyserlingk AG. 2011. Invited review: Effects of milk ration on solid feed intake, weaning, and performance in dairy heifers. *Journal of Dairy Science* 94:1071-1081. <https://doi.org/10.3168/jds.2010-3733>
- McCoard SA, Pavan E, Taukiri K, Zhang R, Realini CE. 2024. Liveweight, body composition, carcass traits and meat quality of artificially reared milk-fed Friesian-Jersey crossbred heifer and bull calves. *New Zealand Journal of Animal Science and Production* 84: 1-3.
- McRae A. 2003. Historical and practical aspects of profitability in commercial beef production systems. *Proceedings of the New Zealand Grassland Association* 65: 29-34. <https://doi.org/10.33584/jnzg.2003.65.2513>
- Ockenden EM, Russo VM, Leury BJ, Giri K, Wales WJ. 2023. Prewaning nutrition and its effects on the growth, immune competence and metabolic characteristics of the dairy calf. *Animals* 13: 829. <https://doi.org/10.3390/ani13050829>
- Raboisson D, Trillat P, Cahuzac C. 2016. Failure of passive immune transfer in calves: A meta-analysis on the consequences and assessment of the economic impact. *PLoS ONE* 11 (3): e0150452 <https://doi.org/10.1371/journal.pone.0150452>
- Salary for Industry: Dairy Farm. 2026. https://www.payscale.com/research/NZ/Industry=Dairy_Farm/Salary
- SMS. 2023 What it costs to rear a calf in 2023. Accessed March 2026. <https://www.smsaccountants.co.nz/post/what-it-costs-to-rear-a-calf-in-2023>
- Sneddon NW, Corner-Thomas RA, Kenyon PR, Brier D. 2025. Preferences in traits and management characteristics for dairy-beef animals from a survey of New Zealand farmers. *New Zealand Journal of Agricultural Research* 68: 785-797 <https://doi.org/10.1080/00288233.2025.2495962>
- Sutter F, Venjakob PL, Heuwiesser W, Borchardt S. 2022. Association between transfer of passive immunity, health, and performance of female dairy calves from birth to weaning. *Journal of Dairy Science* 106: 7043-7055. <https://doi.org/10.3168/jds.2022-22448>
- Thomson BC, Muir PD, Ward KR. 2018. Calf-rearing systems on dairy farms and specialist calf rearing units: results of a New Zealand survey. *New Zealand Journal of Animal Science and Production* 78: 173-176.
- van Keulen P, McCoard SA, Dijkstra J, Swansson H, Khan MA. 2021. Effect of postpartum collection time and colostrum quality on passive transfer of immunity, performance, and small intestinal development in preweaning calves. *Journal of Dairy Science* 104: 11931-11944. <https://doi.org/10.3168/jds.2020-19813>
- Xiao J, Ma H, Tian J, Lu G, Wei X, Peng Y, Hu R, Peng Q, Wang L, Xue B, Wang Z. 2025. Effects of increased milk allowance through within-study comparisons on dairy calf growth and future performance. *Journal of Dairy Science* 108: 10812-10836. <https://doi.org/10.3168/jds.2025-26555>