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Forage Growth Analysis, Forage Digestion Analysis and Ruminant Growth Analysis as related using Simple Equations

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The present study was conducted, using simple equations, to suggest relationships among forage growth analysis, forage digestion analysis and ruminant growth analysis. Forage relative growth rate [RGR] was related to the decrease in dry matter digestibility with forage growth through forage lignification to form indigestible materials. Ruminant RGR was described so as to include forage dry matter digestibility as one of the components. Daily forage intake of the animal, which was one of the components of ruminant RGR, was described using net assimilation rate and leaf area of the forage that were components of forage absolute growth rate. Ruminant RGR was also related to production and utilization characteristics of forages and metabolic characteristics of ruminants. Thus, the present study using simple equations suggested that there were relationships among forage growth analysis, forage digestion analysis and ruminant growth analysis.

INTRODUCTION

Domestic ruminants provide us with animal products, such as meat, milk, wool, and in some cultures source of power (Minson, 1990). Farmers grow ruminants using the land as meadow and pasture that seems to be unsuitable for producing crops for human consumption. The feature of ruminant production from forages is that ruminants can digest plant fibers which are considered unavailable to human digestive system. The forage–ruminant complex is of primary concern to both pasture scientists and ruminant nutritionists who support, theoretically and practically, those farmers who are engaged on the production of ruminants from forages (Hacker, 1982; Van Soest, 1982; Wheeler *et al.*, 1987; Minson, 1990; Humphreys, 1991). It is, therefore, considered of interest to suggest relationships among forage growth, forage digestion and ruminant growth.

In our previous reports using simple equations the following relationships have been suggested: (1) between forage growth analysis and forage digestibility analysis (Shimojo *et al.*, 1998c, d, g, i), (2) between forage growth analysis and ruminant growth analysis (Shimojo *et al.*, 1998f, h, 1999a, b), (3) between ruminant growth analysis and feed digestibility (Shimojo *et al.*, 1999a), (4) between net assimilation rate of forages and forage intake of ruminants (Shimojo *et al.*, 1999b), (5) between accumulation of digestible materials in forages and digestion of forage dry matter (Shimojo *et al.*, 1999c).

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These studies, if taken up in the same paper, might be expected to give a rough description of the forage–ruminant relationships.

The present study was designed, using simple equations, to suggest a broad outline of relationships among forage growth analysis, forage digestion analysis and ruminant growth analysis.

SUGGESTED RELATIONSHIPS

1. Descriptions of growth analysis equations

In the present study growth analysis equations take the basic form of differential equations even when mean value over the growth period is required, because this might be expected to give an easy understanding of primitive concepts of suggested relationships. The necessity of using mean value over the period will occur in the analyzing of forage digestibility changes (section 2) and digestion processes (section 3). In those two sections, therefore, the differential equation will imply the mean value over the period, though this looks somewhat forcible. The present study will deal with primitive concepts of suggested relationships only. If applied to actual data in further studies, it goes without saying that the mean value over the growth period should be calculated.

2. Forage growth analysis and forage digestion analysis

Forage relative growth rate [Forage RGR] is expressed as follows (Watson, 1952; Hunt, 1990):

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

where W=forage dry weight, t=forage growth days.

The decrease in dry matter digestibility [DDMD] with forage growth from t_1 to t_2 is described as follows (Shimojo *et al.*, 1998c, d, g):

$$\begin{aligned} \text{DDMD} &= \frac{D_1}{W_1} - \frac{D_2}{W_2} \\ &= \left(1 - \frac{W_1}{W_2}\right) \cdot \left(\frac{D_1}{W_1} - \frac{\frac{1}{W} \cdot \frac{dD}{dt}}{\frac{1}{W} \cdot \frac{dW}{dt}} \right), \qquad (2) \end{aligned}$$

where W=forage dry weight, D=dry weight of digestible materials in the forage, t=growth days, (D_j/W_j)=dry matter digestibility [DMD] at growth days j, $(1/W)\cdot(dD/dt)$=accumulation rate of D per unit W [ARD], $(1/W)\cdot(dW/dt)$=forage RGR, $(1-W_1/W_2)$=forage growth index [FG index], $[D_1/W_1-\{(1/W)\cdot(dD/dt)\}/\{(1/W)\cdot(dW/dt)\}]$=an index for the decrease in dry matter partition into D [DDMPD index].

Forage RGR [equation (1)] is included in the right–hand side of equation (2). This suggests, therefore, a sort of relationship between forage RGR and forage digestibility decreases during the growth.

The value of DDMD is equal to that of increases in dry matter indigestibility [IDMI] between t_1 and t_2 (Masuda, 1985). Thus,

$$
\begin{aligned}
\text{DDMD} &= \text{IDMI} \\
&= \frac{I_2}{W_2} - \frac{I_1}{W_1} \\
&= \left(1 - \frac{W_1}{W_2}\right) \cdot \left(\frac{\frac{1}{W} \cdot \frac{dI}{dt}}{\frac{1}{W} \cdot \frac{dW}{dt}} - \frac{I_1}{W_1} \right), \qquad (3)
\end{aligned}
$$

where W=forage dry weight, I=dry weight of indigestible materials in the forage, t=growth days, (I_j/W_j)=dry matter indigestibility [DMI] at growth days j, $(1/W)\cdot(dI/dt)$=formation rate of I per unit W [FRI], $(1/W)\cdot(dW/dt)$=forage RGR, $(1-W_1/W_2)$=FG index, $[\{(1/W)\cdot(dI/dt)\}/\{(1/W)\cdot(dW/dt)\}-I_1/W_1]$=an index for dry matter partition into I [DMPI index] (in the present study DMPI index is adopted in place of DMP index which was used in our previous reports (Shimojo *et al.*, 1995, 1997a, c, 1998b, e)).

Equation (3) is modified as follows to include more information about FRI and forage RGR:

$$
\frac{D_1}{W_1} - \frac{D_2}{W_2} = \left(1 - \frac{W_1}{W_2}\right) \cdot \left\{ \frac{\left(\frac{D + \frac{dW}{dt}}{W}\right) \cdot \left(\frac{1}{D + \frac{dW}{dt}} \cdot \frac{dL}{dt}\right) \cdot \left(\frac{dI}{dL}\right)}{\left(\frac{1}{A} \cdot \frac{dW}{dt}\right) \cdot \left(\frac{A}{A_W}\right) \cdot \left(\frac{A_W}{W}\right)} - \frac{I_1}{W_1} \right\}, \qquad (4)
$$

where W=forage dry weight, A=leaf area of the forage, A_W=leaf weight of the forage, $(1/A)\cdot(dW/dt)$=net assimilation rate [NAR], (A/A_W)=specific leaf area [SLA], (A_W/W)=leaf weight ratio [LWR], D=dry weight of digestible materials in the forage, L=amount of lignin [acid detergent lignin (Goering and Van Soest (1970)) was used in our reports (Shimojo *et al.*, 1998a, e, i)], (dW/dt)=new photosynthates (expressed in weight, not in rate), $(D+dW/dt)$=source materials [S] for I formation, $(D+dW/dt)/W$=the ratio of S to W [S ratio], $[\{1/(D+dW/dt)\}\cdot(dL/dt)]$=lignification rate of S [LRS], (dI/dL)=formation of I per unit increase in L [FIL].

Equation (4) shows (a) how forages grow by the assimilation activity of leaves, (b) how the digestible materials and new photosynthates are lignified to form the indigestible materials, and thus, (c) how there occurs the decrease in dry matter digestibility during the growth. In brief, equation (4) shows analyses of forage maturation process, and the relationship between (a) and (c) is mediated by (b). This suggests, therefore, a relationship between forage growth analysis and forage digestion analysis, which gives more detailed description of forage maturation process compared with equation (2).

3. Forage maturation analysis and forage digesting process analysis

In this section the analysis of forage digestion process will be taken up. When DMD is determined by *in vitro* incubation of forages with rumen fluid followed by pepsin, the following equation is suggested (Shimojo *et al.*, 1999c):

$$\mathrm{DDMD} = \mathrm{DMD}_1 - \mathrm{DMD}_2$$

$$= -4 \cdot \left[\left\{ \frac{\left(\frac{1}{W} \cdot \frac{d(ABL)}{dT} \right) \cdot \left(\frac{dW}{d(ABL)} \right) \cdot (W)}{W_0} \right\}_1 - \left\{ \frac{\left(\frac{1}{W} \cdot \frac{d(ABL)}{dT} \right) \cdot \left(\frac{dW}{d(ABL)} \right) \cdot (W)}{W_0} \right\}_2 \right], \quad (5)$$

where T=incubation time (dT=4 in actual calculation), DMD_1=DMD at forage growth days t_1 $=-4\cdot[\{(1/W)\cdot(d(ABL)/dT)\cdot(dW/d(ABL))\cdot(W)\}/W_0]_1$, DMD_2=DMD at forage growth days t_2 $=-4\cdot[\{(1/W)\cdot(d(ABL)/dT)\cdot(dW/d(ABL))\cdot(W)\}/W_0]_2$, W=forage dry weight, ABL=amount of acetyl bromide lignin (Morrison, 1972a, b) in the forage, W_0=W before the incubation, 4=2–day incubation with rumen fluid followed by another 2–day incubation with pepsin, $(1/W)\cdot(d(ABL)/dT)$=degradation rate of ABL [DRL] per unit W, $(dW/d(ABL))$=digestion of W per unit degradation of ABL [DWDL].

Since both equations (4) and (5) describe DDMD, relating them gives

$$\left(1-\frac{W_1}{W_2}\right) \cdot \left\{ \frac{\left(\frac{D + \frac{dW}{dt}}{W} \right) \cdot \left(\frac{1}{D + \frac{dW}{dt}} \cdot \frac{dL}{dt} \right) \cdot \left(\frac{dI}{dL} \right)}{\left(\frac{1}{A} \cdot \frac{dW}{dt} \right) \cdot \left(\frac{A}{A_W} \right) \cdot \left(\frac{A_W}{W} \right)} - \frac{I_1}{W_1} \right\}$$

$$= -4 \cdot \left[\left\{ \frac{\left(\frac{1}{W} \cdot \frac{d(ABL)}{dT} \right) \cdot \left(\frac{dW}{d(ABL)} \right) \cdot (W)}{W_0} \right\}_1 - \left\{ \frac{\left(\frac{1}{W} \cdot \frac{d(ABL)}{dT} \right) \cdot \left(\frac{dW}{d(ABL)} \right) \cdot (W)}{W_0} \right\}_2 \right]. \quad (6)$$

The left–hand side of equation (6) shows analyses of both forage growth and forage lignification to form indigestible materials, and the right–hand side shows analyses of forage lignin degradation to digest dry matter by *in vitro* incubation with rumen fluid and pepsin. This suggests, therefore, a relationship forage maturation analysis and forage digesting process analysis.

4. Ruminant growth analysis and forage digestibility

Ruminant relative growth rate [Ruminant RGR] is suggested as follows when related to forage DMD (Shimojo *et al.*, 1999a):

$$\text{Ruminant RGR} = \frac{1}{W} \cdot \frac{dW}{dt}$$

$$= \left(\frac{1}{W} \cdot \frac{dF}{dt} \right) \cdot \left(\frac{dF_D}{dF} \right) \cdot \left(\frac{dW}{dF_D} \right), \quad (7)$$

where W=animal body weight, t=animal growth days, F=cumulative forage intake of the animal, F_D=cumulative intake of digestible dry matter, $(1/W)\cdot(dF/dt)$=daily forage intake per unit W [DFIW], (dF_D/dF)=forage DMD, (dW/dF_D)=efficiency of F_D for body weight gain [EDG].
Why $[dF_D/dF]$ means forage DMD is explained as follows: if an animal is being fed, during the given period, only the cut forage of the same quality, then it is likely that dF_D/dF gives a round estimate of DMD of the forage over the feeding period.

Equation (7) shows how ruminant RGR is related to forage DMD. This suggests, therefore, a relationship between ruminant growth analysis and forage digestibility.

5. Net assimilation rate of forages and forage intake of ruminants

A relationship between net assimilation rate of forages and forage intake of ruminants has been suggested as follows (Shimojo *et al.*, 1999b):

$$\frac{1}{W}\cdot\frac{dF}{dt}=\frac{1}{W}\cdot\left\{\left(\frac{1}{A}\cdot\frac{dF}{dt}\right)\cdot A\right\}, \qquad (8)$$

where W=animal body weight, F=cumulative forage intake of the animal=forage yield at the meadow, t=animal growth days=forage feeding days=forage growth days, $(1/W)\cdot(dF/dt)$=DFIW, A=forage leaf area, $(1/A)\cdot(dF/dt)$=$NAR_{(f\text{-}r)}$ that suggests a sort of relationship between forage NAR and ruminant DFI.

Equation (8) requires, as mentioned above, that growth period and yield of the forage are equal to its feeding period (=animal growth period) and cumulative intake in the ruminant, respectively. How these adjustments are made is reported in our previous paper (Shimojo *et al.*, 1999b) in which it is shown that relating ruminant DFI with forage NAR might be easy under favorable growth conditions for both forages and ruminants. It seems that a sort of relationship between ruminant DFI and forage NAR might give a broad outline of mutual regulation between the area of meadow and the number of ruminants. Actually, needless to say, this might have some meaning in the cases where the forage yield more than meets the intake by ruminants, because the adjustment includes a very delicate problem.

6. Forage growth analysis and ruminant growth analysis

It is shown by Shimojo *et al.* (1998f, h, 1999a, b) that forage RGR and ruminant RGR are derived from two hypothetic equations as special cases. Two equations suggested hypothetically are as follows:

$$\mathrm{H}=\left(\frac{1}{\alpha}\cdot\frac{d\beta}{dt}\right)\cdot\left(\frac{\alpha}{W}\right)\cdot\left(\frac{dW}{d\beta}\right), \qquad (9)$$

$$\mathrm{H}^*=\left(\frac{1}{\alpha}\cdot\frac{d\beta}{dt}\right)\cdot\left(\frac{\alpha}{W}+\frac{dW}{d\beta}-1\right), \qquad (10)$$

where α and β are a set of parameters related to forage RGR or ruminant RGR, W=dry weight per plant or body weight per animal, t=growth days of the forage or the animal.

If α=A [forage leaf area] and β=W [forage dry weight] in equations (9) and (10), then

$$\mathrm{H}=\left(\frac{1}{A}\cdot\frac{dW}{dt}\right)\cdot\left(\frac{A}{W}\right)\cdot\left(\frac{dW}{dW}\right)$$
$$=\left(\frac{1}{A}\cdot\frac{dW}{dt}\right)\cdot\frac{A}{W}$$
$$=\text{forage RGR}, \tag{11}$$

$$\mathrm{H}^*=\left(\frac{1}{A}\cdot\frac{dW}{dt}\right)\cdot\left(\frac{A}{W}+\frac{dW}{dW}-1\right)$$
$$=\left(\frac{1}{A}\cdot\frac{dW}{dt}\right)\cdot\frac{A}{W}$$
$$=\text{forage RGR}. \tag{12}$$

If $\alpha=W$ [animal body weight] and $\beta=F$ [cumulative forage intake] in equations (9) and (10), then

$$\mathrm{H}=\left(\frac{1}{W}\cdot\frac{dF}{dt}\right)\cdot\left(\frac{W}{W}\right)\cdot\left(\frac{dW}{dF}\right)$$
$$=\left(\frac{1}{W}\cdot\frac{dF}{dt}\right)\cdot\frac{dW}{dF}$$
$$=\text{ruminant RGR}, \tag{13}$$

$$\mathrm{H}^*=\left(\frac{1}{W}\cdot\frac{dF}{dt}\right)\cdot\left(\frac{W}{W}+\frac{dW}{dF}-1\right)$$
$$=\left(\frac{1}{W}\cdot\frac{dF}{dt}\right)\cdot\frac{dW}{dF}$$
$$=\text{ruminant RGR}. \tag{14}$$

Equations (11)~(14) suggest, as it were, a sort of indirect relationship between forage RGR equation and ruminant RGR equation.

In addition to the above indirect relationships, a sort of direct relationship between ruminant growth analysis and forage growth analysis is suggested by inserting equation (8) into ruminant RGR equation (Shimojo *et al.*, 1999b). Thus,

$$\text{Ruminant RGR}=\frac{1}{W}\cdot\frac{dW}{dt}$$
$$=\left(\frac{1}{W}\cdot\frac{dF}{dt}\right)\cdot\frac{dW}{dF}$$
$$=\left[\frac{1}{W}\cdot\left\{\left(\frac{1}{A}\cdot\frac{dF}{dt}\right)\cdot A\right\}\right]\cdot\frac{dW}{dF}, \tag{15}$$

where W=animal body weight, F=cumulative forage intake of the animal=forage yield at the meadow, t=animal growth days=forage feeding days=forage growth days, A=forage leaf area, $(1/A)\cdot(dF/dt)=\mathrm{NAR}_{(f\text{-}r)}$ that might relate forage NAR and ruminant DFI,

(dW/dF)=efficiency of F for body weight gain.

The product of leaf area and $NAR_{(f\text{-}r)}$ in equation (15) gives forage absolute growth rate [AGR], which shows that forage AGR is incorporated into ruminant RGR. This suggests, therefore, a sort of direct relationship between ruminant growth analysis and forage growth analysis.

In addition to above descriptions, equation (10) has another feature shown as follows: if $\alpha=A$ and $\beta=F$, then

$$H^* = \left(\frac{1}{A}\cdot\frac{dF}{dt}\right)\cdot\left(\frac{A}{W}+\frac{dW}{dF}-1\right)$$

$$=\left(\frac{1}{W}\cdot\frac{dF}{dt}\right)+\left(\frac{1}{A}\cdot\frac{dW}{dt}\right)-\left(\frac{1}{A}\cdot\frac{dF}{dt}\right), \qquad (16)$$

where $(1/W)\cdot(dF/dt)$=DFIW, $(1/A)\cdot(dW/dt)$=forage NAR, $(1/A)\cdot(dF/dt)=NAR_{(f\text{-}r)}$. This implies that equation (10) shows the deriving of a sort of coexistence of forages and ruminants in the energy ingestion [equation (16)], as well as the deriving of forage RGR [equation (12)] and ruminant RGR [equation (14)] as special cases.

In this section, the unifying of relative growth analysis equation of forages and that of ruminants into a hypothetic equation suggests some aspects of close relationships between ruminants and forages.

7. Ruminant growth analysis related to factors of both forages and ruminants

It seems that there are some descriptions of this relationship. The first one is given by combining equations (7) and (8). Thus,

$$\text{Ruminant RGR} = \frac{1}{W}\cdot\frac{dW}{dt}$$

$$=\left(\frac{1}{W}\cdot\frac{dF}{dt}\right)\cdot\left(\frac{dF_D}{dF}\right)\cdot\left(\frac{dW}{dF_D}\right)$$

$$=\left[\frac{1}{W}\cdot\left\{\left(\frac{1}{A}\cdot\frac{dF}{dt}\right)\cdot A\right\}\right]\cdot\left(\frac{dF_D}{dF}\right)\cdot\left(\frac{dW}{dF_D}\right), \qquad (17)$$

where W=animal body weight, t=animal growth days=forage feeding days=forage growth days, F=cumulative forage intake of the animal=forage yield at the meadow, A=forage leaf area, $(1/A)\cdot(dF/dt)=NAR_{(f\text{-}r)}$ suggesting a relationship between ruminant DFI and forage NAR, F_D=cumulative intake of digestible dry matter, $(1/W)\cdot(dF/dt)$=DFIW, (dF_D/dF)=forage DMD, (dW/dF_D)=EDG.

Equation (17) suggests how ruminant RGR is related to forage NAR and leaf area, as well as being related to forage DMD and EDG. This suggests, therefore, a sort of relationship of ruminant growth analysis to production and digestion characteristics of forages.

We suggested another equation to the description of ruminant RGR (Shimojo *et al.*, 1996, 1997b, 1999a). Thus,

$$\text{Ruminant RGR} = \frac{1}{W}\cdot\frac{dW}{dt}$$

$$=\left(\frac{1}{W^{0.75}}\cdot\frac{dF_{me}}{dt}\right)\cdot\left(\frac{W^{0.75}}{W}\right)\cdot\left(\frac{dW}{dF_{me}}\right), \qquad (18)$$

where W=animal body weight, $W^{0.75}$=metabolic body size [MBS] of the animal, F_{me}=cumulative intake of metabolizable energy, $(1/W^{0.75})\cdot(dF_{me}/dt)$=daily intake of metabolizable energy per unit MBS, $(W^{0.75}/W)$=metabolic body size ratio [MBS ratio] or maintenance requirements index [MR index], (dW/dF_{me})=efficiency of metabolizable energy for body weight gain [EEG].

Thus, the second one is given by the following procedure. If the animal is given the forage whose leaf area, NAR, gross energy, digestible energy and metabolizable energy are known, then, equation (18) is rewritten as follows:

$$\text{Ruminant RGR} = \frac{1}{W}\cdot\frac{dW}{dt}$$
$$= \left(\frac{W^{0.75}}{W}\right)\cdot\left[\frac{1}{W^{0.75}}\cdot\left\{\left(\frac{1}{A}\cdot\frac{dF_{ge}}{dt}\right)\cdot A\right\}\right]\cdot\left(\frac{dF_{de}}{dF_{ge}}\right)\cdot\left(\frac{dF_{me}}{dF_{de}}\right)\cdot\left(\frac{dW}{dF_{me}}\right), \qquad (19)$$

where W=animal body weight, $W^{0.75}$=MBS, F_{ge}=cumulative intake of forage gross energy, F_{de}=cumulative intake of forage digestible energy, F_{me}=cumulative intake of forage metabolizable energy, $(W^{0.75}/W)$=MBS ratio or MR index, A=forage leaf area, $(1/A)\cdot(dF_{ge}/dt)$=$NAR_{(f-r)}$ expressed as gross energy value of the forage [$NAR_{(f-r)}$ge], $[(1/W^{0.75})\cdot\{(1/A)\cdot(dF_{ge}/dt)\cdot A\}]$=daily intake of forage gross energy per unit MBS, (dF_{de}/dF_{ge})=forage energy digestibility [FED], (dF_{me}/dF_{de})=the ratio of metabolizable energy to digestible energy [RMD], (dW/dF_{me})=EEG.

Equation (19) suggests how ruminant RGR is related to production and utilization characteristics of forages and metabolic characteristics of ruminants. This suggests, therefore, that ruminant growth analysis is related to some factors of both forages and ruminants.

In equation (19), the use of $NAR_{(f-r)}$ge $[(1/A)\cdot(dF_{ge}/dt)]$ in place of $NAR_{(f-r)}$ $[(1/A)\cdot(dF/dt)]$ relates forage production to solar radiation from the viewpoint of the energy flow and fixation. Also in equation (19), since RMD $[dF_{me}/dF_{de}]$ is estimated to be 0.80～0.82 (ARC, 1980; SCA, 1990; Japan MAFF, 1995; NRC, 1996), rewriting equation (19) gives

$$\text{Ruminant RGR} = \frac{1}{W}\cdot\frac{dW}{dt}$$
$$= (0.80\text{～}0.82)\cdot\left(\frac{W^{0.75}}{W}\right)\cdot\left[\frac{1}{W^{0.75}}\cdot\left\{\left(\frac{1}{A}\cdot\frac{dF_{ge}}{dt}\right)\cdot A\right\}\right]\cdot\left(\frac{dF_{de}}{dF_{ge}}\right)\cdot\left(\frac{dW}{dF_{me}}\right). \qquad (20)$$

It is a feature of equation (20) that RMD, 0.80～0.82, is one of the components of, namely a coefficient in, ruminant RGR, as well as the conversion coefficient from digestible energy to metabolizable energy of forages.

8. Overview of suggested relationships

Overview of the present study suggests relationships among forage growth analysis, forage digestion analysis and ruminant growth analysis, namely ruminant production is influenced by production and digestion characteristics of forages. This has long been considered of importance to the production of ruminants from forages (Minson, 1990). It is a feature of the present study that growth analysis equations are used to account for how forages and ruminants are closely related. It goes without saying that there is a necessity for examining suggested relationships using forages and ruminants in various conditions. In addition, the present suggestions give only a partial and superficial viewpoint about the forage–ruminant relationships. These relationships are considered very deep and difficult to clarify, as have been shown in many references. Despite many difficult problems to be investigated, we wish to suggest the importance of standing midway between 'forages' and 'ruminants' from the viewpoint of the original and natural style of ruminant production, 'The domestic ruminant is a forage eater.' This may also be supported by the recent report (Diez–Gonzalez *et al.*, 1998) which shows that the number of acid–resistant *Escherichia coli*, which could survive at low pH of human gastric stomach that is a barrier to food–borne pathogens, is lower in cattle fed hay only than cattle fed mostly grain.

Conclusions

It was suggested from the present study using simple equations that there were relationships among forage growth analysis, forage digestion analysis and ruminant growth analysis.

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