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Toward a predictive model of supplementary feeding response from grazing dairy cows

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ABSTRACT

Many experiments have measured the responses of grazing dairy cows to supplementary feeds, but few have studied the reasons for the large differences in responses between experiments. Data derived from two trials, in which supplementary feeds of either maize grain or a nutritionally balancing ration were offered to cows in early, mid, and late lactation in each of spring, summer, autumn and winter, were used to calculate the marginal milksolids responses to supplements. The data set created was subject to multiple regression analysis in an attempt to quantify the effect of the different variables on the magnitude of the response to supplementary feeds. The factor that was of greatest importance was the relative feed deficit (RFD) of the cows measured by the reduction in milksolids yield (kg MS/cow/day) of the respective control groups that had occurred when the restricted feeding treatments had been imposed. Total marginal milksolids responses were greatest when severe feed restrictions, relative to current feed demand, resulted in large reductions in milksolids yield of the control groups. Total marginal milksolids response increased ($P < 0.01$) by 0.9g MS/MJME offered as supplement per 0.1 kg MS/cow/day RFD. Total marginal milksolids responses also declined ($P < 0.01$) by 0.2 g MS/MJME offered as supplement as pasture allowance increased by 10 MJME/cow/day.

Keywords: Dairy cows; grazing; supplementary feeding; response; model.

INTRODUCTION

Supplementary feeds should only be offered to grazing dairy cows when the value of any additional milk produced exceeds the total cost of purchasing, storing and feeding that supplement. For dairy farmers to gain maximum economic benefit from a limited quantity of feed, the supplement should be offered when the largest increase in milk yield will result. While the value of the milk and the cost of supplement are usually known in advance, experimental evidence of the response by pasture-fed cows to changes in feeding level has been not been sufficient to enable accurate response prediction (Penno, 2001).

In a review of pasture-based supplementary feeding trials published since 1978 (Penno, 2001) it was concluded that, although the average response to supplements was 58 g milk, 4.1 g milksolids, and 10.6 g live weight/megajoule of metabolisable energy (MJME) offered, the reported data were extremely variable. These published values generally referred only to the immediate milk-yield response, measured during the period of supplementary feeding. However, it is well known that the increase in body reserves and milk yield that results from an increase in feeding level often continues to affect milksolids yield for a period after the increase in feeding has finished (Broster & Broster, 1984). Additional milk that is produced after the period of supplementary feeding has been defined as the residual response or the carryover effect (Kellaway & Porta, 1993). Therefore, the immediate milk yield response reported from the majority of experiments generally underestimates the total response from supplementary feeding.

Two series of trials were conducted to determine the effect of stage of lactation and season of the year on the response of dairy cows grazing restricted amounts of pasture to rolled maize grain (MG) or nutritionally balancing (BR) supplementary feeds (Penno, 2001). This paper reports calculations made on the data from these trials to determine the factors affecting the magnitude of the immediate and total milksolids response to supplementary feeds in an

attempt to develop a predictive model. The model derived is used to consider sources of variation in some previously published results.

MATERIALS AND METHODS

Experimental design.

Details of the site, cows, experimental design, and feeding treatments have been described by Penno (2001). Two supplementary feeding experiments were conducted with cows in early, mid and late lactation at four times of the year. In trial one, cows at each stage of lactation were grazed on a restricted allowance of pasture (approximately 25 – 40 kg DM/cow/day) and offered pasture only or supplementary feeding treatments of 50 MJME/cow as either rolled maize grain or a nutritionally balancing ration. In trial two the same supplementary feeding treatments were offered, but at 80 MJME/cow/day. Each experimental period comprised a seven-day uniformity period, followed by a 35-day supplementary feeding period. After each supplementary feeding period cows were grazed, grouped by stage of lactation and offered a generous pasture allowance for a further 28 days to allow the measurement of any carryover effects.

Calculations.

Data for chemical composition of feed, dry matter intake (DMI), milk yield and composition, and liveweight change resulting from the treatments in each experimental period were presented by Penno (2001). Immediate milksolids responses were calculated as the predicted mean daily milksolids yield of each treatment group minus the predicted mean milksolids yield of the respective control group measured during each experimental period, divided by the daily metabolisable energy (ME) intake from supplementary feed (g MS/MJME). Carryover milksolids responses were calculated as mean daily milksolids yield of each early and mid lactation treatment group minus the average milksolids yield of the respective control group measured during the

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four weeks after the cessation of supplementary feeding, divided by the daily ME intake from supplementary feed during the preceding experimental period. Total milk solids responses were calculated for cows in early and mid lactation in the same way. The factor relative feed deficit (RFD) was calculated as the average milk solids yield of each control group measured during the pre-experimental uniformity week minus the average milk solids yield measured during the final three weeks of each experimental period. The factor “unsupplemented milk solids yield” was the average milk solids yield of each respective control groups during each respective experimental period.

Statistical analysis

The combined data from the two experiments were subject to multiple regression analysis using Data Desk 6.1 (Velleman, 1999). Combinations of factors were alternatively analysed to establish models of best fit to the calculated milk solids responses, as indicated by adjusted R^2 . Multiple regression equations are presented with standard errors and P values for each coefficient, adjusted R^2 and a residual standard deviation (rsd).

RESULTS

In the experimental data analysed, stage of lactation had no consistent effect on the magnitude of the immediate milk solids or liveweight gain response to the supplementary treatments (Penno, 2001). Offering supplements in spring generally resulted in smaller increases in milk solids and larger increases in liveweight gain than when supplements were offered during other seasons, although, once again, the pattern was inconsistent. Further, responses in milk solids yield to different forms of supplementary feed were similar, with the exception of improved responses resulting from protein-rich supplements that were offered during periods when the crude protein concentrations of the pasture were too low to sustain high milk solids yield. It was concluded that stage of lactation, season of the year and form of supplement are probably of smaller influence on the magnitude of milk solids yield response to supplementary feed than some other factors (Penno, 2001).

The relationship between the RFD and the subsequent immediate and total milk solids responses by individual

FIGURE 1: The effect of the decline in milk solids yield of the control herd as restricted pasture allowance treatments were imposed, on the immediate milk solids response to supplementary feeds.

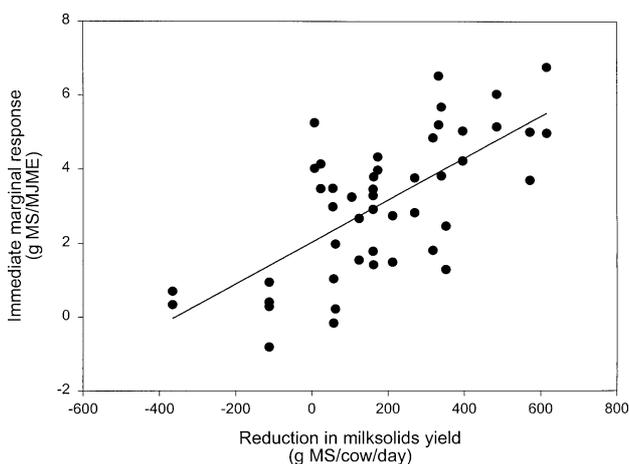
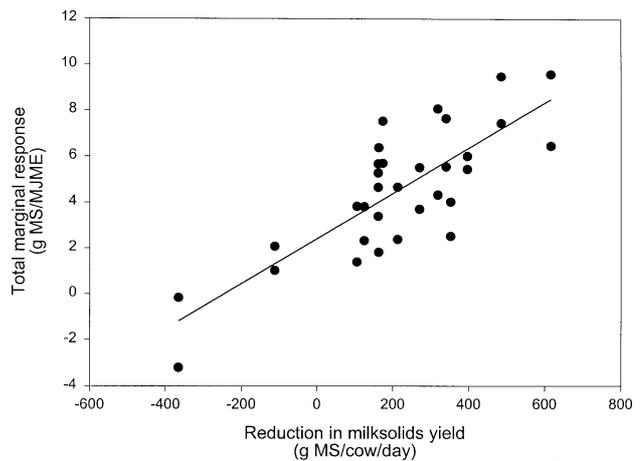


FIGURE 2: The effect of the decline in milk solids yield of the control herd as restricted pasture allowance treatments were imposed, on the total milk solids response to supplementary feeds.



experimental groups to supplementary feeds are shown in Figures 1 and 2, respectively. Tables 1 and 2 describe multiple regressions for the immediate and total milk solids responses, respectively.

Immediate and total milk solids responses to supplementary feeds increased as the decline in milk solids yield that occurred as the restricted feeding levels were imposed on the respective control groups increased ($P < 0.01$). The immediate and total milk solids response increased ($P < 0.05$) as the level of feeding of the unsupplemented cows decreased, as measured by unsupplemented milk solids yield (Table 1) or pasture allowance (Table 2). As the amount of supplement eaten increased, the immediate milk solids response decreased ($P < 0.01$), however, this relationship was not significant ($P > 0.10$) for total milk solids response. Immediate milk solids responses declined slightly ($P = 0.07$) as stage of lactation progressed (Table 1).

TABLE 1: The effect of the reduction in milk solids yield of unsupplemented cows immediately preceding supplementary feeding, the unsupplemented milk solids yield, supplement intake and stage of lactation during a period of supplementary feeding, on the immediate milk solids response to supplementary feeds (g MS/MJME).

Variable	Coefficient	s.e. of coefficient	P
Constant	11.1	1.87	***
Reduction in MS yield (kg/cow/day)	2.1	1.00	*
Unsupplemented MS yield (kg/cow/day)	-4.1	0.99	***
Supplement intake (MJME/cow/day)	-0.06	0.014	*
Stage of lactation (DIM)	-0.005	0.0029	0.07

Adjusted $R^2 = 68.8\%$; r.s.d. = 1.09.

DISCUSSION

Of all the variables analysed, the factor exerting the greatest influence on the marginal milk solids response to supplementary feeds was the reduction in milk solids yield that occurred as the restricted pasture allowance treatments were imposed. This provides a unifying measure of the level of underfeeding that was imposed on the unsupplemented comparison group. Therefore, a large reduction in milk solids yield was assumed to represent a large potential energy deficit.

The importance of the potential energy deficit in determining the response of dairy cows to increasing feeding levels has previously been discussed in concept (Oldham & Emmans, 1989; AFRC, 1998). The cow's potential feed deficit refers to the current feed demand of the animal, which is determined by genetic merit and physiological state (stage of lactation, growth and reproductive cycles) modified by recent nutritional history, minus the current feed supply. The assumption is made that if sub-optimal nutrition is imposed on the cow over a long period of time, energy output will reach equilibrium and a new, lower target milk yield will be derived, thereby gradually reducing feed demand and the potential energy deficit (Oldham & Emmans, 1989; AFRC, 1998).

During the experiments described by Penno (2001), the pasture allowance offered during the experimental periods represented a restriction relative to the pasture allowance offered up to and during the uniformity week. The severity of this feed restriction varied between experimental periods and, to a lesser degree, between cows at different stages of lactation. It has been assumed that the magnitude of the decline in milksolids yield that occurred as the feeding treatments were imposed, provides a measure of the severity of the feed restriction relative to current feed demand and, therefore, of the potential energy deficit for that particular treatment group. Thus, Figures 1 and 2 clearly demonstrate the association between potential energy deficit and the marginal immediate and total milksolids responses. The reduction in milksolids yield (as a measure of potential energy deficit) increased ($P < 0.01$) total marginal total milksolids responses by 9 g MS/MJME per 1.0 kg decline in milksolids yield (Table 2).

TABLE 2: The effect of reduction in milksolids yield of unsupplemented cows immediately preceding supplementary feeding, pasture allowance, supplement intake and stage of lactation during a period of supplementary feeding, on the total milksolids response to the supplementary feeds (g MS/MJME).

Variable	Coefficient	s.e. of coefficient	P
Constant	10.2	2.30	***
Reduction in MS yield (kg/cow/day)	9.1	1.18	***
Pasture allowance (MJME/cow/day)	-0.02	0.006	**
Supplement intake (MJME/cow/day)	-0.02	0.022	0.30
Stage of lactation (DIM)	0.007	0.005	0.17
Adjusted R ² = 79.4%; r.s.d. = 1.35.			

It has been demonstrated that the level of pasture feeding, as measured by pasture allowance, has a large influence over the extent to which cows substitute pasture for supplement. As pasture allowance is increased, pasture substitution increases such that a given amount of supplement has a smaller effect on the total intake of energy and nutrients (Grainger & Mathews, 1989). Both in early and late lactation, as feeding level increases, either as additional pasture or as higher allowances of supplementary feed, the response to each incremental unit of supplement decreases in both grazing (Robaina *et al.*, 1998) and indoor studies (Stockdale & Trigg, 1989). In the present data, this relationship was demonstrated as a reduction in the total milksolids response with increasing pasture allowance (Table 2).

As supplementary feeds are introduced, and energy intake is increased, a declining proportion of the addition

feed energy is partitioned toward milk production and an increasing proportion is partitioned toward increasing body reserves (Broster & Thomas, 1981). Thus, as the amount of supplement is increased at a given pasture allowance or intake, the marginal milksolids response declines (Stockdale *et al.*, 1987, Stockdale & Trigg, 1989, Robaina *et al.*, 1998). In the present data, this is demonstrated in a 0.05 g MS/MJME decline ($P < 0.01$) in marginal immediate response per 1 MJ increase in supplementary feed intake (Table 1). However, it is interesting to note that the effect of supplementary feed intake on total marginal milksolids response was not significant ($P > 0.30$). It could be assumed that, although increasing supplementary feed intake reduced the immediate milksolids response, it resulted in larger deposits of body reserves at the end of the supplementary feeding period that subsequently resulted in larger carryover effects and similar total marginal milksolids responses.

The factors considered by the multiple regression equations contained in Tables 1 and 2, calculated from some recent grazing experiments, are presented in Table 3. One data point from Stockdale & Trigg (1985) was excluded as the immediate milksolids response was two fold greater than any other data points in the published data (Table 3), and two fold greater than the immediate milksolids response in the present data set from which the models were derived. Using the data presented in Table 3, the model presented in Table 1 under-predicted ($P < 0.05$) the immediate milksolids responses calculated from the published values by 0.9 (± 0.29) g MS/MJME (Figure 3). As would be expected, the model presented in Table 2 generally predicted larger total milksolids responses than the immediate milksolids responses calculated from the published values (Figure 4).

Given the wide range of experimental techniques used, and conditions under which these experiments have been undertaken, the model of immediate milksolids yield responses closely predicted the results of the published work. This suggests that the factors considered by the model, particularly the decline in milksolids yield, the unsupplemented milksolids yield, and the amount of

FIGURE 3: A comparison of the predicted immediate milksolids response using the model presented in Table 1, and the immediate milksolids response calculated from the published values of some recent experiments (Table 3).

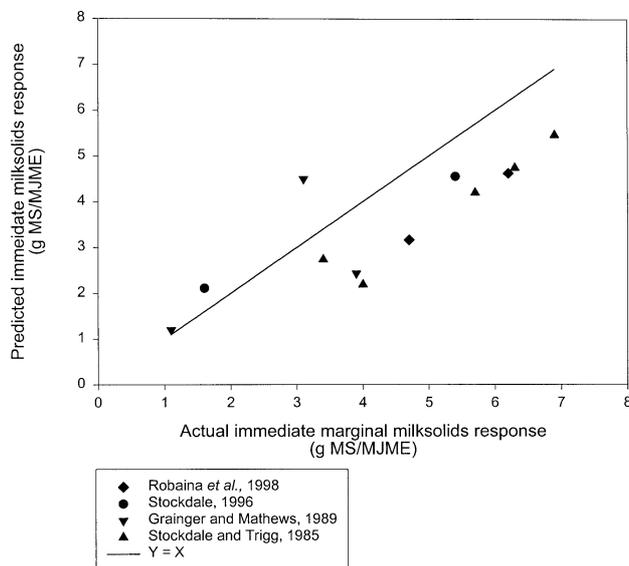
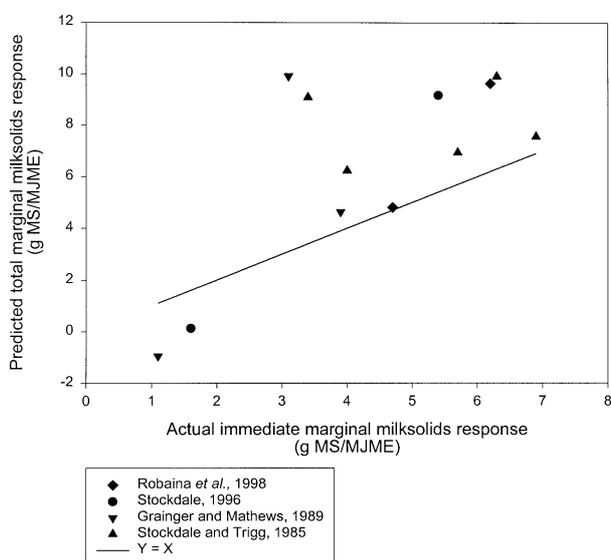


TABLE 3: Data from recently published experiments for the factors used by the models shown in Tables 1 and 2 to predict the immediate marginal milksolids response shown in Figure 3, and the total marginal milksolids response shown in Figure 4.

Reference	Stage of lactation (DIM)	Control MS yiewld (kg/c/d)	Reduction in MS yield (kd/c/d)	Pasture allowance (MFME/c/d)	Supplement intaske (MJME/c/d)	Reported immediate response (g MS/MJME)
Robainia et al., 1998	200	1.03	0.27	421	55	4.7
	200	0.79	0.51	281	55	6.2
Stockdale, 1996	213	0.75	0.34	233	52	5.4
	213	1.15	-0.06	520	52	1.6
Grainger & Mathews, 1989	21	1.18	0.24	94	37	3.1
	21	1.52	-0.09	211	37	3.9
	21	1.72	-0.29	410	37	1.1
Stockdale & Trigg, 1985	240	0.68	0.19	140	46	6.3
	240	0.68	0.19	143	81	3.4
	240	0.78	0.09	242	23	6.9
	240	0.78	0.09	250	45	5.7
	240	0.78	0.09	247	79	4.0

FIGURE 4: A comparison of the predicted total milksolids response using the model presented in Table 2, and the immediate milksolids response calculated from the published values of some recent experiments (Table 3).



supplement offered may account for a high degree of the variation between the variation of published results. Insufficient data is available to test the model's prediction of total milksolids yield, however, it does indicate that the immediate effects published for many experiments underestimate the total response. If this model proves to be accurate, it suggests that the level of feeding of experimental treatments, relative to the level of feeding immediately before treatments have been imposed, is an important factor in determining the milksolids response to supplementary feeds. This is of particular significance for the planning of supplementary feeding experiments and comparing the results of different experiments.

In a practical context, the model may provide a framework to enable farmers to predict the total milksolids responses using RFD, pasture and supplementary feed allowance, and stage of lactation as a basis for determining the probable total responses in milksolids yield. Large total milksolids responses can be expected when (in order of importance): 1) The basal level of feeding has been high but is declining, and at the time of supplementary feeding

will be insufficient to maintain current milksolids yields, 2) the herd will be offered a low pasture allowance, and 3) a small amount of supplement is to be offered.

CONCLUSIONS

These data suggest that the magnitude of the total milksolids response can largely be predicted by the magnitude of the potential energy deficit, as indicated as recent change in daily milksolids yield and the ME allowance from pasture and supplement. These are all factors which can be estimated by farmers in advance of supplementary feeding decisions and they may provide the basis for a tool to allow the milksolids responses of grazing dairy cows to supplements to be predicted more accurately. Irrespective of season of the year and stage of lactation, the largest total milksolids responses are likely to occur during periods when cows have suffered a sudden decline in pasture allowance and when small quantities of supplementary feed are offered.

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