NUTRIENT REQUIREMENTS OF DAIRY CATTLE

Seventh Revised Edition, 2001

USER'S GUIDE

National Research Council
Board on Agriculture and Natural Resources
Committee on Animal Nutrition
Subcommittee on Dairy Cattle Nutrition

Contents

1 Introduction

A compact disk containing a self-executable stand-alone program is provided as a companion to the National Research Council (NRC) *Nutrient Requirements of Dairy Cattle, Seventh Revised Edition, 2001*. This computer software allows the user to apply information presented in the report and equations summarized in Chapter 16 to practical situations. The program predicts requirements and allowable production from the dietary ingredients fed. It is a ration evaluator, not a ration balancer, so it does not perform the calculations necessary to develop least-cost rations. In addition, an Excel spread sheet is provided that calculates nutrient requirements for heifers at different weights and rates of gain.

We have attempted to make the software accurate and user friendly. Program help screens and context sensitive help are available in all portions of the software and in this User's Guide. The help material provides information that may assist the user in choosing inputs and in interpreting and applying outputs.

The focus of this User's Guide is to demonstrate features of the software including program operation, default data, input parameters, model structure, and equation documentation. The user is referred to the appropriate chapters for detailed information on the biological basis for equations and assumptions used in the software.

SYSTEM REQUIREMENTS

The NRC Nutrient Requirements of Dairy Cattle program is designed to run:

- On a Windows 95/98 platform,
- With a minimum of 16 MB of RAM (32 MB recommended), and
- A minimum screen resolution of 600 × 800 pixels

WARNING: The program uses decimal points, not commas, to distinguish whole numbers from decimals. For people whose computers are set to use the comma as the delimiter (primarily, non-U.S. users in Europe and Latin America) settings must be changed in Windows. Before changing the settings uninstall the NRC program using the **Add/Remove Program** option in the **Control Panel** or use the Uninstall routine that comes with the program. Make sure that all parts of the program and the program file are deleted. The **Currency** and **Number** settings can be changed by going to the **Start** icon, then to **Settings**, **Control Panel**, and **Regional Settings.** Both the **Number** and **Currency** settings must be changed.

1. Make the **Number** tab settings look like those in Figure UG-1.
2. Make the **Currency** tab settings like those in Figure UG-2:

RISK OF USE

Because of the many variables involved and judgments that must be made in choosing inputs, interpreting outputs, and general use of this program, the National Research Council makes no claim for the accuracy of this software and the user is solely responsible for risk of use.

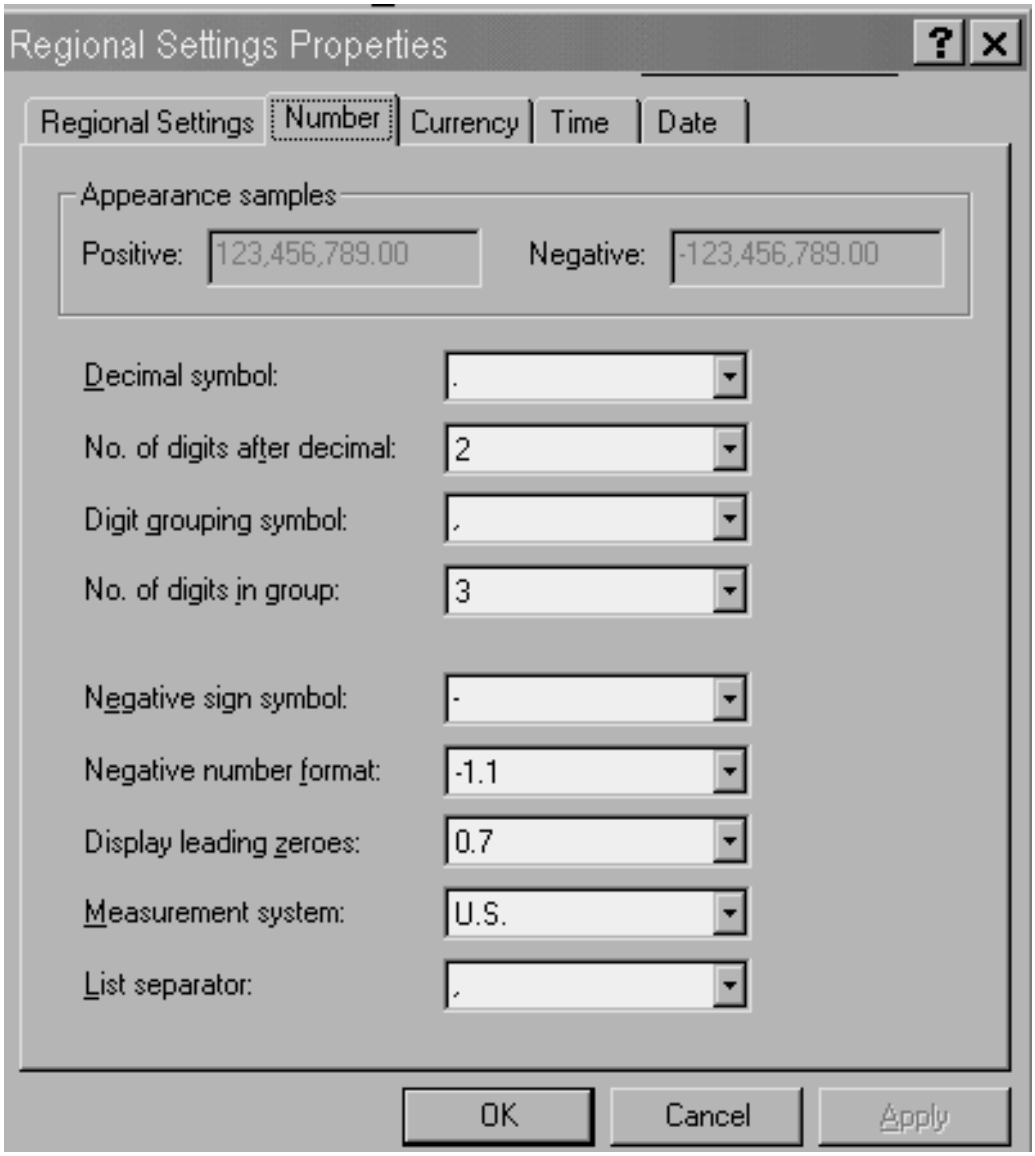

FIGURE UG-1 Settings for number properties.

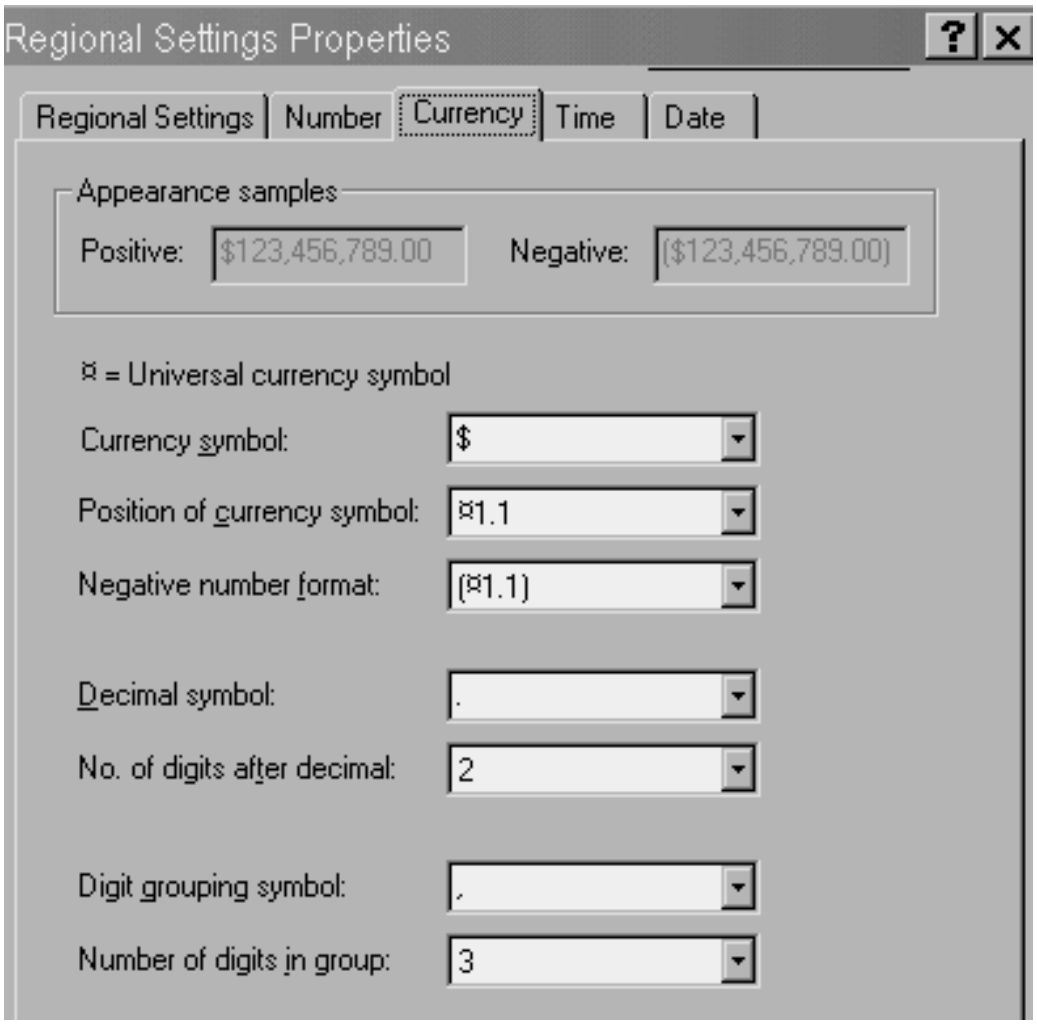

FIGURE UG-2 Settings for Currency.

2 Program Operation and Installation

INSTALLATION

The computer program can be installed from the CD-ROM enclosed with the book by inserting the compact disk into the CD-ROM drive. Before installing the program, other programs should be closed and previous versions of the software should be uninstalled. Failure to properly remove previous versions of the software may result in conflicts and the program may not be stable. During installation, the program will prompt the user for information to complete the installation process.

OVERVIEW

The program has a menu along the top of the program that includes File, Go To, and Help options (Figure UG-3).

Basic file operations for the program are accessed in the "File" menu.

- *New Simulation*: This command creates a new simulation with no feeds.
- *Load Simulation*: Loads a previously saved simulation data file.
- *Save Simulation*: Saves the current simulation. If the user has already loaded a simulation data file, the current simulation data are saved to that file name. Otherwise, the current data are saved to the Default Simulation Data File.
- *Save Simulation As*: Allows the user to save the current simulation with a new name. This option will permit you to save simulations to a specified directory. Normally simulations are saved to the Simulation Files subdirectory located in the NRC Program directory.
- *Save Current Simulation as Default*: Saves the current simulation data to the default data file. Note that this option is only enabled if the Auto-Save option (see below) is unchecked.
- *Auto-Save Default Data On Exit*: When checked, the program will automatically save the current simulation data to the default data file when the user exits the program. If unchecked, the user must manually save simulation data. It is suggested that you keep this option checked for safety.
- *Exit Program*: Quits the program.

There are two ways to move around the program. The easiest way is to use the toolbar located beneath the menu bar. Click on a button to jump to the corresponding screen.

It is also possible to move through the program by using the menu. Click the "Go To" menu option and select the desired section of the program.

As described above, there are four main screens within the program:

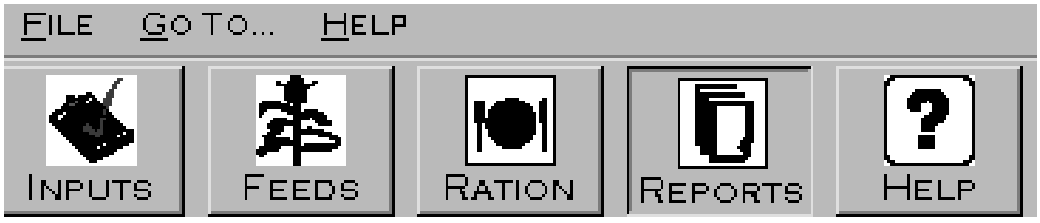

FIGURE UG-3 Program menu bar.

• *Inputs*: Where you enter the general program settings, as well as the animal inputs (e.g., Animal Type, Breed, Body Weight, etc. . . .).
• *Feeds*: Where the feeds in the animal's ration are selected and edited.
• *Ration*: The quantity of each feed in the animal's ration is specified here.
• *Reports*: Go here to view and print output.

DEFAULT DATA

To permit easy movement within the program, the program must always have reasonable input data defined. Error messages starting with "Run Time Error" indicate that the program is attempting a division by zero. The most common cause of this type of error is failure to enter needed data, especially on feed composition. The program attempts to avoid this type of error by using default data files that are accessed automatically whenever the program is run. There are two types of default data:

Default Program Settings: This file stores data that are not specific for a simulation, such as the summary result settings, report headers and footers, and other program settings. It is automatically loaded and saved by the program. If, for whatever reason, this file is lost or corrupted, the program will create new settings for itself.

Default Simulation Data File: This file has exactly the same structure as a simulation data file that can be loaded and saved by the user, except that it will automatically be loaded when the program is started up. The user can control how this default file is saved and what data are saved by using the appropriate commands in the "File" menu (see **Program Operation** for more details).

PROGRAM HELP

In addition to the Help files that are accessed through the menu at the top of the screen, the NRC Dairy Cattle Program also has context-sensitive help for many of its operations.

Context sensitive Help can be accessed in two ways:

• Selecting "What's This?" in the Help menu with the left mouse button. Once this option is selected, the mouse pointer will turn into a pointer with a big question mark next to it. When the question mark is visible, click the input label in question (e.g., "Animal Type") with the left mouse button. If context-sensitive help exists for this label, it will appear.
• Right-clicking the mouse over a label will show a popup menu with "What's This?" as a selection. Left click on the "What's This" help box to view the help message (Figure UG-4). In addition, some labels will have a "Jump to Help Topic" option that will send the user to a specific help topic in this Help section, giving more detailed information concerning the topic.
• Left-clicking on the mouse outside of the help box will cause it to disappear.

Note that when a feed is added to a ration, the program disables the menu system to ensure that the operation is completed before leaving the screen. During this operation the Help system associated with the menus is also disabled.

INPUTS

The Inputs screen consists of a tabbed dialog box with four different subsections. The first, Program Settings, is shown in Figure UG-5.

• *Units*: Select whether to enter inputs and ration quantities in metric or English units. Although all internal computations are performed in the metric system, output units will be converted as appropriate.
• *Basis*: This determines whether ration quantities will be input on a dry matter or "as-fed" basis. The "As-Fed" basis option uses each feed's dry matter value to compute the dry matter intake from the quantity fed.
• *Report Headers/Footers*: Allows the user to set the output for the report headers/footers. The user can select one of the pre-set options, or can compose his own text.
• *Summary Results*: Allows the user to customize which summary results are presented on the Ration screen. Note that there are summary results specific to Young Calf simulations. These are listed with a "(CALF)" prefix. While it is permissible to have calf summary results mixed with non-calf results, and vice-versa, results that are not applicable will not be shown (e.g., Calf Average Daily Gain will be "N/A" for a Lactating Cow).

The Animal Description tab appears in Figure UG-6.

Most of this screen is self-explanatory, except for Body Condition Score and the Calf Variables. A 1 to 5 scale is used for body condition scoring with 1 for emaciated animals and 5 for obese animals. For animals other than young calves, these variables are disabled (shaded). However, if "Young Calf" is chosen as the Animal Type, then these variables will be enabled, with the others disabled. In addition, since only the program's Calf sub-model only uses these variables, the user will not be able to access the Production and Management tabs if "Young Calf" is the selected Animal Type.

The Production is shown in Figure UG-7.

Items to note on this screen:

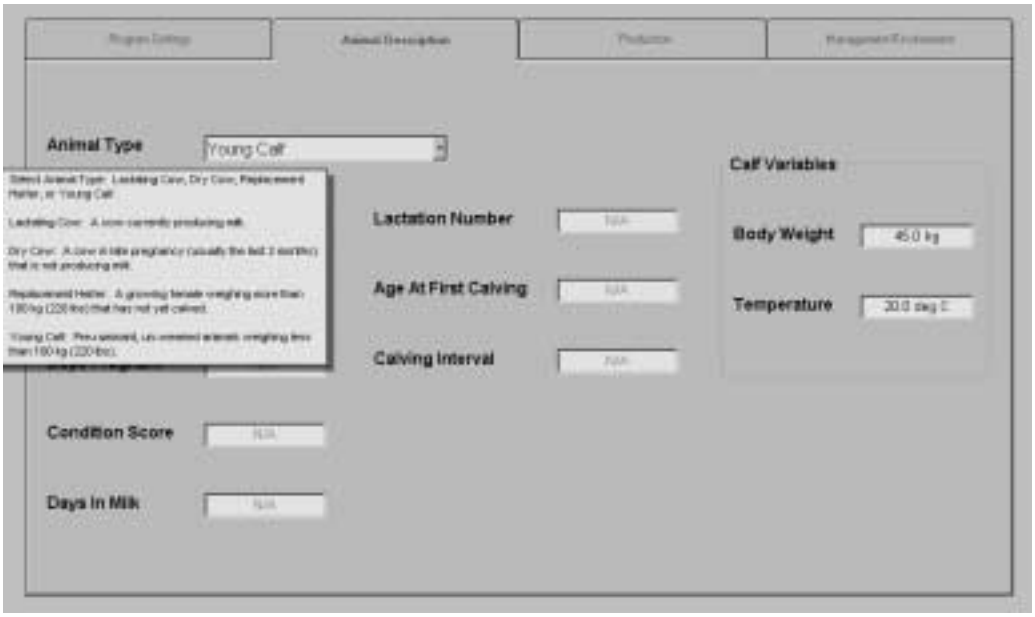

FIGURE UG-4 Help box.

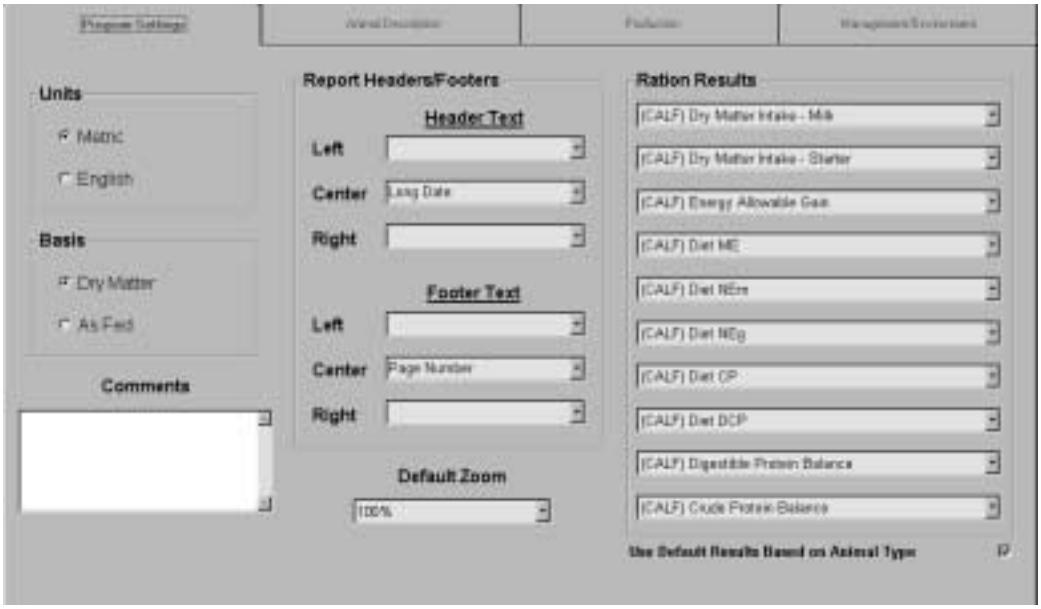

FIGURE UG-5 Program Settings screen.

• If the "Compute Mature Weight from the Breed" option is checked, the mature weight will be set as a function of the selected breed and the user will not be able to change this weight. Likewise, selecting the "Compute Calf Birth Weight from the Mature Weight" option will compute the Calf Birth Weight as a function of the mature weight. These options are recommended if the user does not know the mature weight or calf birth weight of the animals in the herd.

• Whether the Milk Protein is expressed on either a crude or true protein basis can be indicated by selecting the appropriate radio buttons (black dot). True protein equals 0.93 times crude protein.

The Management/Environment screen is shown in Figure UG-8.

• Note that the Previous Temperature, Wind Speed, Coat Condition, Heat Stress, Hair Depth, and Night Cooling variables are only enabled when Replacement Heifer is the chosen Animal Type, since the environmental submodel is only applicable for heifers.

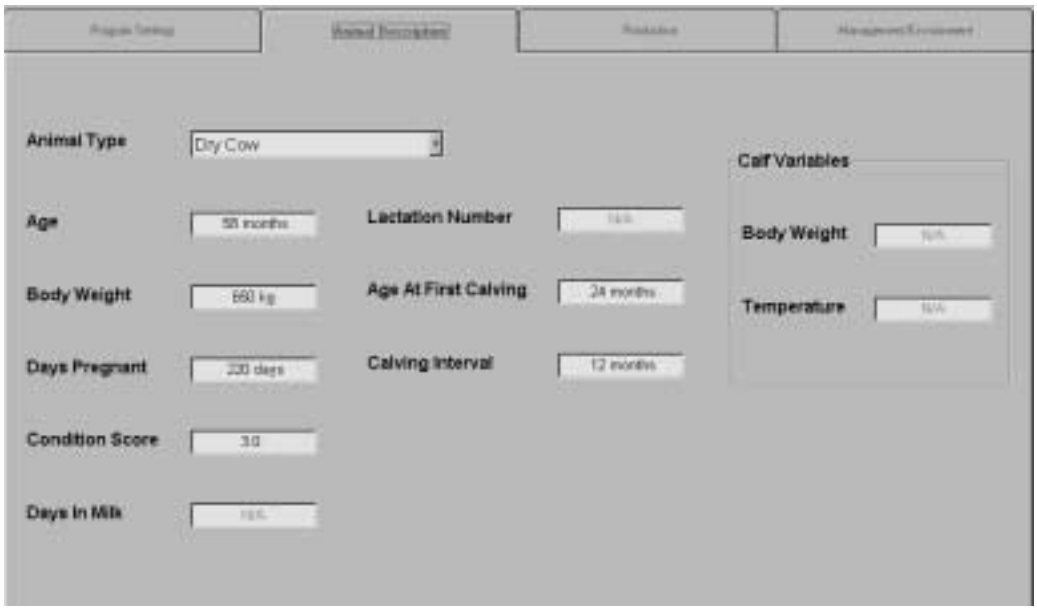

FIGURE UG-6 Animal Description screen.

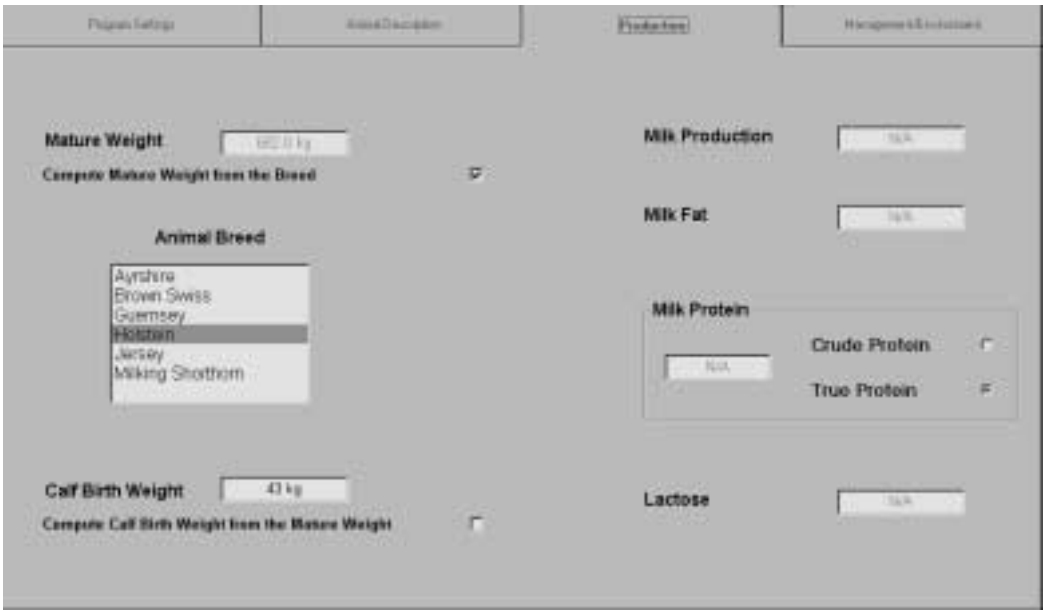

FIGURE UG-7 Production screen.

• If the animal is grazing, then you will have to set the Topography, the Distance Between the Pasture and Milking Center and the Number of One-Way Trips (for Lactating Cows) or the Average Distance Traveled per Day. Distance traveled is measured in either feet or meters.

FEED

The program handles saving and loading feeds in the following manner: The feeds in the Feed Library that comes with the program cannot be edited or deleted. When a feed is imported into a ration, the program actually makes a copy of the feed data that will be saved with the simulation. This copy can be edited as needed. However, these changes to a feed will only be saved in a specific simulation. The values in the core feed library remain unchanged. To access this edited feed in other simulations, you must save it in the Feed Library (i.e., make a user-created feed). Give the feed a new, unique name and select "Save Feed in Feed Library." To protect the integrity of the Feed Library, it is not possible to save changes to Feeds using names already used in the Feed Library.

FIGURE UG-8 Management/Environment screen.

• To edit the composition of a feed, enter a new value in the appropriate cell of the Feed Components grid (Figure UG-9). The energy values of feeds, except for milk-based calf feeds, cannot be entered directly. They are computed from the composition of the feeds. In the case of the milk-based calf feeds, energy values can be edited directly but a fixed relationship among the energy values is always maintained. For example, if the ME value of a feed is changed, all of the other energy variables also will change. If fat, ash, or protein of a milk-based calf feed is changed, all energy values also will be recomputed.

• Feeds can be re-ordered in a ration by using the up and down arrows to the right of the Feeds list within the simulation. Select a feed and click on the down arrow to demote the feed to a lower position in the list or click on the up arrow to promote the feed to a higher position in the list.

• The Add Feed(s) button advances the user to another screen where feeds can be selected for the simulation. The

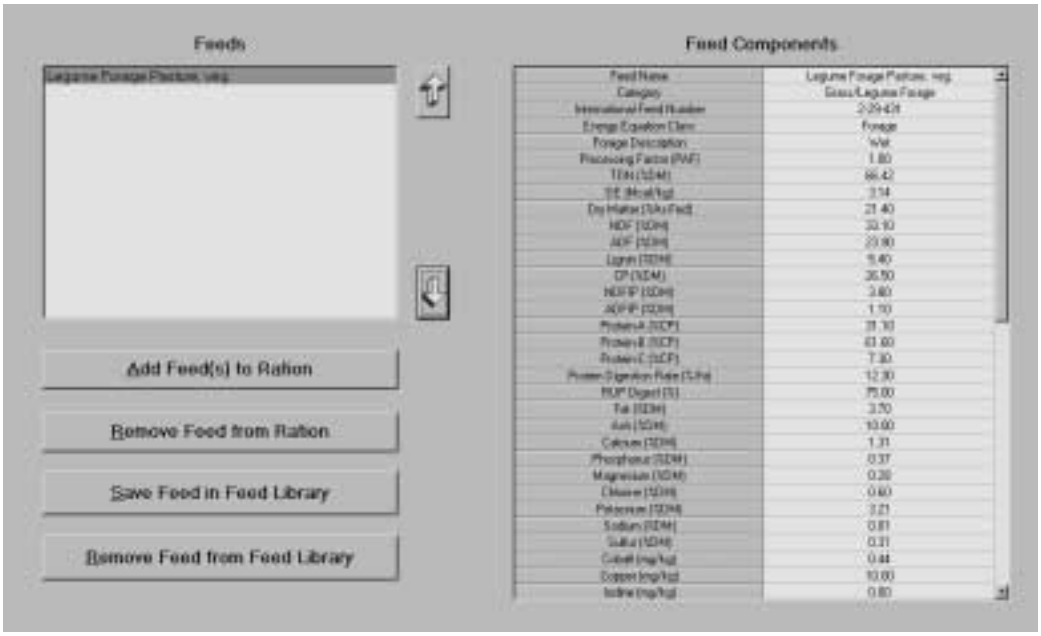

FIGURE UG-9 Feed screen.

feeds in the Feed Library are separated into nine separate categories: Grass/Legume Forages, Grain Crop Forages, Energy Sources, Fats, Plant Protein, Animal Protein, By-Product/Other Feeds, Vitamin and Mineral, and Calf Feeds. As you select feeds in the screen, a grid displaying their component values appears at the bottom of the screen. Also note that user-created feeds are indicated in the different category boxes with a "*" prefix. Multiple feeds can be selected. When the user creates newly defined feeds, it is recommended that the user select a similar feed in the library for editing. This is important for two reasons: 1) if needed information on the new feed is lacking, similar values from the library feed may be used, and 2) the nine boxes to denote feed types also determine which equations are used to predict the energy content of feeds. Mischaracterization of feeds will lead to incorrect energy values.

- The Remove Feed button will remove the selected feed from the ration.
- The Save Feed in Feed Library button will save the current feed in the Feed Library. The program will not allow you to save a feed with a name that matches one of the original feeds in the library. If you want to create and save a user-defined feed in the library, it is recommended that you use a feed that is very similar to the feed that you are entering as a template. Edit the feed as desired but retain feed characterizations such as Category, Energy Equation Class, Forage Description, and Processing Adjustment Factor unless they are patently incorrect. These classifications are used to determine which equations the model uses to predict the energy content of the feed. It is safer to rely on the values in a similar feed than to guess which setting is most appropriate.
- The Remove Feed from Feed Library button allows you to do exactly that. However, only user-created feeds can be removed from the Feed Library.

Backing Up the Feed Library: The name of the file containing the Feed Library is NRC Dairy Cattle Program—Feed Library.mdb. This file is a Microsoft Access Database file. This file, including user-defined feeds, can be backed up or shared with other users by copying it into an appropriate location. It is recommended that you make back-up copies of this file, especially if you have entered many user-defined feeds.

Changing Energy Values of Feeds: The program predicts the energy content of feeds from chemical composition, and it is not possible to directly adjust the energy value of a feed. If you believe that processing or other conditions have altered the digestibility of fat, NDF or RUP, it is possible to alter the digestibility of these components. These adjustments will affect the energy content of the feed.

RATION

- On the Ration screen (Figure UG-10), all of the feeds in the simulation are listed, with the amounts fed. The Total Intake entry-box contains the sum of the amounts of all of the feeds included in the ration. This value also can be used to determine the quantities of each feed as a percent of the total intake are also specified.
- Ration quantities can be entered in several ways. First, a quantity can be directly entered in the "Qty" column. When you change a value in this column, the program will recompute the "% Total" using the new quantity fed and the original Total Intake.
- It is possible to enter a ration quantity as a percent of the original total intake and the quantity fed will change to reflect that percentage of the original intake. Finally, you can change the Total Intake. Then the program will recompute all of the quantities of the feeds based on the specified percent of totals for the individual feeds and the new total intake.
- If you change the ration and offer more or less feed than the quantity listed in the "Total Intake" box, the total percent of the "Total Intake" will not equal 100%. Selecting the "Set to 100%" button, the program will re-compute the "% Total" values for all of the feeds based on the individual quantities fed and the total intake, so that the percentages sum to 100% again.
- Clicking the "Estimate" button will cause the program to fill the "Total Intake" box with the model's Predicted Dry Matter Intake.
- Note that the program also displays summary results, which change every time a change is made to the ration. The outputs included in these summary results on the ration page can be customized by making changes on the Program Settings tab of the Inputs screen. The default choices for each Animal Type reflect data most often used in ration evaluation for that class of animal.

REPORTS

The program's reports are produced in a "Print-Preview" format, where they can be viewed exactly as they will be printed. A typical report screen area is shown in Figure UG-11. Reports are generated on each of the following topics: Summary (of most use to people developing rations), Energy and Protein Supply, Dry Matter Intake, Maintenance Requirements, Growth Requirements, Target Weights and Average Daily Gain, Pregnancy Requirements, Lactation Requirements, and Mineral Requirements.

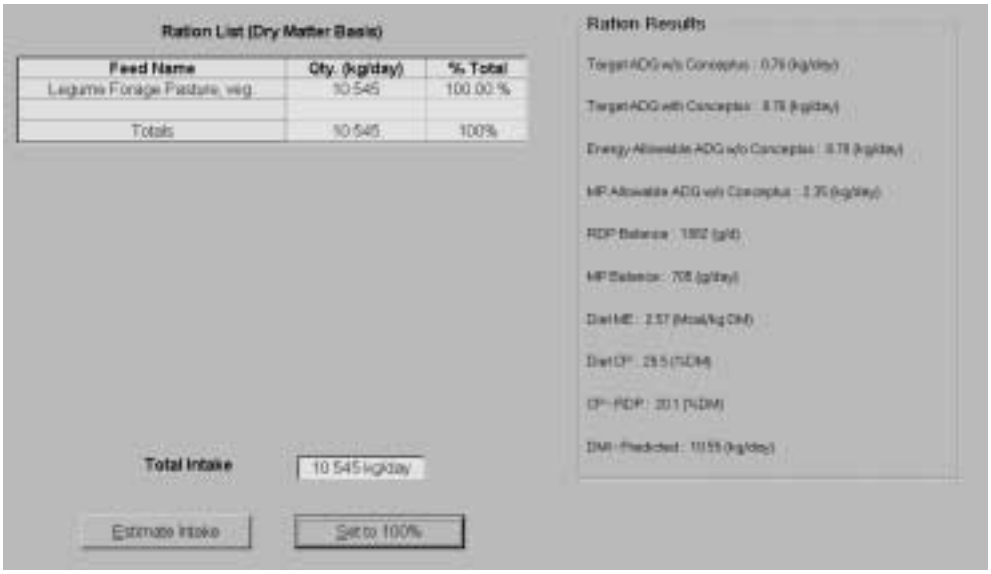

FIGURE UG-10 Ration screen.

FIGURE UG-11 Reports screen.

• To create a report, select the desired report components by checking the appropriate list-box(es) on the left side of the screen and clicking on the "View Report" button.

• The appearance of the page is set using the "Zoom" list-box, giving you the option of seeing the whole page, thumbnails, two-pages, page-width, and zooms from 25-500%. The default zoom setting can be chosen on the "Default Zoom" box on the Program Settings tab of the Inputs screen. If the "Zoom" box on the Report Screen is adjusted, the change will remain in effect only during that visit to the report screen. Changes made on the Program Settings tab remain in effect until they are changed.

• It is possible to scroll through the pages of the report using the "Page x of y" scrollbar. To move the page up or down in the viewing window, you can use the horizontal

and vertical scrollbars. Alternatively, you can click and drag the mouse over the page to move it in any direction you wish. Double-clicking the left mouse button will zoom in, and clicking with the right mouse button will zoom out.

- Reports can be printed out using the "Print Report" button. The page settings such as font type or size or page orientation for the reports can be set by using the "Page Settings" button.

3 Tutorials

GENERAL DESCRIPTION OF THE MODEL STRUCTURE

The model is divided into two major components: prediction of requirements and supply of nutrients. Within this structure, there are sub-models for maintenance, pregnancy, growth, lactation, dry matter intake, minerals, reserves, energy and protein supply, amino acids, and diet evaluation, as well as a young calf sub-model. Chapters 2 and 5 of the accompanying volume describe the biology underlying the equations used in predicting nutrient supply. The equations used in the model are presented in Chapter 16. A glossary of the terms used in the equations is included in this volume. Background information that describes the rationale for choosing the approach and coefficients used in the model is presented in the relevant chapters of the report.

The focus of the tutorials is to demonstrate how to apply the model under various circumstances and conditions. Example lessons are provided for two different situations: one example for mid-lactation cows and one example for heifers.

MID-LACTATION COW CASE STUDIES

Case 1: Mid-Lactation Cow

Load Simulation. Click on Inputs. Click on the Program Settings tab.

Program Settings:

Units:	Metric
Basis:	Dry matter
Report:	Header text: important to provide date, page number, and title of document
Summary results:	Choose information you are interested in displaying or allow defaults based on animal type
Default Zoom:	Set to 75%

Click on Animal Description tab. Enter the following:

Description:

Animal Type:	Lactating cow
Age:	65 months
Body Weight:	680 kg
Days Pregnant:	0
Condition score:	3.0
Days in Milk:	90
Lactation Number:	3
Age at 1st calving	24 months
Calving interval	12 months

Click on Production tab. Enter the following:

Mature Weight:	680 kg
Breed:	Holstein
Calf Birth Weight:	43 kg
Milk Production:	54.5 kg
Milk Fat:	3.5%
Milk True Protein:	3.0%
Lactose:	4.8%

Click on Management/Environment tab. Leave default temperature at 20.0 degrees C.

Click on Feeds. Click on Add Feeds to Ration. Select the appropriate categories, highlight the feed and add the following feeds to the ration:

Legume forage hay, immature
Corn silage, normal
Corn grain, steam-flaked
Calcium soaps of fatty acids

Tallow
Cottonseed, whole with lint
Soybean meal, solv. 48% CP
Blood meal, ring dried
Calcium carbonate
Monosodium phosphate (1 H20)
Salt
Vitamin Premix 1

Click on Ration and enter the following diet (as % of DM):

Legume forage hay, immature	18
Corn silage, normal	40
Corn grain, steam-flaked	22
Calcium soaps of fatty acids	1
Tallow	1
Cottonseed, whole with lint	7.5
Soybean meal, solv. 48% CP	8
Blood meal, ring dried	0.5
Calcium carbonate	0.1
Monosodium phosphate (1 H20)	0.2
Salt	0.5
Vitamin Premix 1	1.2

Click on Estimate Intake. Note: you cannot enter % of DM until you put an amount (kg/d) in the table, then you can put in %. Of course estimated DMI is not as good as measured DMI.

Click on Reports tab. Check Summary Report and click View Report (Table UG-1).
Click on File. Save As DIET A.

The MP and RUP supplied were short of meeting the required needs for this cow. How can MP supplied be less than required and RDP be more than required? RDP requirements are calculated from TDN. The higher the TDN content of the diet, the higher the RDP requirement.

Go to Ration icon. Change the diet to correct the deficiencies in RUP and MP by increasing the blood meal from 0.5 to 1.7% of ration DM and decreasing the SFC from 22.0% to 20.8% of ration DM. Go to the Reports icon and click on View Report. We have now corrected the deficiencies for MP and RUP. We have, however, increased the total protein in the ration from 15.8 to 16.9%, an additional 330 g CP/d or 226 g of MP/d. The reason that CP increased 330 g but MP only increased 226 g is because the RDP above requirement does not contribute to MP. This additional protein is needed to support this level of milk production. MP allowable milk was 50 kg/d and now it is 55.1 kg/d. Changes in the protein sources used may allow for reduced total protein in the ration.

Click on File. Provide a file name under Save As DIET B.

TABLE UG-1 Summary Report for Diet A

Summary Report

Animal Inputs

Animal Type: Lactating Cow
Age: 65 months
Body Weight: 680 kg
Milk Fat: 3.50%
Milk Production: 54.5 (kg/day)
Days Pregnant: 0
Breed: Holstein
Milk True Protein: 3.00%

Diet Nutrient Balances

Requirements	NE (Mcal/day)	MP (g/day)	Ca (g/day)	P (g/day)	K (g/day)
Maintenance	10.7	1034	22	31	209
Pregnancy	0.0	0	0	0	0
Lactation	37.7	2440	62	49	76
Growth	0.0	0	0	0	0
Total Required	48.3	3474	83	80	285
Total Supplied	47.5	3327	92*	80*	355*
Balance	−0.8	−147	9	0	70

*Note that these minerals supplied are total *absorbable* supplied.

Animal Performance

DMI-Actual: 30.0 (kg/day)
DMI-Predicted: 30.0 (kg/day)

NE_L Allowable Milk: 53.3 (kg/day)
MP Allowable Milk: 51.2 (kg/day)

Milk Production: 54.5 (kg/day)

Days to lose one condition score: 506

Daily Weight Change due to Reserves: −0.2 (kg/day)

Diet Concentrations

NDF: 31.2 (%DM)
Forage NDF: 24.5 (%DM)
ADF: 20.6 (%DM)
NFC: 42.4 (%DM)
Undiscounted TDN: 75 (%DM)
ME: 2.48 (Mcal/kg DM)
NE_L: 1.58 (Mcal/kg DM)
NE_G: 1.19 (Mcal/kg DM)
Ca: 0.6 (%DM)
P: 0.4 (%DM)
Ether Extract: 6.0 (%DM)

Protein Values

RDP Required: 2955 (g/d)
RDP Supplied: 3055 (g/d)
RDP Balance: 49 (g/d)

RUP Required: 2046 (g/d)
RUP Supplied: 1871 (g/d)
RUP Balance: −175 (g/d)

MP-Bacterial: 1608 (g/d)
MP-RUP: 1577 (g/d)
MP-Endogenous: 142 (g/d)

CP-Diet: 16.2 (%DM)
CP-RDP: 10.0 (%DM)
CP-RUP: 6.2 (%DM)

Target Diet Concentration

NE_L: 1.61 (Mcal/kg)
MP: 116 (g/kg)

Ca: 3 (g/kg)
P: 3 (g/kg)

Diet Summary

Feed Name	kg/day (Dry Matter)	kg/day (As-Fed)
Legume forage hay, immature	5.41	6.43
Corn silage, normal	12.02	34.25
Corn grain, steam-flaked	6.61	7.50
Calcium soaps of fatty acids	0.30	0.31
Tallow	0.30	0.30
Cottonseed, whole with lint	2.25	2.50
Soybean meal, solv. 48% CP	2.40	2.68
Blood meal, ring-dried	0.15	0.17
Calcium carbonate	0.03	0.03
Monosodium phosphate (1 H2O)	0.06	0.06
Salt	0.15	0.15
Vitamin premix 1	0.36	0.36

Leave this file open.

You can see that this diet is still –0.7 Mcal short of meeting the needs of the cow and NE_L allowable milk is 53.4 kg/d when in fact we hope she will produce 54.4 kg/d.

Go to the Ration icon. Go to the Total Intake frame and type in 30.7 kg. By increasing DMI, NE_L balance is now increased to 0.0 Mcal/d and in the Reports section you will see that NE_L allowable milk is now 54.6 kg/d. Now return to the Ration tab and change the intake by hitting the estimate intake button. It will be 30 kg/d as before. Keep this file open.

Case 2: Changing True Milk Protein

Click on Inputs. Click on Production. Change True milk protein from 3 to 2.8%. Click on the Reports tab. Check Summary report and then click on View Report. The DMI and the ration are not affected, however, the MP requirement for Lactation decreases from 2440 g to 2278 g/d. The RUP required changes from 2099 g to 1874. RUP requirement is calculated as = ((MP requirement – MP from endogenous – MP from bacterial)/RUP digestibility). MP allowable milk is now 59.1 kg/d.

Click on File and Save this simulation as DIET C.

Case 3: Changing Days In Milk (90 vs 120 DIM)

Load simulation file DIET B.

Click on File and Save this as a new simulation, DIET D.

Click on the Inputs tab. Click on Programs tab and label this DIET D.

Click on Animal Description. Change DIM from 90 to 120. Click on the Ration icon. You can see under predicted DMI that the intake has increased from 30 kg/d to 30.77. It is very important that you change the intake to reflect the needs of this cow. Click on Estimate Intake. Even though we have not changed anything regarding the diet, some requirements have increased.

As you can see the MP required for maintenance was increased from 1034 grams to 1057 grams/d, which increases the total MP required. As DMI increases the metabolic fecal requirement increases and this represents an important part of the maintenance requirement. The RDP requirement increases because RDP requirement is calculated from TDN and the total TDN has increased. RUP requirement is decreased. The MP from bacteria increased because it is calculated based on TDN. In addition, now we have also increased NE_L from –0.7 Mcal to 0.1 Mcal /d bringing the NE_L allowable milk from 53.5 to 54.7 kg/d.

Click on File and Save this simulation.

Case 4: Altering Forage Quality

Load file name DIET B.

Click on Feeds. Click on Add Feeds to Ration. Select under Grass/Legumes, Legume Forage Hay, Mature. Click on Add Feed. Click on Ration. Set Legume Hay, immature to 0 % and Legume Hay, Mature to 18%.

There is a message in the right bottom corner: **RDP Limiting-Energy Estimates May be Erroneous.** RDP requirements are calculated from TDN. The higher the TDN content of the diet the higher the RDP requirement. More RDP can be added or the TDN of the ration can lowered or a combination of the two can be used to correct the situation.

Go to the Reports tab.

Highlight Summary Report. Click on View Report. This is a very clear demonstration of how forage quality affects the NE_L and MP allowable milk and puts the cow in greater negative energy and protein balance.

Go to File and Save this simulation as DIET E.

Case 5: When Only RDP is Limiting

Load DIET B.

Click on Ration. Enter under % Total for Legume forage, immature 17%, corn silage 37.8%, SFC 26%, Tallow to 0%, SBM 6.5%, and Blood meal 2.2%.

Go to Reports and highlight Summary Report. Click on View Report. In this case MP balance is positive and RDP is limiting. RDP may be limiting microbial growth, but the diet contains sufficient RUP such that the MP requirements of the animal are met. Go to File and Save simulation as DIET F.

REPLACEMENT DAIRY HEIFERS

In the model accompanying *Nutrient Requirements of Dairy Cattle* (2001), energy and protein requirements are computed from the energy and protein contained in the tissue accreted during growth. The gain can be predicted from the current and mature weights of the animal or a desired rate of gain can be entered. After a proposed ration has been entered, the model predicts the energy and protein allowable daily gain. Daily gain is predicted from the net energy available after the requirements for maintenance and pregnancy have been met. The amount of protein required is based on the energy allowable gain. This exercise begins by describing briefly the concepts underlying the heifer growth model, and then simulations demonstrate the theories used to develop this model and evaluate rations of replacement heifers.

Computing Energy and Protein Requirements of Heifers with Different Mature Weights

The equations used to compute energy and protein requirements for animals at any body weight and any rate of gain were developed from data on body composition of many cattle grown at different growth rates to various mature weights. The energy and protein composition of gain of animals with similar current weights, but different mature weights, differ. To account for the effect of mature weight on chemical composition of gain, a size scaling adjustment using a standard reference animal is used. This adjusted weight is then used to compute the net energy requirement. Table UG-2 compares the net energy and protein requirements of typical and large mature size Holstein heifers, and small Jersey heifers computed with this model.

Table UG-2 shows:

1. Animals with larger mature weights are at an earlier stage of maturity than their peers with smaller mature weights.
2. There is a direct relationship between net energy content of gain and weight as a percentage of mature weight, and an inverse relationship between net protein content of gain and weight as a percentage of mature weight.
3. Efficiency of use of metabolizable protein decreases as weight as a proportion of mature size increases.

Table UG-3 shows the influence of rate of gain on heifer requirements at the same stage of growth for a typical Holstein, a large Holstein, and a Jersey (see Table UG-2). Table UG-3 demonstrates:

1. When the energy and protein content of gain of a typical Holstein, a large Holstein, and a Jersey are the same, the heifer with a largest mature weight will weigh more than the smaller animals.
2. At a given weight, as rate of gain increases, net energy and net protein required increase.
3. At a constant rate of gain, the amount of net energy required increases and net protein required decreases per unit of gain as the animal matures.

TABLE UG-3 Effect of Body Weight and Rate of Gain on Daily Gain

Mature weight	*Live Body weight (kg) at various stages of growth*[a]						
650 kg Holstein	200	250	300	350	400	450	500
800 kg Holstein	246	308	369	431	493	554	616
400 kg Jersey	139	173	208	242	277	312	346
Shrunk weight gain, kg/day	*NE_G required, Mcal/d*[b]						
0.6	1.34	1.58	1.81	2.03	2.25	2.46	2.66
0.8	1.83	2.17	2.48	2.79	3.08	3.37	3.64
1.0	2.34	2.77	3.17	3.56	3.94	4.30	4.65
	Net protein required for growth, g/d[c]						
0.6	122	114	108	101	95	89	83
0.8	161	151	141	132	124	115	107
1.0	199	187	175	163	152	142	131
	Metabolizable protein required for growth, g/d[d]						
0.6	182	183	185	187	190	194	199
0.8	241	241	243	245	248	253	259
1.0	299	299	300	302	305	310	316

[a] The body weights are full, not shrunk, body weights. The weights within the same column are at the same stage of growth.

[b] NE_G requirement is computed from Equation 11-2: Retained energy (RE) = $0.0635\ EQEBW^{.75}\ EBG^{1.097}$, where EQEBW is equivalent empty body weight and EBG is 0.956 SWG.

[c] Net protein in the gain is computed from equation 11-3: RP, g/d = SWG × (268 − (29.4 × (RE/SWG))).

[d] Metabolizable protein required is computed from equation 11-4: MPg = NP_g/(0.83 − (EQSBW × 0.00114)); If EQSBW is > 478 kg, then EQSBW = 478 kg.

4. Metabolizable protein is used less efficiently for growth as body weight as a proportion of mature weight increases.

Target Rates for Herd Replacement Heifers

To compute target weights for replacement heifers, it is assumed that a heifer will weight 55% of mature weight at breeding and 82% of mature weight at first calving. If these targets are reached, the costs of raising replacements will be minimized and first lactation milk production maximized (see Chapter 11). Target weights as a percentage of mature weight (MW) are summarized in Table UG-4 for an average Holstein, a large Holstein, and a Jersey. These target weights are used with current age and weight, age at first calving and calving interval to compute daily gain required to reach the next target weight, as follows.

TABLE UG-2 Net Energy and Protein Requirements of Heifers with Mature Weights of 400, 650, and 800 kg

	Small Jersey	Typical Holstein	Large Holstein
Mature body weight, kg	400	650	800
Current body weight, kg	313	313	313
Shrunk body weight (SBW), kg	300	300	300
% of mature weight	75	46	38
SBW equivalent to standard reference animal, kg	359	221	179
Net energy required for 700 grams daily gain, Mcal	3.09	2.15	1.83
Net protein required for 700 grams daily gain, g	97	124	134
Efficiency of use of metabolizable protein, %	42.1	57.8	62.6
Metabolizable protein required for 700 grams daily gain, g	230	215	214

TABLE UG-4 Target Weights for Dairy Heifers

Reproductive Stage	Target % of MW	650 kg MW	800 kg MW	400 kg MW
1st breeding	55%	358	440	220
1st calving (post-parturition)	82%	533	656	328
2nd calving	92%	598	736	368
3rd calving	100%	650	800	400

For heifers before conception, target daily gain to weight at first breeding is:
((Mature weight × 0.55) − current weight) / ((Age at first breeding − Current age) × 30.4.

For bred heifers, daily gain required is:
((Mature weight × 0.82) − current weight) / (Age at first calving − Current age) × 30.4; the average daily gain of the conceptus is added to get measured weight gain required.

Daily gain required during the first lactation (including the dry period) is:
((Mature weight × 0.92) − current weight) / (calving interval days − days since calving) × 30.4. Daily gain for the second lactation is computed the same way, using 1 to compute the next target weight for the second lactation.

Table UG-5 compares target daily gains for the three mature sizes of replacement heifers. This table shows that daily gain required to reach the target depends on current weight, mature size, and age at first calving.

Heifer Model Exercise

This exercise is designed to demonstrate how the program can be used to compute requirements for dairy heifers for a desired daily gain, and to compute target and diet allowable daily gains based on animal and dietary information entered in the model. Table UG-6 summarizes the inputs that will be needed for each scenario in this exercise (in order that the variables must be entered). Only changes from the no-stress, open heifer are shown for the other scenarios. Answers are provided in italics in parentheses in the scenarios described below.

TABLE UG-5 Target Daily Gains Post Transition to Pre-Conception for Three Mature Sizes of Dairy Heifers

	400 kg mature weight	650 kg mature weight	800 kg mature weight
Current age, days[a]	77	77	77
Current weight, kg[b]	52	84	103
Target bred weight, kg	220	358	440
Gain required to conception, kg	168	274	337
Days to conception[c]			
20 months of age at first calving	251	251	251
24 months of age at first calving	373	373	373
28 months of age at first calving	494	494	494
Daily gain required to first conception, g			
20 months of age at first calving	669	1092	1343
24 months of age at first calving	450	735	903
28 months of age at first calving	340	555	682

[a] Weaning at 8 weeks plus 3 weeks transition.
[b] Birth weight at 6.275% of mature weight plus expected weight gain during starting and transition phases.
[c] Age in days at first calving (280 days gestation; 77 days current age).

Scenario 1. The effect of age, current body weight, and mature weight on nutrient requirements for the desired daily gain, target daily gain, and diet allowable daily gain.

1. Enter the information for the open heifer with no stress conditions. At the ration screen, note that the target daily gain differs from the desired ADG and the ME allowable ADG. The target ADG exceeds the desired ADG entered. The target is the optimum computed by the model based on the age, current weight, age at first calving, and mature weight. The dietary ME and protein allowable ADGs are what the diet will sustain. In this example, ME and MP allowable ADGs exceed the input desired ADG but are less than the target ADG. This screen also shows that the RDP supply is greater than the RDP required and that the MP balance is positive. Thus, more protein is being fed than is necessary to support the entered desired ADG. Also, note the entered dry matter intake is similar to the model predicted intake. *(Desired ADG = 800 g/d, Target ADG = 930 g/d, Energy allowable ADG = 890 g/d, Protein allowable ADG = 850 g/d, RDP balance = 132 g/d, MP balance = 14 g/d, Actual DMI = 5.99 kg/d, Predicted DMI = 5.99 kg/d).*

2. Next click on the report icon and choose the summary screen. In the balance screen at the top of the report, the energy and protein supplied exceed the requirements. *(MEreq = 13.3 Mcal, MEsupplied = 14.0 Mcal, MPreq = 486 g/d, MPsupplied = 501 g/d).*

3. Now click on the input icon and on the animal description tab. Change the desired ADG to match the target ADG (930 grams). Now click on reports, summary report, and note that the diet now provides less than is needed to attain the target ADG. *(MEreq = 14.3 Mcal, MEsupplied = 14.0 Mcal, MPreq = 522 g/d, MPsupplied = 501 g/d).*

4. Now click on inputs, animal description tab, and change the desired ADG back to 800 grams. Then change the age to 7 months, click on ration, and note the new target ADG is lower. This is because the animal now has more time to reach the target weight. *(Target ADG = 770 g/d).*

5. Next, click on the animal description tab, change the age back to 8 months, and change the body weight to 300 kg. Now click on the ration icon and note that the target ADG and ME allowable ADG decreased. The target ADG decreased because the animal now needs to gain less weight

TABLE UG-6 Inputs for Heifer Growth Exercises

INPUT ITEM	Open heifer No stress	Cold temperature	Temp. + wet	Temp. + wind	Bred heifer No stress
Age, months	8				20
Body weight, kg	240				550
Days pregnant	0				220
Condition score	3				3
Age @ first calving	22				22
Calving interval	13				13
Desired ADG, gm	800				800
Mature weight, kg	Breed avg				
Breed	Holstein				
Previous temperature, C	20	0	0	0	
Current temperature, C	20	0	0	0	
Wind speed, kph	1.6			16	
Grazing	No				
Coat condition	Clean + dry		Wet + matted	Wet + matted	
Heat stress	No				
Coat depth, cm	1	2	2	2	
Night cooling	Yes				
Ration (kg/day):					
Legume forage silage, mid maturity	2.81				3.84
Corn silage, normal	3.08				8.67
Corn grain, dry	0.0				0.0
Soybean meal solvent, 48% CP	0.09				0.275
Bloodmeal, ring-dried	0.0				0.0
Calcium phosphate (di-)	0.01				0.012
Calcium carbonate	0.0				0.0

to reach the target by the same age. The ME allowable ADG decreased because the animal has a larger body weight to maintain and the energy content of gain is higher as shown in Table UG-2. The predicted DMI increased because intake is a function of body weight and diet energy density. *(Target ADG = 520 g/d, ME allowable gain = 580 g/d, DMIpredicted = 7.08 kg/d).*

6. Click on the animal description tab and change the body weight back to 240 kg. Now change the age at first calving to 24 months, then click on ration. The target ADG is decreased, because the animal has more time to conceive, as shown in Table UG-4. *(Target ADG = 650 g/d).*

7. Click on the animal description tab and change the age at first calving back to 22 months of age. Now click on the animal production tab, click on the choice of using the model mature weight to remove the check, then enter 650 kg. Now click on the ration icon. The target ADG is reduced, because the target weight at breeding was reduced. The target weight at breeding is 55% of mature weight, so reduction in mature weight lowers the weight at breeding (Table UG-3). *(Target ADG = 650 g/d).*

Scenario 2. The effect of environment on growth rate.

The effect of environment on heifer daily gain depends on several factors as follows:

- Previous temperature changes metabolic rate; therefore as previous temperature decreases, the maintenance requirement increases, leaving less energy and protein available for growth.
- The combined effects of current temperature, insulation to prevent heat loss (hair coat condition and depth), and wind (affects heat loss due to convective cooling) are used to determine the animal's lower critical temperature. If the lower critical temperature is below the animal's current temperature, more of the diet energy will be required to maintain body temperature, leaving less for growth. Table UG-7 summarizes these effects on maintenance requirements.

1. Click on the environment tab and change the current temperature to -1.1°, -12°, and -23° C. Now click on ration and note the decrease in daily gain. The predicted intake

TABLE UG-7 Maintenance Energy Requirement Multipliers for Various Environmental Conditions[a,b]

	−1.1°C		−12°C		−23°C	
Hair coat code[c]	1^3	3^3	1^3	3^3	1^3	3^3
Wind velocity (kph)						
1.6	1.17	1.41	1.37	1.90	1.74	2.39
16	1.33	1.70	1.80	2.27	2.26	2.84

[a] Simulations made using the model presented in chapter 11. Temperature values are current temperature (T_c).

[b] Values given are net energy maintenance requirements (NE_M) required for these conditions divided by the maintenance requirement without stress.

[c] Hair coat code: 1 = dry and clean, 2 = mud on lower body (values not shown), and 3 = wet and matted.

should increase. *(ME allowable gain = 890 g/d, 570 g/d, and 170 g/d when the temperature = -1.1°, -12°, and -23° C respectively.)*

2. Click on the environment tab, and change hair coat to wet and matted. Now click on ration and note the change in daily gain. A wet and dirty hair coat results in the loss of insulation because the hair coat is flattened, losing its insulation value. *(When the temperature = -1.1°, the growth was 450 g/d, and there was no growth for the other 2 temperatures.)*

3. Click on the environment tab, and change wind to 16 kph. Now click on ration, and note the change in daily gain. Wind increases energy loss due to convective cooling. *(When the temperature = -1.1°, the ME allowable ADG was 40 g/d. Weight loss occurred at the two lower temperatures.)*

Scenario 3. The effect of pregnancy on heifer requirements.

Once pregnant, the requirements for the growing fetus and fetal membranes (collectively called the conceptus) must be met in addition to those required for maintenance and growth. Because they are relatively small in early pregnancy, requirements for the conceptus are added after 190 days of pregnancy.

1. Enter the information in Table UG-6 for bred heifers. On the ration screen, note that the target ADG is higher when the conceptus is included. The ME and MP allowable ADG exceed the target ADG and desired ADG that was entered (800 grams). *(The ADG with conceptus was 1380 g/d and ADG without conceptus was 750 g/d.)*

2. Click on the report icon, then choose summary report, and view this report to see the pregnancy requirement for ME and MP. Then choose the animal description screen and change days pregnant to 250 days. Now click on the report icon, choose summary report, and view this report. The ME and MP required for pregnancy increased, and the ME and MP balances were reduced. *(The ME required for pregnancy was 4.5 Mcal, and the MP required for pregnancy was 239 g/d. When days pregnant equaled 250 days, the ME required for pregnancy was 5.2 Mcal and the MP required for pregnancy was 299 g/d.)*

3. Next, click on the ration icon to see the increased target ADG required. This is because there are fewer days left to reach the target weight, requiring a higher ADG. *(The target gain with conceptus was 1700 g/d and 1060 g/d without conceptus.)*

4. Click on the animal description screen and change the days pregnant back to 220. Then click on the animal production screen, and increase the birth weight to 50 kg. Now click on the reports icon, choose the summary report, and view this screen. The ME and MP required for pregnancy increased and the ME allowable ADG without and with pregnancy decreased. This occurred because less energy was available for growth because of the increased pregnancy requirement. *(The ME required for pregnancy was 5.3 Mcal and the MP required for pregnancy was 278 g/d. The ME allowable gain without conceptus was 980 g/d and the ME allowable gain with conceptus was 1720 g/d.)*