放牧仔牛のエネルギー摂取量及び代謝エネルギー利用効率における草種間比較

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Comparison of Energy Intake and Efficiency of Utilization of Metabolizable Energy for Gain on Grazed *Festuca* and *Lolium* Pastures

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Synopsis

KUROKAWA, Y., T. OKUBO, S. ITANO, K. MATSUI. and H. MOCHIMARU (1993) : Comparison of energy intake and efficiency of utilization of metabolizable energy for gain on grazed *Festuca* and *Lolium* pastures. *J. Japan. Grassl. Sci.* 38, 396-407.

For investigating the influence of digestibility on energy efficiencies for grazing heifers, following energy constituents were estimated from some measurements on Italian ryegrass (Ir) pasture and perennial ryegrass (Pr) pasture. Let available herbage energy supply (HA), grazing intensity based on fasting metabolism (GI) and consumed herbage energy by heifers (HCE) be described using unit of GJ/10 a/grazing period ; and energy retention (DRE ; estimated by ARC's method) and heat prodution (DHP ; estimated from heart rate), metabolizable energy intake (DMEI ; DRE + DHP) be described by unit of MJ/F/day, where F is fasting metabolism estimated by ARC's method. Using GI and HA, HCE was expressed as following equation : $HCE = 12.6GI - 70.5GI^2/HA - 0.248$ ($R^2 = 0.81$). The values of HCE estimated from this equation were similar to those estimated on tall fescue pasture in the previous report. Relationships between DMEI and DRE were expressed as follows : on Ir pasture in spring, $DRE = 0.63\,DMEI - 1.76$; on Pr pasture in spring, $DRE = 0.65\,DMEI - 1.72$; on Ir and Pr pasture in summer, $DRE = 0.43\,DMEI - 1.04$. The regression coefficients in above equations, including those on tall fescue pasture in the previous report, were positively correlated to *in vitro* dry matter digestibility in each pasture significantly.

Key words : Digestibility, Efficiency of utilization of metabolizable energy, Grazing, Herbage intake.

Introduction

Digestibility of herbage plays an important role in energy flow on grazed pasture. OKUBO *et al.*[11] reported that lower digestibility of subtropical grass, in comparison with temperate grass pasture, caused lower animal production in spite of higher plant production. TAKAHASHI

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et al.[16] reported seasonal change in *in vitro* dry matter digestibility, and discussed that it is one of the causes of seasonal change in animal production. Digestibility affects not only a process from gross energy intake to digestible energy but also some other processes from herbage to animal gain. HODGSON *et al.*[3] and OSORO and MERCEDES CEBRIAN[13] reported correlation between digestibility and intake by animals. ARC[20] have proposed a system for predicting efficiency of utilization of metabolizable energy (k) using metabolizability which is seriously affected by digestiblity.

Therefore, influence of digestibility on energy flow on grazed pasture should be evaluated comprehensively. Modelling approach is one of the most effective ways for such evaluation. TSUIKI *et al.*[17] investigated an effect of increase in digestibility on animal gain using their model developed.

In the present report, energy efficiency from herbage available to animal gain on Italian ryegrass and perennial ryegrass pastures was investigated and compared with that on tall fescue pasture reported by OKUBO *et al.*[12] and KUROKAWA *et al.*[7]. Such comparison enabled us to discuss the effect of difference in digestibility between species of grasses on each process of energy conversion.

Materials and Methods

1. Pasture and grazing animals

The present study was carried out at three sites of pastures in the Animal Husbundry Experiment Station, Faculty of Agriculture in the University of Tokyo. This station is located at the Ibaraki Pref. Japan. The three sites are called A, B and C, and their areas were 38 a, 39 a and 36 a, respectively. In the sites A and B used for meadow till 1988, regrowth of Italian ryegrass (*Lolium multiflorum* LAM.) and reed canarygrass (*Phalaris arundinacea*) was used for grazing in 1989. In autumn of 1989, perennial ryegrass (*Lolium perenne* L.) pastures were established by plowing at the sites of A and B. The site C was tallfescue pasture grazed till summer of 1989, in which in autumn of 1989 Italian ryegrass pasture was established by resowing. At the time of plowing or resowing, compound fertilizer ($N : P_2O_5 : K_2O = 12 : 8 : 10$), lime material and fused magnesium phosphate were spread at the rate of 40 kg/10 a, 100 kg/10 a and 110 kg/10 a, respectively. During grazing season, compound fertilizer (30–50 kg/10 a) was applied two times a year at the end of each grazing period.

Groups of 3–5 head of Holstein heifers (4–20 months in age) were rotated in the three sites of pasture (Table 1). Concentrated feed (1–2 kg/head/day) was fed to grazing heifers according to their body weight. At the end of grazing on each pasture, trimming was carried out. During the periods when herbage in the all pastures was insufficient, hay or haylage and above concentrated feed were fed to heifers on the other weed-dominant paddok than the three sites.

2. Sampling methods

In the present report, observations were carried out under following 3 conditions : (1) condition under grazing on Italian ryegrass (Ir) pasture in spring, (2) condition under grazing on perennial ryegrass (Pr) pasture in spring and (3) condition under grazing on Ir and Pr pasture in summer. Energy efficiency from herbage available to heifers gain was investigated

Table 1. Outline of grazing.

Grazing period	Pasture[a]	Number of grazing days (days)	Number of grazing heifers (head/pasture)	Total mean body weight (kg/10a)	Herbage intake (gDM/kg BW)	Daily gain (kg/head/day)
'89 4/25-5/11	Ir	16	3	227	29.5	1.65
'89 5/15-26	Ir	11	3	244	34.5	0.45
'89 6/16-29	Ir	13	3	213	19.8	0.68
'89 6/21-7/4	Ir	13	4	300	44.0	1.04
'89 7/21-8/4	Ir	14	4	280	24.3	−0.20
'90 4/10-23	Pr	13	5	420	31.2	1.08
'90 4/24-5/7	Pr	13	5	431	40.1	1.66
'90 5/9-19	Ir	10	5	496	33.4	1.82
'90 5/28-6/10	Pr	13	5	497	30.6	0.94
'90 6/13-23	Ir	10	5	535	26.5	0.15
'90 7/18-28	Pr	10	4	313	15.4	0.70
'90 7/30-8/9	Ir	10	4	328	32.9	0.13

a) Ir : Italian ryegrass pasture. Pr : Perennial ryegrass pasture.

by the same methods as ones by Okubo *et al.*[12] and Kurokawa *et al.*[7]

The amount of herbage higher part than 5 cm above ground surface, on the assumption that it is available part, was measured by cutting method and the amount of herbage consumed by heifers was calculated from the equation by Linehan *et al.*[8] The amount of available herbage supply during each grazing period was calculated from herbage consumed during each grazing period plus the amount of available herbage left uneaten at the end of each grazing period. Body weight of heifers was measured at the beginning and the end of each grazing period in successive 2 or 3 days repeatedly. Heart rate was measured by Matsui and Okubo's method[9] for 24 hours, more than twice, around the middle of each grazing period.

From the above measurements, energy constituents presented in Table 2 were calculated on the basis of two kinds of unit. The values of herbage dry matter were converted to energy values, by multiplication of calolific values[19]. DDEI was calculated as follows :

$$\text{DDEI} = \{\text{Dig} \times (\text{DGEI from herbage}) + (\text{digestibility of concentrated feed}) \times (\text{DGEI from concentrated feed})\}/100,$$

where Dig is digestibility of herbage available (%). Dig was calculated by the following formula :

$$\text{Dig} = \text{sum of } \{(\text{composition ratio of each portion of each grass}) \times (\text{IVDMD of each portion of each grass})\}$$

Here, IVDMD was measured by the method by Iowerth *et al.*[5] and corrected by the equation presented in their report. IVDMD and composition ratio of each grass including dead plant portion and weeds were investigated at the beginning of grazing period. How to calculate other energy constituents are summarized in Table 2. Two heifers were applied to heat production measurements in each grazing period. HA, HCE, GI, RE, DGEI and DDEI are the values for the whole group of grazing heifers, whereas DMEI and DRE are the values for each

Table 2. Energy constituents.

Unit··················GJ/10a/grazing period
HA : Amount of available herbage energy supply.
HCE : Herbage energy consumed by heifers.
GI : Grazing intensity based on F[a]. (total F of whole group of heifers)
RE : Total energy retention[b] by the group of heifers.
Unit··················MJ/F/day
DGEI : Daily gross energy intake[c].
DDEI : Daily digestible energy intake[c].
DRE : Daily energy retention[b].
DHP : Daily heat production[d].
DMEI : Daily metabolizable energy intake[e].

a) F : Fasting metabolism of each heifer (MJ/day) calculated using ARC's method[20].
b) Energy retention was estimated by ARC's method[20].
c) DGEI and DDEI consist of energy from herbage and concentrated feed. Herbage intake was estimated using cutting method and Linehan *et al.*'s equation[8].
d) Heat production was estimated from heart rate using Yamamoto *et al.*'s method[18].
e) DMEI was calculated from DHP+DRE.

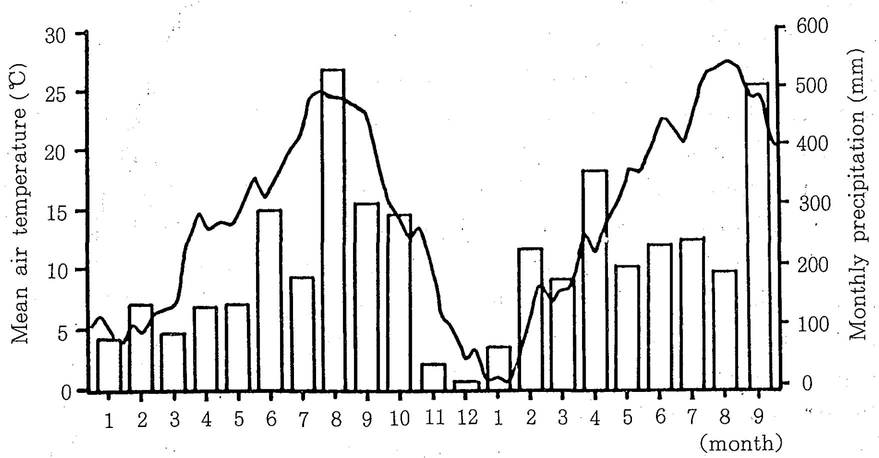

Fig. 1. Ten-day-mean air temperature (——) and monthly precipitation (□) in 1989 and 1990.

heifer applied to heat production measurements.

3. Weather condition

Air temperature and precipitation were recorded at this Station. Ten day mean air temperature and monthly precipitation from January, 1989 to September, 1990 are shown in Fig. 1. The periods from April to middle July and from late July to early September are defined as spring and summer, respectively due to the previous description (OKUBO *et al.*[20]).

Table 3. Sward

Grazing period	Pasture[a)]	At the beginning of grazing				
		Coverage(%)			Sward height	Amount of herbage available
		Italian ryegrass	Perennial ryegrass	Reed canarygrass	(cm)	(kgDM/10a)
'89 4/25-5/11	Ir	67.8	—	31.1	37.6	321
'89 5/15-26	Ir	93.9	—	5.1	27.8	198
'89 6/16-29	Ir	93.9	—	6.0	27.9	124
'89 6/21-7/4	Ir	83.6	—	14.3	52.0	297
'89 7/21-8/4	Ir	69.3	—	27.9	38.1	146
'90 4/10-23	Pr	1.5	94.4	1.3	27.5	353
'90 4/24-5/7	Pr	4.6	87.5	4.9	40.7	622
'90 5/9-19	Ir	95.6	—	—	31.6	210
'90 5/28-6/10	Pr	3.3	93.7	3.1	49.8	397
'90 6/13-23	Ir	97.9	—	—	35.4	221
'90 7/18-28	Pr	5.1	79.0	15.8	21.5	198
'90 7/30-8/9	Ir	37.8	—	—	20.4	335

a) Ir : Italian ryegrass pasutre. Pr : Perennial ryegrass pasture.

Results

1. Sward condition, herbage intake and daily gain

As shown in Table 3, coverage of Italian ryegrass in Ir pasture at the beginning of grazing was higher than 83% in spring except for the first grazing in 1989, and decreased to less than 70% in summer. Coverage of perennial ryegrass on Pr pasture at the beginning of grazing was higer than 79% in spring and summer. The amount of available herbage on Ir pasture in spring, on Pr pasture in spring and on Ir and Pr pasture in summer ranged as 124–321, 353–622 and 146–335 kgDM/10 a at the beginning of grazing, respectively and 121–317, 261–357 and 95–349 kgDM/10 a at the and of grazing, respectively. The range of herbage intake by heifers on Ir pasture in spring, on Pr pasture in spring and on Ir and Pr pasture in summer were 20–44, 31–40 and 15–33 gMD/kgBW, respectively. Daily gain of grazing heifers on the respective pasture was 0.45–1.8, 0.9–1.7 and −0.2–0.70 kg/head/day.

2. In vitro dry matter digestibility

Seasonal changes in IVDMD of Italian ryegrass, perennial ryegrass and reed canarygrass for leaf-brade and stem with leaf-sheath, are shown in Table 4. IVDMD of each species tended to be highest in April or May and to decrease in summer. IVDMD of leaf-brade in Italian ryegrass, perennial ryegrass and reed canarygrass ranged from 69 to 78%, from 74 to 81% and from 59 to 71%, respectively. IVDMD of stem with leaf-sheath of Italian ryegrass, perennial ryegrass and reed canarygrass ranged from 63 to 77%, from 67 to 82% and from 63 to 77%, respectively.

Digestibility for the whole herbage available (Dig) was 66–76% (mean = 69.3%) on Ir pasture in spring, 70–73% (mean = 70.9%), and 64–71% (mean = 67.7%) on Ir and Pr pasture in summer (Table 4).

condition.

At the end of grazing				
Coverage(%)			Sward height	Amount of herbage available
Italian ryegrass	Perennial ryegrass	Reed canarygrass	(cm)	(kgDM/10a)
34.8	—	2.8	29.1	317
62.4	—	4.4	22.9	167
96.1	—	3.4	17.8	121
81.0	—	15.6	24.2	230
55.4	—	32.6	16.7	94.6
0.8	94.6	2.1	16.0	261
2.9	92.6	4.0	19.9	357
94.1	—	—	14.5	131
9.4	88.8	—	14.1	289
94.7	—	—	14.6	159
1.4	86.6	10.9	13.9	181
27.8	—	—	18.4	349

Table 4. Seasonal changes in in vitro dry matter digestibility (IVDMD, %).

Sampling date	Itarian ryegrass		Perennial ryegrass		Reed canarygrass		Dig[a]
	Leaf-brade	Stem with leaf-sheath	Leaf-brade	Stem with leaf-sheath	Leaf-brade	Stem with leaf-sheath	
'89 5/15	76.5	64.8	—	—	71.0	63.4	66.3
'89 6/16	74.2	70.0	—	—	70.2	61.2	71.1
'89 6/21	69.0	62.9	—	—	58.6	56.2	60.6
'89 7/21	71.7	67.8	—	—	64.6	62.5	64.1
'90 4/10	—	—	80.9	81.6	—	—	69.6
'90 4/24	—	—	76.0	76.9	—	—	72.9
'90 5/9	77.9	76.5	—	—	—	—	76.1
'90 5/28	—	—	75.7	69.6	—	—	70.3
'90 6/13	75.0	73.0	—	—	—	—	72.5
'90 7/18	—	—	74.0	66.5	—	—	70.5
'90 7/30	72.5	73.7	—	—	—	—	68.5

a) Digestibility of the whole herbage available at the beginning of grazing.

3. Energy budget of grazing

Table 5 shows the energy budget per 10a per each grazing period. In accordance with the form of the equation represented by OKUBO *et al.*[12], the relationship among HA, GI and HCE on Ir and Pr pasture in spring was investigated, using the data in Table 5. As shown in Fig. 2, the surface (solid line) describing the HA-GI-HCE relationship is expressed by the following equation :

$$HCE = 12.6\ GI - 70.5\ GI^2/HA - 0.248. \quad (R^2 = 0.81)$$

The surface describing that on tallfescue pasture (dotted line), cited from OKUBO *et al.*[12], is

Table 5. Energy budget of grazing.

Grazing period	pasture[a]	HA	HCE	GI	RE[b]	DMEI/DGEI[b]
		—GJ/10a/grazing period—				
'89 4/25–5/11	Ir	7.69	1.96	0.273	0.351	0.38
'89 5/15–26	Ir	3.24	1.72	0.201	0.055	0.60
'89 6/16–29	Ir	3.24	1.01	0.213	0.113	0.62
'89 6/21–7/4	Ir	7.41	3.16	0.292	0.214	0.32
'89 7/21–8/4	Ir	3.60	1.86	0.294	−0.092	0.36
'90 4/10–23	Pr	7.68	2.97	0.394	0.301	0.46
'90 4/24–5/7	Pr	10.5	4.09	0.402	0.492	0.32
'90 5/9–19	Ir	5.52	3.08	0.357	0.521	0.42
'90 5/28–6/10	Pr	8.93	3.45	0.442	0.341	0.50
'90 6/13–23	Ir	5.59	2.64	0.375	0.020	0.37
'90 7/18–28	Pr	4.26	0.89	0.234	0.103	0.59
'90 7/30–8/9	Ir	8.49	2.01	0.251	0.014	0.35

a) Ir : Italian ryegrass pasutre. Pr : Perennial ryegrass pasture.
b) RE, DMEI and DGEI includes energy originated from subsidiary concentrated feed.
The relationship among HA, GI and HCE on Ir and Pr pasture in spring is described in Fig. 2.
HA, HCE, RE, GI, DMEI : see Table 2.

also shown in Fig. 2 for comparison.

DMEI/DGEI on Ir pasture in spring, on Pr pasture in spring and on Ir and Pr pasture in summer was 0.47, 0.44 and 0.40, respectively. Including all three conditions, correlation between DGEI and DMEI was not significant ($r = 0.46$), whereas that between DDEI and DMEI was significant ($DMEI = 0.38\ DDEI + 1.21$, $r = 0.64$, $p < 0.05$). Here, DMEI is mean value of DDEI of two heifers applied to heat production measurements.

Fig. 3 shows the relationship between DMEI and DRE. Within each condition, there was significant positive relationship between DMEI and DRE. The relationships were expressed by the following regression equations :

on Ir pasture in spring	$DRE = 0.63\ DMEI - 1.76$ ($r = 0.87$, $p < 0.01$)
on Pr pasture in spring	$DRE = 0.65\ DMEI - 1.72$ ($r = 0.97$, $p < 0.01$)
on Ir and Pr pasture in summer	$DRE = 0.43\ DMEI - 1.04$ ($r = 0.90$, $p < 0.05$)

Differences in regression coefficients between conditions were not significant. The regression lines on tall fescue pasture in spring and autumn and that in summer, cited from KUROKAWA *et al.*[7] are also shown in Fig. 3.

Discussion

Digestibility has two aspects. One is ratio of matter or energy digested to that ingested, which is measured by *in vivo* method. The other is index of quality of herbage, which is measured by *in vitro* method. Originally *in vitro* method was developed for estimating *in vivo* digestibility. In the present report, we used *in vitro* dry matter digestibility (IVDMD) on above two aspects. Compared in the same season, IVDMD of Italian ryegrass and perennial ryegrass shown in Table 4 was about 10% higher than that of tall fescue in OKUBO

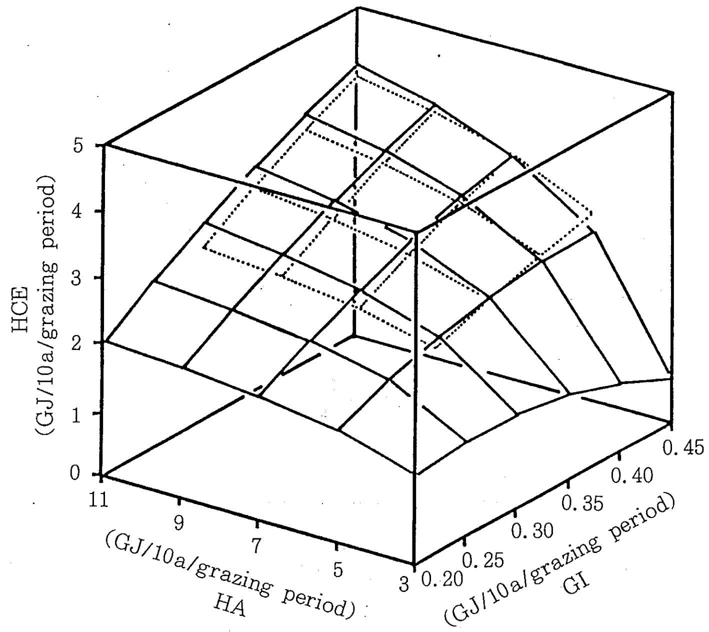

Fig. 2. Relationship among available herbage energy supply (HA), grazing intensity caluculated using fasting metabolism (GI) and consumed herbage energy by heifers (HCE) on Italian ryegrass pasture and perennial ryegrass pasture in spring (——), $HCE = 12.6\,GI - 70.5\,GI^2/HA - 0.248$ ($R^2 = 0.81$)
Regression surface on tallfescue pasture in spring and autumn (······), cited from OKUBO *et al.*[12] is also shown for comparison.
$HCE = 12.3\,GI - 49.2\,GI^2/HA - 0.709$ ($R^2 = 0.94$)

et al.[12] Mean Dig (average of digestibility of whole herbage available on each pasture in each season) in the present report was about 5% higher than that of tall fescue pasture in OKUBO *et al.*[12] The effect of this difference on energy conversion at grazed pasture is discussed here.

As OKUBO *et al.*[12] stated, the relationship among HA, GI and HCE (Fig. 2) represents energy conversion from herbage available to consumption by animals. That is, under given GI, HA is converted to HCE according to the eqation expressing the HA-GI-HCE relationship. As shown in Fig. 2, within the range of HA and GI values in the present report, the estimated values of HCE on Ir pasture and Pr pasture was only a little higher than those on tall fesce pasture cited from OKUBO *et al.*[12] Thus, the effect of difference in digestibility between grass species could not be detected on the process from HA to HCE. HODGSON *et al.*[3] and OSORO and MERCEDES CEBRIAN[13] reported correlation between digestibility and intake by animals. Other factors than those considered in the present report, for example sward characterisitcs[4], may have affected this process.

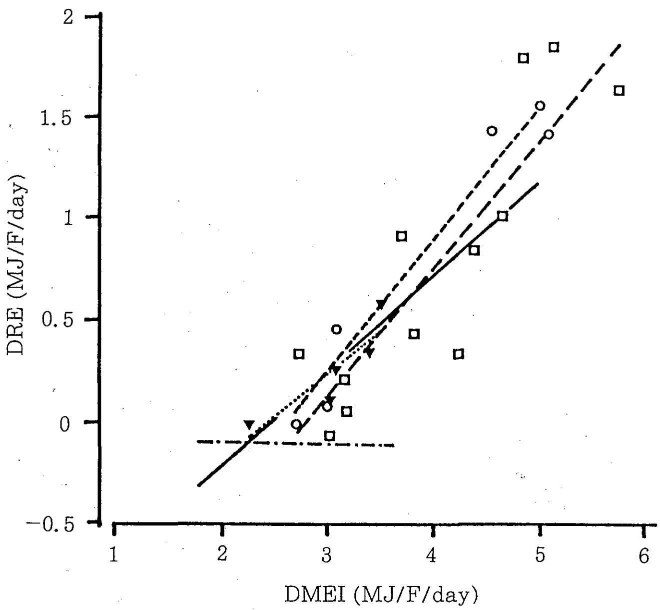

Fig. 3. Relationship between daily metabolizable energy intake (DMEI) and daily energy retention (DRE).
□, — — — : on Italian ryegrass pastures in spring.
DRE = 0.63 DMEI − 1.76 (r = 0.87)
○, ---- : on perennial ryegrass pastures in spring.
DRE = 0.65 DMEI − 1.72 (r = 0.97)
▼, ··· : on Italian ryegrass or perennial ryegrass pastures in summer.
DRE = 0.43 DMEI − 1.04 (r = 0.90)
Regression lines on tallfescue pasture in spring and autumn (——, DRE = 0.47 DMEI − 1.16) and in summer (-·-·, DRE = − 0.02 DMEI − 0.092) cited from Kurokawa *et al.*[7] are also shown in the figure for comparison.

Significant correlation between DDEI and DMEI suggests that the low correlation between DGEI and DMEI might partly owe to large variation in digestibility. DMEI/DGEI (q) in the present report was higher than that on tall fescue pasture (0.36 in spring and autumn and 0.31 in summer). This difference in q partly owes to difference in digestibility. DMEI/DDEI in the present report (0.61 on Ir pasture in spring, 0.56 on Pr pasture in spring and 0.59 on Ir and Pr pasturre in summer) were also higher than those on tall fescue pasture (0.53 and 0.46). NRC[21] has used fixed value (0.82) for DMEI/DDEI. We could not detect the reason for such differences in DMEI/DDEI. Lower DMEI/DDEI in the present report than that in NRC[21] may owe mainly to overestimation of herbage intake by cutting method, because cutting method often causes overestimation of herbage intake[15].

The regression coefficients of DRE on DMEI (Fig. 3) are equal to efficiency of utilization of metabolizable energy (k)[20]. ARC[20] has proposed a system predicting k and maintenance requirement for DMEI ($DMEI_m$) using q. According to the system using q in the present

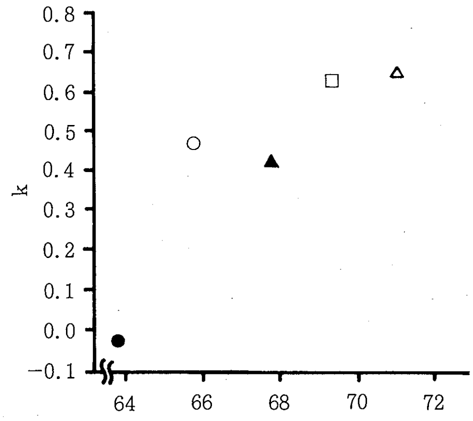

Fig. 4. Relationship between mean digestibility of herbage available and efficiency of utilization of metabolizable energy for gain (k).
□ : on Italian ryegrass pasture in spring.
△ : on perennial ryegrass pasture in spring.
▲ : on Italian ryegrass or perennial ryegrass pasture in summer.
○ : on tall fescue pasture in spring and autumn.
● : on tall fescue pasture in summer.

report, k_f (k for gain) on Ir pasture in spring, that on Pr pasture in spring and that on Ir and Pr pasture in summer was 0.37, 0.35 and 0.32, respectively. All of the values of k_f are lower than k in the present report. It is partly because q has been underestimated owing to overestimation of DGEI[15]. Even if that is considered, the values of k (0.63 or 0.65) on Ir or Pr pasture in spring seems too high because q should be more than 0.75 if k_f were predicted to be more than 0.60 by ARC's method[20], and digestibility should be more than 0.92 if q were more than 0.75 (DMEI/DDEI = 0.82)[21]. CAMMELL *et al.*[2] reported k_f for perennial ryegrass fed to housed growing cattle was 0.42. Their value was also lower than k on Ir pasture and Pr pasture in spring, and similar to k on Ir and Pr pasture in summer. $DMEI_m$ on Ir pasture in spring, Pr pasture in spring and Ir and Pr pasture in summer were 80%, 68% and 51% higher than predicted values, respectively, i.e., 2.79, 2.65 and 2.41 v.s. 1.55, 1.57 and 1.60.

As shown in Fig. 4, k looks significantly related to mean Dig. Dig and k on tall fescue pasture were cited from OKUBO *et al.*[12] and KUROKAWA *et al.*[7], respectively. Fig. 4 suggests that seasonal changes in k in the present report and the report by KUROKAWA *et al.*[7] depended on seasonal change in digestibility of herbage. ARC[20] tells that there is a correlation between k and q_m (q at maintenance), and q_m seriously depends on digestibility.

Thus, we agreed with ARC[20] on tendency to correlate between digestibility and k. On the other hand, on the values of k or $DMEI_m$ we did not agree with ARC[20]. Higher $DMEI_m$ than ARC's prediction[20] appears to express higher energy expenditure of grazing animals against housed animals[10]. Concerning k, more observations are required.

Systems approach[14] will permit us to integrate the results obtained in the present study, and to evaluate the effect of difference in grass species or digestibility on energy flow on grazed pasture. Such approach is needed for investigating the effects of air temperature[16] or growing stage of grasses[1,6] on energy flow, because it is known that they affect digestibility.

References

1) BUXTON, D. R. and G. C. MARTEN (1989) Forage quality of plant parts of perennial grass and relationship to phenology. *Crop Sci.* **29**, 429–435.

2) CAMMELL, S. B., D. J. THOMSON, D. E. BEEVER, M. J. HAINES, M. S. DHANOA and M. C. SPOONER (1986) The efficiecy of energy utilization in growing cattle consuming fresh perennial ryegrass (*Lolium perenne* cv. Melle) or white clover (*Trifolium repens* cv. Blanca). *Brit. J. Nutr.* **55**, 669–680.

3) HODGSON, J., J. M. RODRIGUEZ CAPRILES and J. S. FESLON (1977) The influence of sward characterisitics on the herbage intake of grazing calves. *J. agric. Sci., Camb.* **89**, 743–750.

4) HODGSON, J. (1985) The control of herbage intake in the grazing ruminant. *Proceedings of the Nutrition Society* **44**, 339–346

5) IOWERTH, D., H. JONES and MARGARET V. HAYWARD (1975) The effect of pepsin pretreatment of herbage on the prediction of dry matter digestibility from solubility in fungal cellulase solution. *J. Sci. Fd Agric.* **26**, 711–718.

6) KONDO, T., K. MIZUNO and T. KATO (1987) Some characteristics of forage plant lignin. *JARQ* **21**, 47–52.

7) KUROKAWA, Y., T. OKUBO, K. MATSUI, H. MOCHIMARU and E. SHIOSE (1993) Seasonal changes in energy efficiencies from herbage allowance to retention by grazing heifers on tall fescue (*Festuca arundinacea* SCHRED.) pasture. *J. Japan. Grassl. Sci.* **38**, 385–395.

8) LINEHAN, P. A., J. LOWE and R. H. STEWART (1947) The output of pasture and its measurement. part II. *J. British Agr. Soc.* **2**, 145–168.

9) MATSUI K. and T. OKUBO (1989) A 24-hour automatic recording of grazing and ruminating behaviour in cattle on pasture by a data logger method. *Jap. J. Zootec. Sci.* **60**, 940–945.

10) OCHIAI, K., I. TAHATA, F. ANDOH, S. SHIOYA and T. AMI (1985) Heat production of free grazing cattle. *Proceedings of the XV IGC,* 1086–1088.

11) OKUBO, T., M. HIRAKAWA, T. OKAJIMA, R. KAYAMA, H. TANO and N. KIHIRA (1985) Energy efficiency of primary and secondary prodution in grazed pasture of *Dactylis glomerata* as compared with those of *Paspalum notatum*. *Proceedings of the XV IGC,* 736–738.

12) OKOBO. T., Y. KUROKAWA, K. MATSUI, T. SAWASAKI and H. MOCHIMARU Seasonal change in solar energy utilization on grazed pasture of tall fescue (*Festica arundinacea* SCHREB.), with special reference to availabe herbage and animal production. *J. Japan. Grassl. Sci.* **38**, 369–384.

13) OSORO, K. and MERCEDES CEBIRIAN (1989) Digestibility of energy and gross energy intake in fresh pastures. *Grass and Forage Science* **44**, 41–46.

14) SHIYOMI, M. (1989) Systems approach for grassland ecosystems. 1. Experimental approach for energy and matter flows in grassland. *J. Japan. Grassl. Sci.* **34**, 344–354.

15) TAKAHASHI, S., T. OKUBO, T. AKIYAMA and M. SHIYOMI (1981) Factors determining standing crop biomass and its consumption by cattle in a grazing field. *Bull. Natl. Grassl. Res. Inst.* **18**, 13–26.

16) TAKAHASHI, S. T. AKIYAMA, M. SHIYOMI and T. OKUBO (1984) Seasonal changes in *in vitro* dry matter digestibility of several herbage species on pasture. *J. Japan. Grassl. Sci.* **30**, 264–268.

17) TSUIKI, M., M. SHIYOMI and N. KOYAMA (1990) Preliminary study of a model describing the growth of grazing cattle. *Bull. Natl. Grassl. Res. Inst.* **43**, 1–11

18) YAMAMOTO, S., J. A. MCLEAN and A. J. DOWINE (1979) Estimation of heat production from heart-rate measurements in cattle. *Br. J. Nutr.* **42**, 507–513.

19) AGRICULTURE, FORESTRY and RESEACH COUNCIL SECRETARIAL MINISTRY of AGRICULTURE,

FORESTRY and FISHERIES (1987) Standard Tables of Feed Composition in Japan, Central Association of Livestock Industry. Tokyo. pp. 8-9.

20) AGRICULTURAL RESEARCH COUNCIL (1980) The Nutrietnt Requirmenets of Ruminant Livestock. Commonwealth Agricultural Breaux. Slough. pp. 72-119.

21) NATIONAL RESEARCH COUNCIL (1984) Nutrient Requirements of Beef Cattle. sixth revised Edition. National Academy Press. Washington. pp. 3.

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放牧仔牛のエネルギー摂取量及び代謝エネルギー利用効率おける草種間比較

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要　　約

放牧草地のエネルギーの流れに対する牧草の消化率の影響を調べることを目的として，イタリアンライグラス（Ir）またはペレニアルライグラス（Pr）放牧草地において各種の実測を行い，以下のエネルギー要素を計算した。牧草エネルギー供給量（HA），絶食時代謝量に基づく放牧強度（GI），牧草エネルギー被食量（HCE），以上単位は，GJ/10 a/放牧期。増対蓄積エネルギー量（DRE），熱産生量（DHP），代謝エネルギー摂取量（DMEI），以上単位は，MJ/F/day。F は ARC (1980) の方法で計算した放牧牛の絶食時代謝量（MJ/day）。HA, HCE は刈り取り法に基づいて求め，DRE は放牧牛の体重増加量から ARC (1980) の方法で計算した。DHP は心拍数から推定した。DMEI は DRE + DHP として求めた。

HA, GI と HCE との関係は以下のように表された。

$$HCE=12.6\,GI-70.5\,GI^2/HA-0.248\ (R^2=0.81)$$

この式により推定される HCE と，大久保らの報告のトールフェスク放牧草地のそれとに大きな違いはなかった。*in vitro* 法により求めた牧草消化率（IVDMD）はトールフェスクの IVDMD より約 10% 高く，牧草供給量から牧草被食量へのエネルギーの流れに対する牧草消化率の影響は明かでなかった。

DMEI と DRE との関係は以下の回帰式で表された.

Ir 春　季	$DRE=0.63\,DMEI-1.76$
Pr 春　季	$DRE=0.65\,DMEI-1.72$
Ir および Pr 夏季	$DRE=0.43\,DMEI-1.04$

黒川らの報告におけるトールフェスクの場合を含めると，上記の回帰式の回帰係数（代謝エネルギーの利用効率，k）は，IVDMD から計算した可食部全体の消化率と有意な（$p<0.05$）相関関係にあり，k に対する牧草消化率の影響が確かめられた.

キーワード：消化率，代謝エネルギー利用効率，放牧，牧草摂取量.

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