Introducing Viewpoints of Mechanics into Basic Growth Analysis : (IX) Hypothetic Quasi-Four-Dimensional Growth Mechanics

Shimojo, Masataka
Laboratory of Animal Feed Science, Division of Animal Science, Department of Animal and MarineBioresource Sciences, Faculty of Agriculture, Kyushu University

Asano, Yoki
Employed Research Scientist, Miyazaki University

Ishiwaka, Reiko
Research Fellow, Faculty of Agriculture, Kyushu University

Nakano, Yutaka
University Farm, Faculty of Agriculture, Kyushu University

他

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Introducing Viewpoints of Mechanics into Basic Growth Analysis – (IX) Hypothetic Quasi–Four–Dimensional Growth Mechanics –

Masataka SHIMOJO*, Yoki ASANO[1], Reiko ISHIWAKA[2], Yutaka NAKANO[3], Manabu TOBISA[4], Noriko OHBA[5], Minako EGUCHI[6] and Yasuhisa MASUDA[7]

Laboratory of Animal Feed Science, Division of Animal Science, Department of Animal and Marine Bioresource Sciences, Faculty of Agriculture, Kyushu University, Fukuoka 812–8581, Japan

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This study was conducted to suggest quasi–four–dimensional basic growth mechanics for the ruminant animal and the forage plant by introducing three–dimensional (3–D) space. Suggested quasi–four–dimensions were composed of width, length from front to back and height of the body frame for 3–D space, and one–dimensional time with which the body frame was formed. The results obtained were as follows. (1) A group of expressions were suggested for weight increase and 3–D body frame formation with the passage of time. (2) A group of expressions were suggested for weight increase with time and 3–D body frame formation with weight increase. (3) A group of expressions were suggested for weight increase based on time and 3–D space, where time and space were treated equally to form weight–space–time relationships. (4) Quasi–four–dimensional growth mechanics with feed intake suggested the ruminant animal growth analysis and that with leaf area suggested the forage plant growth analysis. It was suggested that introducing 3–D space with an equal treatment of space and time gave hypothetic quasi–four–dimensional growth mechanics for the ruminant animal and the forage plant.

INTRODUCTION

Basic growth analysis of the ruminant animal (Brody, 1945; Shimojo *et al.*, 1997) and the forage plant (Blackman, 1919; Watson, 1952; Radford, 1967; Hunt, 1990) is given by weight changes with the passage of time. Shimojo *et al.* (2006, 2007a, 2007b, 2008) introduced viewpoints of mechanics into basic growth analysis to suggest basic growth mechanics with the aid of an analogy with Newton's laws of motion (Kawabe, 2006), which also showed the growth with time. However, the growth is closely related with the formation of body frame not only with time but also in space. This suggests adding the body frame formation in three–dimensional space that is composed of width, length from front to back and height of an individual ruminant animal and forage plant. Combining time and three–dimensional space might be expected to give quasi–four–dimensional growth mechanics for the ruminant animal and the forage plant.

The present study was designed to investigate the concept of quasi–four–dimensional growth mechanics in analyzing the body frame formation in the ruminant animal and the forage plant.

SUGGESTED CONCEPT OF QUASI–FOUR DIMENSIONAL GROWTH MECHANICS

(A) Basic growth mechanics based on time

The function of basic growth mechanics with the passage of time is given by a series of the following calculations.

$$(1/W)\cdot(dW/dt)=r_W, \tag{1}$$

$$W=W_0\cdot\exp(r_W\cdot t), \tag{2}$$

where W=weight, t=time, r_W = relative growth rate (RGR), W_0=the weight at t=0.

$$\mathrm{AGR}=dW/dt=r_W\cdot W_0\cdot\exp(r_W\cdot t), \tag{3}$$

$$\mathrm{GA}=d^2W/dt^2=r_W^{\,2}\cdot W_0\cdot\exp(r_W\cdot t), \tag{4}$$

where AGR=absolute growth rate, GA=growth acceleration.

$$\frac{dW/dt}{W}=\frac{d^2W/dt^2}{dW/dt}=r_W, \tag{5}$$

$$(dW/dt)^2=W\cdot(d^2W/dt^2), \tag{6}$$

$$dW/dt=\sqrt{W\cdot(d^2W/dt^2)}. \tag{7}$$

It is differential equation (7) that gives basic growth mechanics of an individual ruminant animal and forage plant (Shimojo *et al.*, 2006). It shows an analogy with Newton's equation of motion (Shimojo *et al.*, 2006, 2007a, 2007b, 2008).

[1] Employed Research Scientist, Miyazaki University, Miyazaki 889–2192, Japan
[2] Research Fellow, Faculty of Agriculture, Kyushu University
[3] University Farm, Faculty of Agriculture, Kyushu University
[4] Faculty of Agriculture, Miyazaki University, Miyazaki 889–2192, Japan
[5] Former Research Student, School of Agriculture, Kyushu University
[6] Technical Official, School of Agriculture, Kyushu University
[7] Emeritus Professor of Kyushu University
* Corresponding author (E–mail: mshimojo@agr.kyushu–u.ac.jp)

(B) Basic growth mechanics for body frame formation based on time

The basic growth mechanics for three–dimensional body frame formation of an individual ruminant animal and forage plant is given by the following differential equations when based on the passage of time,

$$dx/dt=\sqrt{x\cdot(d^2x/dt^2)},$$
$$dy/dt=\sqrt{y\cdot(d^2y/dt^2)},$$
$$dz/dt=\sqrt{z\cdot(d^2z/dt^2)}, \quad (8)$$

where x=width, y=length from front to back, z=height. Therefore, combining equations (7) and (8) gives a group of differential equations (9) for body frame formation,

$$dW/dt=\sqrt{W\cdot(d^2W/dt^2)}, \quad dx/dt=\sqrt{x\cdot(d^2x/dt^2)},$$
$$dy/dt=\sqrt{y\cdot(d^2y/dt^2)}, \quad dz/dt=\sqrt{z\cdot(d^2z/dt^2)}. \quad (9)$$

Basic growth functions corresponding differential equations (9) are as follows,

$$W=W_0\cdot\exp(r_W\cdot t), \quad x=x_0\cdot\exp(r_x\cdot t),$$
$$y=y_0\cdot\exp(r_y\cdot t), \quad z=z_0\cdot\exp(r_z\cdot t). \quad (10)$$

Functions (10) show that weight and space are not related, though each of them is related with time.

(C) Basic growth mechanics for body frame formation based on weight

The body frame formation is related with the weight, because the distribution of matter forms the body frame. Therefore, the following differential equations are given,

$$dW/dt=\sqrt{W\cdot(d^2W/dt^2)}, \quad dx/dW=\sqrt{x\cdot(d^2x/dW^2)},$$
$$dy/dW=\sqrt{y\cdot(d^2y/dW^2)}, \quad dz/dW=\sqrt{z\cdot(d^2z/dW^2)}, \quad (11)$$

$$W=W_0\cdot\exp(r_W\cdot t), \quad x=x_0\cdot\exp(r_j\cdot W),$$
$$y=y_0\cdot\exp(r_k\cdot W), \quad z=z_0\cdot\exp(r_l\cdot W). \quad (12)$$

The relationship between weight (W) and time is different from that between W and space in expressions (11) and (12).

(D) Basic growth mechanics of weight based on time and space

We suggest the following expressions, where W is related with time and space. Thus,

$$dW/dt=\sqrt{W\cdot(d^2W/dt^2)}, \quad dW/dx=\sqrt{W\cdot(d^2W/dx^2)},$$
$$dW/dy=\sqrt{W\cdot(d^2W/dy^2)}, \quad dW/dz=\sqrt{W\cdot(d^2W/dz^2)}, \quad (13)$$

$$W=W_0\cdot\exp(r_W\cdot t), \quad W=W_0\cdot\exp(r_a\cdot x),$$
$$W=W_0\cdot\exp(r_b\cdot y), \quad W=W_0\cdot\exp(r_c\cdot z). \quad (14)$$

Differential equations (13) suggest that the rate of matter distribution along axes of space and time is described using the product of weight and distribution acceleration. Basic growth functions (14) lead to the following equality (15), and thus equality (16),

$$W=W_0\cdot\exp(r_W\cdot t)=W_0\cdot\exp(r_a\cdot x)=W_0\cdot\exp(r_b\cdot y)$$
$$=W_0\cdot\exp(r_c\cdot z), \quad (15)$$

$$r_W\cdot t=r_a\cdot x=r_b\cdot y=r_c\cdot z. \quad (16)$$

The feature of equality (16) is that time and space are treated equally and there is an inverse proportion. Thus, if $x < y < z < t$, then $r_a > r_b > r_c > r_W$. This shows how much the matter is distributed along not only space axes but also time axis, where r_a, r_b, r_c and r_W suggest values of resistance to matter distribution along each axis of time and three–dimensional space. Equality (15) and equality (16) show weight–space–time relationships, suggesting quasi–four–dimensional growth mechanics.

(E) Basic growth mechanics for the ruminant animal based on time, space and feed intake

The basic growth mechanics of the ruminant animal is given by inserting feed intake (dF) into differential equations (13). The term dF is derived from cumulative feed intake (F) according to the procedure: $F\rightarrow\Delta F\rightarrow dF$. Thus,

$$\frac{dW/dt}{dF}=\sqrt{\frac{W}{dF}\cdot\frac{d^2W/dt^2}{dF}},$$
$$\frac{dW/dx}{dF}=\sqrt{\frac{W}{dF}\cdot\frac{d^2W/dx^2}{dF}},$$
$$\frac{dW/dy}{dF}=\sqrt{\frac{W}{dF}\cdot\frac{d^2W/dy^2}{dF}},$$
$$\frac{dW/dz}{dF}=\sqrt{\frac{W}{dF}\cdot\frac{d^2W/dz^2}{dF}}. \quad (17)$$

There are two features in expressions (17). One is that feed intake, as well as weight, is related to space and time, intake–weight–space–time relationships in the growth of the ruminant animal. The other is that feed intake is given to the denominator of every term in expressions, suggesting that the ruminant animal itself and its growth are supported by nutrients of eaten feeds. Expressions (17) suggest, in the ruminant animal body, the matter distribution along axes of space and time based on feed intake.

(F) Basic growth mechanics of the forage plant based on time, space and leaf area

The growth mechanics of the forage plant is given by inserting leaf area (A) into differential equations (13). Thus,

$$\frac{dW/dt}{A} = \sqrt{\frac{W}{A} \cdot \frac{d^2W/dt^2}{A}} ,$$

$$\frac{dW/dx}{A} = \sqrt{\frac{W}{A} \cdot \frac{d^2W/dx^2}{A}} ,$$

$$\frac{dW/dy}{A} = \sqrt{\frac{W}{A} \cdot \frac{d^2W/dy^2}{A}} ,$$

$$\frac{dW/dz}{A} = \sqrt{\frac{W}{A} \cdot \frac{d^2W/dz^2}{A}} . \qquad (18)$$

There are two features in expressions (18). One is that leaf area, as well as weight, is related to space and time, leaf–weight–space–time relationships in the growth of the forage plant. The other is that leaf area is given to the denominator of every term in expressions, suggesting that the forage plant itself and its growth are supported by photosynthesis of leaves. Expressions (18) suggest, in the forage plant body, the matter distribution along axes of space and time based on leaf area.

(G) Problems

The concept suggested to quasi–four–dimensional growth mechanics is only a hypothesis that includes many problems. Expressions suggested here include terms whose forms may look strange. Treating time and space equally may look illogical. Weight–space–time relationships may look unnatural. There is a need of further studies that will correct problems and introduce new ideas in order to develop growth mechanics with four–dimensions for the ruminant animal and the forage plant.

(H) Conclusions

It is suggested from the present study that introducing three–dimensional space with an equal treatment of space and time gives hypothetic quasi–four–dimensional growth mechanics for the ruminant animal and the forage plant.

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