Diet Check—a tactical decision support tool for feeding decisions with grazing dairy cows

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Abstract

Dairy farmers in the northern irrigation region of Victoria (NIRV) in Australia predominantly produce milk from flood irrigated pastures, although increasing amounts of concentrate and forage supplements are being incorporated into lactating cow diets to increase their milk production. The competitive advantage of the irrigated dairy industry has been the low cost of production, but total productivity gains over the last 20 years have only been about 1.3%. While some farmers have made substantial productivity gains through improved pasture utilisation and effective use of supplements, others have combined these feeds inefficiently. There is a role for decision support tools to assist farmers in making both strategic and tactical feeding decisions to feed their herd as efficiently as possible. This paper reports on a simple tactical decision support tool, 'Diet Check', developed to help dairy farmers in the NIRV estimate whether their cows are consuming sufficient metabolisable energy (ME), crude protein (CP) and neutral detergent fibre (NDF) for a specified level of milk production. Diet Check has a unique method of estimating pasture intake and nutrient intake from pasture, as well as substitution of supplements for pasture, and is useful when cows consume more than 50% of their total energy intake from pasture in strip-grazing or small paddock rotation systems. Model inputs can be determined on-farm, and it allows the user to test the effects of different feeding and herd management scenarios before applying them. It has provided a means of packaging local research results into a practical and user-

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friendly tactical decision support tool and, also provides a valuable learning tool used in extension activities.

1. Introduction

Dairy farmers in the northern irrigation region of Victoria (NIRV) in Australia predominantly produce milk from flood irrigated pastures. However, since the early 1980's, lactating dairy cows have been fed increasing amounts of concentrates and forages to supplement their pasture intake (Doyle et al., 2000b). The region produces about 26% of Australia's milk, of which 93% is used for manufacturing (Kompas et al., 2001). The competitive advantage of the irrigated dairy industry has been the low cost of production, but average total factor productivity gains over the last 20 years have only been about 1.3% (Knopke and O'Donnell, 2001).

While lactating cows in the NIRV consume 75% of their diet dry matter (DM) as pasture, on average, there is a wide range of feeding systems in operation, and pasture makes up to 30–100% of total metabolisable energy (ME) intake (Armstrong et al., 1998). While some farmers have made substantial productivity gains through improved pasture utilisation and effective use of supplements, others have combined these feeds inefficiently (Armstrong et al., 1998; Doyle et al., 2000a).

A number of computer programs are commercially available to assist dairy farmers with both strategic and tactical feeding decisions. 'Camdairy' (Hulme et al., 1986) allows formulation of the most profitable ration to meet the nutrient requirements of cows, but the user has to specify the intake of pasture and other components of the diet. 'GrazFeed' (Freer et al., 1997) is a predictive model that estimates pasture intake from descriptions of the pasture, supplement and the herd. Neither program is widely used by dairy farmers or their advisers in the NIRV, at least partly due to the difficulty in accurately estimating some of these variables.

This paper reports a simple tactical decision support tool, 'Diet Check', developed to help dairy farmers in the NIRV estimate whether their cows are consuming sufficient ME, crude protein (CP) and neutral detergent fibre (NDF) for a specified level of milk production. The program has provided a medium for regionally-specific research results to be packaged into a decision support tool for farmers and service providers. The program also predicts pasture intake of grazing dairy cows, and substitution when supplements are fed, and provides estimates of marginal responses in milk yield to supplements.

2. Model overview

Diet Check is a series of Microsoft Excel spreadsheets navigable via visual basic commands. It is made up of an input and a results screen, and is supported by a number of help

files. The application requires Microsoft Excel 97. It has been tested on an IBM compatible Pentium 100 with 32 MB RAM running Windows NT4 work station, but will run under Windows 95, 98 or 2000 environments. A stand-alone version may be developed.

The program estimates requirements of grazing lactating cows for ME from Australian feeding standards (SCA, 1990), and best estimates of both CP and NDF after herd and feed details have been entered by the user. Pasture and nutrient intakes are estimated, taking into account substitution, which is defined as the reduction in pasture intake when supplements are fed (kg DM/kg DM). Excesses or deficits of ME, CP and NDF are then calculated by difference. The immediate marginal milk response (defined as the increase in milk produced (kg) for each incremental increase in supplement intake (kg DM)) and a simple cost benefit analysis of feeding supplements are also provided.

The program's strength lies in its ability to predict the amount of pasture and nutrients consumed by lactating cows that are strip-grazing pasture with or without consumption of supplements. It incorporates region-specific relationships between pasture nutritive characteristics and intake of herbage from research conducted over the last 15 years at the Department of Primary Industries (DPI) Kyabram. Models boundaries are defined by the nature of the research used to develop it (i.e. strip-grazing dairy systems in the NIRV where lactating cows consume at least 50% of their total ME intake from pasture). A schematic representation of the program logic is Fig. 1. Model inputs, major assumptions and calculations used in the program, and results from testing the importance of key variables, are outlined below.

3. Estimating energy requirements of cows

Ruminant requirements for ME comprise four main categories—maintenance, including energy for walking and grazing, pregnancy, milk production and tissue change.

The ME requirement for maintenance, pregnancy and milk production are calculated from appropriate equations in SCA (1990) with two modifications (Appendix A). Firstly, ECOLD, the additional ME required to alleviate cold stress, is not included in the program. This is because the lower critical temperature of lactating dairy cattle would be lower than the ambient temperature in Victoria in all but the most extreme scenarios. Secondly, the EGRAZE component of the maintenance requirement (SCA, 1990; equation 1.22), which accounts for the additional energy expended during grazing, is computed in a way that is more appropriate for lactating dairy cows. This increment has two parts. The cost of strip-grazing is set at 10% of the basic maintenance requirement, consistent with 'best grazing conditions' (SCA, 1990). This alternative approach was taken because the equation presented by SCA (1990) was developed based on data derived from extensive, set stocked, experiments and so this term was considered an overestimate of the ME requirement of strip-grazing lactating dairy cows, common to the intensive dairy management systems of the NIRV. The cost of walking from the paddock to the milking area is computed from the horizontal and vertical components of this distance according to the terrain (SCA, 1990). The vertical increment of this term accounts for variation in the gradation of terrain and is defined by the km vertical climb per km walked (flat = 0.001; undulating = 0.04; steep = 0.1 km/km).

The calculation of the ME exchanges associated with mobilisation and accretion of body tissue is complicated, particularly during late pregnancy and early lactation, by the unreli-

Metabolisable Energy Requirements	Metabolisable Energy Supply

Total estimated ME requirements from dietary sources, including

Maintenance

+

Activity

+

Energy associated with grazing

+

Pregnancy

+

Milk production

+

Tissue mobilisation/ accretion

Pasture

Pasture Height (PH)

Pasture Mass (PM) → Nutrient concentration in pasture

Pasture Allowance (PA)

Unsupplemented pasture intake (UPI)

+/- supplements → substitution

Nutrient concentration in consumed pasture

nutrient concentration in supplements

Pasture intake without (UPI) or with (SPI) supplements

marginal milk production response

Nutrient intake (pasture and supplements)

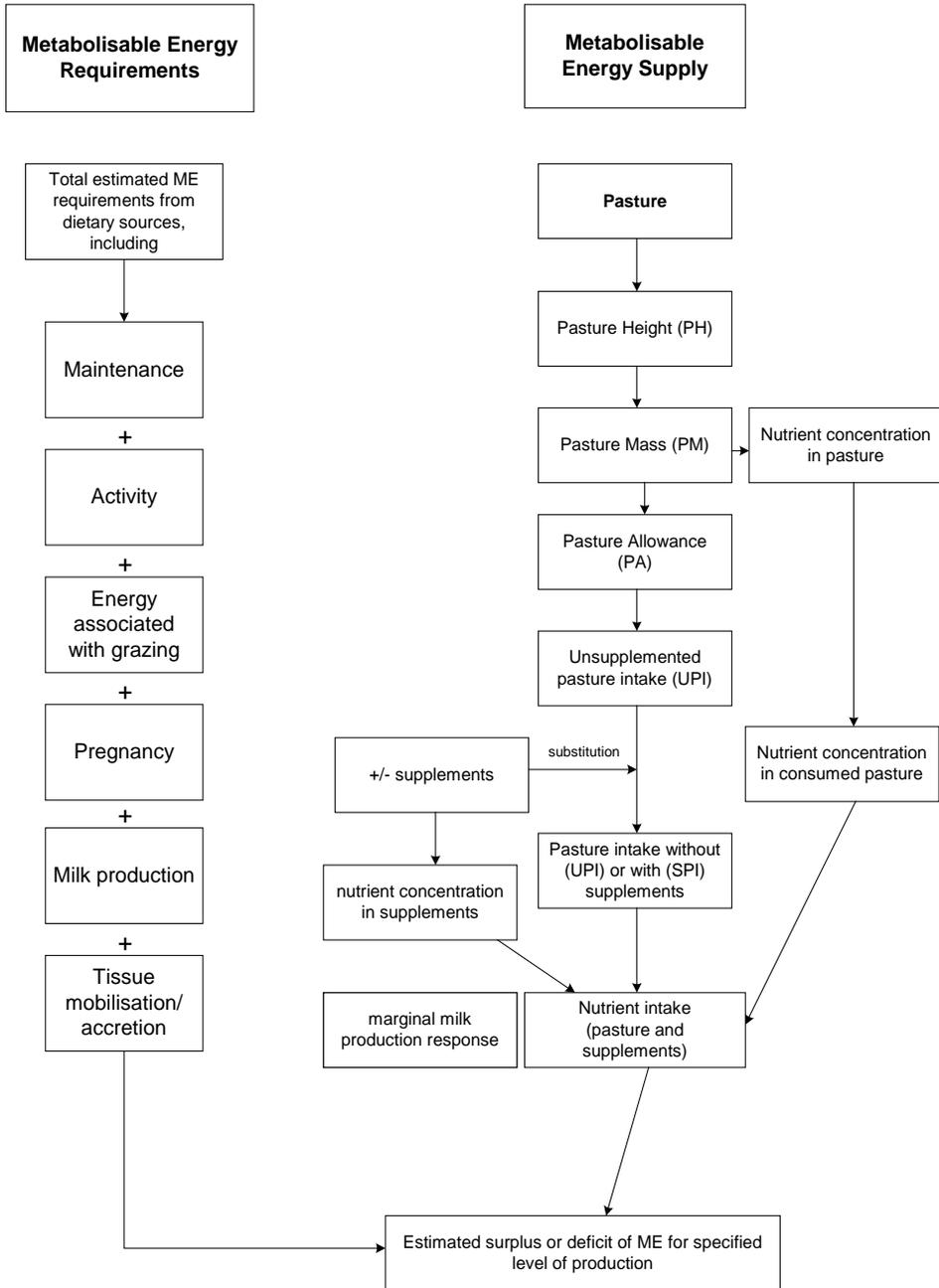Estimated surplus or deficit of ME for specified level of production

Fig. 1. Schematic representation of the Diet Check program, showing defined categories for cow requirements for metabolisable energy, and the steps used to calculate pasture intake and metabolisable energy supply from pasture and supplements.

ability of short-term liveweight (W) changes as indicators of energy changes (Butler-Hogg et al., 1985). This is due mainly to changes in body water retention. An alternative, adopted in the Diet Check program, is to use changes in body condition score (CS) over time to predict changes in energy retention. In Australia, CS scoring for dairy cattle is generally on a scale of 1 (emaciated) to 8 (very fat) as described by Earle (1976). The weight of tissue (of 'normal' energy content) associated with each unit of CS is: $0.08 \times$ SRW (SCA, 1990), where SRW is the standard reference W (kg) of the cow. This is defined as her W when skeletal development is complete and she is in average condition. In Diet Check, SRW is calculated from the user inputs of current W (kg), and current CS as:

$$SRW = \left[\frac{W}{(0.08 \times CS) + 0.64} \right]$$

Change in W (W_c; kg) that is expected from a specified change in CS is therefore calculated as:

$$W_c = 0.08 \times CS_c \times SRW$$

The energy content (EV, MJ/kg) of catabolised or retained tissue increases with CS and is calculated by the equation from Hulme et al. (1986) as recommended by SCA (1990) as:

$$EV = 10.1 + 2.47 \times CS$$

Finally, ME (MJ) required for tissue retention, or the equivalent in mobilised tissue, is calculated as:

$$ME = \frac{W_c \times EV \times b}{k_l \text{ (tissue mobilisation) or } k_g \text{ (tissue gain)}}$$

where $b = 1.0$ for retained tissue and 0.84 for mobilised tissue, k_l is the net efficiency of use of ME for milk production, calculated as: $k_l = (0.02 \times$ average ME/kg DM of diet$) + 0.4$ (SCA, 1990), and k_g is a generalised value of 0.60 for net efficiency of conversion of ME to gain in lactating dairy cattle.

A comparison of the energy requirement predictions for maintenance, walking, pregnancy and milk production from Diet Check with those from Grazfeed (Freer et al., 1997) and Camdairy (Hulme et al., 1986) indicated that this aspect of Diet Check was robust (data not shown).

4. Estimating protein requirements of cows

In Diet Check, CP requirements are set at 185, 165, 150 and 120 g/(kg DM) intake for early, mid and late lactation and the dry period, respectively. While this does not accurately reflect current knowledge on the various pathways of protein metabolism, it provides adequate information for interpretation of the grazing management systems that Diet Check was designed to address. It allows the user to address identified CP imbalances with appropriate supplementation, as required. It does not, however, adequately account for the energy

costs associated with excess Nitrogen (N) excretion, common when cows graze spring pastures which often have a high clover content (Cohen, 2001). Thus, the system adopted for Diet Check has limitations, particularly when feeding diets rich in degradable N, or when formulating optimal diets for high producing animals.

5. Estimated neutral detergent fibre (NDF) requirements of cows

The physical and chemical properties of NDF in pastures, conserved forage and concentrates are important for lactating cows as NDF stimulates salivation, which buffers the rumen, and is also important for the production of acetate and β-hydroxybutyrate which are used in milk fat synthesis. High grain/low forage diets, in association with increased levels of dietary long chain fatty acids, have been linked to low fat milk, through an alteration in the bio-hydrogenation pathways favouring production of inhibitors of milk fat synthesis (Bauman and Griinari, 2001).

The NDF requirements included in Diet Check are 295, 305, 340 and 380 g/kg DM in the diet for early, mid, and late lactation and when cows are dry, respectively, which are similar to NRC (1989) recommendations. However, NRC (1989) reports that values relating to NDF requirements of lactating cows should be used with caution as 'there is little information on the interaction of milk production, milk composition and dietary NDF when NDF is supplied by a number of feeds at various stages of lactation and levels of milk production'.

6. Estimating nutrients consumed

6.1. Unsupplemented pasture intake

The greatest limitation to grazing dairy cows achieving their potential milk production is their intake of DM, and consequently of energy (Ulyatt and Waghorn, 1993; Doyle et al., 2000b). While calculating energy balance in stall or lot feeding systems is relatively simple, pastures are dynamic, and the amount of pasture consumed by a grazing cow will depend on a complex mix of animal, feed and climatic factors (Doyle et al., 2000a). For practical use, it is important that decision support tools for nutritional management of grazing dairy cows have reliable inputs for pasture intake prediction. In Diet Check, pasture intake is predicted from descriptions of pre-grazing pasture in strip-grazing systems.

Pasture mass (PM, kg or t DM/ha), the amount of above ground herbage per unit area available to a grazing animal (Hodgson, 1979), has important effects on DM intake. Stockdale (1985) reported a 1.1 kg DM increase in pasture intake for each additional t DM/ha increase in pasture mass. Wales et al. (1999) supported this finding, reporting that at common pasture allowances between 20 and 70 kg DM/cow/day, cows consumed 2.3 and 1.3 kg DM per cow per day more pasture for each additional t of DM/ha of pasture mass in spring and summer respectively.

Functions within Diet Check estimate PM from inputs of pasture height measured with a rising plate meter (RPM, Earle and McGowan, 1979). The RPM is a non-destructive device that relates pasture height to PM. The meter has a $0.1 \, m^2$ plate which exerts a downward

pressure of 5.0 kg/m², and a counter that records cumulative height to the nearest 5 mm (Stockdale, 1984). A series of regression equations have been developed for the NIRV, and these relationships are embedded in the model to calculate PM within each month (Appendix B). If other methods of estimating PM are adopted by the user, the user must alter RPM height to achieve the desired PM.

Pasture allowance is defined as the weight of pasture, measured to ground level, per unit of animal *W* (kg DM/100 kg *W*) at a point in time (Hodgson, 1979), and it is an important determinant of herbage intake and, therefore, performance of grazing animals (Bryant, 1980). Stockdale (1985, 2000) reported positive, curvilinear relationships between pasture intake and pasture allowance, with a diminishing pasture intake response at high pasture allowances. This is supported by Wales et al. (1998) who found that pasture intake increased curvilinearly on high and medium mass paspalum pastures over a range of pasture allowances of 15–75 kg DM/cow/day.

Diet Check incorporates a relationship describing how sward characteristics influence pasture DM intake (DMI, kg) which is based on experiments conducted in the NIRV. A series of published experiments (Stockdale, 1985, 1997, 1999, 2000; Stockdale et al., 2001; Wales et al., 1997, 1998, 1999) that have quantified the effects of sward characteristics on DMI and milk production of dairy cows at various stages of lactation have been used to derive the relationship used to predict pasture DMI. Experimental pasture intake measurements were uniformly determined using pre- and post-grazed PM (Stockdale and King, 1983).

Data from these reports have been collated and analysed, and it was been found that daily pasture allowance had the greatest significant influence on pasture DMI. Height of pasture, which influences the quantity of pasture consumed per bite, had a small, but significant, effect on pasture DMI, and pseudo-variables to differentiate between species present in the grazed sward were also significant. These latter terms encompass differences in the nutritive characteristics and degradabilities of different pasture types and may also, at least partly, describe seasonal and stage of lactation effects of pasture intake. A Mitscherlich regression was developed to estimate pasture intake based on observable pasture variables, described by the equation:

$$\text{UPI} = 4.01 - [3.32 \times \exp(-0.01 \times \text{PA})] + (0.06 \times \text{PH})$$
$$- (0.41 \times \text{Spp1}) - (0.06 \times \text{Spp2})$$

where UPI is unsupplemented pasture intake (kg DM/100 kg *W*), PA is the daily pasture allowance (kg DM/100 kg *W*), PH is the pasture height (cm) measured with an RPM, and Spp1 and Spp2 are pseudo-variables defined by dominant pasture species (Spp1, Clover: 0, Ryegrass: 1, Paspalum: 1; Spp2, Clover: 0, Ryegrass: −1, Paspalum: 1).

This relationship accounts for 79.6% of the variation observed in pasture intake. It should be noted, however, that this relationship is restricted to situations where lactating dairy cows graze pasture under strip-grazing management, and does not apply to set stocking situations.

6.2. Substitution

Feeding supplements to grazing dairy cows can have a marked effect on herbage intake, as cows generally substitute the supplement for some of the pasture they would have otherwise

eaten (Leaver et al., 1968; Stockdale et al., 1997). Substitution rates are variable and influenced by PM and allowance, pasture quality, and amount and type of supplement consumed. Stockdale (2000) published a regression equation to estimate substitution based on significant variables derived from grazing experiments in the NIRV. This equation has been incorporated into the Diet Check program. Substitution is expressed as the kg DM reduction in pasture intake per kg DM of supplement consumed, as:

$$\text{substitution} = -0.34 + (0.16 \times \text{UPI}) + (0.16 \times \text{Spp1})$$
$$+ (0.11 \times \text{season1}) + (0.03 \times \text{SI})$$

where season1 is a pseudo-variable defined by season (summer: 0, autumn: −1, winter: 0 and spring: 1), which incorporates both pasture and stage of lactation effects, and SI is supplement intake (kg DM/cow/day).

This relationship accounts for 50.9% of the variation observed in level of substitution. Effects of supplementary feeding, and associated substitution, result in a supplemented pasture intake (SPI), as:

$$\text{SPI(kgDM/cow/day)} = \text{UPI} - (\text{substitution} \times \text{SI}).$$

6.3. Nutrient intake

Considerable information exists on the nutritive characteristics of pastures used for dairying in the NIRV (Stockdale and King, 1983; Wales et al., 1997, 1998, 1999; Doyle et al., 2000b; Stockdale et al., 2001). Data from these reports, as well as other experiments conducted as part of the Victoria Department of Primary Industry's state-wide dairy program, have contributed to development of a Perennial Pasture Database (Cohen and Doyle, 2000). This database captures data from the analysis of over 15,000 perennial pasture samples, for which there is information on harvest time (month and season), pasture mass, pasture height, botanical composition and nutritive characteristics (i.e. ME, CP and NDF). The database is available on the internet at: http://www.nre.vic.gov.au/cgi-bin/exsysweb.exe?KBNAME=nut05, and can be used to estimate the nutritive characteristics of pastures from descriptions of month of year, pasture mass and estimated botanical composition.

Samples contributing to the database have been cut to ground level, in a standardised experimental approach, in order to remove effects of subjectivity in trying to sample what cows eat. As this does not necessarily reflect the nutritive characteristics of material consumed by grazing cows, selection differentials that specify the ratio of the concentration of a nutrient in pasture consumed by a cow to that in the pre-grazed pasture cut to ground level have been incorporated into the database. A range of selection differentials for estimated ME, CP and NDF relating to pastures in the NIRV have been reported by Wales et al. (1997, 1998, 1999) and Stockdale et al. (2001).

A summarised version of the Perennial Pasture Database is included in Diet Check. Monthly values are provided for three broad species groups—ryegrass dominant (>50% DM ryegrass in the pasture sward), clover dominant (>50% DM clover in the sward) and 'other grasses' (>50% DM 'other grasses'). This is further categorised into six pasture

mass groups, ranging from <1 to >5 t DM/ha. All values within the program are on a 'cow consumes' basis (i.e. selection differentials have been included).

As an alternative to relying on values within the program, users also have the option to enter pasture nutritive characteristics. By using the on-line Perennial Pasture Database, users have the ability to further refine the description of pastures by more accurately defining the botanical composition of the sward. Alternatively, the Victoria Department of Primary Industries at Hamilton offers Feedtest®, a service for analysing feed samples for various nutritive characteristics. If this method of data entry is employed, it is important that the appropriate selection differential is applied if the sample has been cut to ground level. Seasonal selection differentials for ME, CP and NDF are provided in a help file within the program.

While Diet Check accounts for substitution of supplements for pasture, it does not include estimates of the negative associative effects that can occur between concentrate supplements and digestion of DM from pasture or conserved forages (Mould, 1988). Although these effects are likely to occur, there is insufficient data on which to estimate these negative effects on estimated ME.

6.4. Supplement intake

Diet Check contains a supplement database that includes the DM (%) and estimated concentration of ME, CP and NDF for over 50 commonly fed supplements, based on feed analyses at the Department of Primary Industries in Hamilton. Users can select up to five different supplements, and modify the nutritive characteristics or include other supplements if required. The user can also specify cost of supplement to obtain a cost:benefit analysis, based on immediate marginal milk production response.

Knowledge of estimated nutrient intake can be balanced to estimated nutrients required in order to assess the level of nutrients that the average herd animal is receiving relative to her needs.

7. Immediate marginal milk production response to feeding supplements

Animals respond to supplementary feeding in two ways. There is an immediate marginal milk response, defined as the extra milk produced for each kg of supplement DM eaten per day (Stockdale et al., 1997). Concurrently, cows may lose less CS or even gain CS, and this may affect milk production at a time in the future. The immediate marginal milk response to feeding a supplement is on the Results page of Diet Check, but additional long-term effects of feeding supplements are not considered.

A relationship was developed to estimate the immediate marginal milk response to concentrate feeding based on data derived from supplementary feeding experiments at the DPI-kyabram. At this time, the relationship does not account for type of supplement and would not account for decreasing marginal milk production responses at high supplement intakes. The relationship is described as:

$$\text{IMMR} = 3.07 - (0.24 \times \text{UPI}) - (0.36 \times \text{BC}) - (0.29 \times \text{season})$$

where IMMR is the immediate marginal milk response to feeding supplements (kg milk/kg DM supplement), BC is the body condition on the 1–8 scale of Earle (1976), and season is a pseudo-variable to describe time of year (spring: 1, summer and autumn: 0).

While milk produced in the NIRV is primarily used for manufacturing, prices paid vary throughout the year, structured to provide greater incentive to produce milk in autumn and winter. However, herds in the NIRV are predominantly managed for spring calving, to match periods of peak pasture growth and quality with peak animal requirements. Diet Check provides a cost:benefit analysis for feeding of a supplement from inputs of supplement cost, milk price and the estimated supplement IMMR. This calculation does not include the cost associated with growing the pasture, and does not consider the potential for increased CS on subsequent lactation or reproductive performance from feeding supplement.

8. Sensitivity testing of the model

The energy requirement functions within Diet Check were reviewed by comparing them to functions in two published Australian nutrition models (i.e. GrazFeed and Camdairy). This confirmed that the calculations used to estimate animal requirements for ME were robust (data not shown).

The ability of Diet Check to accurately characterise on-farm conditions was also tested using data from controlled experiments in the NIRV. As with many such models, data sets for evaluation were mainly from work used to establish the relationships in the model, with few truly independent data sets from more recent research. Therefore, in testing the sensitivity of the model, at least in part, we demonstrated variability in the experimental data. It is difficult to compare Diet Check outputs with other similar Australian computer models, because Diet Check estimates energy excess or deficit, with known production parameters, based on predictions of pasture and supplement intake. In comparison, Camdairy requires the user to enter pasture intake, and both Camdairy and GrazFeed partition energy towards metabolic functions, such as milk production and/or tissue mobilisation or deposition. Some comparison has been made of predicted pasture intake between Diet Check and GrazFeed in the following discussion.

Diet Check predictions of pasture mass from monthly regression equations relating pasture plate meter heights to pre-grazing pasture mass with over 3000 data points showed that 34% were within 250 kg DM/ha, and that a further 23% were between 250 and 500 kg DM/ha of the experimentally derived values. At any given plate meter height, there is considerable variation in measured pre-grazing pasture mass due to differences in botanical composition and proportions of dead material in the sward, and effects of differences in uniformity of cutting and processing of calibration cuts.

Predictions of unsupplemented pasture and supplemented pasture intake in Diet Check were compared with measured values in experiments using the measured pre-grazing pasture mass as model input. This removes errors associated with predictions of pasture mass from rising plate meter height. There were no differences ($P > 0.01$) between measured and predicted unsupplemented pasture intake ($r^2 = 0.87$) with predicted DMI within ± 1 kg DM/day of measured intake for 52% of the 27 data sets and within ± 2 kg DM/day for 82% of predictions. In comparison, there was no difference ($P > 0.05$) between measured

and predicted unsupplemented pasture intake when the experimental data was inputted into GrazFeed; 41% of GrazFeed predictions fell within ± 1 kg DM/day of measured DMI, and 56% of predictions fell within ± 2 kg DM per day.

When supplemented herds were used, the relationship between predicted and measured pasture intake in Diet Check had an r^2 of 0.48, with 48% of predictions of pasture intake within ± 1 kg DM/day of measured values and 81% within ± 2 kg DM/day. In comparison, the same relationship tested in GrazFeed had an r^2 of 0.15, and predicted intake within ± 1 kg DM/day of measured values for 31% of the 26 data sets, and within ± 2 kg DM/day for 62% of predictions. Diet Check would be expected to predict tested data better than GrazFeed in this situation, since the tested data was also used to build the Diet Check model. The complexity of predicting pasture intake in supplemented cows is associated with variations in substitution rate, which is affected by pasture characteristics, supplement characteristics, pasture allowance, amount of supplement fed and physiological state of the cow (Stockdale, 2000). There were no differences between Diet Check predicted and measured substitution rates, with 88% of predictions being within 0.25 kg/kg of measured values among 25 data sets.

Comparisons were made of predictions of ME in pasture consumed from Diet Check with actual values from experiments when the pre-grazing pasture mass in the model was the same as that measured in the experiments. There were no differences ($P > 0.05$) between predicted values and actual values among 54 data sets. Predictions were within 0.3 and 0.6 MJ ME/kg DM for 11 and 41% of the data sets, respectively. Deviations in predicted values above and below measured values were random.

This sensitivity process revealed that the greatest error associated with estimation of nutrient intake was derived from calibration equations relating pasture height (PH) to PM. However, when experimental PM was entered directly into the program, rather than predicted from RPM height, estimates of pasture and nutrient intake were within set sensitivity boundaries. While this potential error associated with PH/PM equations occurred, farmers involved in Diet Check's development preferred to maintain RPM as an input for estimating PM, as many farmers lack confidence in their ability to visually assess pastures. Diet Check allows the user to manipulate RPM to obtain a specified pasture mass if desired.

9. Application of the model

The input page of Diet Check for a typical dairy management system in the NIRV is shown in Fig. 2. Inputs required by the user are shaded, or are from drop down menus. In this example, a farm in October is illustrated where 150 spring calving cows are being milked with a target milk production of 28 L per cow per day, and is being paid Aus$ 0.2/L. Cows are currently in CS 4 with an average W of 500 kg, and are expected to lose 0.5 CS over the next 4 weeks. The farmer is offering 2 ha of 10 cm tall ryegrass-dominant pasture to 150 cows. Cows are consuming 2 kg fresh weight of barley grain/day (costing Aus$ 200 t^{-1} fresh weight). The paddock is 500 m from the dairy and so cows walk 2 km/day for twice a day milking.

Estimated pasture mass is directly related to pasture height and month of year and, in this example, is calculated to be 3.9 t DM/ha. The concentration of ME, CP and NDF consumed

Fig. 2. Input page of Diet Check.

by the grazing cow is dependent on the dominant pasture species, pasture mass and month of the year, and is estimated to be 11.9 MJ/kg, 22.1 and 38.5% DM, respectively. Details of supplements included in the program can be viewed by clicking the 'View all Supplements' button. Diet Check calculates cost per kg of DM, cost per MJ, supplement costs/cow/day and supplement costs for the herd/day. In this example, substitution, which is calculated by the model, was estimated to be 0.47 kg DM per cow reduction in pasture intake for each kg of DM of supplement consumed. Diet Check suggests whether this figure comes within the practical limitations of the data that make up the program with a display of either 'Accept' or 'Substitution rates have not been validated for this level of supplement intake'.

The output page of Diet Check is separated into three sections—(1) pasture and supplement intake; (2) nutrient excess or deficit; and (3) estimated benefit from feeding supplements (Fig. 3). For the example in Fig. 2, daily pasture allowance is calculated to be 53 kg DM/cow/day. Based on inputs of pasture height, pasture allowance and species present in the sward, UPI was estimated to be 15.2 kg DM/cow/day. After considering substitution associated with feeding 2 kg fresh weight (1.7 kg DM) of barley grain, actual SPI is estimated to be 14.4 kg DM/cow/day, with a total DMI of 16.2 kg DM per cow. The average estimated ME intake of the total diet consumed was 12.0 MJ/kg DM. A pie chart showing relative proportions of pasture and supplement to total DMI is also shown.

Calculated nutrient excesses or deficits are shown in tabular and graphical format. In the scenario previously outlined, a cow requires 188 MJ dietary ME, 18.5% CP and 29.5% NDF in diet DM. Based on entered information, the contribution of ME, CP and NDF from consumed feed and from tissue mobilisation will be approximately 194 MJ ME, 21.1% CP and 35.9% NDF, suggesting that the diet is sufficient in terms of ME, CP and NDF for the indicated level of production.

Identified nutrient excesses or deficits can be addressed via management options. A nutrient deficit, suggesting that the feeding system is insufficient to meet the target of specified level of milk production and CS change, allows farmers to decide whether they can afford to increase pasture allowance, while still fitting in with their current rotation system, or whether increasing use of supplements is more suitable. Alternatively, they may be willing to accept a lower milk production target, or greater CS change within their herd. Such scenarios can be tested with the program prior to making potentially costly changes on-farm.

An assessment of the estimated economic benefit of feeding supplements is provided on the results page of the model. Calculated immediate marginal milk production response to feeding supplements in the above scenario is 0.6 kg milk/kg DM supplement consumed, a return of Aus$ 0.12/kg DM supplement fed, since the supplement cost Aus$ 0.23/kg DM, identifying a potential financial loss from feeding supplements. With this information, farmers can make more informed on-farm feeding decisions.

Diet Check is an excellent education tool, as well as being of use in practical farming. It helps farmers to allocate pasture more consistently, and demonstrates effects of substitution on total intake and of supplementation on responses in milk production. Information on all of these is necessary to assess the value of a supplement in a dairy farming system.
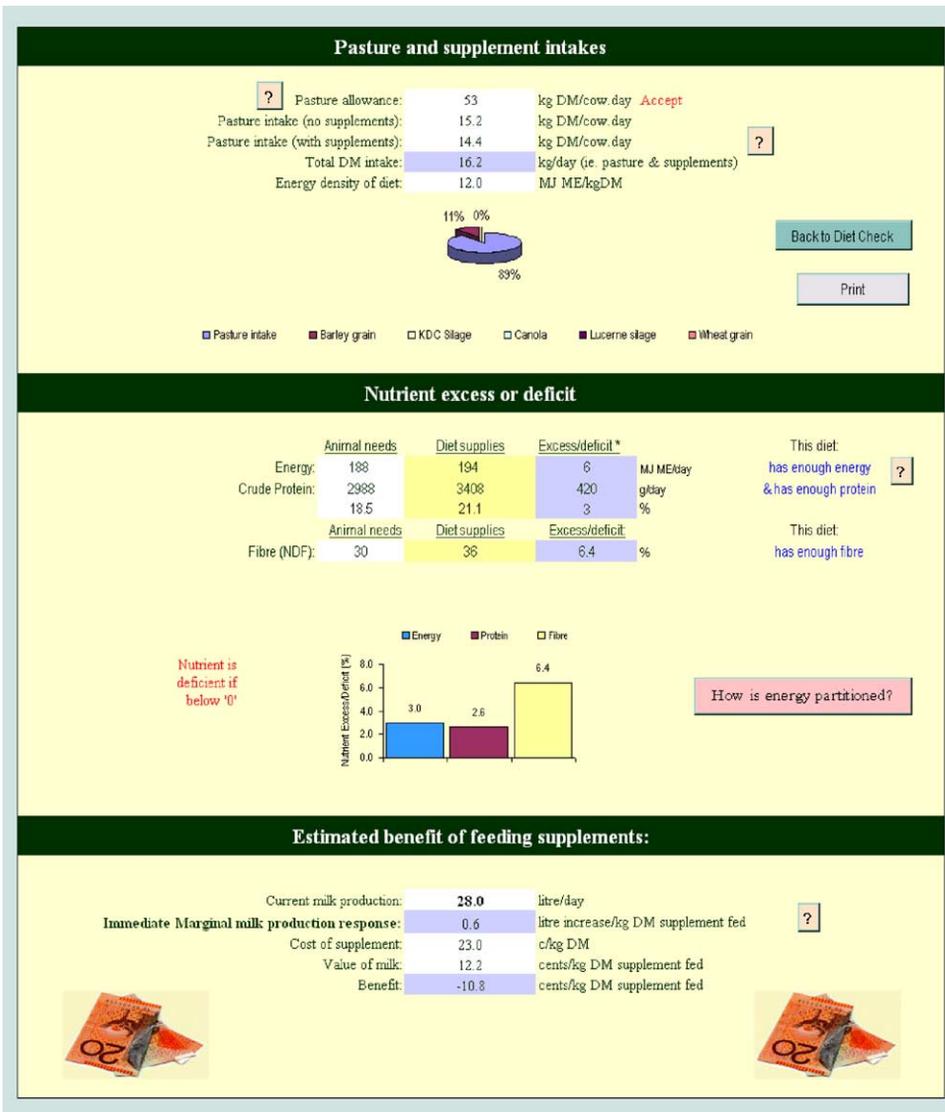
Fig. 3. Results page of Diet Check.

10. Summary

Diet Check provides a method of estimating whether cows are receiving sufficient ME, CP and NDF for a specified level of milk production and is a useful extension tool. Diet Check has a unique method of estimating pasture intake and nutrient intake from pasture, and substitution of supplements for pasture, and is useful when cows consume more than 50% of their total energy intake from pasture in strip-grazing or small paddock rotation

systems. Model inputs are determined on-farm, and so allows the user to evaluate potential effects of different feeding and herd management scenarios before applying them on-farm. It has provided a means of packaging local research results into a practical and user-friendly tactical decision support tool and, importantly, also provides a valuable learning tool used in extension activities. Training courses/workshops for service providers (i.e. government extension officers, milk company field officers, veterinarians and private consultants) have been conducted and the model is now used in nutrition courses for farmers in the region.

Acknowledgements

Appendix A. Equations to estimate the metabolisable energy requirements of grazing dairy cows

(a) The following equation is used in Diet Check to calculate ME requirements for maintenance (ME_m) for *Bos taurus* cattle (SCA, 1990, p. 24, eq. 1.21):

$$ME_m \text{ (MJ per day)} = \frac{1.4 \times (0.26W^{0.75} \exp(-0.03A))}{k_m} + 0.09 \, MEI$$

where W is the liveweight (kg), A the age (years), k_m the net efficiency of use of ME for maintenance, and MEI is the total ME intake.

(b) The ME requirements for pregnancy (ME_c) in Diet Check are defined by the equation (SCA, 1990, p. 39, eq. 1.29):

$$MEc = \frac{\exp(349.222 - 349.164 \exp(-0.0000576t)) \times 0.0201 \exp(-0.0000576t)}{k_c}$$

where t is the time (days) after conception, and $k_c = 0.133$, which describes the gross efficiency of use of ME for all the energy costs of gestation, expressed as a function of gain in the conceptus (SCA, 1990). Predictions are based on a 281 days gestation period, and calf weight of 40 kg.

(c) Two terms are incorporated into calculations within Diet Check and summed to quantify energy expenditure for activity (i.e. energy costs associated with walking to and from the dairy and energy costs associated with strip-grazing). Energy allowance for walking is based on published energy costs of physical activities from calorimetric studies (ARC, 1980), where:

walking (horizontal component) = 2.6 kJ/km/kg W

walking (vertical component) = 28 kJ/km/kg W

The horizontal and vertical components of the activity allowance are therefore calculated as:

$$HA = \frac{0.0026 \times \text{distance} \times W}{k_m}$$

and:

$$VA = \frac{(0.028 \times (\text{distance} \times \text{vert.}) \times W}{k_m}$$

where HA is the energy cost associated with horizontal activity, VA is the energy cost associated with vertical activity, distance is the distance (km) walked per day when away from the paddock, vert. accounts for variation in the gradation of terrain and is defined by the km vertical climb per kilometre walked (flat: 0.001; undulating: 0.04; steep: 0.1), and k_m is the net efficiency of use of ME. The energy cost associated with strip-grazing is included as 10% of maintenance energy requirement, in agreement with best-grazing conditions reported by the SCA (1990).

(d) The equation to predict the ME cost/L of milk (ME_{milk}) is from SCA (1990, p. 54) and expressed as:

$$MEmilk = \frac{0.0458 \times F + 1.222}{k_1}$$

where F is the fat concentration (g/kg milk) and k_1 is the net efficiency of use of ME for milk production calculated as: $k_1 = (0.02 \times \text{average ME/kg DM of diet}) + 0.4$ (SCA, 1990, p. 55, eq. 1.48).

Appendix B. Regression coefficients in the model PM = a + b × RPM, where PM is pasture mass (t DM/ha) and RPM is rising plate meter height (cm)

NIRV	a	S.E.	b	S.E.	CV (%)	r^2
January	1.58	0.096	0.16	0.006	14.81	0.69
February	2.05	0.106	0.13	0.006	16.74	0.60
March	2.27	0.133	0.12	0.008	17.75	0.33
April	0.77	0.141	0.20	0.010	20.43	0.51
May	1.17	0.179	0.18	0.015	18.32	0.57
June	0.62	0.052	0.24	0.006	5.57	0.94
July	1.27	0.127	0.12	0.012	18.42	0.56
August	0.25	0.219	0.24	0.017	16.24	0.82
September	1.87	0.103	0.08	0.005	21.86	0.54
October	1.98	0.118	0.10	0.005	22.87	0.43
November	1.96	0.150	0.12	0.008	22.55	0.41
December	0.97	0.148	0.20	0.010	17.15	0.65

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