PCDairy for Windows: Ration Formulation and Analysis Programs for Dairy Cattle

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Abstract

PCDairy for Windows is a package of programs for formulating and analyzing rations for dairy cattle that has been designed to run on IBM PC compatible computers running Windows 95, Windows 98, Windows 2000 and Windows XP. This paper describes some of the programs in the PCDairy package. Examples of data input screens and ration printouts are shown.

Key words: Dairy Cattle, Ration Formulation, Ration Evaluation, Feed Loading / Unloading Schedules.

Introduction

The PCDairy program consists of eight modules (Fig. 1):

1. MAXIMIZE – This module formulates a ration for lactating cows that maximizes income over feed costs based on cow weight, milk yield, fat test, weight change, feed prices and milk price.
2. LC – This module formulates a least cost ration for lactating or dry cows based on cow weight, milk yield, milk fat test, body weight change, stage of lactation and feed prices.
3. GROWING – This module formulates a least cost ration for growing dairy animals based on sex, breed, age, body weight gain and feed prices.
4. EVAL-L – This module estimates the nutrient content of a ration being fed to lactating or dry cows, compares it with PCDairy nutrient standards, and estimates the amount of milk that is possible from the ration as well as showing limiting nutrients.
5. EVAL-G – This module estimates the nutrient content of a ration being fed to growing dairy animals, compares it with PCDairy nutrient standards, and estimates the amount of body weight gain that is possible from the ration as well as showing limiting nutrients.
6. FEEDLIST – This module allows users to set up a customized list of feed ingredients for use in any of the above programs.
7. DELIVERY – This module is a spreadsheet program for loading ration ingredients into a mixer for a specified number of cows, and for unloading the mixed ration to a specified number of cows.
8. FEEDTAG – This module calculates the energy content of feeds based on their chemical analysis.

PCDairy was designed to minimize the amount of typing necessary to enter feeds or evaluate a ration. Popup menus appear with a list of data entry choices. The arrow keys on the computer can then be used to select the entry. Feeds are stored in a standard feed library and can be selected to enter directly into the ration. Input and output can be expressed in either English units (lb) or in metric units (kg).

Ration Formulation: Input Data

Users may select either a least cost or maximum profit basis for ration formulation. Fig. 2 shows the screen used to input data for formulating a ration for a 1400 lb dairy cow using the LC program.
LC and GROWING module users may select the type of protein (i.e., crude protein, undegradable protein, degradable protein) to use as a minimum constraint when the ration is formulated, or all three. Similarly, users of the LC, MAXIMIZE and GROWING modules may select the fiber formulation basis (i.e., effective crude fiber, acid detergent fiber, neutral detergent fiber) or any combination. In addition, GROWING module users may select the energy system to use for ration formulation (i.e., net energy system (NEM and NEG) or the total digestible nutrients (TDN) system).

PCDairy then calculates the nutrient requirements for the ration, based upon inputted cow information. The program allows users to override any of the default nutrient requirements prior to ration formulation.

After entering cow information, users select the feed ingredients that are available in the standard (STD) feed library and their prices ($ per ton, $ per cwt, or $ per kg). Ingredients not included in the standard library may be entered into the program, with users providing required nutrient data. Users may specify a minimum constraint on a feed by entering a constraint amount and then selecting the proper constraint type from the following list of choices that appear in a pop-up window:

- LB_AF  lbs (kgs) as fed
- LB_DM  lbs (kgs) of dry matter
- %CON_DM  percent of concentrate portion of ration on a 100% DM basis
- %RGH_DM  percent of roughage portion of ration on a 100% DM basis
- %TOT_DM  percent of total ration on a 100% DM basis
- %CON_AF  percent of concentrate portion of ration on an "as fed" basis
- %RGH_AF  percent of roughage portion of ration on an "as fed" basis
- %TOT_AF  percent of total ration on an "as fed" basis

In addition, users may specify a maximum constraint on a feed in the same manner. The concentrate ingredients provided by the standard feed library have default maximum values assigned to them that can be changed as described above. Fig. 3 shows feeds available for a sample ration using the LC program.

Users may customize ration formulation by placing minimum and maximum constraints on groups of feeds, such as wheat products. Individual feed, feed group and nutrient ratio constraints may also be specified.

**The Formulation Process: Using Infeasible Feeds**

During the ration formulation process, PCDairy automatically appends a set of "infeasible feeds" to the feed list. These are "fake" feeds, which PCDairy will use to avoid an infeasible solution when it cannot fulfill the nutrient requirements with the available feed ingredients. The names of the infeasible feeds are descriptive of the nutrient deficiency or excess in the ration. Infeasible feeds will enter the ration only if there is no other way to fulfill the nutrient requirements within existing constraints. When infeasible feeds appear in the formulated ration, users should either modify the existing constraints or add ingredients that can be used to satisfy the nutrient deficiency.

**Ration Formulation: Printout**

The information included in the ration printout is: 1) Ration composition, 2) Price ranges for feeds used in the ration, 3) Opportunity prices for feeds not used in the ration, 4) Nutrient analysis of the ration, and 5) Nutrient composition of all available feeds. Fig. 4 shows the composition of the least cost ration.
formulated using data from Figs. 1 and 2. Price ranges for feeds used and opportunity prices for feeds not selected are in Fig. 5.

Fig. 6 shows a portion of the estimated nutrient analysis of the least cost ration. Minimum and maximum nutrient constraints that were in effect at the time of formulation are listed, as well as minimum and maximum suggested constraints.

The Delivery Module

The DELIVERY program calculates feed loading and unloading schedules (up to 12) for any number of animals. DELIVERY produces a loading schedule that lists the order in which feeds are to be added, the amount of each, and the scale reading after each feed is added to the mixture. If a feed is to be fed separately from the mixture, an amount per feeding will be listed. The unloading schedule lists the amount of the mixture that is to be fed per feeding for the number of animals specified. Fig. 7 shows the loading schedule for the ration formulated using the LC program.

Applied Research Consideration

In developing PCDairy, challenges to create a database management system, a linear program and a feed energy estimation calculation were overcome.

Database Management System

Feed libraries can have up to 1000 records and therefore the best way to handle them is to use a database management system. We decided to conduct applied research and develop a database engine. Among various options, we decided to implement the file structure of dBASE, and to store the feed libraries in dBASE III file format. dBASE is one of the oldest database management systems developed for personal computers (Simpson, 1987). This feature allows PCDairy feed libraries to be accessed by other database management programs, such as Microsoft Access, to perform custom tasks not supported by the current version of PCDairy.

A set of generic functions and procedures to manipulate dBASE data files was developed using the Visual C++ programming language. The dBASE engine can be re-used in other software projects, such as ‘Taurus’, a ration formulation program for beef cattle supported by our research group.

Linear Programming

The heart of the PCDairy program is a linear programming engine. It is used to solve least cost ration formulation problems. We decided to conduct applied research and develop a linear programming engine. Among various options, we decided to implement the “Primal-Dual” algorithm, described by Wolfe (1985). A set of generic functions and procedures to perform matrix operation was developed using the Visual C++ programming language. The Linear Programming engine can be re-used in other software projects.

Energy Estimation of Feeds

Estimating the energy values of feeds often requires expensive and extensive chemical analyses of feeds. Many dairy producers, especially in developing countries, are interested in calculating energy values from the chemical analysis of the feeds provided by the manufacturer, often printed on the feed’s tag. We completed statistical regression analysis using feeds with known energy values to meet this need.

We further divided feeds into seven groups. For each group, we determined a regression equation between DE (Digestable Energy, Mcal/kg) and the four independent variables (i.e., CP (Crude Protein), EE (Ether Extract), CF (Crude Fiber) and Ash) that are commonly listed on feed tags (Fig.8).
The algorithm for estimating energy values of feeds first converts all values to a 100% DM basis and then calculates Digestible Energy in Mcal/kg for different groups using the equations:

1. Group A: \[ DE = 3.916828 - 0.00812 \times CP + 0.04554 \times EE - 0.0176 \times ash - 0.0422 \times CF \]
2. Group B: \[ DE = 2.811904 + 0.0209413 \times CP + 0.006492 \times EE + 0.01302 \times ash - 0.0274 \times CF \]
3. Group C: \[ DE = 3.264743 + 0.06363 \times CP - 0.0761 \times EE - 0.0508 \times ash - 0.0283 \times CF \]
4. Group D: \[ DE = 3.723255 + 0.002459 \times CP + 0.0815818 \times EE - 0.0211 \times ash - 0.036135 \times CF \]
5. Group E: \[ DE = 3.681242 - 0.0130 \times CP + 0.04553 \times EE - 0.0328 \times ash - 0.0284 \times CF \]
6. Group F: \[ DE = 3.729697 + 0.008047 \times CP + 0.04582 \times EE - 0.0393 \times ash - 0.0392 \times CF \]
7. Group G: \[ DE = 4.706482 - 0.0158 \times CP + 0.034633 \times EE - 0.0241 \times ash - 0.0598 \times CF \]

It then calculates all other energy values using DE as:

1. Metabolizable Energy, Mcal/kg:
   \[ ME = 0.82 \times DE \]

2. Net Energy for Maintenance, Mcal/kg:
   \[ NEM = 1.37 \times ME - 0.138 \times ME \times ME + 0.0105 \times ME \times ME \times ME - 1.12 \]

3. Net Energy for Gain, Mcal/kg:
   \[ NEG = 1.42 \times ME - 0.147 \times ME \times ME + 0.0122 \times ME \times ME \times ME - 1.65 \]

4. Total Digestible Nutrients, %:
   \[ TDN = 100 \times (DE/4.4) \]

5. Net Energy for Lactation, Mcal/kg:
   \[ NEL = 0.0245 \times TDN - 0.12 \]

Finally it converts calculated values to the English system and/or to an 'As Fed' basis if necessary.

Conclusions

The PCDairy program can formulate rations for lactating cows that maximize income over feed costs and/or formulate least cost rations for lactating cows, growing heifers or dry cows. In addition, the PCDairy program can evaluate an existing ration for nutrient limitations or oversupply, and indicates the amount of milk or growth that is possible with the such user defined rations. The PCDairy program includes a module for loading ration ingredients into a mixer for a specified number of cows, and for unloading the mixed ration to a specified number of cows. The program also allows users to create a customized list of feed ingredients for use in any of the modules, and allows estimation of the energy content of feeds based on defined chemical analysis.

The PCDairy ration formulation and evaluation program has wide potential application in the dairy feeding industries worldwide, and its Windows based format makes it compatible with current computer operating systems.

References


Figures

**Fig. 1** Main menu of PcDairy for Windows

**Fig. 2** Animal Information dialog box: LC program
Fig. 3: Feed List dialog box: LC program

Fig. 4: Ration Composition: LC program
Fig. 5 Price Range: LC program

Fig. 6 Nutrient Analysis of Entire Ration: LC program
Fig. 7 Loading Schedule: DELIVERY program

Fig. 8 The Feed Tag dialog box