Estimation of a premium for milk with a high concentration of unsaturated fatty acids based on farm and processor profit: A simulation study.

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Abstract

The objective of this study was to determine, via simulation, the premium required for dairy farmers supplying milk with a high concentration of unsaturated fatty acids (UFA) to a dairy processor to equal the operating profit ($/ha) of average farms, under New Zealand conditions. Fifty average farms (AVE farms) and fifty farms that fed an oilseed supplement to dairy cows (UFA farms) were simulated. The processing of milk produced by AVE farms and UFA farms into skim-milk powder and butter was also simulated. The physical and financial characteristics of dairy farms and a dairy processor were investigated under two scenarios: 1) no premium for UFA and 2) a premium for UFA which equalled the operating profit ($/ha) of UFA farms to that of AVE farms. UFA farms were not different from AVE farms in yields of milk, milkfat and protein, but their farm expenses were greater ($P<0.05$) than for AVE farms. A premium of $0.15/kg milkfat (for each 0.1 g UFA/100 g milkfat increase) was necessary for UFA farms to have an operating profit ($/ha) similar to AVE farms. These results may be used to further evaluate the impact of modifying milkfat UFA concentration at the farm level.

Keywords: farm model; processing model; unsaturated fatty acids; butter

Introduction

The emergence of niche markets for food products containing a higher-than-average concentration of unsaturated fatty acids (UFA) has prompted researchers to investigate options to modify milkfat composition. Several studies have investigated the feeding of oilseed supplements to dairy cattle to increase the concentration of unsaturated fatty acids (UFA) in milkfat (Thomson & MacGibbon 2000; Shingfield et al. 2013). These studies indicated that a payment system with a premium for milkfat UFA concentration would be necessary before a programme to increase the UFA concentration in milkfat is implemented (Elgersma et al. 2006). The objective of the present study was to estimate, via simulation, the premium required to compensate a group of New Zealand dairy farmers for the extra costs associated with the use of an oilseed supplement on farm to increase the UFA concentration in milk.

Materials and methods

Simulation of AVE farms and UFA farms

The farm model developed by Silva-Villacorta et al. (2012) was used to simulate 50 dairy farms that produced milk with average milkfat composition (AVE farms) and 50 dairy farms that fed dairy cows an oilseed supplement to produce milk with a high UFA concentration (UFA farms). The farm model, which simulated milk production and composition of individual cows, was described in detail by Silva-Villacorta et al. (2012).

Model inputs used in the simulation of each AVE farm and UFA farm were: farm size (120 ha), herd size (325 cows), replacement rate (20.6%), spring calving (20th Jul – 10th Oct, 90% of the herd calved in the first 46 days), last drying-off date (10th May), pasture consumption and quality (11 t DM eaten/ha, 11 MJME/kg DM) and oilseed supplement (27% oilseed fat, 14 MJ ME/kg DM) offered per cow (0 kg in AVE farms, and 2.5% of daily DM intake as fat from oilseed supplement in UFA farms). Model assumptions were: R1 and R2 heifers grazed off farm, feed deficits were covered with imported supplements made of conserved pasture (10 MJME/kg DM), pasture substitution was negligible, 90% of cows in each herd got pregnant during the mating season, the energy requirements of calves were met by milk (3.6 MJ ME/litre, 4 litres/day) and meal (12.5 MJ ME/kg DM). Model inputs and assumptions were based on values reported in previous studies (Shingfield & Garnsworthy 2012, Silva-Villacorta et al. 2012).

In the simulation of UFA farms, the effects of oilseed supplementation on milk yield, concentrations of milkfat and protein, liveweight and milkfat-UFA concentration were simulated as deviations (percentage difference) in the corresponding traits from oilseedunsupplemented cows. A (co)variance matrix of order 5×5 was used to simulate the effect of oilseed supplementation for each trait, using the methodology described by Silva-Villacorta et al. (2012) for the simulation of milk production and composition. The (co)variance matrix used to simulate the effect of oilseed supplementation was developed using means, standard deviations and correlations corresponding to the percentage difference in each trait between oilseed-supplemented and oilseed-unsupplemented cows in the studies by Chichlowski et al. (2005), Bobe et al.(2007), Lerch et al. (2012), Oeffner et al. (2013) and Schroeder et al. (2013). In these studies, oilseed supplementation did not affect the yields of milk, milkfat and protein significantly.

Simulation of milk processing

The processing of 100% of milk produced by AVE farms and UFA farms into butter and skim-milk powder (SMP) was simulated using the milk-processing model developed by Garrick & Lopez Villalobos (2000). Inputs for the milk-processing model were the daily concentrations of milkfat, protein, casein (percentage of total protein), lactose, and minerals in milk produced by AVE farms and UFA farms. Butter manufactured from UFA milk (UFA butter) was the value-added dairy product characterised by a higher-than-average UFA concentration.

Dairy processor revenue and expenses

Dairy-processor financial performance was investigated under two premium scenarios for milkfat UFA concentration above 37.50 g /100 g milkfat: 1) NoPremium (milk payment with no premium for milkfat UFA concentration) and 2) Premium (milk payment with a premium for milkfat UFA concentration which gave UFA farms the same operating profit per hectare as AVE farms).

Dairy processor revenue was calculated as follows:

Dairy processor revenue ($) = ∑ (Tonnes of each dairy product × corresponding market price).

The market prices used for dairy products were (GlobalDairyTrade 2013, average from May 2010 to Dec 2012): US $3,450/t for SMP, US $3,641/t for butter manufactured from AVE milk, US $2,885/t for butter milk powder (BMP), US $8,000/t for casein and US $1,177/t for whey protein concentrate (WP) (NZ $1 = US $0.7184).

The minimum market price of UFA butter was determined using a premium pricing strategy, with the size of the premium being the amount necessary to equal the operating profit of UFA farms to that of AVE farms:

$$V_{\text{UFA butter}} = V_{\text{AVE butter}} + (\Psi \,/\, \text{total tonnes of UFA butter manufacture})$$

Where $V_{\text{UFA butter}}$ = premium price of UFA butter, $V_{\text{AVE butter}}$ = market price of AVE butter, and Ψ = aggregate premium for milkfat UFA concentration. Ψ in the NoPremium scenario (Ψ_0) was zero. Ψ in the Premium (Ψ_p) scenario was estimated as follows:

$$\Psi_p = (\Omega_{ave} - \Omega_{ufa}) + ((\delta_{ufa} - \delta_{ave})\times 50)$$

Where Ω_{ave} = Aggregate payment for milk generated by AVE milk in the NoPremium scenario (mean of 1000 replicates), Ω_{ufa} = Aggregate payment for milk generated by UFA milk in the NoPremium scenario (mean of 1000 replicates), δ = farm expenses ($/farm) in the NoPremium scenario, δ_{ave} = Farm expenses ($/farm) of AVE farms in the NoPremium scenario (mean of 1000 replicates), δ_{ufa} = Farm expenses ($/farm) of UFA farms in the NoPremium scenario (mean of 1000 replicates), and $((\delta_{ufa} - \delta_{ave})\times 50)$ = Aggregate difference in farm expenses between 50 UFA farms and 50 AVE farms (mean of 1000 replicates).

Dairy processor costs were obtained from Geary et al. (2013) and Fonterra (Fonterra 2012). The difference between dairy processor revenue and dairy processor costs represented the aggregate payment for milk.

Milk payment system

Milk suppliers were paid according to the kilograms of milkfat (A) and protein (B) supplied to the dairy processor, penalised according to the volume of milk supplied (C), and paid a premium for a high UFA concentration in milkfat (UFA):

$$\Psi_{relative} = \text{milkfat}_{kg} + \text{protein}_{kg} + \text{volume}_{L} + \text{UFA}_{0.1g>37.50}$$

Where $\Psi_{relative}$ = relative contribution of SMP, butter, BMP, casein, WP, volume-related costs and aggregate premium for milkfat UFA concentration to the aggregate payment for milk, milkfat_{kg} = kilograms of milkfat in the total volume of each dairy product manufactured, protein_{kg} = kilograms of protein in the total volume of each dairy product manufactured, and volume_{L} = total volume of milk processed. $\text{UFA}_{0.1g>37.50}$ is the total 0.1 g UFA/100 g milkfat above 37.50 g UFA/100 g milkfat, in milkfat processed.

Farm revenue and expenses

Farm operating profit was estimated as the difference between gross farm income and farm expenses. Gross farm income was determined by the sum of milk income (milk supplied to the dairy processor × milk payment system used by the dairy processor), stock income (carcass weight × beef price) and other dairy income ($46/ha). Beef prices used for this simulation were those reported by Silva-Villacorta et al. (2012).

Farm expenses were estimated as the sum of marginal expenses (farm expenses excluding feed costs of milking herd), assumed to be $1,187/cow (DairyNZ 2013), and feed expenses (kilograms feed eaten by the herd × feed cost). The price of pasture and imported supplements were assumed to be $0.10/kg DM and $0.25/kg DM, respectively. The price of the oilseed supplement was assumed to be $1.20/kg DM.

Statistical analysis

Means and confidence intervals were estimated by bootstrapping. The simulation of AVE farms and UFA farms, and the simulation of milk processing, were replicated 1000 times, so that each trait (θ) studied had 1000 bootstrap values. A 95% confidence interval for the mean of each trait was determined using the percentile method of bootstrapping (Henderson 2005), which comprised sorting the bootstrap values of a trait from smallest to largest, and identifying the 25th and 975th ordered bootstrap values.

Results

Physical characteristics of dairy farms

The physical characteristics of simulated dairy farms are presented in Table 1. There was no difference in cow live weight, lactation length and the yields of milk, milksolids, milkfat and protein, both per cow and per hectare, between AVE farms and UFA farms. Cows in UFA farms produced milk with lower ($P<0.05$) concentrations of milkfat and protein, but 28.8% more UFA ($P<0.05$), than cows in AVE farms (Table 1). Although cows in UFA farms had lower ($P<0.05$) DM intake than cows in AVE farms, there were no differences in annual energy intake per cow between UFA farms (50,009 [49,379 - 50,655] MJME) and AVE farms (50,179 [49,518 - 50,867] MJME).

Per farm, there was no difference between AVE farms and UFA farms in the volume of milk, milkfat, protein, casein, lactose and minerals, supplied to a dairy processor (Table 1).

Physical and financial characteristics of dairy processor

There was no difference in the volumes (Tonnes/year) of butter, SMP and BMP manufactured from UFA milk and AVE milk, but UFA milk produced less ($P<0.05$) casein and WP than AVE milk (Table 2). Butter manufactured from UFA milk had a higher UFA concentration than butter manufactured from AVE milk (38.78 and 30.11 g UFA/100 g fat, respectively).

Table 1 Physical characteristics (mean and [95% confidence interval]) of simulated dairy farms that produce milk with average (AVE farms) or high (UFA farms) concentration of unsaturated fatty acids (UFA) in milkfat.

Trait	AVE farms (50 farms)		UFA farms (50 farms)	
Farm size (ha)	120		120	
Herd size (cows)	325		325	
Stocking rate (Cows/ha)	2.71		2.71	
Per cow (per year)				
Lactation length (days)	267	[266 - 268]	267	[266 - 268]
Milk yield (litres)	4,348	[4,246 - 4,459]	4,433	[4,328 - 4,538]
Milkfat yield (kg)	187	[182 - 192]	182	[178 - 187]
Protein yield (kg)	156	[152 - 160]	153	[149 - 156]
Milksolids yield (kg)	343	[335 - 352]	335	[328 - 343]
Milkfat %	4.30 [a]	[4.24 - 4.36]	4.11 [b]	[4.06 – 4.17]
Protein %	3.59 [a]	[3.56 - 3.62]	3.45 [b]	[3.43 - 3.48]
g UFA/100 g of milk fat	30.11 [a]	[29.82 - 30.38]	38.78 [b]	[38.41 – 39.14]
Live weight (kg)	491	[487 - 496]	488	[484 - 493]
Total feed intake (kg DM) [1]	4,574 [a]	[4,509 - 4,643]	4,434 [b]	[4,373 - 4,497]
Total supplement intake (kg DM) [1]	513 [a]	[447 - 581]	376 [b]	[313 - 438]
Oilseed intake (kg DM)	0		303	[298 - 307]
Per hectare (per year)				
Milk yield (litres)	11,780	[11,502 - 12,014]	12,010	[11,726 - 12,291]
Milkfat yield (kg)	506	[494 - 519]	494	[482 - 505]
Protein yield (kg)	422	[412 - 433]	414	[404 - 424]
Milksolids yield (kg)	929	[908 - 952]	908	[887 - 929]
Total feed intake (t DM) [1]	12.39 [a]	[12.24 - 12.58]	12.02 [b]	[11.93 - 12.13]
Total supplement intake (t DM) [1]	1.39 [a]	[1.24 - 1.58]	1.02 [b]	[0.92 - 1.12]
Oilseed intake (t DM)	0		0.82	[0.81 - 0.83]

[a,b] Within a row, means with different superscript letter are significantly different ($P<0.05$).
[1] Total feed intake = pasture intake + supplement intake, total supplement intake = oilseed intake + other supplements intake.

Dairy-processor financial performance was similar in the NoPremium and Premium scenarios when AVE milk was processed. In the NoPremium scenario, there were no differences in dairy processor revenue from the sales of butter, SMP and BMP between AVE milk and UFA milk (Table 2). In the Premium scenario, the average premium price of UFA butter was US $4,833/t, 32.7% higher than the market value of standard butter. In this scenario, the processing of UFA milk resulted in both higher ($P<0.05$) revenue from the sales of butter (+29%) and higher ($P<0.05$) total revenue (+23%) than the processing of AVE milk (Table 2).

In the NoPremium and Premium scenarios there was no difference in dairy processor expenses (volume costs, product costs, fixed costs, capital costs, total expenses) between UFA milk and AVE milk. The aggregate payment for milk generated by UFA milk was 12% higher ($P<0.05$) than AVE milk in the Premium scenario (Table 2).

Milk payment system and UFA premium

In the Premium scenario, the aggregate premium needed for UFA milk was on average $5.63 million. Across premium scenarios, there was no difference between AVE milk and UFA milk in the average value of milkfat and milk volume, but the value of protein was higher for UFA milk than AVE milk ($P<0.05$) in the Premium scenario (Table 3). In the Premium scenario, the premium for each 0.1 g UFA/100 g milkfat increase (above 37.50 g UFA/100 g milkfat) was $0.15(0.13-0.16)/kg milkfat (Table 3).

Table 2 Dairy-processor physical and financial performance (mean [and 95% confidence interval]) when the processing of milk with average (AVE milk) or high (UFA milk) concentration of unsaturated fatty acids (UFA) was simulated in the presence (Premium) and absence (NoPremium) of a premium for milkfat UFA concentration.[1]

	AVE milk		UFA milk	
Physical performance				
Milk processed (l/year, millions)	70.66	[69.00 - 72.45]	72.04	[70.33 - 73.75]
Yield of dairy products (Tonnes/year, thousands)				
Skim-milk powder	5.09	[4.95 - 5.23]	5.33	[5.20 - 5.46]
Butter	3.57	[3.47 - 3.65]	3.47	[3.38 3.55]
g UFA/100 g fat	30.11[a]	[29.82 - 30.38]	38.78[b]	[38.41 - 39.14]
Butter milk powder	0.39	[0.38 - 0.40]	0.37	[0.36 - 0.38]
Casein	0.59[a]	[0.57 - 0.62]	0.49[b]	[0.46 - 0.51]
Whey powder	0.43[a]	[0.41 - 0.45]	0.35[b]	[0.33 – 0.37]
Financial performance (NZ $, millions) [1]				
Butter price (US $/t)				
NoPremium scenario	3,641		3,641	
Premium scenario	3,641[a]		4,833[b]	[4,746 - 4,926]
Revenue				
From sales of butter				
NoPremium scenario	18.10	[17.70 - 18.60]	17.57	[17.15 - 17.98]
Premium scenario	18.10[a]	[17.70 - 18.60]	23.36[b]	[22.95 – 23.82]
From sales of skim-milk powder	24.44	[23.79 - 25.10]	25.60	[24.96 - 26.33]
From sales of butter milk powder	1.56	[1.52 - 1.60]	1.49	[1.45 - 1.53]
From sales of casein	6.70[a]	[6.40 - 6.99]	5.45[b]	[5.16 - 5.73]
From sales of whey powder	0.71[a]	[0.67 - 0.74]	0.58[b]	[0.55 - 0.61]
Total revenue				
NoPremium scenario	51.34	[50.56 - 52.12]	50.68	[50.02 - 51.34]
Premium scenario	51.34[a]	[50.56 - 52.12]	56.31[b]	[55.55 - 56.99]
Expenses				
Volume costs	2.97	[2.90 - 3.04]	3.03	[2.95 - 3.10]
Product costs	2.72	[2.66 - 2.79]	2.70	[2.64 - 2.77]
Fixed costs	1.77	[1.72 - 1.81]	1.77	[1.73 - 1.81]
Capital costs	4.93	[4.81 - 5.05]	5.03	[4.91 - 5.14]
Total expenses	12.40	[12.09 - 12.70]	12.52	[12.23 - 12.82]
Aggregate payment for milk				
NoPremium scenario	38.95	[38.18 - 39.55]	38.16	[37.47 - 38.84]
Premium scenario	38.95[a]	[38.18 - 39.55]	43.79[b]	[43.05 - 44.43]

[ab] Within a row, means with different letters are significantly different (P<0.05).
[1]Dairy processor financial performance is reported in NZ $, with the exception of butter price which is given in US dollars.

Financial characteristics of dairy farms

In the NoPremium scenario, per hectare, there was no difference in milk income, stock income, other income and gross farm income between UFA farms and AVE farms (Table 4). In the Premium scenario, the milk income ($/ha) and gross farm income ($/ha) of UFA farms were 12% and 11% higher (P<0.05), respectively, than those of AVE farms (Table 4). Per hectare, UFA farms had 56% higher (P<0.05) feed expenses and 17% higher (P<0.05) farm expenses than AVE farms. In the NoPremium scenario, the operating profit ($/ha) of UFA farms was 40% lower (P<0.05) than that of AVE farms, but in the Premium scenario there was no difference in operating profit between UFA farms and AVE farms.

Discussion

The results concerning milk production and composition per cow (Table 1) in this simulation study replicated the results from the field studies used to derive the matrix for the simulation of oilseed supplementation. Oilseed supplementation did not affect cow liveweight and the yields of milk, milkfat and protein, but significantly reduced the concentrations of milkfat and protein, and increased the milkfat UFA concentration (Bobe et al. 2007; Lerch et al. 2012; Oeffner et al. 2013). However, some studies have reported a significant increase (Thomson & MacGibbon 2000), or decrease (Nicolae et al. 2011), in milk, milkfat or protein yields, when dairy cows were fed oilseed supplements.

Table 3 Value (mean [and 95% confidence interval]) of milkfat, protein, milk volume and concentration of unsaturated fatty acids (UFA) in milkfat, when simulated AVE milk and UFA milk were processed in the presence (Premium scenario) and absence (NoPremium scenario) of a premium for milkfat UFA concentration.

	AVE milk		UFA milk	
Milk processed				
Milk processed (l, millions)	70.66	[69.00 - 72.43]	72.04	[70.33 - 73.75]
Milkfat processed (kg, millions)	3.04	[2.97 - 3.13]	2.96	[2.89 - 3.03]
Protein processed (kg, millions)	2.53	[2.47 - 2.60]	2.48	[2.42 - 2.54]
Milksolids processed (kg, millions)	5.57	[5.46 - 5.72]	5.45	[5.32 - 5.57]
$UFA_{0.1g}$ (0.1 g UFA, millions) [1]	0[a]		3.79[b]	[2.71 - 4.78]
Value of milk components				
Aggregate payment for milk ($, millions)				
NoPremium scenario	38.95[a]	[38.18 - 39.55]	38.16[a]	[37.47 - 38.84]
Premium scenario	38.95[a]	[38.18 - 39.55]	43.79[b]	[43.05 - 44.43]
Milksolids payout ($/kg)				
NoPremium scenario	6.99[a]	[6.98 - 7.01]	7.00[a]	[6.99 - 7.02]
Premium scenario	6.99[a]	[6.98 - 7.01]	8.03[b]	[8.02 - 8.05]
Milkfat value ($/kg)	4.63	[4.63 - 4.64]	4.65	[4.64 - 4.65]
Protein value ($/kg)	10.98[a]	[10.97 - 11.00]	11.04[b]	[11.02 - 11.05]
Volume value ($/L)	-0.042	[-0.042 - 0.042]	-0.042	[-0.042 - -0.042]
UFA value ($/0.1 g UFA/kg milkfat)				
NoPremium scenario	0		0	
Premium scenario	0[a]		0.15[b]	[0.13 – 0.16]

[ab] Within a row, means with different letters are significantly different (P<0.05).
[1] Total 0.1 g UFA/100 g milkfat (above 37.50 g UFA/100 g milkfat) in milkfat processed = (UFA concentration in milkfat processed - 37.50 g UFA/100 g milkfat) × kg milkfat processed ×10.

Table 4 Financial characteristics (mean [and 95% confidence interval]) of simulated dairy farms that produce milk with average (AVE farms) or high (UFA farms) concentration of unsaturated fatty acids (UFA) in milkfat, in the presence (Premium scenario) and absence (NoPremium scenario) of a premium for milkfat UFA concentration.[1]

	AVE milk		UFA milk	
Farm income ($/ha)				
Milk income				
NoPremium scenario	6,492	[6,338 - 6,641]	6,359	[6,235 - 6,484]
Premium scenario	6,492[a]	[6,338 - 6,641]	7,299[b]	[7,149 - 7,442]
Stock income	500	[490 - 509]	495	[486 - 504]
Other income	46		46	
Gross farm income				
NoPremium scenario	7,037	[6,886 - 7,184]	6,901	[6,775 - 7,026]
Premium scenario	7,037[a]	[6,886 - 7,184]	7,839[b]	[7,697 - 7,969]
Farm expenses ($/ha)				
Marginal expenses	3,215		3,215	
Feed expenses	1,447[a]	[1,403 - 1,493]	2,256[b]	[2,219 - 2,297]
Total expenses	4,662[a]	[4,618 - 4,708]	5,470[b]	[5,426 - 5,516]
Operating profit ($/ha)				
NoPremium scenario	2,375[a]	[2,270 - 2,496]	1,432[b]	[1,338 - 1,531]
Premium scenario	2,375	[2,270 - 2,496]	2,369	[2,273 - 2,474]

[ab] Within a row, means with different letters are significantly different (P<0.05).
[1] Milk payment for AVE farms: $4.63/kg milkfat + $10.98/kg protein + - $0.042/L milk + UFA premium. Milk payment for UFA farms = $4.65/kg milkfat + $11.04/kg protein + $0.042/L milk + UFA premium. UFA premium ($/kg milkfat) for each 0.1 g UFA/100 g milkfat increase above 37.50 g/100 g milkfat: NoPremium = 0, Premium = $0.15.

The premium price of UFA butter in the Premium scenario was 32.7% higher than that of standard butter. In New Zealand, up to 100% difference in price between standard butter and value-added butter has been reported (Brown 2013). In the NoPremium scenario, although UFA farms and AVE farms were not different in gross farm income ($/ha), the use of oilseed supplements significantly increased feed expenses on UFA farms and reduced their operating profit by $943/ha compared to AVE farms.

In the Premium scenario, the inclusion of a premium ($0.15/kg milkfat) for each 0.1g/100g milkfat increase in UFA above 37.50 g UFA/100 g milkfat resulted in UFA farms having significantly higher milk income ($/ha) and gross farm income ($/ha) than AVE farms, but similar operating profit ($/ha) to AVE farms (Table 4).

The present study enabled, via simulation, the quantification of the physical and financial effects of the use of an oilseed supplement on-farm. However, caution should be taken when generalising the results from this study as the results described are specific to the conditions and assumptions described in the present study (but model inputs could be altered to investigate other scenarios). Also, other factors related to oilseed supplementation (e.g., type of oilseed supplement, method of feeding, increase in milk trans fatty acids, the cost of storage and feeding of the oilseed supplement) were not considered in the present study. Further studies are needed to determine the value of the premium for milkfat UFA concentration that could motivate dairy farmers to alter their farm system to produce milk with a high concentration of UFA and to cover other dairy processor costs involved with specific UFA butter marketing and brand development.

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