
THE PROCEEDINGS OF THE
NEW ZEALAND SOCIETY
OF
ANIMAL PRODUCTION
VOLUME 62 2002

Farm management implications of a seasonal price differential for factory supply milk production

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ABSTRACT

A number of New Zealand dairy companies have proposed a differential pricing scheme that would discount the price paid for "peak milk" and provide a premium for milk supplied "off peak". A linear programming model was developed to analyse the on-farm impact of a differential milk pricing scheme. The differential pricing scheme used in the study was based on a dairy company where farmers supplied 30% of total milk during the October/November peak and 70% during the off-peak period (peak-to-shoulder ratio of 30:70). The impact of three price differentials of $0.82/kg MS, $1.63/kg MS and $2.45/kg MS between peak and off-peak milk was analysed. The results showed that if the case study farmer made no management changes to his system, there would be little change in the farm gross margin per hectare under a differential pricing scheme, provided the farm had a peak-to-shoulder ratio close to that used by the dairy company to set the price differential. However, returns declined by $182/ha, if the farm peak-to-shoulder ratio was 40:60 and increased by $185/ha if the ratio was 20:80. A price differential of at least $1.71/kg milksolids ($3.00/kg MF) between peak and shoulder milk, was required to reduce peak milk production significantly. As the price differential increased, the LP model selected solutions that reduced both total milk production and the ratio of peak-to-shoulder milk. Management changes selected to modify the pattern of milk production included; a reduction in stocking rate, a shift to an earlier calving date (and then a split calving), an increased lactation length, higher cow condition at calving and greater use of supplements.

Keywords: Linear programming; farm management; dairy farming; seasonal price differential.

INTRODUCTION

New Zealand's temperate climate allows year round pasture production and dairy farmers have taken advantage of this to develop low-cost, seasonal production systems. The adoption of these dairying systems has important implications for dairy companies because the pattern of milk production is also seasonal with about 30% of total milk supplied during the peak months of October-November. The companies must process the peak milk on the day it is received and therefore, adequate processing plant, transport vehicles and storage facilities are required (Paul 1982). This can create a number of serious problems for dairy companies. First, the large capacity needed to accommodate peak milk flow is under-utilised at other times of the year and this is reflected in New Zealand's low capacity utilisation index relative to major European competitors (Paul 1985). Second, during periods when cow numbers increase significantly, such as from 1969 - 1983 (Paul 1982) and the early 1990's, dairy companies need to build new factories to ensure peak milk is processed. From 1969 to 1983 the increase in peak milk flow was proportionally greater than the increase in total milk supply. Third, high peak milk flow may force companies to either dump milk, or divert milk from high value products into lower value bulk commodities (Watters pers. comm.). This reduces the overall value of the returns to the farmer.

To overcome these problems, a number of dairy companies have proposed the introduction of differential pricing schemes, where the price paid for peak milk is discounted and a premium is paid for non-peak milk. For example, Tui Milk Products has on average, 30% of total milk supplied in the peak months of October and November, and therefore, a peak-to-shoulder ratio of 30:70. Assuming the company proposed to discount the price paid for peak milk by $0.57/kg MS ($1.00/kg MF) below the base price of $3.42/kg MS ($6.00/kg MF), then it would reallocate this at a ratio of 30:70 to pay a premium for shoulder milk of $0.24/kg MS. In this situation, a farmer would receive $2.85/kg MS for peak milk, $3.67/kg MS for shoulder milk, with a price differential between peak and shoulder milk of $0.82c/kg MS. In this paper, a method for analysing the impact of a differential pricing scheme for an individual supplier is described and the implications of the results for the dairy industry are discussed.

METHOD

The impact of, and opportunities offered by, a differential pricing scheme for dairy farming was investigated using a case study approach. Resources, management and physical and financial performance data were collected from a case study farmer. Brookes' (1990) simulation model, "Supacow", was used to derive cow feed requirements and apparent pasture growth rates for an "average" year for the case study farm.

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Linear programming (LP) was chosen as the method of analysis because it has been used previously for solving resource allocation problems for dairy farms (Taylor and Miller, 1979; Miller, 1980; Ridler *et al.*, 1987). An LP model of a dairy farm, developed by Mendizabal (1991) was modified to represent the case study farm. The "average" pasture growth rates derived through simulation modelling were entered into the LP model. The simulation model was also used to derive cow feed requirement patterns for the cow "activities" used in the LP model. Management strategies that could be used to alter the pattern of milk production, including changes in calving date, stocking rate, cow condition at calving, lactation length, and the use of various forms of feed supplementation (silage, hay, meal, nitrogen, grazing off, summer brassica crop) were then investigated with the LP model.

The objective function of the LP model was to maximise gross margin per hectare by choosing the best combination of activities (stocking rate, calving date, cow condition at calving, lactation length, supplements used) that were technically feasible and operated within the specified resource constraints. The model was subject to two important sets of constraints;

(i) FEED DEMAND$_t$ - FEED SUPPLY$_t$ ≤ 0 where "t" denotes each of 12 periods corresponding to a month of the year,

(ii) AVERAGE PASTURE COVER$_t$ $\geq$ lower limit$_t$ $\leq$ upper limit$_t$ where AVERAGE PASTURE COVER is the amount of pasture on the farm at the end of each period "t", and the limits are set at technically feasible levels throughout the year.

A pasture activity supplied pasture (kg DM/ha/month) for each month of the year. Supplementary feed activities either supplied feed (kg pasture DM equivalent) in a specific month (nitrogen, meal, grazing) or transferred feed from one period to another (silage, hay, summer forage crop). Pasture cover activities were used to constrain the amount of feed that could be transferred *in situ* from one month to the next. Minimum average pasture cover levels were set at 1600 kg DM/ha throughout the year, but maximum average pasture cover ranged from 2200 kg DM/ha in April-May to 3000 kg DM/ha in November-December.

Twelve cow activities were defined (Table 1). The LP model could choose between cows that calved in July, August or September, at a condition score of 4.5 or 5.0 with a 258 or 289 day lactation, and associated level of milksolids production. The gross margin for each cow activity included revenue from stock (calves, cull cows) and milk sales, less direct costs (animal health, breeding, shed costs, etc). Revenue from milk sales reflected the value of milk supplied in different months.

Hay and silage were costed on the basis of cents per kilogram dry matter harvested. The model allowed this feed, less wastage and change in energy content to be transferred to periods of feed deficit. Meal was costed as cents per kilogram dry matter equivalent (less wastage). Pasture responses to nitrogen of 8:1 and 10:1 (kg DM/kg N) for autumn and spring applications respectively were assumed. Nitrogen applications were constrained, at the case study farmer's request, to 25 kg N/ha/season across the whole farm. The cost of off-farm grazing was $5/cow/week and the cost of the summer brassica crop and regrassing was $458/ha.

TABLE 1: A description of the cow activities in the linear programming model.

Activity	Production kg MS/cow/yr	Calving Month	Days in milk	Condition score*
Cow 1	298	July	258	4.5
Cow 2	305	July	258	5.0
Cow 3	325	July	289	4.5
Cow 4	332	July	289	5.0
Cow 5	298	August	258	4.5
Cow 6	305	August	258	5.0
Cow 7	325	August	289	4.5
Cow 8	332	August	289	5.0
Cow 9	298	September	258	4.5
Cow 10	305	September	258	5.0
Cow 11	325	September	289	4.5
Cow 12	332	September	289	5.0

*At the commencement of calving.

Initially the model was used to investigate the potential for increasing the profitability of the current farm system under the normal pricing scheme ($3.42/kg MS or $6.00/kg MF). The impact of a differential pricing scheme on the profitability of the case study farmer's current system was then analysed. An analysis was undertaken to evaluate the effect of a differential pricing scheme based on a company peak to shoulder ratio of 30:70, on farms with peak to shoulder ratios that were quite different from 30:70. The case study farm has a current peak to shoulder ratio of 29:71. Gross margin analysis was used to estimate the profitability of the case study farm if it had a peak to shoulder ratio of 20:80 or 40:60. Finally, the opportunities for increasing farm profitability under a differential pricing scheme were evaluated for three price differentials between peak and shoulder milk ($0.82/kg MS, $1.63/kg MS and $2.45/kg MS).

RESULTS AND DISCUSSION

Analysis of the current system

Analysis of the current system under the normal pricing scheme ($3.42/kg MS) showed that gross margins could be increased from $2944/ha to $3232/ha (Table 2). The solution indicated the farmer should run a higher stocking rate (3.58 cows/ha vs 3.43 cows/ha), calve the herd slightly later (August 3 vs August 1) and at a higher condition score (5.0 vs 4.5 units), and milk the herd for longer (269 vs 258 day lactation) than the current system. The new system produced more milksolids per hectare (1125 vs 1023 kg MS/ha) and per cow (314 vs 298 kg MS/cow).

To meet the increased feed demand for the new system the entire herd would be grazed off during May, June and July, compared with the present situation of 53%, 76% and 71% of the herd being off the farm each month, respectively. Use of nitrogen during autumn (25 vs 0 kg N/ha) and early spring (25 vs 17 kg N/ha) was greater and at the maximum allowable level. Less supplements were made (85 vs 458 kg DM/ha) and the LP model selected silage rather than hay which is the current practice.

TABLE 2: A comparison between the case study farmer's current system and the LP optimal solution under the normal pricing scheme.

Parameters	Current System	Optimal Solution
Gross margin ($/ha)	2944	3232
MS/cow (kg)	298	314
MS/ha (kg)	1023	1125
Stocking rate (cows/ha)	3.43	3.58
Planned start of calving (% of herd)		
August	100	95
September		5
Lactation length (% of herd)		
258 day lactation	100	65
289 day lactation		35
Grazing off (%)[a]	53	100
May	76	100
June	71	100
July	71	100
August	0	100[b]
Hay made (kg DM/ha)	458	0
Silage made (kg DM/ha)	0	85
Autumn nitrogen (kg N/ha)	0	25
Spring nitrogen (kg N/ha)	17	25

[a] (Number of cows grazed off/potential number of cows that could be grazed off) x 100.
[b] The LP solution calved 5% of the herd in September and all these animals were grazed off.

Profitability of the current system for different peak to shoulder ratios

The profitability of the farm would only increase by $10/ha ($2953/ha vs $2943/ha) for a price differential of $1.63/kg MS if the farmer made no changes to his current system and maintained a peak-to-shoulder ratio of 29:71. However, if the farmer had a higher peak-to-shoulder ratio (40:60), the gross margin would decrease by $182/ha, whereas for a lower peak-to-shoulder ratio (20:80), the gross margin would increase by $185/ha.

Increasing farm profitability with differential pricing

At a price differential of $2.45/kg MS between peak and shoulder milk, the gross margin was $55/ha greater than the base solution for the current pricing scheme (Table 3). For the solutions selected by the LP model, milksolids production declined from 1125 kg MS/ha to 1095 kg MS/ha in association with a reduction in stocking rate from 3.58 cows/ha to 3.29 cows/ha as the price differential was increased. However, milksolids production per cow increased from 314 kg MS/cow to 333 kg MS/cow.

The base solution output was 1125 kg MS/ha, of which 71% was produced in non-peak months. As the price differential increased, the model selected options that produced less milksolids (1095 vs 1125 kg MS/ha), but had a lower peak to shoulder ratio (24:76 vs 29:71). However, the total peak was only reduced by 37 kg MS/ha or 11%, and shoulder production was increased by 7 kg MS/ha or 1% for a price differential of $2.45/kg MS.

Cows were always calved at a condition score of 5.0 rather than 4.5, but as the price differential increased, earlier calving dates were selected. For pricing scheme 3, a split calving with 66% of the herd calving in July and 34% of the herd calving in September was optimal (Table 3).

As the price differential increased, cow lactation length was increased and systems where the pattern of feed demand was increasingly less well matched to the pattern of pasture growth were selected. As a consequence, a greater proportion of silage was made to transfer feed to periods of feed deficit. Thus, only 85

TABLE 3: A summary of the LP solutions chosen for a range of different pricing schemes.

Parameters	Base	1	2	3
Base Price ($/kg MS)	$3.42	$3.42	$3.42	$3.42
Price (peak/shoulder)	$3.42/$3.42	$2.85/$3.67	$2.28/$3.91	$1.71/$4.16
Differential (shoulder - peak)	$0.00	$0.82	$1.63	$2.45
Gross margins ($/ha)	3232	3242	3258	3287
MS/cow (kg)	314	315	331	333
Peak (kg MS/ha)*	326(29)	325(29)	298(27)	289(26)
Shoulder (kg MS/ha)*	799(71)	798(71)	799(73)	806(74)
Total (kg MS/ha)	1125	1123	1097	1095
Stocking rate (cows/ha)	3.58	3.55	3.30	3.29
Planned start of calving (% of herd)				
July 1		1%	32%	66%
August 1	95%	99%	68%	
September 1	5%			34%
Lactation length (% of herd)				
258 day lactation	65%	60%	0%	0%
289 day lactation	35%	40%	100%	100%
Supplementary feed				
Hay made (kg DM/ha)	0	0	0	0
Silage made (kg DM/ha)	85	115	456	533
Nitrogen use				
Autumn (kg N/ha)	25	25	25	25
Spring (kg N/ha)	25	25	25	25

* Figures in brackets represent percentage of total milksolids production.

kg DM/ha of silage was made for the base solution, while 533 kg DM/ha was ensiled for pricing scheme 3.

Despite a price differential of $2.45/kg MS, meal or a summer forage crop were not incorporated into the optimal solution for pricing scheme 3. This can be explained by the shadow price of feed or the return that can be generated through the addition of an extra unit (kg DM) of feed into the optimal solution for each month of the year (Table 4). Additional feed was worth 15-16c/kg DM during periods of feed surplus (October-December) and 33-38c/kg DM during periods of feed deficit (January-September). A feed source will be used when the true cost of the feed is less than or equal to the marginal revenue generated by the feed, providing other constraints are not violated.

TABLE 4: The monthly value (shadow price) of an extra kilogram of dry matter (cents/kg DM) for different milk pricing schemes. (See Table 3 for definition of alternative systems).

Month	Base	1	2	3
July	33	34	37	38
August	35	36	37	38
September	35	36	37	38
October	15	15	15	16
November	15	15	15	16
December	15	15	15	16
January	36	36	35	35
February	36	36	35	35
March	36	36	35	35
April	36	36	35	35
May	33	34	35	35
June	33	34	35	35

Table 5 shows the true cost of the feed sources used in the model. Some feeds accrue only a direct cost when they are purchased (meal, grazing, nitrogen). However, other feed sources have an opportunity cost because the farmer must remove feed (pasture) or forego pasture production from one or more periods in order to supply feed to another period. The feed foregone has some value and this is its opportunity cost. For example, the direct cost of making hay is 14c/kg DM harvested. If wastage and the reduction in energy content is taken into account, a farmer needs to harvest 2.17 kg DM in spring to supply 1.0 kg DM of equivalent energy value during winter, a direct cost of 30c/kg DM supplied. The shadow price of spring pasture is 15-16c/kg DM; the opportunity cost of supplying 1.0 kg DM equivalent of hay in winter, by using 2.17 kg DM of spring pasture is therefore 33-37c/kg DM.

TABLE 5: Summary of supplementary feed costs ($/kg DM pasture equivalent)

Supplement	N Response	Direct Cost	Opport. Cost	Total Cost
Grazing off		0.11-0.12	0.00	0.11-0.12
Hay		0.30	0.33-0.37	0.63-0.67
Silage		0.11	0.25-0.27	0.36-0.38
Meal		0.42	0.00	0.42
Crop (Brassica)		0.08	0.45	0.53
Nitrogen	10:1	0.15	0.00	0.15
Nitrogen	8:1	0.18	0.00	0.18

The opportunity cost for crop is even higher than hay and although the crop yields 5489 kg DM/ha, some 10,042 kg DM/ha of pasture production is foregone. The income from pasture that is foregone because the land is in a brassica crop equates to 45c/kg of crop dry matter supplied.

The total cost data in Table 5 shows that off-farm grazing and nitrogen (provided a reasonable response can be obtained) are the most cost effective sources of feed. Silage was preferred to hay as a method of conserving surplus feed, and ensuring the maximum spring pasture cover constraint was met, because it was almost half the cost of hay. If the only benefit from meal was increased milk production, costs would need to fall at least 6c/kg DM equivalent at current milk prices before it would be incorporated into any solution. The true cost of the crop (53c/kg DM) far exceeds the revenue the additional feed could generate from milk during the summer period (35-38c/kg DM) and therefore, this crop can only be justified for the purposes of pasture renovation or as a risk management strategy for dry conditions or animal health. These results would change for situations where pasture production was low relative to crop yield. For example, in an LP study of a central Hawkes Bay dairy farm, Bramwell *et al.*, (1993) found that it was profitable to grow a high yielding hybrid maize crop because the crop outyielded pasture production in this environment.

CONCLUSION

Dairy companies have advocated a differential pricing scheme as one means of solving the problems associated with high peak milk flows. This study shows that major changes to physical management (calving date, lactation length, cow condition) and a greater use of inputs (silage, nitrogen), would be required under a differential pricing scheme for limited financial benefit. A differential pricing scheme would allow farmers to use inputs that are uneconomic under the current pricing regime and may, in the long term erode New Zealand's competitive advantage in relation to low cost dairy production. The study also showed that a price differential of at least $1.71/kg MS would be required to bring about a significant change in the pattern of milkflow from the case study farm. This suggests that the dairy company would need to offer a large price differential between peak and shoulder milk to obtain significant change in milkflow from its suppliers. Farmers have voiced concern about the inequity of a price differential scheme and the results suggest that under such a scheme, farmers with high peak-to-shoulder ratios would be disadvantaged relative to other suppliers.

Linear programming was an effective method for carrying out a preliminary investigation of this type of farm management problem and identified the major limitations to changing the seasonal pattern of milk production. The linear programme model calculated the shadow price of feed at different times of the year and the cost of alternative supplementary feeds. The data shows that greater use of supplementary feeds will only occur when the cost of these feeds is equal to or less than the shadow price of feed. The study highlighted the need for both the farmers' and the dairy company's situation to be analysed prior to the implementation of any new pricing policy.

ACKNOWLEDGEMENTS

The authors sincerely acknowledge the contributions of Mr Aidan Bichan, New Zealand Dairy Board Consulting Officer; Mr Andrew Watters, Tui Milk Products' Production Officer; Mr N McLean, Agriculture New Zealand and particularly the case study farmer, Mr Murray Holdaway. Thanks also to Professor Warren Parker, Associate Professor Alan Wright and Mr Alan McRae for their assistance with the paper.

REFERENCES

Bramwell, N.F.; Parker, W.J.; Gray, D.I.; McCutcheon, S.N. 1993. The potential of industry byproducts as supplementary feeds for dairy cows in the Hawkes Bay region. *Proceedings of the New Zealand Society of Animal Production* **53:** 55-59.

Brookes, I.M. 1990. Supacow model and dairy cow models. *Agricultural Systems and Information Technology Newsletter* **2:** (1), 3-4.

Mendizabal, M. 1991. A study of milk production from grazed pastures and the development of a simple linear programming model of the dairy production system. Unpublished Dip.Agr.Sc. Dissertation, Massey University, New Zealand.

Miller, C.P. 1980. Modelling the contribution of forage crops to production, profitability and stability of North Island dairy systems. *Proceedings of the New Zealand Society of Animal Production* **40:** 64-67.

Paul, K.J. 1982. Spreading milk intake; advantages and disadvantages for factories and farmers. *Proceedings of the Ruakura Farmers' Conference* pp. 91-95.

Paul, K.J. 1985. A new direction for the payment of milk. *Proceedings of the Ruakura Farmers' Conference* pp. 77-85.

Ridler, B.J.; Brookes, I.M.; Holmes, C.W.; Stachurski, L.J.; Hurley, E.M. 1987. Use of a linear programming model to investigate alternative dairy production systems. *Proceedings of the 4th Animal Science Congress of the Asian-Australian Association of Animal Production Societies,* (Hamilton) pp. 454.

Taylor, A.O.; Miller, C.P. 1979. The use of linear program modelling to optimise farming systems for smoothing seasonal dairy production. Technical Report No. 8, Plant Physiology Division, Department of Scientific and Industrial Research, Palmerston North.

Watters, A. 1992. Personal communication. Milk Production Officer, Tui Milk Products, Limited.