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Relative Growth Rate of Beef Cattle Expressed Using Factors Related to Feed Intake, Maintenance Requirements and Feed Efficiency

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This study was conducted to present a method for growth analysis of beef cattle using factors related to feed intake, maintenance requirements and feed efficiency.

The following equation was taken up for growth analysis,

$$\frac{1}{W}\cdot\frac{dW}{dt}=\left(\frac{1}{W^{0.75}}\cdot\frac{dI}{dt}\right)\cdot\frac{W^{0.75}}{W}\cdot\frac{dW}{dI},$$

where W = body weight, t = day, $W^{0.75}$ = metabolic body size, I = cumulative intake of metabolizable energy, $(1/W)\cdot(dW/dt)$ = relative growth rate [RGR], $(1/W^{0.75})\cdot(dI/dt)$ = daily intake of metabolizable energy per unit metabolic body size [DIM], $W^{0.75}/W$ = metabolic body size ratio [MBS ratio] or maintenance requirements index [MR index], dW/dI = efficiency of metabolizable energy for gain in body weight [EEG].

Mean value over the interval t_1 to t_2 was calculated for each of RGR, DIM, MBS ratio or MR index, and EEG when applied to feeding and growth data.

An application of this analytical method to Japanese Black Cattle whose feeding and growth data were cited from Japanese Feeding Standard (1995) showed that $\overline{\text{RGR}}$ was controlled by $\overline{\text{DIM}}$, $\overline{\text{MBS ratio}}$ or $\overline{\text{MR index}}$, and $\overline{\text{EEG}}$, in beef cattle weighing 300 kg to 500 kg. A feature of this method was that it might account for how MR index was involved in the growth analysis of beef cattle.

INTRODUCTION

The production from beef cattle depends mainly on body weight increase during growth and this is affected by the amount of feed eaten and its efficiency for weight gain (Brody, 1945a). When formulating ration for growing cattle, the amount of feed given to the animal contains requirements for both maintenance and gain. This is the principal concept that runs in feeding standards or nutrient requirements for beef cattle (Japan MAFF, 1995; NRC, 1984; ARC, 1980; AAC, 1990). Thus, the growth of cattle is controlled by intake and how it is in excess of maintenance requirements.

How these factors are involved in the growth has been analyzed extensively, using various equations which were reviewed by Parks (1982) and are adopted in various feeding standards and nutrient requirements. Many studies have indicated the importance of analytical approach to the relationship between feeding and growth, but

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there seems to be a need of developing simple methods from a practical point of view. Shimojo *et al.* (1996) presented, in a preliminary study, a simple method for growth analysis of beef cattle, but gave it brief and insufficient descriptions.

The present study was designed to give more detailed explanation to this analytical method and its use. This was performed by describing the constructing process of this method using factors related to feed intake, maintenance requirements and feed efficiency, and by its application to Japanese Black Cattle whose feeding and growth data were cited from Japanese Feeding Standard for Beef Cattle (Japan MAFF, 1995).

CONSTRUCTION OF ANALYTICAL METHOD

The rate of growth is inevitably taken into account when the productivity of beef cattle is evaluated, and absolute growth rate is usually used. However, growth rate per unit body weight is preferable when the comparison is made between animals different in size (Brody, 1945b). Thus, relative growth rate (RGR) is taken up as follows:

$$\mathrm{RGR} = \frac{1}{W} \cdot \frac{dW}{dt}, \qquad (1)$$

where W = body weight, t = day.

When two growths are the same in both the initial weight and the final weight, the comparison using relative growth rate gives the same evaluation as that using absolute growth rate.

As for the comparison of feed intake made between animals different in size, metabolizable energy intake per unit metabolic body size is used rather than the amount expressed in dry or organic matter (Kleiber, 1975). Feed intake is the primary factor for animal growth, therefore, it is expressed as daily intake of metabolizable energy per unit metabolic body size (DIM). DIM is equal to RIM which was used in the previous report (Shimojo *et al.*, 1996) to express the rate of increase in cumulative intake of metabolizable energy per unit metabolic body size. In the present study, DIM is used and expressed as follows:

$$\mathrm{DIM} = \frac{1}{W^{0.75}} \cdot \frac{dI}{dt}, \qquad (2)$$

where $W^{0.75}$ = metabolic body size, I = cumulative intake of metabolizable energy.

Relating RGR to DIM gives

$$\frac{1}{W} \cdot \frac{dW}{dt} = \left(\frac{1}{W^{0.75}} \cdot \frac{dI}{dt}\right) \cdot \frac{W^{0.75}}{W} \cdot \frac{dW}{dI}, \qquad (3)$$

where $W^{0.75}/W$ is interpreted as not only metabolic body size ratio (MBS ratio) but also maintenance requirements index (MR index), dW/dI = efficiency of metabolizable energy for gain in body weight (EEG).

Why $W^{0.75}/W$ has two meanings is explained as follows. $W^{0.75}/W$ originally means just the ratio of $W^{0.75}$ to W, and the product of this ratio and DIM gives daily intake of metabolizable energy per unit body weight (DIB). This usage of $W^{0.75}/W$ is why it is called MBS ratio. In addition to the ordinary interpretation, it is noticed in the previous report

(Shimojo *et al.*, 1996) that the metabolizable energy required for maintenance is expressed as $p \cdot W^{0.75}$ in which p is set at a fixed value for beef cattle of the same breed and same sex in Japan MAFF (1995). In NRC (1984) net energy is used and p is set at a fixed value for various types of beef cattle. In Australia (AAC, 1990) the metabolizable energy per unit $W^{0.75}$ is taken into account when maintenance requirements are estimated. In ARC (1980), however, the metabolizable energy required for maintenance is estimated using an equation in which there is a term of fasting heat production related to $W^{0.67}$. In a recent English book on growth of farm animals $W^{0.75}$ is used for the estimation of metabolizable energy for maintenance (Lawrence and Fowler, 1997). Anyway, where $W^{0.75}$ is adopted $W^{0.75}/W$ is associated with maintenance requirements per unit W. This is why $W^{0.75}/W$ is called MR index.

Equation (3) shows that RGR is expressed using DIM, MBS ratio or MR index, and EEG. When this analytical equation is applied to feeding and growth data of beef cattle, mean value over the interval t_1 to t_2 is calculated for each of RGR, DIM, MBS ratio or MR index, EEG and DIB [given by DIM • (MBS ratio)] as follows:

$$\overline{\text{RGR}} = \frac{log_e W_2 - log_e W_1}{t_2 - t_1} , \qquad (4)$$

$$\overline{\text{DIM}} = \frac{log_e W_2^{0.75} - log_e W_1^{0.75}}{W_2^{0.75} - W_1^{0.75}} \cdot \frac{I_2 - I_1}{t_2 - t_1} , \qquad (5)$$

$$\overline{\text{MBS ratio}} = \overline{\text{MR index}} = \frac{W_2^{0.75} - W_1^{0.75}}{log_e W_2^{0.75} - log_e W_1^{0.75}} \cdot \frac{log_e W_2 - log_e W_1}{W_2 - W_1} , \qquad (6)$$

$$\overline{\text{EEG}} = \frac{W_2 - W_1}{I_2 - I_1} , \qquad (7)$$

$$\overline{\text{DIB}} = \overline{\text{DIM}} \cdot \overline{\text{MBS ratio}}$$

$$= \frac{log_e W_2 - log_e W_1}{W_2 - W_1} \cdot \frac{I_2 - I_1}{t_2 - t_1} , \qquad (8)$$

where e is the base of natural logarithm.

There are two points to which we should pay attention when applying this method to beef cattle. [1] The value for power to which W is raised is considered unequal to 0.75 in very young animals. [2] In the later stage of fattening period it is considered difficult to compare RGR values that are very low, which is related to high body weight and low rate of weight increase. It appears, however, that a very low RGR becomes easy to see when magnified appropriately, for example, as shown in the following equation.

$$10^3 \cdot \overline{\text{RGR}} = (10 \cdot \overline{\text{RIM}}) \cdot (10 \cdot \overline{\text{MBS ratio}}) \cdot (10 \cdot \overline{\text{EEG}}). \qquad (9)$$

Anyway, in the present study the application of this method is limited to beef cattle weighing 300 kg to 500 kg.

AN APPLICATION OF ANALYTICAL METHOD TO JAPANESE BLACK CATTLE

An application of this method to growth analysis of beef cattle was examined using feeding and growth data of castrate, male and female Japanese Black Cattle which were cited from Japanese Feeding Standard for Beef Cattle (Japan MAFF, 1995). According to the preceding attention, two examples were taken up as follows to compare growths in each example.

Example 1.

Example 1 consisted of two sets of data on feeding and growth in each of castrate, male and female beef cattle (Table 1). In three types of cattle two growths were the same in both the initial weight and the final weight, but were different in daily gain, growth period and cumulative intake of metabolizable energy.

Table 1. Feeding and growth data of Japanese Black Cattle cited from Japanese Feeding Standard for Beef Cattle (1995) for Example 1.

Growth (kg)	Daily gain (kg/day)	Growth period (days)	Cumulative intake of metabolizable energy during the growth (MJ/head)
Castrate			
400→410	0.5	20	1254.37
400→410	1.0	10	828.40
Male			
400→410	0.5	20	1344.47
400→410	1.0	10	842.42
Female			
400→410	0.5	20	1344.22
400→410	1.0	10	920.34

Table 2. Growth analysis of Japanese Black Cattle using feeding and growth data in Example 1.

Growth (kg)	Period (days)	$\overline{\text{RGR}}$[1] (kg/kg/day)	$\overline{\text{DIM}}$[2] (MJ/kg$^{0.75}$/day)	$\overline{\text{MBS ratio}}$[3] $\overline{\text{MR index}}$[4] (kg$^{0.75}$/kg)	$\overline{\text{EEG}}$[5] (kg/MJ)	$\overline{\text{DIB}}$[6] (MJ/kg/day)
Castrate						
400→410	20	0.0012	0.6947	0.2229	0.0080	0.1549
400→410	10	0.0025	0.9176	0.2229	0.0121	0.2046
Male						
400→410	20	0.0012	0.7446	0.2229	0.0074	0.1660
400→410	10	0.0025	0.9332	0.2229	0.0119	0.2080
Female						
400→410	20	0.0012	0.7445	0.2229	0.0074	0.1660
400→410	10	0.0025	1.0195	0.2229	0.0109	0.2273

Mean value during the growth for 1) relative growth rate (RGR), 2) daily intake of metabolizable energy per unit metabolic body size (DIM), 3) the ratio of metabolic body size to body weight (MBS ratio), 4) maintenance requirements index (MR index), 5) efficiency of metabolizable energy for gain in body weight (EEG), 6) daily intake of metabolizable energy per unit body weight (DIB) [=DIM • (MBS ratio)].

The results for growth analyses using these data are shown in Table 2. In any type of cattle differences in attributes between two growths showed the same or similar tendencies. $\overline{RGR}$ over 400 to 410 kg with 1.0 kg daily gain was almost twice as high as that with 0.5 kg daily gain. $\overline{DIM}$ was higher for 1.0 kg gain than for 0.5 kg gain per day. Both growths showed the same $\overline{MBS}$ ratio and the same $\overline{MR}$ index in three types of cattle, though metabolizable energy required for maintenance was actually different between cattle types (Japan MAFF, 1995). $\overline{EEG}$ was higher when daily gain was 1.0 kg than when it was 0.5 kg. As $\overline{DIM}$ was higher in 1.0 kg daily gain and two growths show the same $\overline{MBS}$ ratio, $\overline{DIB}$ was higher in 1.0 kg gain compared with 0.5 kg gain per day. Thus, higher $\overline{RGR}$ for the growth with 1.0 kg daily gain was due to higher $\overline{DIM}$ and higher $\overline{EEG}$ in the comparison with the growth with 0.5 kg daily gain. The same $\overline{MR}$ index in the two growths made some contribution to higher $\overline{RGR}$ in 1.0 kg gain per day.

Example 2.

Example 2 was composed of three sets of feeding and growth data in each of castrate, male and female beef cattle (Table 3). In three sets of data there were differences in body weight, daily gain and cumulative intake of metabolizable energy, except that the growth period was the same. The results for growth analyses are shown in Table 4. In three growths, the growth from 300 to 312 kg was designated as growth–1, likewise, 450 to 462 kg was growth–2, and 450 to 474 kg was growth–3. The comparison was made between growth–1 and growth–2, between growth–1 and growth–3, between growth–2 and growth–3, respectively.

(1) Comparison between growth–1 (300 to 312 kg) and growth–2 (450 to 462 kg)

There were the same or similar differences in attributes between two growths in all

Table 3. Feeding and growth data of Japanese Black Cattle cited from Japanese Feeding Standard for Beef Cattle (1995) for Example 2.

Growth (kg)	Daily gain (kg/day)	Growth period (days)	Cumulative intake of metabolizable energy during the growth (MJ/head)
Castrate			
300→312	0.6	20	1084.94
450→462	0.6	20	1463.68
450→474	1.2	20	1991.73
Male			
300→312	0.6	20	1149.51
450→462	0.6	20	1550.79
450→474	1.2	20	1989.23
Female			
300→312	0.6	20	1175.07
450→462	0.6	20	1585.28
450→474	1.2	20	2227.54

Table 4. Growth analysis of Japanese Black Cattle using feeding and growth data in Example 2.

Growth (kg)	$\overline{\text{RGR}}$[1)] (kg/kg/day)	$\overline{\text{DIM}}$[2)] (MJ/kg$^{0.75}$/day)	$\overline{\text{MBS ratio}}$[3)] $\overline{\text{MR index}}$[4)] (kg$^{0.75}$/kg)	$\overline{\text{EEG}}$[5)] (kg/MJ)	$\overline{\text{DIB}}$[6)] (MJ/kg/day)
Castrate					
300→312	0.0020	0.7415	0.2391	0.0111	0.1773
450→462	0.0013	0.7417	0.2164	0.0082	0.1605
450→474	0.0026	0.9995	0.2157	0.0120	0.2156
Male					
300→312	0.0020	0.7857	0.2391	0.0104	0.1879
450→462	0.0013	0.7858	0.2164	0.0077	0.1701
450→474	0.0026	0.9983	0.2157	0.0121	0.2153
Female					
300→312	0.0020	0.8031	0.2391	0.0102	0.1920
450→462	0.0013	0.8033	0.2164	0.0076	0.1738
450→474	0.0026	1.1179	0.2157	0.0108	0.2411

Mean value during the growth for 1) relative growth rate (RGR), 2) daily intake of metabolizable energy per unit metabolic body size (DIM), 3) the ratio of metabolic body size to body weight (MBS ratio), 4) maintenance requirements index (MR index), 5) efficiency of metabolizable energy for gain in body weight (EEG), 6) daily intake of metabolizable energy per unit body weight (DIB) [=DIM • (MBS ratio)].

types of cattle (Table 4). $\overline{\text{RGR}}$ was lower in growth–2 than in growth–1. $\overline{\text{DIM}}$ was almost the same between two growths. $\overline{\text{MBS ratio}}$ and $\overline{\text{MR index}}$ were lower in growth–2 compared to growth–1. $\overline{\text{EEG}}$ in growth–2 was lower than that in growth–1. Growth–2 showed lower $\overline{\text{DIB}}$ than growth–1, because $\overline{\text{DIM}}$ showed little difference and $\overline{\text{MBS ratio}}$ was lower. Thus, lower $\overline{\text{RGR}}$ in growth–2 was caused by lower $\overline{\text{MBS ratio}}$ and lower $\overline{\text{EEG}}$ when compared with growth–1, though $\overline{\text{MR index}}$ was lower in growth–2.

(2) Comparison between growth–1 (300 to 312 kg) and growth–3 (450 to 474 kg)

Differences in attributes between two growths showed the same or similar tendencies in all types of cattle (Table 4). $\overline{\text{RGR}}$ for growth–3 was higher than that for growth–1. $\overline{\text{DIM}}$ was higher in growth–3 than in growth–1. $\overline{\text{MBS ratio}}$ and $\overline{\text{MR index}}$ in growth–3 were lower compared to those in growth–1. $\overline{\text{EEG}}$ was slightly higher for growth–3 than for growth–1. $\overline{\text{DIB}}$ was higher in growth–3 than in growth–1 due to higher $\overline{\text{DIM}}$, though $\overline{\text{MBS ratio}}$ was lower in growth–3. Thus, higher $\overline{\text{RGR}}$ in growth–3 was due to higher $\overline{\text{DIM}}$ and slightly higher $\overline{\text{EEG}}$ in the comparison with growth–1, and lower $\overline{\text{MR index}}$ made some contribution to higher $\overline{\text{RGR}}$ in growth–3.

(3) Comparison between growth–2 (450 to 462 kg) and growth–3 (450 to 474 kg)

There were the same or similar differences in attributes between two growths in any type of cattle (Table 4). $\overline{\text{RGR}}$ in growth–3 was twice as high as that in growth–2. $\overline{\text{DIM}}$ for growth–3 was higher than that for growth–2. Both growths showed almost the same $\overline{\text{MBS ratio}}$ and $\overline{\text{MR index}}$. $\overline{\text{EEG}}$ was higher in growth–3 compared to growth–2. As there were little differences in $\overline{\text{MBS ratio}}$ between two growths, $\overline{\text{DIB}}$ was higher in growth–3 due to higher $\overline{\text{DIM}}$. Thus, higher $\overline{\text{RGR}}$ in growth–3 was due to higher $\overline{\text{DIM}}$ and higher $\overline{\text{EEG}}$ when compared with growth–2. There were little differences in $\overline{\text{MR index}}$ between the two growths and this made some contribution to higher $\overline{\text{RGR}}$ in growth–3.

There are cases in which the content of metabolizable energy (ME) is not known for the feed given to the animal. If digestible energy (DE) content is known, it is possible to estimate its ME by multiplying DE and 0.82 together (NRC, 1984). However, where only dry matter content is known, it is recommended to use the following equation for growth analysis.

$$\frac{1}{W} \cdot \frac{dW}{dt} = \left(\frac{1}{W} \cdot \frac{dI_D}{dt}\right) \cdot \frac{dW}{dI_D}, \qquad (10)$$

where I_D = cumulative intake of dry matter.

The present method for growth analysis of beef cattle showed that RGR was controlled by DIM, MBS ratio or MR index, and EEG, in beef cattle weighing 300 kg to 500 kg. A feature of this method was that it might account for how MR index was involved in the growth analysis of beef cattle.

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