A MODEL OF DIGESTIBILITY DYNAMICS IN LEAF SEGMENTS IN GRASS SWARDS

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ABSTRACT
A mechanistic model which describes the dynamics of dry matter digestibility (DMD) in leaves in a grass sward was developed. The model treats the leaves in the sward canopy as a set of 2 cm-long canopy components, and simulates DMD dynamics in the components from their emergence through aging. Each component has its own initial DMD at emergence, and the DMD decreases as the component ages. The model was parameterized and tested against data from a bahiagrass (*Paspalum notatum* Függe) pasture. This new, mechanistic approach was proved to be useful in developing our mechanistic understanding of DMD dynamics in a growing plant. The model is considered to be of use as a part of an integrated model of sward canopy structure which can be used to simulate herbage intake of a grazing animal at a level of a bite.

KEYWORDS
Model, digestibility dynamics, leaf segment, grass sward

INTRODUCTION
A number of modeling approaches have been made to herbage quality changes in a growing plant (Fick *et al*., 1994). In these approaches, herbage is treated as a bulk above an arbitrary height, and its quality attribute (e.g. digestibility) is empirically related to plant and/or environmental factors (e.g. age of herbage and growth temperature). A major disadvantage of such empirical models is that they are not general and do not deepen our mechanistic understanding of quality dynamics in a plant (Fick *et al*., 1994). In this paper, a new, mechanistic approach was taken to modeling the dynamics of DMD in leaves in grass swards. The model was parameterized and tested against data from a bahiagrass pasture (Hirata, 1996).

THE MODEL
The model treats the leaves in a sward canopy as a set of 2 cm-long canopy components, and simulates the DMD dynamics in the components from their emergence through aging. Figure 1 shows an example of data, which was collected from the vegetative tillers in a bahiagrass pasture in summer (Hirata, 1996). The figure shows the stem as well as the leaves, and the spatial distribution as well as the DMD, in order to give a stylized view of the canopy. The model expresses the DMD of a canopy component on day t (Dt, g DM (g DM)$^{-1}$) as:

$$D t = D\mathrm{I} - \text{Ð}D \qquad (1)$$

where D_t is the initial DMD of the component (g DM (g DM)$^{-1}$), and ÐD is the decrease in DMD with aging (g DM (g DM)$^{-1}$). DI is defined as the DMD when the component finished emerging, i.e. when the base end of the component emerged (day t_E). The model also defines the day when the component started emerging, i.e. when the tip end of the component emerged, as tS. The age of the component (tA, day) is expressed as:

$$t\mathrm{A} = t - t\mathrm{E} \qquad (2)$$

Parameterization to data from the tillers in spring and autumn and the vegetative tillers in summer (Hirata, 1996) resulted in the following equations for DI and ƒÇD (Hirata, unpublished):

$$D\mathrm{I} = 0.816 - 0.00815T\mathrm{E} \qquad (3)$$

$$\text{Ð}D = t\mathrm{A}(-0.01454 + 0.000825T\mathrm{A}) \qquad (4)$$

where TE and TA are the mean daily air temperatures during emergence (from tS to tE) and aging (from tE to t) of the component, respectively (½C).

MODEL PERFORMANCE
The model performance was tested using data from the tillers in summer, i.e. vegetative, booting and heading tillers (Hirata, 1996). The data from the vegetative tillers were used for parameterizing the model, but those from the booting and heading tillers were completely independent. Emergence and elongation of leaves were assumed to have stopped 7 days before the DMD measurements in the booting tillers, and 16 days before the measurements in the heading tillers. tS and tE of the components were estimated based on the leaf emergence and elongation rates (Hirata, unpublished).

There was a positive correlation between simulated (Dsim) and measured (Dmeas) DMD (r=0.840, P<0.001) (Fig. 2). The root mean square error (RMSE) was 0.039 g DM (g DM)$^{-1}$. With the independent data sets only, r was 0.774 (P<0.001) and RMSE was 0.046 g DM (g DM)$^{-1}$.

DISCUSSION
Previous models of herbage quality changes in a growing plant treat the herbage as a bulk above an arbitrary height, and empirically relate a quality attribute to plant and/or environmental factors. A major disadvantage of such empirical models is that they do not develop mechanistic understanding of quality dynamics (Fick *et al*., 1994).

By contrast, the new, mechanistic approach employed in the present model can overcome this problem. For example, one of the major characteristics of a bahiagrass sward is a drastic decline in DMD from spring to summer (Hirata *et al*., 1996). The model clearly indicates that this decline is caused by both the decrease in DI (Equation 3) and the increase in ÐD (Equation 4) with increasing air temperature.

In addition, the model is considered to be of potential use as a part of an integrated model of sward canopy structure which can be linked to a model of ingestive behavior of a grazing animal, to simulate herbage intake at a level of a bite (Hodgson *et al.*, 1994). For this purpose, further modeling approaches are needed to such aspects as the spatial distribution (Fig. 1) and mass of the components.

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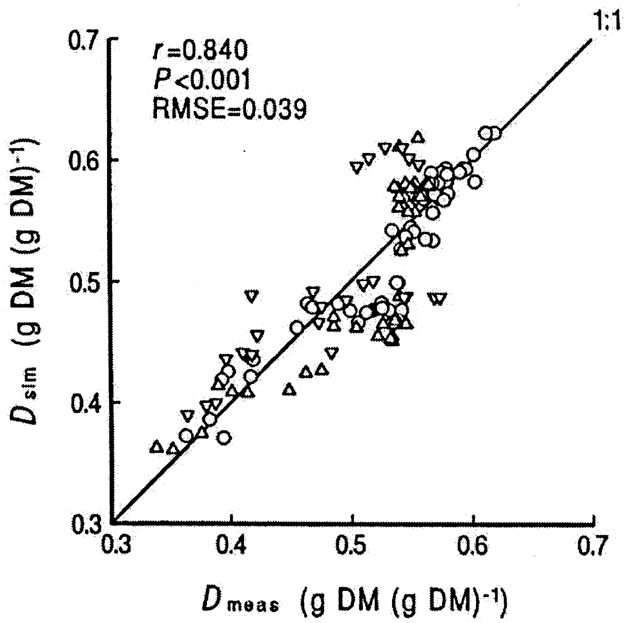

Figure 2
Comparison of simulated (*D*sim) and measured (*D*meas) DMD of canopy components in the vegetative (O), booting (Ð) and heading (Ð) tillers in the canopy in summer.

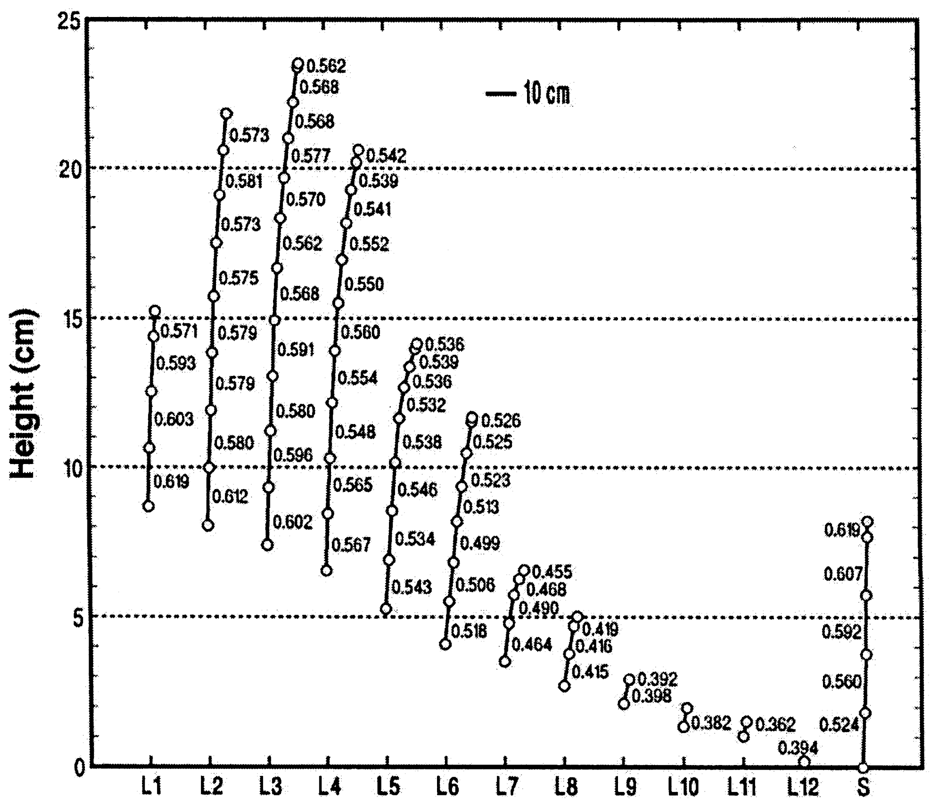

Figure 1
Spatial distribution and DMD of canopy components in the vegetative tillers in the canopy in summer (Hirata, 1996). L1 to L12 indicate leaf position (L1=the youngest leaf), and S indicates stem. Circles indicate the positions of the base, every 2 cm from the base, and the tip of the leaves and the stem. Canopy components are defined as the segments between two adjacent circles. Figures by each component indicate DMD (g DM (g DM)$^{-1}$) of the component. Horizontal bar shows the horizontal distance of 10 cm. Inclination of the components can be read with the height scale and the horizontal bar.