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THE BIOCHEMICAL ASSESSMENT OF ENERGY STATUS IN THE GRAZING LACTATING RUMINANT

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SUMMARY

The value of milk fatty acid composition as a biochemical indicator of energy status has been examined in grazing trials with lactating beef cattle, dairy cattle and sheep.

It was found that the ratio of oleic acid to decanoic acid was remarkably constant for fully fed cattle and was rather similar for sheep with a value of 5 to 7. Increases in the mean ratio for groups of ruminants into the range of 10 to 20 were indicative of tissue fat mobilization due to inadequate energy intake. The variability in individual values of the ratio was too great to permit individual assessment. The ratio changes within a week of change in intake in cattle, thus indicating at an early stage the likelihood of loss of body weight occurring in a particular situation, but this may not be operative in ruminants already in a depleted condition.

INTRODUCTION

A continuing problem in the extensive grazing situation is the assessment of energy status and intake. Often direct measurement of pasture intake is not practical, and liveweight change is only meaningful over long periods owing to variability in gut fill.

Attempts to relate biochemical indices such as blood glucose or plasma free fatty acids to the degree of undernutrition have not been successful except under extreme conditions (Stobbs and Brett, 1976; Parker, 1977).

The fatty acids of milk fat are derived from two sources, one exogenous and the other endogenous. The short-chain acids are synthesized from ruminal acetate (*i.e.,* from dietary origin), whereas the long-chain acids are derived from either body fat or, to a lesser degree, ingested lipid. Since milk-fat production is maintained to a reasonable degree during underfeeding, the proportions of short- and long-chain acids in milk fat should depend on the intake of energy and tissue energy reserves of the animal.

Recently, Stobbs and Brett (1974, 1976) reported that the levels of short-chain fatty acids and of oleic acid in milk fat varied significantly with intake of digestible organic matter. To determine whether this technique would have application in New Zealand, the changes in fatty acid composition of milk fat with varying energy intake have been determined in a number of trials. These trials include indoor trials with dairy cattle where intakes were measured, and grazing trials with dairy cattle, beef cattle and sheep offered varying pasture allowances.

EXPERIMENTAL

Dairy Cattle

This trial was part of a study investigating the effect of restricted feeding on the efficiency of lactation, using indirect calorimetry. Briefly, the trial involved up to eight pairs of monozygous twin cows of mixed breeds grazing pasture at varying allowances to achieve *ad libitum* intake or intakes restricted to 60% of N.R.C. recommendations for 6 weeks from 4 days after calving. Following a 2-week period during which all cows received unrestricted grazing, six pairs of cows were offered freshly cut grass indoors, either *ad libitum* or about 70% of N.R.C. recommendations, for 3 weeks. Each twin set was offered each of the two levels of feeding after being spelled for 1 week at pasture after each treatment. Milk was sampled at 1, 6, 11 and 14 weeks after starting differential grazing pressures. All 1- and 6-week samples were taken while cows were grazing; 11- and 14-week samples were usually taken while cows were indoors. However, some cows were sampled also at pasture between feeding levels.

Beef Cattle

The 1977 trial involved 20 Angus and 20 Friesian cows given pasture allowances of 20 or 8 kg DM/head/d for the last 8 weeks prior to calving, when half the groups were changed over to the other ration. Milk samples were obtained by hand milking after 8 weeks' lactation.

The 1978 trial involved 24 Angus and 24 Friesian cows given pasture allowances of 8 kg/h/d for 8 weeks prior to calving, and then split into three groups on pasture allowances of 16, 12 and 8 kg/h/d. Milk sampling occurred after a mean lactation of 30 and 60 days.

Sheep

The trial design has been described by Rattray and Jagusch (1978). This was a changeover feeding trial in which the sheep were fed three different pasture allowances up to lambing, when each group was reassigned randomly to one of the three pasture allowances. Milk samples were obtained 1 day, 2 weeks and 5 weeks after lambing.

Methods

Milk samples were extracted with equal volumes of ethanol and then shaken vigorously with 2.5 volumes of petrol ether. Fatty acid butyl esters were produced by a modification of the method of Parodi (1970). Fatty acids were determined by temperature programmed gas liquid chromatography (100 to 180° at 7°/min) or under isothermal conditions at 190° on 17% DEGS. Areas were measured by electronic integration and no corrections were found necessary for response factors.

RESULTS

Dairy Cows

In the grazing period prior to the indoor period on measured intakes the proportions of individual short-chain fatty acids such as C10, C12, total C4-C14 were significantly lower ($P < 0.001$) in cows offered restricted compared with *ad libitum* levels of feeding (Table 1). Correspondingly, the proportion of oleic acid (C18 : 1) and the ratio (C18 : 1)/C10, which is a relative measure of the origins of the fatty acids of milk fat, were significantly higher ($P < 0.001$) in cows offered restricted grazing. Examination of the data showed that after only 1 week of feeding the restricted allowance the ratio was 25.3 compared with 6.3 for the group grazed *ad libitum* and such differences were maintained for the next 5 weeks.

As seen in Table 1, when intakes were measured indoors the change in mean ratio for a change in mean intake to 70% of the control group was highly significant ($P < 0.01$). This differed from the grazing trial only in the slightly higher level of the ratio in the high intake group. While 8 out of 10 cows showed strongly increased levels of the ratio with lowered intake, no attempt was made to regress the ratio with intake because of the small number of observations, the narrow range of intakes and the confounding effects of body condition and ability to mobilize tissue.

The ratio (C18:1)/C10 was plotted against the tissue fat change as calculated from carbon-nitrogen balance data (Fig. 1). It can be seen that 8 of the 10 cows showed an increase in the ratio

TABLE 1: THE EFFECT OF LEVEL OF FEEDING AND TIME OF LACTATION ON MILK COMPOSITION OF DAIRY COWS

Time after Weaning	*Regime*	*Dry Matter Intake (kg/h/d)*		*Fatty Acids (g/kg milk fat)* C10	C12	C18:1	C4-C14	(C18:1')/C10
1 wk	Grazing	*Ad lib.*	(8)	36	42	221	272	6.3
		60% *ad lib.*	(8)	15	16	346	157	25.3
6 wk		*Ad lib.*	(7)	42	49	212	304	5.2
		60% *ad lib.*	(5)	21	23	334	188	18.9
11 wk		*Ad lib.*	(7)	36	40	223	283	6.3
14 wk		*Ad lib.*	(5)	39	42	226	290	5.9
Significance								
Intake				***	***	***	***	**
Lactation period				*	*		**	
Twin sets				*	*		**	†
11-14 wk	Indoors	13.4	(10)	33	39	232	262	7.3
		9.3	(10)	26	30	279	224	11.0
Significance				*	**	**	†	**

Numbers in parentheses indicate numbers of animals sampled with decreased tissue fat deposition. It was also evident that individual cows could have considerably different values of the ratio for similar tissue fat changes. However, when fat change was taken as a covariate there was no significant effect of intake on the ratio.

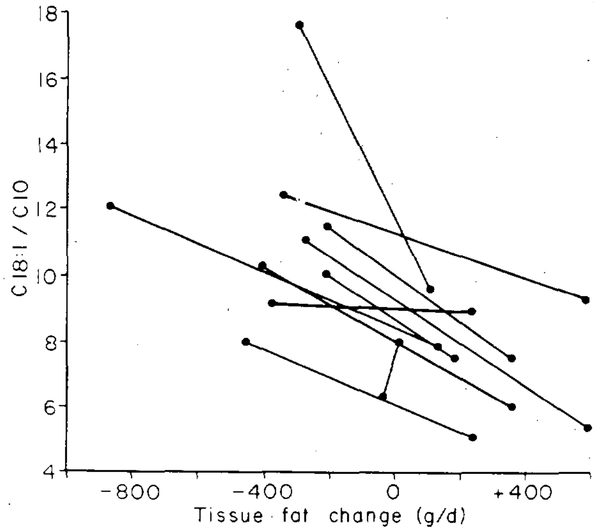

FIG. 1. *The variation in (C18:1)/C10 with tissue fat change in dairy cows.*

Analysis of the data in Table 1 showed that of the three parameters tested, dry matter intake had by far the greatest effect on fatty acid composition. There was also some effect of period of lactation on the level of short-chain acids ($P < 0.01$) but not on C18:1 levels, and little on the ratio (C18:1)/C10. Differences between twin sets were also significant for short-chain acids ($P < 0.01$).

BEEF CATTLE

Results of these trials are shown in Table 2. In 1977 there was a significant difference in fatty acid parameters between high and low pasture allowances and between breeds on the low pasture allowance. There were no residual effects of pre-calving treatments, so groups are presented in Table 2 as post-calving treatments.

In 1978, where the differences between treatments were less extreme, again there was a difference between breeds in the ratio. There were no differences observed in the Friesian cows, but

TABLE 2: EFFECT OF PASTURE ALLOWANCE AND BREED ON FATTY ACID COMPOSITION (g/kg) OF MILK FAT IN CATTLE GRAZED AS BEEF CATTLE IN HILL COUNTRY AFTER 8 WEEKS OF LACTATION

	Friesian			*Angus*			*Significance*	
							Breed	*All'ce*
1977								
Number of cows	10		10	10		10		
Pasture allowance (kg/h/d)	20		8	20		8		
Calving weight	467		433	396		357		
Weight change (kg) (wk 8-wk 1)	58.4		−24.3	58.3		−18.6		
Condition score	5.1		2.6	7.2		3.9		
C10	40		28	34		20	*	***
C18:1	208		318	204		341		***
C4-C14	288		215	282		170	**	***
(C18:1)/C10	5.3		11.8	6.1		18.1	**	***
1978								
Number of cows	8	8	8	8	8	8		
Pasture allowance (kg/h/d)	16	12	8	16	12	8		
Calving weight	410	428	411	374	389	411		
Weight change (kg) (wk 8-wk 1)	49.2	22.0	21.4	29.5	13.7	−1.7	**	**
Condition score	5.3	4.5	3.4	6.0	6.6	5.5	***	**
(C18:1)/C10	8.1	7.7	7.6	6.6	7.2	11.3	*	*

there was a highly significant difference ($P < 0.001$) between the Angus cows on 8 kg/h/d allowance and the groups given 12 and 16 kg/h/d allowance. Similar results were also found at 4 weeks of lactation.

In 1977 on the low allowance, the Friesians lost more weight than the Angus cows, but in 1978 only the Angus showed a loss of body weight. While condition scores at the time of milk sampling mostly reflected body-weight changes, it can be seen that in 1978 condition score of the Angus was only slightly lower for the most restricted group despite a significant difference in body-weight change.

Sheep

A summary of some of the results is given in Table 3 for 1 day after lambing and for 5 weeks after lambing. Results at 2 weeks are not shown as they still strongly reflected the effects of pre-lambing pasture allowances.

Rather similar changes in the fatty acids and the ratio (C18:1)/C10 to those already noted for cattle were observed between the low allowance group and the higher allowance groups. As also observed with cows, there is a certain insensitivity to change in the group on the moderately reduced pasture allowance. This was especially evident 5 weeks after lambing. Suckling two lambs also caused a significant increase in the levels of C18:1 ($P<0.01$) and ratio (C18:1)/C10 ($P<0.05$), as compared with singles.

TABLE 3: EFFECT OF VARIOUS LEVELS OF PASTURE ALLOWANCE ON THE FATTY ACID COMPOSITION (g/kg) OF OVINE MILK 24 HOURS AND 5 WEEKS AFTER LAMBING.

	24 h			*Sig.*	*5 wk*			*Sig.*
Number of ewes	17	15	16		15	17	17	
Pasture allowance (kg DM/ewe/d)	2.1	3.5	5.8		2.1	4.7	6.9	
Ewe gain[1] (kg/ewe/wk)	−0.47	0.84	1.03	***	−1.8	−1.0	0.9	***
Milk production in week 5 (l/ewe/d)					1.6	1.9	2.3	**
Fatty acids								
C10	35	41	43		36	56	56	***
C18:1	322	288	268	**	357	299	309	***
(C18:1)/C10	10.2	7.6	7.1	*	10.7	5.3	5.7	***

[1]Conceptus free basis averaged over the last 6 weeks prepartum and 1 to 5 weeks post partum.

DISCUSSION

The data obtained from the present trials support in general the reports of Stobbs and Brett (1974, 1976), who found a correlation of fatty acid composition of milk fat and digestible organic matter intake. The ratio (C18:1)/C10 shows changes in magnitude as great as the individual fatty acids, and moreover the analysis can be much simpler and quicker. It takes only 10 min by isothermal gas chromatography compared with 30 to 40 min by temperature programmed gas chromatography for the individual short-chain acids. As a result, only the ratio was determined in the 1978 beef trial.

The use of the ratio or the individual fatty acid levels has distinct limitations, and the results suggest that careful interpretation is required. The variability of individual values suggests that the ratio would have little accuracy as a predictor of individual intakes. However, the mean level of the ratio appears to have value as an index of the current energy balance of a herd.

The variability in the results for 1977 with beef cattle also shows further limitations. Significant increases in the ratio appear only when body weight was lost. There appeared to be a lack of change of the ratio for Friesian cows offered pasture allowances above maintenance, but less than fully adequate. The difference in performance of the Friesian cows on the low pasture allowance between the 2 years could only be attributed to the fact that in the second trial the cows calved at a lower body weight which may have lowered milk production as a result of lowered tissue fat reserves.

The lack of change of ratio in Friesians in 1978, where gain varied between groups, is also indicative of factors other than acetate availability that are controlling fatty acid composition. Lack of tissue fat may cause restriction of milk output to such an extent that a low energy intake may be sufficient to maintain a low (C18:1)/C10 in the small milk output and even allow a small rise in body weight. Thus the significant figure is the high value indicating a negative energy balance.

The rapid change in ratio in the dairy cattle suggests that the value of the ratio (C18:1)/C10 probably lies in the fact that within a week of a dietary change or immediately in cattle of unknown history or intake, the ratio could indicate if conditions are likely to cause a loss in body weight much more quickly than liveweight changes could be measured.

This rapid change in ratio in dairy cows is similar to that reported by Stobbs and Brett (1974) and contrasts with the situation in sheep where there were significant effects of previous dietary regimes for several weeks after the change to a new regime.

The difference observed between breeds occurred only on the low allowances. Possibly it is explained by differences in milk production or fat mobilization between breeds. This suggests that extrapolation of results for dairy cattle to beef cattle such as those of the Angus breed could cause difficulties.

Another point in favour of using the ratio (C18:1)/C10 rather than the levels of short-chain acids is the minimum variation due to twin sets and periods of lactation.

The changes of fatty acid composition with intake in ovine milk are similar to those for cattle, but the magnitude of C18:1 is much higher in the well-fed sheep than in cattle. This indicates that sheep draw much more heavily on endogenous fat reserves in early lactation than do cattle. This may be related to the higher fat content in sheep milk. The increased changes in (C18:1)/C10 observed when suckling twin lambs is undoubtedly the result of increased energy demand for milk to meet the needs of two lambs rather than one resulting in greater maternal fat mobilization and weight loss.

To date there has been no accurate biochemical indicator of energy intake or status. Stobbs and Brett (1976) found that plasma-free fatty acids were not correlated with intake. Likewise, Parker (1977) found that neither blood glucose nor plasma-free fatty acids were correlated with energy intake. He found that different energy intakes resulted in either body-weight and/or milk yield changes, and the direction of the partition towards milk production or body condition varied between feeding groups and between individual cows. As previously discussed, the fatty acid ratio may not be meaningful in cows that have exhausted body reserves, but for animals in better condition (C18:1)/C10 could be a useful biochemical indicator of energy balance.

ACKNOWLEDGEMENTS

Jewell Jackson for skilled technical assistance; D. Duganzich for statistical analyses.

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