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Two Different-Type Equations Analyzing Decrease in Dry Matter Digestibility with Growth of Forages

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This study was conducted to present a new equation for analyzing the decrease in dry matter digestibility [DDMD] with growth of forage, and to relate it and the previous equation analyzing DDMD (Shimojo *et al.*, 1998b).

The following equation showed the relationship between two equations, namely, the new equation on the left-hand side and the changed form of the previous equation on the right-hand side.

$$\frac{D_1}{W_1} \cdot \left[1-\exp\left\{\left(\overline{\mathrm{RGR_d}}-\overline{\mathrm{RGR_w}}\right)\cdot\left(t_2-t_1\right)\right\}\right]=\left(1-\frac{W_1}{W_2}\right)\cdot\left(\frac{D_1}{W_1}-\frac{\overline{\mathrm{RGR_d}}}{\overline{\mathrm{RGR_w}}}\cdot\frac{D}{W}\right), \quad \text{(A)}$$

where W = dry weight of forage ($W_1 \neq W_2$), D = dry weight of digestible materials ($D_1 \neq D_2$), $\overline{\mathrm{RGR_w}}$ = mean relative growth rate of forage, $\overline{\mathrm{RGR_d}}$ = mean relative growth rate of D, $(1 - W_1/W_2)$ = forage growth index [FG index], $\{D_1/W_1 - (\overline{\mathrm{RGR_d}}/\overline{\mathrm{RGR_w}})\cdot(D/W)\}$ = a changed form of DDMPD index (DDMPD index: index for the decrease in dry matter partition into D).

The following results were obtained:

Equation (A) showed that DDMD was expressed using $\mathrm{RGR_d}$ and $\mathrm{RGR_w}$ as main factors in either of two different-type equations. It was suggested that there was a new equation analyzing DDMD, and using the new and previous equations some information was obtained for the change in dry matter digestibility with growth of forages.

INTRODUCTION

The dry matter digestibility usually decreases with growth of forage (Van Soest, 1982; Minson, 1990). This process has been analyzed using simple equations in a report of Shimojo *et al.* (1998b). It might be expected that there are other equations available for the analysis of digestibility decreases, because Masuda (1985) and Shimojo *et al.* (1995) gave different-type equations to analyze the increase in dry matter indigestibility and these two equations have been closely related in a recent report (Shimojo *et al.*, 1998a).

This study was planned to construct a new equation for analyzing the decrease in dry matter digestibility with growth of forage, and to relate it and the previous equation reported by Shimojo *et al.* (1998b).

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NEW EQUATION FOR ANALYZING THE DECREASE IN DRY MATTER DIGESTIBILITY AND THE RELATION WITH PREVIOUS EQUATION

New equation

A new equation for analyzing the decrease in dry matter digestibility [DDMD] with growth of forage is constructed according to the following process that is after the equation construction by Masuda (1985) to analyze the increase in dry matter indigestibility.

Thus,

$$\begin{aligned}(\overline{\mathrm{RGR_d}}-\overline{\mathrm{RGR_w}})\cdot(t_2-t_1) &= \left(\frac{\log_e D_2-\log_e D_1}{t_2-t_1}-\frac{\log_e W_2-\log_e W_1}{t_2-t_1}\right)\cdot(t_2-t_1)\\ &= (\log_e D_2-\log_e W_2)-(\log_e D_1-\log_e W_1)\\ &= \log_e\left(\frac{D_2}{W_2}\right)-\log_e\left(\frac{D_1}{W_1}\right)\\ &= \log_e\left\{\left(\frac{D_2}{W_2}\right)\cdot\left(\frac{D_1}{W_1}\right)^{-1}\right\}, \qquad (1)\end{aligned}$$

where W = dry weight of forage, D = dry weight of digestible materials,
$\overline{\mathrm{RGR_d}}$ = mean relative growth rate of D over the interval t_1 to t_2,
$\overline{\mathrm{RGR_w}}$ = mean relative growth rate of forage over the interval t_1 to t_2,
e = the base of natural logarithm.

Equation (1) is rewritten as follows:

$$\left(\frac{D_2}{W_2}\right)\cdot\left(\frac{D_1}{W_1}\right)^{-1}=\exp\left\{(\overline{\mathrm{RGR_d}}-\overline{\mathrm{RGR_w}})\cdot(t_2-t_1)\right\}, \qquad (2)$$

namely,

$$\left(\frac{D_2}{W_2}\right)=\left(\frac{D_1}{W_1}\right)\cdot\exp\left\{(\overline{\mathrm{RGR_d}}-\overline{\mathrm{RGR_w}})\cdot(t_2-t_1)\right\}. \qquad (3)$$

Then, DDMD is expressed as follows:

$$\begin{aligned}\frac{D_1}{W_1}-\frac{D_2}{W_2} &= \frac{D_1}{W_1}-\frac{D_1}{W_1}\cdot\left[\exp\left\{(\overline{\mathrm{RGR_d}}-\overline{\mathrm{RGR_w}})\cdot(t_2-t_1)\right\}\right]\\ &= \frac{D_1}{W_1}\cdot\left[1-\exp\left\{(\overline{\mathrm{RGR_d}}-\overline{\mathrm{RGR_w}})\cdot(t_2-t_1)\right\}\right]. \qquad (4)\end{aligned}$$

Thus, equation (4) gives a new description of the analysis of DDMD.

Previous equation

The previous equation presented by Shimojo *et al.* (1998b) for the analysis of DDMD is as follows:

$$\begin{aligned}\mathrm{DDMD} &= \frac{D_1}{W_1}-\frac{D_2}{W_2}\\ &= \left(1-\frac{W_1}{W_2}\right)\cdot\left(\frac{D_1}{W_1}-\frac{\overline{\mathrm{ARD}}}{\overline{\mathrm{RGR_w}}}\right), \qquad (5)\end{aligned}$$

where W = dry weight of forage ($W_1 \neq W_2$), D = dry weight of digestible materials, $\overline{\text{ARD}}$ = mean accumulation rate of D per unit W over the interval t_1 to t_2, $\overline{\text{RGR}_w}$ = mean relative growth rate of forage over the interval t_1 to t_2, $(1 - W_1/W_2)$ = forage growth index [FG index], $(D_1/W_1 - \overline{\text{ARD}}/\overline{\text{RGR}_w})$ = index for the decrease in dry matter partition into digestible materials [DDMPD index].

Thus, DDMD is expressed as the product of FG index and DDMPD index.

$\overline{\text{ARD}}$ is approximately as follows:

$$\overline{\text{ARD}} = \frac{\log_e W_2 - \log_e W_1}{W_2 - W_1} \cdot \frac{D_2 - D_1}{t_2 - t_1}, \qquad (6)$$

where e = the base of natural logarithm.

Relating new and previous equations

Equation (5) is changed in form as follows to relate it and equation (4).

Thus,

$$\frac{\text{ARD}}{\text{RGR}_W} = \frac{\frac{1}{W} \cdot \frac{dD}{dt}}{\frac{1}{W} \cdot \frac{dW}{dt}}$$

$$= \frac{\frac{1}{D} \cdot \frac{dD}{dt}}{\frac{1}{W} \cdot \frac{dW}{dt}} \cdot \frac{D}{W}, \qquad (7)$$

where $(1/D) \cdot (dD/dt) = \text{RGR}_d$, $(1/W) \cdot (dW/dt) = \text{RGR}_w$, D/W = the ratio of D to W [D ratio]. Then, equation (7) is rewritten as follows:

$$\frac{\overline{\text{ARD}}}{\text{RGR}_W} = \frac{\overline{\text{RGR}_d}}{\text{RGR}_W} \cdot \frac{D}{W}. \qquad (8)$$

$\overline{\text{D ratio}}$ over the interval t_1 to t_2 is approximately as follows:

$$\overline{\text{D ratio}} = \frac{D_2 - D_1}{\log_e D_2 - \log_e D_1} \cdot \frac{\log_e W_2 - \log_e W_1}{W_2 - W_1}, \qquad (9)$$

where $D_1 \neq D_2$, $W_1 \neq W_2$.

Inserting equation (8) into equation (5) gives

$$\text{DDMD} = \left(1 - \frac{W_1}{W_2}\right) \cdot \left(\frac{D_1}{W_1} - \frac{\overline{\text{RGR}_d}}{\text{RGR}_w} \cdot \frac{D}{W}\right), \qquad (10)$$

where $\{D_1/W_1 - (\overline{\text{RGR}_d}/\overline{\text{RGR}_w}) \cdot (\text{D/W})\}$ is a changed form of DDMPD index.

Relating the new equation (4) and the previous equation (10) leads to the following equation (11).

$$\frac{D_1}{W_1} \cdot \left[1 - \exp\left\{\left(\overline{\text{RGR}_d} - \overline{\text{RGR}_w}\right) \cdot (t_2 - t_1)\right\}\right] = \left(1 - \frac{W_1}{W_2}\right) \cdot \left(\frac{D_1}{W_1} - \frac{\overline{\text{RGR}_d}}{\text{RGR}_w} \cdot \frac{D}{W}\right). \qquad (11)$$

This equation shows that DDMD is expressed using RGR_d and RGR_w as main factors in

either of two different-type equations. In other words, RGR_d and RGR_w may substantially relate the new and the previous equations analyzing DDMD. RGR_d and RGR_w are considered the essential elements required for constructing the method that analyzes DDMD as simply as possible.

If the following equation (12) is used to transfer the method for analyzing DDMD from the left-hand side equation to the right-hand side equation in the original form (Shimojo *et al.*, 1998b),

$$\frac{D_1}{W_1} \cdot \left[1-\exp\left\{\left(\overline{RGR_d}-\overline{RGR_w}\right) \cdot \left(t_2-t_1\right)\right\}\right]=\left(1-\frac{W_1}{W_2}\right) \cdot \left(\frac{D_1}{W_1}-\frac{\overline{ARD}}{\overline{RGR_w}}\right), \quad (12)$$

then, ARD in the right-hand side equation is available for analyzing the accumulation of D from digestible materials present in forage and new photosynthates in the growth of forages (Shimojo *et al.*, 1998b).

Conclusions

It is suggested from this study that there is a new equation for analyzing the decrease in dry matter digestibility with growth of forages, and both the new and previous equations are expressed using relative growth rate of forage and that of digestible materials.

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