Effect of Level of Feed Intake on Metabolizable Energy Values in Diets for Cattle

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Abstract

Recently, feed intake levels of cattle have increased by more than three to five times the maintenance levels in Japan. In order to improve the production efficiency, feed intake is being increased. However a large feed intake may depress the energy values of diets. The objective of this report is to analyse the effect of feed intake on the metabolizable energy (ME) values of diets for lactating cows and beef cattle fed 30 to 70 % concentrate diets. To estimate the ME values at a maintenance intake level, the following equation was derived based on the results of 19 energy balance experiments in goats ; ME (Mcal/kgDM) = $-2.062+0.0751\times$crude protein $+0.1025\times$ether extract $+0.0481\times$organic a fraction $+0.0285\times$organic b fraction $+0.0515\times$nitrogen cell wall free extract, %DM (SE = 0.0613, $R^2 = 0.908$). This equation gave a good accuracy for the ME values of maintenance diets in cattle. ME values at high intake levels were determined in lactating cows ($1.84\sim3.87\times$maintenance (M)) and growing steers ($1.89\sim2.12\times$M). The decrease in the ME values, expressed as a percentage of the ME value at the maintenance level for each increase in intake equivalent to the maintenance level, was $3.92\pm1.82\%$ for lactating cows (n = 5) and $3.06\pm1.90\%$ for growing steers (n = 7). Based on the results of experiments carried out in dry cows ($1\times$M) and lactating cows ($3\sim4\times$M) fed the same kind of diets, the energy loss in feces increased with the increase of the amount of feed intake. However the loss was compensated in part by the decrease of the energy loss in urine and of the formation of methane.

Introduction

In order to improve the efficiency of animal production, emphasis has been placed on the increase of the level of feed intake. Actually, feed intake levels of cattle have increased by more than three to five times the maintenance levels in Japan. The decrease of digestibility associated with high feed intake has been well documented (Tyrrell and Moe, 1975) and it was suggested that the effect of the intake accounted for more than 60% of the total variation in digestibility (Tyrrell and Moe, 1972). However, most of the available data on digestibility were obtained at the maintenance intake level. Therefore it is important to clarify the effects of the level of feed intake on nutritive values, especially energy values in diets. Although metabolizable energy (ME) is commonly used as a feed evaluation unit, the determination of the intake effect on the ME values is more difficult than that on digestibility and considerably more research is needed to identify and describe the effect of feed intake on the ME values.

The ME values of diets for cattle at a maintenance feeding level can be accurately predicted based on the chemical composition of diets determined by enzymatic analysis (Terada *et al.*, 1988). Using this technique, information can be obtained from the comparison

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of the determined ME values at two to four times the maintenance level with the estimated ME values at the maintenance level. The objective of this report is to analyse the effect of feed intake on the ME values of diets for lactating cows and beef cattle fed 30 to 70% concentrate diets.

Equation for estimating ME values at the maintenance level

To estimate the ME values at the maintenance intake level from the chemical composition of diets, an equation was derived by multiple regression analysis. For this analysis, the results of 19 energy balance experiments in goats were used. Table 1 shows the ME content and chemical composition of the diets in the energy balance experiments. These experiments were conducted with 2 to 4 goats fed a diet containing 25 to 70% concentrate at the near maintenance feeding level. Each balance trial consisted of a 14 day preliminary period and a 7 day collection period of feces and urine including a 2 day measurement of methane production using a respiration chamber (Iwasaki *et al.*, 1982). Chemical analysis of the diets was carried out according to Abe's method (enzymatic analysis system, Abe *et al.*, 1979a; b).

The equation derived by multiple regression analysis for estimating the ME values from

Table 1 ME content and chemical composition of the diets for the energy balance experiments in goats

Item	Mean	SD	Range	
			Min.	Max.
Metabolizable energy (ME), Mcal/kgDM	2.62	0.17	2.36	2.98
Chemical composition, % DM				
Organic matter (OM)	91.1	2.4	85.3	94.7
Organic cellular content (OCC)	50.3	7.2	41.7	64.6
Crude protein (CP)	16.1	3.5	11.0	27.3
Ether extract (EE)	2.9	0.7	1.8	4.0
Organic cell wall (OCW)	40.8	6.7	28.2	50.7
Organic a fraction (Oa)	14.7	6.5	5.9	33.0
Organic b fraction (Ob)	26.1	6.1	15.9	36.2
Nitrogen cell wall free extract (NCWFE)	33.5	8.1	19.3	48.0

Table 2 Comparison between observed and estimated ME values in cattle fed at near maintenance intake level

(Mcal/kgDM)

		Feed	Observed ME	Estimated ME[z]
Expt.	1	IRG wafer (35%), Alf cube (15%), Conc (50%)	2.69	2.69 (1.00)[y]
	2	CS (35%), Alf cube (13%), Conc (52%)	2.66	2.73 (1.02)
	3	CS (35%), Alf hay (13%), Conc (52%)	2.72	2.83 (1.04)
	4	IRG wafer (30%), Conc (70%)	2.69	2.70 (1.00)
	5	IRG wafer (30%), Conc (70%)	2.68	2.73 (1.02)
	6	IRG wafer (30%), Conc (70%)	2.79	2.78 (1.00)

[z] ME (Mcal/kgDM) = $-2.062+0.0751\times CP+0.1025\times EE+0.0481\times Oa+0.0285\times Ob+0.0515\times NCWFE$, %DM

[y] Estimated value / observed value.

Note : IRG : Italian ryegrass. Alf : Alfalfa. Conc : Concentrate. CS : Corn silage.

the chemical composition of a diet was as follows :

$$ME\ (Mcal/kgDM) = -2.062 + 0.0751 \times CP + 0.1025 \times EE + 0.0481 \times Oa + 0.0285 \times Ob + 0.0515 \times NCWFE,\ \%DM\ (R^2 = 0.908,\ SE = 0.06)$$

where CP, EE, Oa, Ob and NCWFE are crude protein, ether extract, organic a fraction, organic b fraction and nitrogen- cell wall- free extract, respectively.

Accuracy of the equation was tested using the data of energy balance experiments in cattle at near maintenance intake level (Table 2). The ratio of observed value to estimated value was 1.01 ± 0.02, suggesting that there was a good accuracy for the ME values of maintenance diets in cattle. Kurihara *et al.* (1991) reported that the equation derived from the results of enzymatic analysis showed a good accuracy for the maintenance diets of cattle except for corn silage. Moreover, it is suggested that a prediction equation derived from the experiments in goats or sheep could be used to evaluate the nutritive values of feeds for cattle. Terada *et al.* (1985) reported that sheep and goats showed similar ME values to those of cattle under restricted feeding conditions (near maintenance feeding level, more than 12% CP content in diets and less than 60% concentrates in diets).

Decrease of ME values at high intake levels

1 Lactating cows

ME values at high intake levels were determined in lactating cows ($1.84 \sim 3.87 \times$ maintenance (M)). The balance trials were conducted by applying the same method as that in goats. Table 3 shows the results of a comparison between observed values and estimated values. Cows in Expts. $7 \sim 10$ produced 30 to 35kg milk/day, in Expt. 12, 20kg and in Expt. 11, 10kg. Cows in Expt. 12 were fed continuously (2 hr interval). The decrease in the ME values, expressed as a percentage of the ME value at the maintenance level for each increase in intake equivalent to the maintenance level, was $3.92 \pm 1.82\%$ for lactating cows (the mean of Expts. 7 to 11). There were considerable variations among the diets fed to lactating cows in the intake effect on the ME values. Especially, the diets containing corn silage induced a larger decrease of ME. Feeding of long hay seemed to reduce the rate of decrease (Expt. 7 versus Expt. 8 and Expt. 9 versus Expt. 10). Expt. 12 which involved the continuous feeding method did not induce any decrease of ME at all.

Van Es (1975) assumed that the decline amounted to 1.8% for each multiple of the maintenance level. Compared with his assumption, the values obtained in this study were higher. In the same kind of experiment using Italian ryegrass hay plus concentrate diets ($1.93 \sim 3.09 \times$ M), Kurihara *et al.* (unpublished data) obtained a 3.5% value for the decrease of ME, which is similar to that obtained in the current study.

Table 3 Effect of feed intake on ME values of diets fed to lactating cows

		Feed	×Maint.[z] (A)	Observed value	Estimated value	Obs./Est. (B)	Rate of depression[y]
Expt.	7	IRG wafer (35%), Alf cube (10%), Conc (55%)	3.87	2.53	2.80	0.905	3.31
	8	IRG wafer (35%), Alf hay (15%), Conc (50%)	3.48	2.62	2.71	0.965	1.41
	9	CS (35%), Alf cube (13%), Conc (52%)	3.72	2.23	2.70	0.827	6.36
	10	CS (35%), Alf hay (13%), Conc (52%)	3.81	2.44	2.82	0.867	4.73
	11	IRG silage (45%), Alf cube (16%), Conc (39%)	1.84	2.20	2.28	0.968	3.81
	12	IRG wafer (40%), Conc (60%)	2.94	2.77	2.69	1.028	−1.44

[z] Multiple of maintenance level. [y] $(1-(B))/((A)-1) \times 100$

Note : IRG : Italian ryegrass. Alf : Alfalfa. Conc : Concentrate. CS : Corn silage.

2 Growing and finishing steers

Table 4 shows the results of experiments in growing and finishing steers. These experiments were conducted with 2 to 6 steers at two times the maintenance feeding level. Diets contained 30 to 70% concentrate. The decrease in the ME values, expressed as a percentage of the ME value at the maintenance level for each increase in intake equivalent to the maintenance level, was 3.06±1.90% for growing steers (n=7), a value similar to those recorded in lactating cows.

Table 4 Effect of feed intake on ME values of diets fed to growing and finishing steers

		Feed	×Maint.[z] (A)	Observed value	Estimated value	Obs./Est. (B)	Rate of depression[y]
Expt.	13	OG wafer (70%), Conc (30%)	2.00	2.47	2.50	0.989	1.10
	14	OG wafer (30%), Conc (70%)	2.12	2.67	2.81	0.953	4.20
	15	IRG wafer (30%), Conc (70%)	2.02	2.61	2.70	0.969	3.04
	16	IRG wafer (30%), Conc (70%)	1.94	2.61	2.73	0.957	4.57
	17	IRG wafer (30%), Conc (70%)	1.89	2.65	2.78	0.952	5.39
	18	Alf cube (56%), RS (8%), Conc (36%)	2.02	2.46	2.53	0.969	3.04
	19	IRG wafer (30%), Conc (70%)	2.01	2.76	2.76	0.999	0.10

[z] Multiple of maintenance level. [y] $(1-(B))/((A)-1)\times 100$

Note : OG : Consisted primarily of orchardgrass. Conc : Concentrate. IRG : Italian ryegrass. Alf : Alfalfa. RS : Rice straw.

Cause of the decrease of the ME values in diets

In this report, the ME values decreased by 3 to 4% for each multiple of the maintenance level in cows and steers. The cause of that decrease was analysed based on the results of 3 experiments carried out in dry cows (Expts. 1, 2 and 3) and lactating cows (Expts. 8, 9 and 10) fed the same diets. The energy loss in the feces increased by 6.29% for the increase of each multiple of the maintenance level of intake and showed a wide range of variations (3.73 ~8.63%). However urine and methane energy decreased by a value of 1.01 ± 0.08, 1.91 ± 0.35% for each increase in intake equivalent to the maintenance level, respectively. Consequently, the loss was compensated in part by the decrease of the energy loss in urine and the loss as methane.

Fig. 1 shows the decrease of the digestible content in these experiments. The decrease of the fraction of OCW and NCWFE in cows contributed 47% and 37% to the total decrease, respectively. Robertson and Van Soest (1975) indicated that the cell wall fraction is associated with a greater decrease in digestibility than the cell soluble fractions of hay diets fed to sheep. However, it appears that the decrease in the cell wall fraction of diets fed to cows is not the only factor contributing to the decrease in digestibility, but that the decrease in cell soluble fraction also plays a role. This is in agreement with the results obtained by Wheeler *et al.* (1975) and Colucci *et al.* (1982).

The rate of decrease of digestibility at high intake levels varied with the physical form of diets, ratio of forage to concentrate, type and quality of forage and management factors such as feeding frequency, etc. It is generally accepted that the feed intake is negatively correlated with the retention time (Blaxter *et al.*, 1956 ; Colucci, *et al.*, 1982 ; Staples *et al.*, 1984 ; Shaver *et al.*, 1986). Furthermore, it is possible that the decrease in the rate of digestion plays some role in intake effects (Staples *et al.*, 1984). Quantification of the relationship between intake and ME is required to improve the accuracy of energy systems and feed

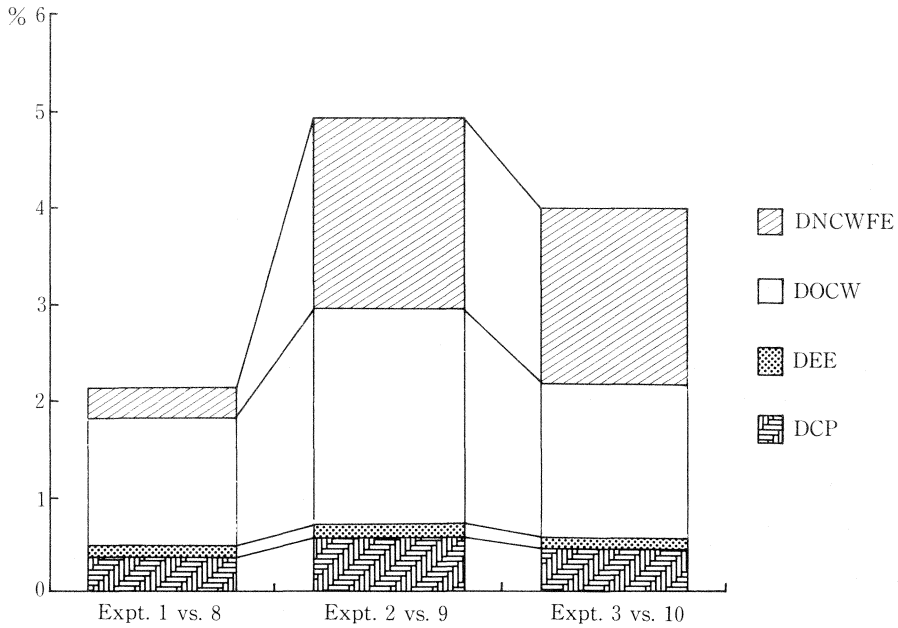

Fig. 1 Effect of level of feed intake on digestible nutrients (Observed value at maintenance level minus that at three to four times the maintenance level).

Note : DNCWFE : Digestible NCWFE. DOCW : Digestible OCW. DEE : Digestible EE. DCP : Digestible CP. (See Table 1)

values in formulating rations. For the precise prediction of the intake effect on the ME values of diets, further research on the relation with the changes of the gastrointestinal environment and kinetics of digestion as affected by the amount of feed ingested is needed.

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