A decision tool for calculating herbage mass and metabolisable energy requirements of growing cattle and sheep

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Abstract

Decisions about feeding livestock on pasture are complicated because of the large number of ingestive and digestive factors affecting pasture intake. As a result, pasture allowance, because of its simplicity, has evolved as a commonly used basis for feeding rules by scientists. This method has not been widely adopted by farmers, however, because it is not able to account for the effects of either pasture quality or herbage mass, both of which are frequently limiting to animal performance. A computer model, "QuickFeed", was therefore constructed, in association with the West Waikato Feed Quality Study Group, to predict intake and performance of growing cattle and sheep on pasture. QuickFeed encapsulates a large amount of scientific information to give instant predictions of the outcomes of grazing duration and supplementation decisions on livestock performance, thereby assisting precise decision making for everyday grazing management.

Keywords: allowance, computer model, decision support, herbage mass, livestock feeding, ME, pasture intake, pasture quality

Introduction

A daily decision faced by farmers is how best to feed livestock in order to achieve performance targets. This decision depends on knowing the energy content of the feed offered to the animals, how much the animals will eat, and then what the resultant performance will be. While the nutritional values of various feeds can be obtained from tables or NIRS analysis (Corson *et al.* 1999; Waghorn & Barry 1987), and the energy requirements of many classes of animals have been well documented (Geenty & Rattray 1987), pasture intake itself is difficult to predict, because it depends on a bewildering array of both animal and pasture factors (Poppi *et al.* 1987). These include animal liveweight, pasture herbage mass, pasture growth rate, pasture quality (e.g., metabolisable energy, ME), pasture structure and the quantity and quality of supplements fed (Hodgson 1985; Ingvartsen 1994). The result is that it is difficult to know how much animals will eat on a given pasture, and therefore whether or not their energy requirements will be met.

One solution is to relate animal performance directly to pasture allowance (as in Nicol 1987). In this method, intake is assumed to be dependant only on pasture allowance, which is defined as the total pre-grazing herbage mass divided by the number of animal-days (definitions of variables are given in Table 1):

$$Allowance = \frac{\text{Pre} \times A}{NT} \tag{1}$$

Table 1 Table of variable abbreviations and units used in this paper.

Variable	Units	Description
A	ha	grazing area
DM		dry matter
DMI	kg DM/head/d	dry matter intake
HM	kg DM/ha	herbage mass
LW	kg/head	liveweight
LWG	kg/head/d	liveweight gain
ME	MJ ME/kg DM	metabolisable energy
MEI	MJ ME/head/d	ME intake
N	head	number of animals
Post	kg DM/ha	post-grazing HM
Pre	kg DM/ha	pre-grazing HM
ROG	kg DM/ha/d	rate of growth
T	d	grazing duration

Alternatively, the effects of changing animal liveweight may be incorporated by expressing allowance per kg liveweight instead of per head. In the empirical relationships which are then used to estimate intake and performance, the level of pasture utilisation is implicitly dependant on allowance alone (Poppi *et al.* 1987). The obvious appeal of the concept of allowance is that it is very easy to calculate, and the lack of convenient alternatives probably explains why it continues to be used by researchers. It is however a very blunt instrument for predicting animal performance, particularly when intake may be inhibited by low pasture quantity (ingestive constraints) or quality (digestive constraints) (Illius & Gordon 1993). For this reason, adoption by farmers has been poor.

The impact of ingestive constraints on pasture intake was studied in detail by McCall *et al.* (1986). Their data suggested that pasture intake could be linearly related to herbage mass, a result also observed by Chacon & Stobbs (1976) in tropical pastures. This resulted in intake being calculated as (again see Table 1 for definitions of symbols):

$$DMI = \frac{\mathrm{Pre} \times A}{NT}\left(1 - \exp\left(-k\frac{NT}{A}\right)\right) \qquad (2)$$

where k is an empirical constant related to the stock class (Bircham & Sheath 1986; Illius & Gordon 1987). Comparison of equations (1) and (2) shows that the bracketed term in equation (2) is the level of utilisation, and that this increases with the length of time that animals spend in a paddock, and/or with stocking density, as expected.

Equation (2) does not take into account growth of pasture in the paddock during the period of grazing, which is significant under long grazing breaks or continuous grazing, nor does it admit the presence of an ungrazeable sward layer, consisting of old dead and stem material, which may inhibit grazing. These two factors may be added relatively easily (Bircham & Sheath 1986). More crucially however, neither of these equations account for limits to intake imposed by digestive constraints, which become particularly important when animals are offered pasture either of high mass or of low quality (Bines 1971), a situation common in New Zealand pastures.

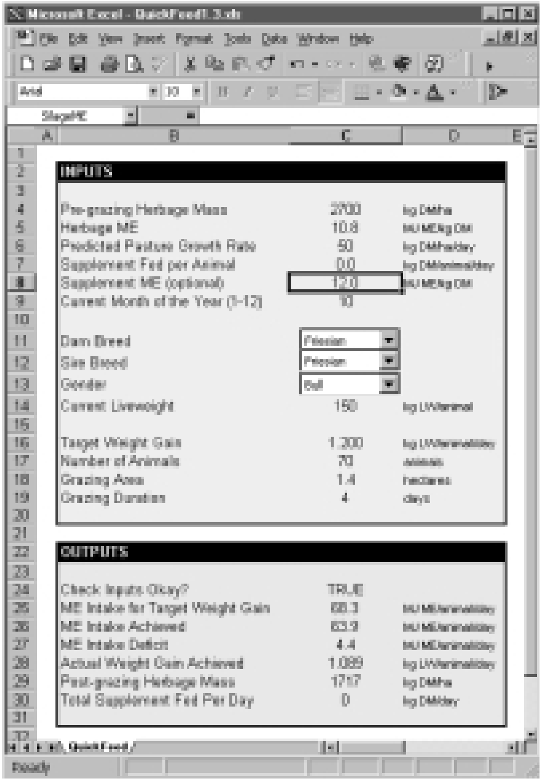
The effect of pasture quality, expressed as metabolisable energy (MJ ME/kg DM), on the maximum dry matter intake of cattle and sheep of different ages and lactational states, was studied by Ulyatt *et al.* (1980), who showed the extent to which low quality forages depress intake because of digestive constraints. Combining this information with an ingestive model such as that of McCall *et al.* (1986) offers a solution to the problem of estimating pasture intake.

This paper describes a computer model ("QuickFeed") which uses this approach to calculate pasture intake required by cattle or sheep to achieve target liveweight gains during a grazing break of up to 30 days. Different options for feeding stock can be rapidly evaluated, by identifying the best combination of pasture allowance, supplementation and grazing duration to achieve the liveweight gain targets. Once decisions are made, the accuracy of the model predictions can be evaluated by comparison with pasture and liveweight measurements. This allows more accurate feed budgeting and tactical grazing decisions for growing stock than could be carried out using feed tables and manual calculations.

Model overview

The QuickFeed model was commissioned from AgResearch by the West Waikato Feed Quality Study Group. QuickFeed was constructed using user-defined functions in a Microsoft Excel 97 spreadsheet (Figure 1), which allowed the model to be put together relatively quickly. This also allowed advantage to be taken of users' previous familiarity with Excel, and Excel's printing, saving and optimisation features.

Figure 1 The QuickFeed1.3 model interface, showing all input and output variables.



The input variables can be seen in Figure 1. The pasture is defined in terms of pre-grazing herbage mass, herbage ME and paddock area. In the QuickFeed model, herbage ME refers to the quality of the grazed zone of the pasture, with an assumed grazing residual. Samples can be taken by plucking to grazing height, and ME can then be obtained from NIRS analysis (Corson *et al.* 1999). Alternatively, herbage ME can be estimated from past NIRS or wet chemistry analyses. The assumption is made that this ME is representative of the herbage eaten over the whole grazing break.

Supplementation is entered as the quantity of supplement fed per animal per day and its ME. The animals are defined by their breed, gender, number, and liveweight. Breed and gender are used to calculate the mature liveweight of the animals, which affects both intake and liveweight responses. Target weight gain is also entered for comparison purposes, although this does not affect the performance predictions produced by the model. Additional inputs are the month of the year, which affects ungrazeable residuals and compensatory growth in cattle, and the grazing duration for this break.

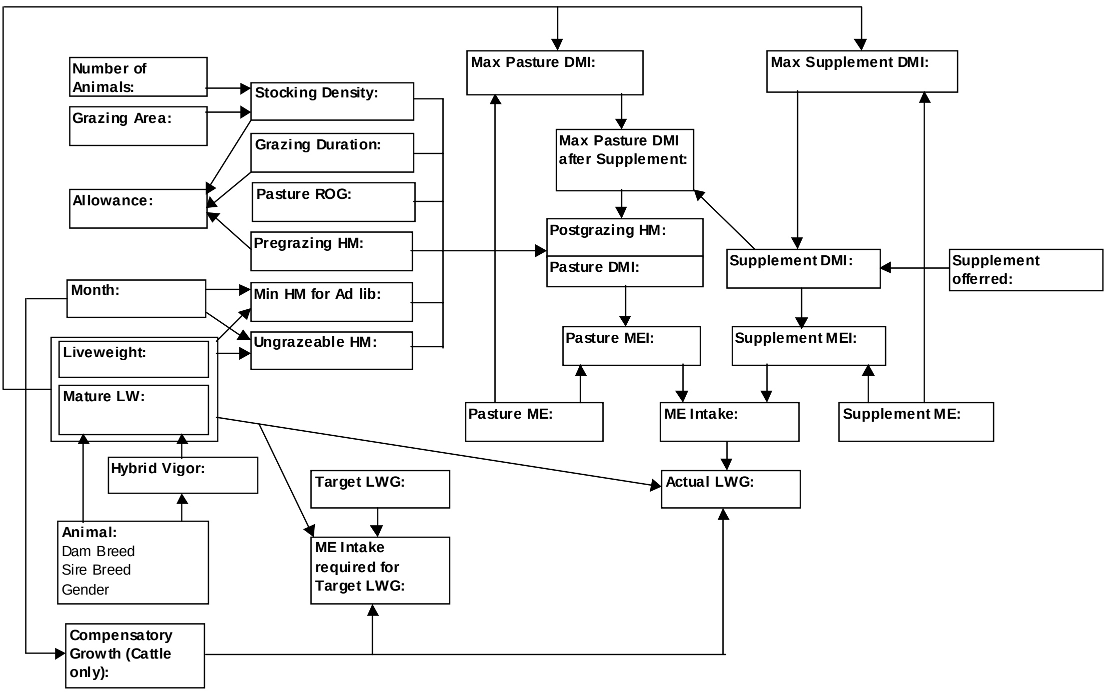
Whenever the animal or pasture inputs are changed, the software instantly recalculates the predicted pasture intake and liveweight gain, and compares these with targets. By trying different combinations of grazing duration, supplementation and grazing area, the user may explore options to achieve animal performance targets. This rapid trial and error approach is very flexible in that it allows the user to keep their goals and farm constraints in mind while searching for the best option for growing the animals.

Calculation of intake and liveweight gain

The logic of the model calculations is shown in Figure 2. The model equations themselves are proprietary and so are not able to be published. The arrows in this diagram show the flow of information from the input variables, such as liveweight and herbage ME, through intermediate variables, such as maximum pasture and supplement DMI, through to the output variables, such as ME intake and actual LWG. These abbreviations are explained in Table 1. The steps in the full calculation cycle are as follows:

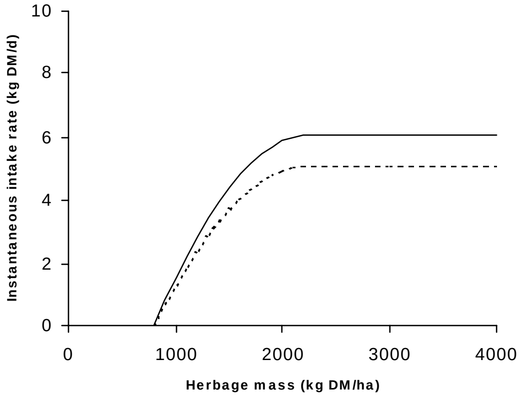
1. The animals' mature liveweight is calculated from their breed and gender. If the parents are of different breeds, 5% heterosis is included.
2. The maximum pasture and supplement intakes (DMI) are calculated using the results reported in Ulyatt *et al.* (1980). These depend on the ME of the herbage and supplement (if any) offered, as well as on the animals' liveweight and maturity (i.e., the liveweight : mature liveweight ratio).
3. The animals are then assumed to eat any supplement offered, up to the maximum calculated in step 2.
4. Actual pasture DMI is calculated using an ingestive constraint-based intake model (similar to that of McCall *et al.* 1986) to calculate the effect of declining herbage mass during a grazing break on dry matter intake (Figure 3). The ungrazeable residual and herbage mass above which *ad lib.* intake is achieved are calculated first. These calculations are based on the work of Allden & Whittaker (1970) on pasture height effects on intake at different times of year, and converted to a dry matter basis using Webby & Pengelly (1986). The instantaneous intake

Figure 2 Flow chart showing how the input data are used to calculate the output predictions in QuickFeed 1.3. See Table 1 for definitions of variables.



rate at herbage masses between these two values is then interpolated with a quadratic function.

Figure 3 The pasture intake function, for 150 kg Friesian bulls eating ME 10.8 pasture in October. The dotted curve shows the reduction in pasture intake resulting from feeding 1 kg DM/hd/d of maize silage with ME 11.1.



If supplement is eaten, maximum pasture DMI is reduced proportionally, by the supplement DMI divided by the maximum supplement DMI multiplied by 100%. This results in a substitution rate of,

$$\frac{\textit{Unsupplemented Pasture DMI}}{\textit{Maximum Supplement DMI}} \text{ kg DM/kg DM} \quad (3)$$

5. The intake function (Figure 3) is then integrated over the grazing duration to calculate the post-grazing mass, and hence daily intake, taking daily pasture growth into account along the way.
6. Supplement and pasture ME intake can then be calculated.
7. After subtracting maintenance energy requirements, liveweight gain is calculated using the information reported in Geenty & Rattray (1987).

The model thus synthesises the considerable amount of field data that is summarised in the papers mentioned above, and is therefore "validated" with respect to these data sets. Field validation is currently underway as farmers in the study group use the model for day-to-day decision making and compare its predictions with pasture and animal data collected routinely as part of their farm monitoring programmes.

This kind of analysis can theoretically be carried out using feed tables, although prediction of pasture intake remains a problem if herbage mass becomes low. This would be laborious, however, particularly if it was necessary to calculate several scenarios. Condensing these calculations into a spreadsheet or computer program allows them to be done instantly, which makes it easy to rapidly compare different management options to achieve liveweight gain targets.

Options for achieving target performance

In many cases, the model will simply confirm that liveweight gain targets are likely to be met by grazing the desired paddock. However, in the case where the scheduled paddock does not immediately meet a farmer's liveweight gain targets, there are three main options that might be explored. These are reducing the number of days that the animals will graze in the paddock, feeding supplement, or, in some cases, adjusting the paddock area. The particular option used will depend on the situation and on the farmer's priorities, as the following examples show. In all cases, the model predictions should be assessed in light of the user's knowledge of their own farm, along with previous pasture growth and animal performance records.

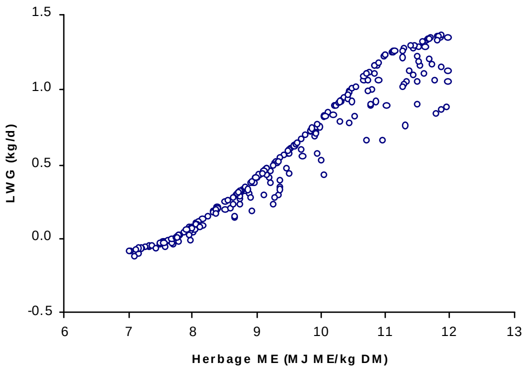
Example 1: Friesian Bulls

A first example involves a mob of fifty 150 kg Friesian bulls in March, to be grown at 0.7 kg/d over the next 30 days. The paddock to be grazed is 15 ha in area and has a pre-grazing herbage mass of 2500 kg DM/ha. Previous pasture growth measurements and NIRS analyses from the farm at this time of year indicate that a pasture growth rate of 20 kg DM/ha/d and a grazed herbage quality (ME) of 9.0 MJ ME/kg DM are expected.

The QuickFeed model calculates that, if grazed on this paddock, the actual LWG achieved by the bulls will only be 0.4 kg/d, even though the herbage mass at the end of 30 days will have increased to 2700 kg DM/ha. This indicates that the animals have plenty of herbage available but that the herbage quality is restricting intake and growth. Reducing the grazing duration or the grazing area will not improve this situation; the only option in this case is to increase the quality of the feed. Trials using QuickFeed show that a herbage ME of 9.9 would be required to meet the targets. Since pasture quality cannot be readily changed however, the only option is to feed high quality supplements instead. If maize silage of ME 11.1 is available, for example, calculations performed with QuickFeed indicate that the target weight gains will be achieved by feeding 2.3 kg DM/head/d of silage along with the pasture.

Predictions based on herbage allowance alone can not support such accurate decision making, because of the number of important variables that are not counted in pasture allowance. This is illustrated in Figure 4, where the LWG response of the same animals to a pasture allowance of 25 kg DM/head/d (the same allowance as offered above) is graphed against herbage ME. Herbage ME itself clearly has a major effect on animal performance, which is not expressed in pasture allowance. In addition, the vertical spread of the graph at any given ME indicates that animal response is also affected by changing herbage mass (resulting from variation in pre-grazing mass, stocking density, and grazing days even when allowance remains the same). This confirms the limited usefulness of pasture allowance calculations in making this kind of decision.

Figure 4 March LWG predictions for 150 kg Friesian bulls against grazed herbage ME at a constant pasture allowance of 25 kg DM/head/day (but with variable pre-grazing mass, stocking density and grazing duration).



Example 2: Coopworth Ram Lambs

A second example involves finishing two hundred and fifty 35 kg Coopworth ram lambs in January. Suppose the target weight gain for these lambs is 200 g/head/d, and the paddock to be grazed is 7 ha with a herbage mass of 2000 kg DM/ha when the lambs are introduced. Previous data indicate an expected pasture growth rate for January of 20 kg DM/ha/d, and a grazed herbage ME of 10.8 MJ ME/kg DM at this time. How long could the lambs can be grazed in this paddock without compromising their performance?

QuickFeed indicates that the target will be met exactly if the lambs are grazed in this paddock for 23 days only, at which point the herbage mass will have dropped to 1300 kg DM/ha. Grazing longer would result in intake restrictions to the point that liveweight targets would not be met.

Conclusion

QuickFeed is a farmer-friendly tool for supporting tactical feed management decisions. It is a succinct and useable package that encapsulates a considerable amount of science and technology which has previously been of limited use to farmers because of its complexity. This kind of tool has the potential to be invaluable in day-to-day stock feeding decisions, and represents a considerable technological advance over existing methods for supporting grazing management and supplementation decision making. QuickFeed is currently being field-tested by the members of the West Waikato Feed Quality Study Group, and it is hoped that a version will be made available on the Internet in the near future.

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