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Milk production response to replacement of carbohydrate with lipid and the addition of ruminally protected protein

N.A. THOMSON

Dairying Research Corporation, Private Bag 3123, Hamilton

ABSTRACT

Cows grazing a restricted pasture allowance of 25 kg DM/cow/day during November (75 days in milk) were offered five supplementary feeds in a factorial experiment. The supplements were iso-energetic supplying an additional 68 MJME/cow/day but varied in whether the energy source was lipid or carbohydrate (rapeseed vs. maize), crushed or whole rapeseed (crude protein (CP), 20.6%), or with and without ruminally protected protein (formaldehyde treated sunflower meal, 37.8% CP). The CP contents of the pasture and the maize supplement were 14.7% and 9% respectively giving an average CP of the feed consumed of 13%. Cows on the control treatment supplemented with maize grain produced means of 10.5 l/d of milk, 0.61 kg/d of fat, 0.43 kg/d of protein and 1.03 kg/d of milksolids. Partial replacement of maize with 20 MJME/cow/day of rapeseed (CP of supplement, 11.8%) increased daily milk (9.3%), fat (8.6%), protein (4.4%) and milksolids (6.9%) yields. Crushed rapeseed resulted in twice the yield increase as whole rapeseed. Additional replacement of maize with 13 MJME/cow/day of ruminally protected protein (CP of supplement, 18.3%) resulted in further increases of 15.9%, 16%, 17.4% and 16.8% for milk, fat, protein and milksolids yields respectively. The response to ruminally protected protein was greater when incorporated with maize/crushed rapeseed than maize/whole rapeseed. Crushed rapeseed depressed fat and protein content in milk. Other supplements had no effect on fat, protein or lactose contents. Replacement of maize with crushed rapeseed and ruminally protected protein increased yields of milk (36.1%), fat (32.9%), protein (23.5%) and milksolids (31.8%) compared to maize alone. For cows 75 days in milk the result demonstrated that a dairy ration comprising 13-14% CP provided insufficient protein to sustain full milk production.

Keywords: Dairying; milk yield; milk composition; lipid supplementation; carbohydrate and protein supplementation.

INTRODUCTION

Feeding rapeseed (Murphy *et al*., 1995 a & b) can modify the fatty acid profile (FAP) of milkfat. The resultant changes, a reduction in the shorter chain (C10:0 to C16:0) and an increase in the unsaturated longer chain (C18:1-C18:3) fatty acids, are associated with a decrease in the solid fat content (SFC) of milkfat. With the changes in the FAP there is an improvement in the spreadability of butter processed from such milk (Murphy *et al.,* 1990; MacGibbon & McLennan, 1987). Trial work at DRC in 1995 (Thomson unpublished) showed similar changes in FAP to those reported through feeding crushed rapeseed. Associated with feeding crushed rapeseed to cows fed ad libitum on pasture, were an increase in milk yield and a reduction in milkfat and protein concentrations. This resulted in a minimal increase in milksolids yield. The decrease in protein content through feeding oilseeds is consistent with many trials (Wu & Huber, 1994) but the literature shows variable effects on fat content (Wu *et al.,* 1993; Cant *et al*., 1993; Harrison *et al*., 1995).

The effect of feeding oilseed on milkfat concentration appears to be dependent on the degree of rumen protection or the degree of saturation of the supplemented fat (Pantoja, 1996). The hypothesis is that free lipid in the rumen reduces cellulase activity thus reducing fibre digestion and acetate production. As a result there is less acetate available for de novo synthesis and a decline in milkfat content. As the level of unsaturation of the dietary fat increases the depressing effect on milkfat concentration increases (Pantoja, 1996). This suggests that rumen protection would be of greater importance in maintaining milkfat concentration when feeding oilseeds high in unsaturated fat rather than fats such as tallow with a high degree of saturation.

The cause of the decline in protein content could be due to a number of factors. When fats are fed there is a decline in both dry matter intake (DMI) and in propionic acid production Khorasani *et al.*, (1992). This could result in an increased utilisation of plasma amino acids for gluconeoneogenesis, thereby reducing the amino acid supply for milk protein synthesis. When cows on high fat diets were fed ruminally-protected methionine and lysine (Canale *et a*l., 1990) or abomasal infused casein (Cant *et al*., 1993) increases in milk protein concentration occurred.

This trial tested the hypothesis that the adverse effects on milk composition resulting from feeding high fat diets can be overcome by:

- protection of the fat against bio-hydrogenation in the rumen
- more ruminally protected protein
- increased readily available carbohydrate to increase propionic acid production.

METHOD

An iso-energetic supplement (65 MJME/cow/day) combining rapeseed, maize meal and a ruminally protected protein supplement (By-Pass P™) was fed to July/August calving Friesian cows during November and December 1997. There were five treatments with each treatment comprising 10 cows balanced for milk yield, milk composition,

live weight age and calving date. The treatments were:
Control (C); Pasture + 4.7 kg maize meal/cow/day
Whole rapeseed (WR); Pasture + 1.8 kg whole rapeseed + 2.2 kg maize meal
Crushed rapeseed (CR); Pasture + 1.8 kg crushed rapeseed + 2.2 kg maize meal
WR with protein (WRP); Pasture + 1.2 kg whole rapeseed + 1.2 kg maize meal + 1 kg By-Pass P™
CR with protein (CRP); Pasture + 1.2 kg crushed rapeseed + 1.2 kg maize meal + 1 kg By-Pass P™

The trial ran for four weeks with the first week being the preliminary period when all cows were grazed as a herd on an ad libitum pasture allowance (>40 kg DM/cow/day). During the three week experimental period the trial herd was offered a restricted pasture allowance (25 kg DM/cow/day) and fed the respective supplements in individual stalls at 0800 hours.

Measurements

Cow live weight and body condition score was assessed over two consecutive days during the preliminary period and at the end of the experimental period.

During the preliminary and experimental period milk yields were recorded weekly from each cow using in-line milk meters (True-Test Ltd., Auckland, New Zealand) and samples of daily milk analysed for concentrations of fat, protein and lactose (Milkoscan 133B; Foss Electric, Hollered, Denmark).

The herbage mass of the next two paddocks to be grazed and the last two paddocks grazed were measured three times a week during the experimental period using the rising plate meter and taking 80 measurements of each grazing area. Herbage mass (kg DM/ha) was calculated from plate meter readings using the mid-spring equation of L'Huillier & Thomson (1988). At each measurement of a pre-grazed paddock, a pasture sample was collected (cutting to grazing height using hand shears). Pasture samples and samples of the three supplements were each bulked weekly during the experimental period and analysed for organic matter (OM), *in vitro* digestibility, neutral detergent fibre (NDF) and total nitrogen (N). OM content of pasture and supplements was determined by the method of the AOAC (1984), *in vitro* digestibility (DOM) by the method of Tilly & Terry (1963) and NDF by the method of Goering & Van Soest (1970). The fatty acid profile (FAP) of feed was analysed by the method of Garces & Mancha (1993) and total fat determined from total peak area.

Blood samples were collected from the coccygeal vein of each cow at 0700 hrs on the final day of the experiment for analysis of β-hydroxy butyric acid (BHBA), glucose, urea, albumin and non-esterified fatty acids (NEFA) in blood serum. The Ruakura Animal Health Laboratory (RAHL) analysed the metabolites using reagent kits (Boehringer Mannheim; Auckland, New Zealand) and a Hitachi 717 auto-analyser. The normal range provided by RAHL was used to compare values.

Statistical analyses

The trial was a 2x2+1 design, analysed by analyses of covariance (Genstat 5, Rothamsted) using as the covariate, the milk yield, milk composition, live weight and body condition score recorded during the preliminary period. The caparisons made included: the form of supplement (maize vs. average of all rapeseed treatments), the type of rapeseed (crushed or whole) and the effect of protein (rapeseed with or without protein). The interaction taking account of the type of rapeseed and the addition of protein was also examined.

RESULTS

Feed

The pre-grazing herbage mass levels during the experimental period averaged 3880 ± 420 kg DM/ha, the post grazing 2550 ± 80 kg DM/ha with an average rate of DM disappearance of 7 ± 0.7 kg DM/cow/day.

The total N content of pasture recorded during the experimental period (Table 1) was low (2.25%) compared to the level of 3.1% or greater expected for the November/December period (Hutton, 1962).

Table 1: Chemical composition (%) of pasture and supplements.

	Gross feed composition				Major fatty acids (% of total fat)		
	DOM	NDF	Total N	Fat	C18:1	C18:2	C18:3
Pasture	75.5	53.5	2.35	3.22	2.4	14.8	50.5
Rapeseed	59	22.4	3.37	42.1	63.3	18.9	9.6
Maize	95.7	42.2	1.44	4.8	25.5	55.6	2.3
By-Pass P	58.8	34.9	6.04	3.8	43.6	30.0	2.2

Milk yield increased with replacement of maize meal with rapeseed and with protein meal (Table 2). The increase was greater for the CR then the WR treatment. Within the rapeseed preparations, milk yield increased by a similar amount with the addition of protein. Milk composition was influenced by the formulation of the supplement. CR depressed fat% and protein% and the addition of protein restored protein% but had no effect on fat%. Liveweight increased with feeding CR and with the addition of protein to WR and CR.

TABLE 2: Effect of supplement on milk yield, milk composition and liveweight change.

Treatment	MY	Fat%	Fat Y (kg/c/d)	Prot.%	Prot. Y (kg/c/d)	MS Y (kg/c/d)	LWt (kg)	CS
C	10.54	5.91	0.61	4.08	0.43	10.3	348	4.6
WR	11.01	5.95	0.64	3.95	0.43	1.08	350	4.4
CR	12.02	5.62	0.67	3.82	0.46	1.13	354	4.6
WRP	12.38	5.86	0.72	4.03	0.50	1.22	357	4.4
CRP	14.34	5.64	0.81	3.93	0.56	1.36	360	4.5
SED and significance								
Supp.	0.45**	0.14	0.03**	0.06*	0.02**	0.05**	2.87*	0.08
Supp x form	0.40**	0.12*	0.03*	0.05*	0.02*	0.04*	2.6	0.07
Supp x protein	0.40**	0.12	0.03**	0.05	0.02**	0.04**	2.6*	0.07
Supp x form x protein	0.57	0.18	0.04	0.07	0.02	0.06	3.60	0.10

*P<0.05; ** P<0.01

Blood metabolites presented in Table 3 show low urea levels for the C, WR and CR treatments compared to those considered adequate by RAHL. The addition of protein to WR and CR increased albumin and urea in blood. The feeding of WR increased NEFA but CR had no effect.

TABLE 3: Effect of supplement on blood metabolites (mmol/litre).

Treatment	Albumin	BHBA	Glucose	Urea	NEFA
C	29.9	0.40	3.69	2.75	0.06
WR	29.6	0.45	3.58	2.51	0.07
CR	29.8	0.38	3.54	2.25	0.13
WRP	31.8	0.39	3.59	3.58	0.09
CRP	31.8	0.40	3.65	3.73	0.12
SED and significance					
Supp.	0.69	0.03	0.09	0.23	0.04*
Supp x form	0.62	0.03	0.08	0.21	0.03*
Supp x protein	0.62	0.03	0.08	0.21	0.03
Supp x form x protein	0.88**	0.04	0.11	0.29**	0.05
Adequate Range (RAHL)	25-40	0.0-1.0	2.5-4.1	3.3-8.1	No value

* P< 0.05, ** P<0.01

DISCUSSION.

The low total N recorded in pasture was unexpected and cannot be explained. The pasture was green and dominant in perennial ryegrass with 5-10% white clover. Also, moisture stress which has been reported to depress pasture N levels (Thomson, 1996) was not apparent. Low pasture N levels was found to be the dominant factor affecting dairy cow performance and thus confounded the hypotheses the trial was designed to test.

The nitrogen concentration of the three different diets were (assuming a common pasture intake of 7 kg DM/cow/day) 12.4%, 13.7% and 16.3% for the control WR/CR and WRP/CRP treatments respectively. These CP levels would be considered low and possibly limiting milk production. However, milk yield of the control herd was low (10.4 litres/cow/day) and the crude protein requirements for this level of production were adequately met by the level of protein in the diet (NRC 1998). Assuming a pasture intake of 7 kg DM/cow/d and a ME value for pasture of 10.5 MJ/kg DM, the cows were estimated to be consuming 142 MJME/cow/day. This was sufficient energy for cows at this stage of lactation to produce 15.5 litres of milk (NRC 1998). The protein required to produce at this level was calculated as 2 kg/day. At an intake of 12kg DM/cow/day, the protein content of the feed would have needed to be 16.7%. Therefore differences in dairy cow performance between treatments would have been a response to extra protein rather than a response to the varying lipid:starch:protein ratios established to test the original hypotheses. An examination of the nitrogen components of blood metabolites supports this view. Blood urea levels for the C, WR and CR treatments were low (Table 3) and following the addition of a protein supplement the increase is minimal. Similarly, blood albumin was low and increased with protein supplementation.

The lesser effect of WR compared to CR on milk production and composition and the lack of an effect of WR on NEFA, led to the assumption that the seed coat of WR was not sufficiently broken down during digestion to release lipid and protein. The feeding of CR depressed both fat and protein concentration. The decrease in protein concentration with feeding oilseeds was consistent with many trials (Wu & Huber, 1994). The hypothesis that the depressing effect on milk protein concentration could be overcome to feeding a supplement high in carbohydrate as suggested by Pantoja *et al.,* (1996) and Cant *et al.,* (1993) was not substantiated. However, supplementation of the diet with protected protein, reduced the protein depressing effect created by the CR treatment. This result was similar to that reported by Cant *et al.,* (1993) and Canale *et al.,* (1990) who found that abomasal infusion of casein or the inclusion of ruminally protected methionine and lysine in the ration of cows fed high fat diets, increased milk protein content.

The lack of an effect of WR on milkfat concentration suggests the seed coat provided ruminal protection but considering there was no increase in NEFA to feeding WR it is assumed the seed coat was not broken down sufficiently in the intestine to fully release lipid. The increase in milk yield to WRP was less than CRP, which indicated protein, also was less available in WR than CR. From these results it is concluded the use of WR to provide ruminal protection for lipid was unsuccessful. Hussein *et al.,* (1996) treated whole canola seed with an alkaline H_20_2 treatment and found the seed coat was sufficient weakened post-ruminal to make the oil available to the animal.

CONCLUSIONS.

The idea that feeding an oilseed in the presence of a concentrate feed would eliminate the milkfat depressing effect was not substantiated. However, the supplementation of an oilseed/maize/pasture diet with a ruminal-protected protein reduced the depressing effect of the oilseed on milk protein concentration. The low pasture protein concentration that occurred during the trial confounded these conclusions. The response in milk production to supplementary feeding was due to the supplemented rations being higher in crude protein and thus overcoming the effect of the protein deficiency on dairy cow performance. It was estimated the crude protein of the diet increased from 12.4% to 16.3% with the replacement of maize meal with rapeseed (21% CP) and the addition of ruminal protected protein (37.8% CP). This maize/CR/protein ration increased milk yield by 36% when compared with a maize supplement alone fed at a similar amount of ME.

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