

SELECTED VARIATIONS IN MANAGEMENT OF U.S. DAIRY PRODUCTION SYSTEMS: IMPLICATIONS FOR WHOLE FARM GREENHOUSE GAS EMISSIONS AND ECONOMIC RETURNS

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ABSTRACT

Selection among the many options to reduce greenhouse gas (GHG) emissions must consider the consortium of direct and collateral effects on supply of food, fiber, quality of environments, and economic viability. This paper summarizes GHG emissions (as CO₂ equivalents) and economic return for representative U.S. dairy production systems and examines selected emission reduction possibilities. The resource inputs, product and emission outputs using a 'whole farm' approach evaluate primary source strengths of methane, nitrous oxide, fuel carbon dioxide, and soil carbon from both current management practices and management alternatives to explore tradeoffs in GHG emissions with profitability. Dairy system simulations in California and Wisconsin based on state, federal, and industry data generated CO₂eq emissions of 1072 and 834 t per 100 cows annually. The emissions equated to 1.21 and 1.14 kg/kg of milk, or 38 and 104 kg/\$1 of profit. Increasing the annual average milk production per cow by selection or by use of hormonal treatment (bST) increased herd GHG but decreased GHG/milk approximately 5% for each 10% increase in milk yield. Profit change per t of GHG change increased twice as much when milk yield increased through simulated response to selection as compared to the response to bST use. Reducing culling rate by 10 units decreased GHG emissions by 5% and increased profit \$88/t GHG decrease, another win, win. GHG emissions decreased approximately linearly by decreasing herd size but with decreased \$ profits of \$113/t GHG saved. Switching the California system from dry lot to anaerobic lagoon disposal of manure markedly increased manure methane, 1.9X, but decreased nitrous oxide emissions. Overall emissions increase ~ 10%, along with an increased cost, a lose, lose proposition. The use of intensive grazing, where applicable, is expected to increase N fertilization/ha, excess dietary-N, and pasture quality and yield, but decrease feed requirements and GHG/milk as well as being cost negative, (-\$253/t). These results illustrate some of the many tradeoffs in gas source and profitability that result from management changes.

INTRODUCTION

Next to domestic beef cattle, the dairy cow sector is the largest contributor of livestock system greenhouse gases (GHG). A series of linked spreadsheets were developed to estimate the GHG emissions and profitability of two disparate U.S. dairy operations, representative of prominent production systems. The objectives of this phase of the project were to: 1) sum the total whole enterprise emissions per product and profit and 2) determine the changes in GHG/milk and GHG/profit resulting from imposed changes in management strategies.

MATERIALS AND METHODS

Linked spreadsheets describe dairy enterprise GHG related inputs and outputs to the farm gate (Phetteplace et al., 2001). The 'whole-farm' simulations estimate CH₄, N₂O, and CO₂ emissions from cattle enteric sources, from their manure storage and disposal, from crop production and fertilization of their feedstuffs, transportation, processing, etc., as well as annual economic returns. The simulations represent average production and management practices, termed 'conventional' of two different but prominent systems in the U.S. (California and Wisconsin), with budgetary data from 1997. Revenues were those from sale of cull cows and bulls, week-old calves and all milk produced. Information sources were similar to those described for beef systems (Johnson et al., 2003a) but also included the California Department of Food and Agriculture (1998), NRC (1989) and USDA (1997).

Important variations in the two systems (Table 1) showed the CA cows to be 45 kg heavier, produce 1800 kg more milk/yr, never on pasture, and to use anaerobic lagoons for 50% of manure handling. Calving rate (93%) and calving interval (13 mo) were similar. The methodology for determining the amount of feedstuffs, correction for byproduct feeds, CH₄/feed, N₂O/N fertilizer and manure-N, and fuel CO₂ was as previously described in Johnson et al. (2003a). Manure CH₄ followed IPCC (2001) procedures. In warmer climates more of the manure volatile solids are converted to methane. California, a 'temperate' climate, has a 50% larger methane conversion factor compared to Wisconsin with a 'cool' climate.

Five different management scenarios were compared to each conventional dairy system. These were 1) use of bovine somatotropin ('bST') to increase milk production; 2) increasing milk production by 20% through genetic selection 'Milk +20%'; 3) decreasing culling by 10 units 'Cull -10', 4) reducing herd size by 20% ('Herd -20%'); or 5) use of 100% anaerobic lagoon manure (AL) management ('AL 100%') for non-pasture excretions. No expenses were assigned to manure management practices due to difficulty in obtaining reliable estimates. A sixth management scenario of intensive grazing (IG) was imposed in the Wisconsin dairy simulation. Pasture productivity was assumed to increase 50% and harvest fraction was assumed to increase 10 units while N fertilization requirements increased by 20%. Nutritionally, the IG pasture averaged 5% more TDN and almost 20% more crude protein than the conventional pastures. Lactating cows on IG pasture were assumed to produce the same amount of milk as the conventional herd

RESULTS AND DISCUSSION

The conventional dairy operations produced from approximately 800 to 1100 t of GHG as CO₂eq per 100-cow herd (Table 2). Expressed per unit of milk, the systems produced 1.14 and 1.21 kg GHG/kg. Higher total emissions are largely a reflection of AL use, and increased productivity, while higher GHG/milk largely reflect lower milk yield per cow. The emissions arise roughly equally from CH₄, N₂O, and CO₂, except when extensive AL CH₄ adds to this category.

Increasing milk productivity through bST or genetic selection resulted in greater feedstuff inputs, particularly grains and protein feeds, thus an additional 10% more cropland along with small increases in land for forage. Nevertheless, increased milk/cow resulted in the expected decrease in GHG/kg milk. Each 10% increased productivity/cow decreased GHG/milk by 5 to 6%. Reduction in culling rate by 10 percentage units was also effective in decreasing land, fuel, and feed resource inputs, although this evaluation did not attempt to evaluate impacts of less genetic progress in selection for milk yield.

Lower emissions due to decreased pasture forage and ha required along with improved C-sequestrations with the IG adaptation to the Wisconsin system more than offset the emissions from increased N-fertilizer and excess diet N when compared to the conventional system. The GHG/milk declined by 18%. Maximizing IG quadrupled the amount of carbon sequestration contributing to a large decrease in net GHG emissions for these scenarios. However, IG is not applicable to all production systems. In addition to the climate, rainfall limitations noted for beef cattle, high producing dairy cows face additional problems. Some authors have noted a reduction in milk productivity with IG particularly if pasture quality was compromised (Fink et al., 1933; Hlubik, 1988) or if fed as the only diet to high producing cows, e.g., > 30 kg/d, (Kolver and Muller, 1998).

Net CO₂eq emissions per unit milk were reduced for all management comparisons except '100% AL' (Table 2). Converting from 'dry lot' to a 100% AL manure management system nearly doubling the manure CH₄ emissions in the temperate climate of California but decreased N₂O emissions, offsetting about 1/3 of the CH₄ increase. Overall the AL system produced approximately 10% more CO₂eq/milk. Similar responses to changing management scenarios were noted in recent Colorado dairy simulations (Johnson et al., 2003b).

Profit or loss varied greatly depending on management practices and expense of feedstuffs (Table 2). Improving milk production/cow was the most profitable of scenarios tested. Profits/herd increasing by 2X to 4X in these simulations in response to 20% more milk reflecting the strong 'dilution of maintenance' effects on profit, paralleling responses noted for GHG/product. It is interesting to note that if the cows in the two locations produce the same amount of milk per cow the Wisconsin herd would be more profitable, illustrated by 'Milk+20%' simulation. Also illustrated by this simulation is that utilizing genetic selection to increase milk production will be nearly twice as profitable as to increase milk production with hormonal injections via bST. The next best response in profit came from the use of IG in the Wisconsin simulation. Improved profitability during IG was primarily due to a reduction in total feed costs. Economic benefits of IG vary depending on many factors including quality and yield of pasture, climate, rainfall, stocking rate, etc.

Computer spreadsheet models have shown break-even points with IG use in dairy herds (Parker et al., 1992). Production costs were reduced by \$1.56/45.4 kg milk using IG pastures in fifteen small New York State dairies, however the benefits could easily be removed by insufficient pasture for the entire grazing season (Emmick & Toomer, 1991). Limitations on cow productivity as mentioned previously, must also be considered. Reducing the culling rate by 10 units resulted in greater profit per herd, primarily by reducing the expense of raising replacement heifers. Income from milk remained the same while income from cull cattle and calves was reduced. Please note that no profit data are presented for 100%AL systems. To date we have not developed cost differentials we are comfortable with and have chosen to leave this task to another day or another group to assigned capital costs, revenue, or energy credits to these manure management systems.

DIFFERENTIALS IN \$PROFIT AND GHG

Expressing profit per unit of GHG emissions (\$/t) presents a comparison that is numerically and relatively similar to the \$ profit/herd (Table 2). The profit per ton of GHG emissions was \$10 and \$26 for typical management of these two production systems. Altering management scenarios ranged from -\$20 to \$50/t GHG largely reflecting the impacts of changing cow productivity and the high cost of reducing herd size as described above.

The presentation of the response to management as changes in \$ and GHG when compared to 'conventional' is informative. Again the most positive responders were increased milk/cow with added profits of around \$400 per each ton of increase in GHG emissions. On the flip side, reducing the herd size decreased profitability approximately \$110 for every t of CO₂eq saved. Two of the scenario changes from conventional, reduced culling and IG, are indicated to give negative \$/t values. This is because they increase profit and simultaneously decrease emissions, very desirable responses. Implementation of IG on Wisconsin dairies is suggested to earn \$253 for each of the 107 t of GHG emissions saved. Again we must keep in mind limitations in practical application of IG or other scenarios. Also, the IG response assumes a healthy, however impermanent, C-sequestration. The AL manure management systems are unfortunately not thoroughly examined in this comparison but their importance can be surmised, including their role as alternative energy sources.

CONCLUSION

Management decisions can impact both GHG emissions and profitability of dairy production systems. Simulations of U.S. dairy production systems indicate that improving production efficiency through genetics or bST decreases GHG emissions/product and improves profitability. Where applicable, IG could also reduce GHG emissions and improve profitability. These whole-farm simulations are a tool to evaluate various GHG mitigation options and their impact on profitability. Most importantly, this exercise illustrates the importance of 'whole system' comparisons including evaluation of the multitude of 'tradeoffs' between GHG sources, sinks and economic returns.

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Table 1. Characteristics of simulated U.S. dairy production systems, 100 lactating cows/herd^a.

Characteristic	California:						Wisconsin:						
	Conv ^a	bST	Milk +20%	Cull -10	Herd -20%	AL 100%	Conv	bST	Milk +20 %	Cull -10	Herd -20%	AL 100%	IG
Cow weight, kg	635	635	635	635	635	635	590	590	590	590	590	590	590
Total animals, hd	167	167	167	167	134	167	180	180	180	160	144	180	180
Replacement, %	33	33	33	23	33	33	40	40	40	30	40	40	40
Calving rate, %	93	93	93	93	93	93	93	93	93	93	93	93	93
Calf mortality, %	9.1	9.1	9.1	9.1	9.1	9.1	10.8	10.8	10.8	10.8	10.8	10.8	10.8
Adult mortality, %	5.0	5.0	5.0	5.0	5.0	5.0	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Live weight sold, t	20.2	20.2	20.2	15.5	16.2	20.2	22.0	22.0	22.0	17.5	17.6	22.0	22.0
Milk sold, t/herd	887	976	1064	886	710	887	712	801	854	712	570	712	712
Pasture, %	0	0	0	0	0	0	31	31	31	31	31	31	57
Other forage, %	43	40	39	42	43	43	30	28	27	30	30	30	15
Total ha/herd	102	111	117	98	82	102	147	154	159	140	119	147	117
N, syn., 10 ³ kg	9.3	9.4	9.6	8.8	7.4	9.3	4.4	4.9	5.1	4.3	3.6	4.4	3.5
Fuel, herd, 10 ³ l	33.1	35.4	37.1	31.8	26.5	33.1	28.8	31.6	33.5	28.3	23.0	28.8	25.0
Manure-graze, %	0	0	0	0	0	0	42	42	42	42	42	42	58
-An. lagoon, %	50	50	50	50	50	100	3	3	3	3	3	58	3

^a'Conv' equals conventional dairy system, bST=Bovine somatotropin, AL=anaerobic lagoon.

Table 2. Annual dairy GHG emissions (CO₂eq/100 cow herd) and profit under conventional and altered management^a.

Source of GHG	California:						Wisconsin:						IG
	Conv	bST	Milk +20%	Cull – 10	Herd –20%	AL 100%	Conv	bST	Milk +20%	Cull – 10	Herd –20%	AL 100%	
Enteric CH ₄ , t	320	331	341	304	257	320	293	303	309	278	235	293	299
Manure CH ₄ , t	185	187	187	176	148	357	19	19	19	18	15	224	20
N ₂ O, t	326	332	341	308	261	261	262	275	281	245	210	239	262
CO ₂ , t	242	257	269	231	201	242	260	282	295	251	212	260	215
C-sequest., t	0	0	0	0	0	0	19.8	20.2	20.4	18.3	15.8	19.8	88.2
Net CO ₂ eq:													
t per herd	1072	1107	1138	1020	868	1181	815	859	884	774	655	998	708
kg/kg milk	1.21	1.13	1.07	1.15	1.22	1.33	1.14	1.07	1.03	1.09	1.15	1.40	0.99
Profit:													
\$ per herd, 10 ³	28	33	57	33	9	28	8	15	34	11	-13	8	34.8
\$ per t GHG	26	30	50	33	10	NA	10	17	39	14	-20	NA	49
Change from conv., d\$/dt		138	438	-97	93	0		158	387	-79	132	0	-253

a. Conv = Typical system in county, bST=bovine somatotrophin, AL=anaerobic lagoon.