Basic Dividing of Foods between Ruminants and Humans when based on the Production of Forages or Grain Crops, or Both - A Simple Analytic Description -

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Basic Dividing of Foods between Ruminants and Humans when based on the Production of Forages or Grain Crops, or Both – A Simple Analytic Description –

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The present study suggested a simple analytic description of the basic dividing of foods between ruminants and humans when it was based on the production of forages or grain crops, or both. The results obtained were as follows. (1) Humans depended basically on the grain crop and forage production for the raw materials of foods, where harvest index of grain crops and the production ratio between forages and grain crops were essential factors. (2) Forages and straws from grain crops were used as ruminant feeds. (3) Grains and animal protein from ruminants were used for human consumption. The results (1), (2) and (3) supported the human life.

INTRODUCTION

The production of ruminants from forages is of importance due to the ruminants' capability of converting plant fibers into animal protein for human consumption (Van Soest, 1982; Minson, 1990; Cecava, 1995b). This can avoid the grain competition between ruminants and humans, because straws from grain crops and forages are unavailable in the digestive tract of humans. The food competition problem is very difficult to solve because of the effects of many complicated factors, but simple analytic descriptions might be expected to help us to understand the basic dividing of foods between ruminants and humans.

The present study was designed, using the hypothetic equation reported by Shimojo *et al.* (1998), to suggest a simple analytic description of the basic dividing of foods between ruminants and humans when based on the production of forages or grain crops, or both.

ANALYSES OF BASIC DIVIDING OF FOODS

Procedures common to analyses

There are three procedures (A), (B) and (C) common to analyses in the present study.

(A) The following hypothetic equation [H] suggested by Shimojo *et al.* (1998), which

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shows a stretch of W as follows, is used. Thus,

$$H=\left(\frac{1}{\alpha}\cdot\frac{d\beta}{dt}\right)\cdot\left(\frac{\alpha}{\gamma}\right)\cdot\left(\frac{dW}{d\beta}\right), \quad (1)$$

where W=weight of something, t=time, α, β and γ are parameters.

(B) The following items are taken up for the insertion into equation (1) in various analyses. (i) W_R=ruminant body weight. (ii) W_H=human body weight. (iii) F [F is regarded as not only the harvested forage weight but also the cumulative forage intake by ruminants on condition that there is a complete consumption]. (iv) $G+S$ [$G+S$, where G is the grain weight for human consumption and S is the straw weight as a ruminant feed, is regarded as the cumulative grain and straw intake as well as the harvested grain crop weight on condition that there is a complete consumption].

(C) Equation (1) is used in the form of differential equation basically, but in some cases $dW/d\beta$ is allowed to be regarded as W/β when W and β show plant factors, because they are each given the cumulative value over the period of growth.

Food dividing based on forage or grain crop production

(A) Analysis based on forage production

In equation (1) $\alpha=W_R$, $\beta=F$ and $\gamma=W=W_H$, then, H based on the forage production [H_F] is described as follows:

$$H_F=\left(\frac{1}{W_R}\cdot\frac{dF}{dt}\right)\cdot\left(\frac{W_R}{W_H}\right)\cdot\left(\frac{dW_H}{dF}\right), \quad (2)$$

$$=\frac{1}{W_H}\cdot\frac{dW_H}{dt}. \quad (3)$$

Three terms in equation (2) are explained as follows. (i) $(1/W_R)\cdot(dF/dt)$ shows the forage ingestion rate per unit W_R [$FIRW_R$]. (ii) W_R/W_H, which is the body weight ratio, is regarded as the ruminant body mass supplied for human consumption [RBMHC]. (iii) dW_H/dF is regarded as the ratio of W_H changes to F [W_H–F ratio]. W_H–F ratio is not the efficiency of F for W_H changes, because F is unavailable for direct human consumption. The term in equation (3), $(1/W_H)\cdot(dW_H/dt)$, shows the relative growth rate of W_H [$RGRW_H$].

Equations (2) and (3) show that humans depend basically on the forage production [dW_H/dF, or (W_H changes)/F] for the raw materials of foods, where ruminants eat forages [$(1/W_R)\cdot(dF/dt)$] and supply animal protein for human consumption [W_R/W_H] to support the human life [$(1/W_H)\cdot(dW_H/dt)$]. This agricultural system may be found in the region where the land is unavailable for grain crop production for human consumption.

(B) Analysis based on grain crop production

In equation (1) $\alpha=W_R$, $\beta=G+S$ and $\gamma=W=W_H$, then, H based on the grain crop production [H_G] is described as follows:

$$H_G=\left(\frac{1}{W_R}\cdot\frac{d(G+S)}{dt}\right)\cdot\left(\frac{W_R}{W_H}\right)\cdot\left(\frac{dW_H}{d(G+S)}\right), \quad (4)$$

$$=\frac{1}{W_H}\cdot\frac{dW_H}{dt}. \quad (5)$$

Three terms in equation (4) are explained as follows. (i) $(1/W_R)\cdot(d(G+S)/dt)$ shows the grain and straw ingestion rate per unit W_R [$GSIRW_R$]. (ii) W_R/W_H =RBMHC. (iii) $dW_H/d(G+S)$ is regarded as the ratio of W_H changes to $G+S$ [W_H–GS ratio]. W_H–GS ratio is not the efficiency because S is unavailable for direct human consumption. The term in equation (5), $(1/W_H)\cdot(dW_H/dt)$, is $RGRW_H$.

Equations (4) and (5) show that humans depend basically on the grain crop production [$dW_H/d(G+S)$, or (W_H changes)/$(G+S)$] for the raw materials of foods, where only animal protein from ruminants is available for human consumption [W_R/W_H] to support the human life [$(1/W_H)\cdot(dW_H/dt)$] because ruminants eat grains as well as straws [$(1/W_R)\cdot(d(G+S)/dt)$]. This agricultural system is unusual because the grain eating habit of humans is ignored. Therefore, the form of equation (4) should be changed so as to include the grain eating by humans. Thus,

$$
\begin{aligned}
H_G &= \left(\frac{1}{W_R}\cdot\frac{d(G+S)}{dt}\right)\cdot\left(\frac{W_R}{W_H}\right)\cdot\left(\frac{dW_H}{d(G+S)}\right)\\
&= \left\{\frac{1}{W_R}\cdot\left(\frac{dG}{dt}+\frac{dS}{dt}\right)\right\}\cdot\left(\frac{W_R}{W_H}\right)\cdot\left(\frac{dW_H}{d(G+S)}\right)\\
&= \left(\frac{1}{W_R}\cdot\frac{dG}{dt}\right)\cdot\left(\frac{W_R}{W_H}\right)\cdot\left(\frac{dW_H}{d(G+S)}\right)+\left(\frac{1}{W_R}\cdot\frac{dS}{dt}\right)\cdot\left(\frac{W_R}{W_H}\right)\cdot\left(\frac{dW_H}{d(G+S)}\right)\\
&= \left(\frac{dW_H}{d(G+S)}\right)\cdot\left\{\left(\frac{1}{W_H}\cdot\frac{dG}{dt}\right)+\left(\frac{1}{W_R}\cdot\frac{dS}{dt}\right)\cdot\left(\frac{W_R}{W_H}\right)\right\}. \qquad (6)
\end{aligned}
$$

Four terms in equation (6) are explained as follows. (i) $dW_H/d(G+S)$=W_H–GS ratio. (ii) $(1/W_H)\cdot(dG/dt)$ shows the grain ingestion rate per unit W_H [$GIRW_H$]. (iii) $(1/W_R)\cdot(dS/dt)$ shows the straw ingestion rate per unit W_R [$SIRW_R$]. (iv) W_R/W_H =RBMHC.

Equation (6) shows that straws are used as a ruminant feed $[(1/W_R)\cdot(dS/dt)]$ and humans consume both grains $[(1/W_H)\cdot(dG/dt)]$ and animal protein from ruminants $[W_R/W_H]$. Straws from grain crops are low in the nutrient concentration and are usually given various treatments to improve the nutritive value before given to ruminants (Sundstøl and Owen, 1984; Preston and Leng, 1987). This agricultural system may avoid the food competition between ruminants and humans.

Food dividing based on forage and grain crop production

(A) Analysis based on the grain crop and forage production

In equation (1) $\alpha=W_R$, $\beta=G+S$, $\gamma=W_H$ and $W=F$, then, II based on the grain crop and forage production [H_{G-F}] is described as follows:

$$
\begin{aligned}
H_{G-F} &= \left(\frac{1}{W_R}\cdot\frac{d(G+S)}{dt}\right)\cdot\left(\frac{W_R}{W_H}\right)\cdot\left(\frac{dF}{d(G+S)}\right)\\
&= \left\{\frac{1}{W_R}\cdot\left(\frac{dG}{dt}+\frac{dS}{dt}\right)\right\}\cdot\left(\frac{W_R}{W_H}\right)\cdot\left(\frac{dF}{d(G+S)}\right)\\
&= \left(\frac{1}{W_R}\cdot\frac{dG}{dt}\right)\cdot\left(\frac{W_R}{W_H}\right)\cdot\left(\frac{dF}{d(G+S)}\right)+\left(\frac{1}{W_R}\cdot\frac{dS}{dt}\right)\cdot\left(\frac{W_R}{W_H}\right)\cdot\left(\frac{dF}{d(G+S)}\right)
\end{aligned}
$$

$$= \left(\frac{1}{W_R}\cdot\frac{dF}{dt}\right)\cdot\left(\frac{W_R}{W_H}\right)\cdot\left(\frac{dG}{d(G+S)}\right)+\left(\frac{1}{W_R}\cdot\frac{dF}{dt}\right)\cdot\left(\frac{W_R}{W_H}\right)\cdot\left(\frac{dS}{d(G+S)}\right), \quad (7)$$

$$= \left(\frac{1}{W_H}\cdot\frac{dG}{dt}\right)\cdot\left(\frac{dF}{d(G+S)}\right)+\left(\frac{1}{W_R}\cdot\frac{dS}{dt}\right)\cdot\left(\frac{W_R}{W_H}\right)\cdot\left(\frac{dF}{d(G+S)}\right). \quad (8)$$

Four different terms in equation (7) are explained as follows. (i) $(1/W_R)\cdot(dF/dt)$=FIRW$_R$. (ii) W_R/W_H=RBMHC. (iii) $dG/d(G+S)$ is regarded as $G/(G+S)$, the proportion of G to $G+S$ [G–GS proportion]. G–GS proportion is something like harvest index of grain crops. (iv) $dS/d(G+S)$ is regarded as $S/(G+S)$, the proportion of S to $G+S$ [S–GS proportion]. (S–GS proportion)+(G–GS proportion)=1. Three terms, which are given in equation (8) but not shown in equation (7), are explained as follows. (v) $(1/W_H)\cdot(dG/dt)$=GIRW$_H$. (vi) $(1/W_R)\cdot(dS/dt)$=SIRW$_R$. (vii) $dF/d(G+S)$ is regarded as $F/(G+S)$, the ratio of F to $G-S$ [F–GS ratio]. F–GS ratio is associated with the production ratio between them.

Equations (7) and (8) show the basic dividing of foods between ruminants and humans, where ruminants eat forages $[(1/W_R)\cdot(dF/dt)]$ and straws from grain crops $[(1/W_R)\cdot(dS/dt)]$ and humans consume grains $[(1/W_H)\cdot(dG/dt)]$ and animal protein from ruminants $[W_R/W_H]$. This agricultural system also includes, as essential factors, harvest index of grain crops $[dG/d(G+S)$, or $G/(G+S)]$ and the production ratio between forages and grain crops $[dF/d(G+S)$, or $F/(G+S)]$. Modern rice plant breeders have bred the short culm type showing higher harvest index than the long culm type of native breeds, because the short culm type shows resistance to lodging compared with the long culm type (Tanaka, 1987). It was suggested that resistance to lodging was related to a higher content of silica in the culm, but silicified straws were less digestible to ruminants (Hasan *et al.*, 1993). Mahadevan (1982) reported that the net annual calorie balance in the human food production was much better in the grain crop production than in the forage production, when the human food composed of grains and milk from buffaloes fed alkali–treated straws and other by–products supplemented with minerals and non–protein nitrogen was compared with that composed of milk from buffaloes given the cultivated forage and concentrates. This choice is considered of great importance in the region where there are many people and the agricultural land use is limited.

(B) Summarizing the suggestions from equations (7) and (8)

Equations (7) and (8) are summarized into an equation [H$_S$] when $\alpha = W_R$, $\beta = (G+S)+F$, $\gamma = W = W_H$ in equation (1). Thus,

$$H_S = \left\{\frac{1}{W_R}\cdot\frac{d\{(G+S)+F\}}{dt}\right\}\cdot\left(\frac{W_R}{W_H}\right)\cdot\left\{\frac{dW_H}{d\{(G+S)+F\}}\right\}. \quad (9)$$

Equation (9) gives the following two equations (10) and (11), respectively.

$$H_S = \left\{\frac{1}{W_R}\cdot\frac{d(G+S+F)}{dt}\right\}\cdot\left(\frac{W_R}{W_H}\right)\cdot\left\{\frac{dW_H}{d(G+S+F)}\right\}$$

$$= \left(\frac{1}{W_R}\cdot\frac{dG}{dt}\right)\cdot\left(\frac{W_R}{W_H}\right)\cdot\left(\frac{dW_H}{d(G+S+F)}\right)+\left(\frac{1}{W_R}\cdot\frac{d(S+F)}{dt}\right)\cdot\left(\frac{W_R}{W_H}\right)\cdot\left(\frac{dW_H}{d(G+S+F)}\right)$$

$$= \left\{ \frac{dW_H}{d(G+S+F)} \right\} \cdot \left\{ \left(\frac{1}{W_H} \cdot \frac{dG}{dt} \right) + \left(\frac{1}{W_R} \cdot \frac{d(S+F)}{dt} \right) \cdot \left(\frac{W_R}{W_H} \right) \right\}. \quad (10)$$

$$H_S = \left\{ \frac{1}{W_R} \cdot \frac{d(G+S+F)}{dt} \right\} \cdot \left(\frac{W_R}{W_H} \right) \cdot \left\{ \frac{dW_H}{d(G+S+F)} \right\}$$

$$= \frac{1}{W_H} \cdot \frac{dW_H}{dt}. \quad (11)$$

Four terms in equation (10) are explained as follows. (i) $dW_H/d(G+S+F)$ is regarded as the ratio of W_H changes to $G+S+F$ [W_H-GSF ratio], but it is not the efficiency due to the unavailability of $S+F$ for direct human consumption. (ii) $(1/W_H)\cdot(dG/dt)$=GIRW$_H$. (iii) $(1/W_R)\cdot(d(S+F)/dt)$ shows the straw and forage ingestion rate per unit W_R [SFIRW$_R$]. (iv) W_R/W_H=RBMHC. The term in equation (11), $(1/W_H)\cdot(dW_H/dt)$, is RGRW$_H$.

Equations (10) and (11) show that humans depend basically on the grain crop and forage production [$dW_H/d(G+S+F)$, or (W_H changes)/$(G+S+F)$] for the raw materials of foods, where humans consume, to support the life [$(1/W_H)\cdot(dW_H/dt)$], grain crops [$(1/W_H)\cdot(dG/dt)$] and animal protein from ruminants [W_R/W_H] eating straws from grain crops and forages [$(1/W_R)\cdot(d(S+F)/dt)$]. This agricultural system is considered reasonable because it gives the basic dividing of foods to avoid the food competition between ruminants and humans.

Suggestions from the present analyses

The present study shows a simple analytic description of the basic dividing of foods between ruminants and humans. A feature of these analyses is that forages, grain crops, ruminants and humans are all included in a hypothetic equation and basic relationships among them are derived from this equation, suggesting a sort of harmonic relationship between ruminant agriculture and human life.

Masuda (1999) suggests that grassland and forage crop sciences will make a contribution to the avoiding of food crisis, the solving of environmental issues and the establishing of sustainable agriculture. This implication seems to be based on the following three points. (1) The life zone of ruminants, which live on herbage basically, spreads from the human life zone to the zone of wildlife, where plants produce organic matter from solar energy (Cecava, 1995a). (2) This wide distribution of ruminants is supported by the capability of plant fiber digestion in the rumen and conversion into animal protein for human consumption without food competition with humans. (3) The vegetation of both native and improved grasslands, as well as the undergrowth of forests, may be controlled appropriately by the skillful use of ruminants, which will lead to the sustainable agriculture, the green sphere preservation and the protection from desertification.

The basic dividing of foods between ruminants and humans, which is shown analytically by equations (10) and (11) in the present study, may make a small contribution to the avoiding of food crisis, the point (2) related to Masuda's implication (1999).

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