**CAPRICORN: A Windows Program for Formulating and Evaluating Rations for Goats**

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**Abstract**

CAPRICORN is a package of least cost computer formulation programs to create rations for growing, meat and lactating goats. The programs were developed from animal nutrient requirements and feed nutrient analyses in the US National Research Council book entitled ‘Nutrient Requirements Of Small Ruminants: Sheep, Goats, Cervids, And New World Camelids (2006)’. CAPRICORN is designed to run under Windows 95, 98, 2000, XP and Vista operating systems. This paper describes some of the programs in the CAPRICORN package, and provides examples of data entry screens and ration printout screens.

**Key words:** Decision Support Tools, Farm Management Systems Ration Formulation.

**Introduction**

The Capricorn program consists of seven modules:

1. **LC** – This module formulates a least cost ration for lactating or dry goats based on weight, milk yield, milk fat test, body weight change, stage of lactation and feed prices.

2. **GROWING** – This module formulates a least cost ration for growing and meat goats based on sex, breed, age, body weight gain and feed prices.

3. **EVAL-L** – This module estimates the nutrient content of a ration being fed to lactating or dry goats, compares it with Capricorn nutrient standards, and estimates the amount of milk that is possible from the ration as well as showing limiting nutrients.

4. **EVAL-G** – This module estimates the nutrient content of a ration being fed to growing goats, compares it with Capricorn nutrient standards, and estimates the amount of body weight gain that is possible from the ration as well as showing limiting nutrients.

5. **FEEDLIST** – This module allows users to set up a customized list of feed ingredients for use in any of the above programs.

6. **DELIVERY** – This module is a spreadsheet program for loading ration ingredients into a mixer for a specified number of goats, and for unloading the mixed ration to a specified number of goats.

7. **FEEDTAG** – This module calculates the energy content of feeds based on their chemical analysis.
Capricorn is 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 start by selecting a least cost basis for ration formulation. Capricorn then calculates the nutrient requirements of the ration, based upon inputted information on the goats. The program allows users to override any of the default nutrient requirements prior to ration formulation.

After entering goat 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, lb (kg) as fed
- LB_DM, lb (kg) 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.

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, Capricorn automatically appends a set of "infeasible feeds" to the feed list. These are "fake" feeds, which Capricorn 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. Price ranges for feeds used and opportunity prices for feeds not selected for inclusion in the ration are also included.

In the estimated nutrient analysis of the least cost ration, the 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 module calculates feed loading and unloading schedules (up to 12) for any number of goats. It 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 goats specified.

**Applied Research Consideration**

In developing Capricorn, challenges to create a database management system, a linear program and a feed entry 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 Capricorn 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 Capricorn.

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 UC Davis research group.

**Linear Programming**

The heart of the Capricorn 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.
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 and, 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. 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:

- **Group A**: \( DE = 3.916828 - 0.00812 \times CP + 0.04554 \times EE - 0.0176 \times ash - 0.0422 \times CF \)
- **Group B**: \( DE = 2.811904 + 0.0209413 \times CP + 0.006492 \times EE + 0.01302 \times ash - 0.0274 \times CF \)
- **Group C**: \( DE = 3.264743 + 0.06363 \times CP - 0.0761 \times EE - 0.0508 \times ash - 0.0283 \times CF \)
- **Group D**: \( DE = 3.723255 + 0.002459 \times CP + 0.0815818 \times EE - 0.0211 \times ash - 0.036135 \times CF \)
- **Group E**: \( DE = 3.681242 - 0.0130 \times CP + 0.04553 \times EE - 0.0328 \times ash - 0.0284 \times CF \)
- **Group F**: \( DE = 3.729697 + 0.008047 \times CP + 0.04582 \times EE - 0.0393 \times ash - 0.0392 \times CF \)
- **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:

- **Metabolizable Energy, Mcal/kg**: \( ME = 0.82 \times DE \)
- **Net Energy for Maintenance, Mcal/kg**: \( NEM = 1.37 \times ME - 0.138 \times ME \times ME + 0.0105 \times ME \times ME \times ME - 1.12 \)
- **Net Energy for Gain, Mcal/kg**: \( NEG = 1.42 \times ME - 0.147 \times ME \times ME + 0.0122 \times ME \times ME \times ME - 1.65 \)
- **Total Digestible Nutrients, %**: \( TDN = 100 \times (DE/4.4) \)
- **Net Energy for Lactation, Mcal/kg**: \( NEL = 0.0245 \times TDN - 0.12 \)

Finally, Capricorn converts calculated values to the English system and/or ton 'As Fed' basis if necessary.

**Conclusions**

In addition, the Capricorn program can evaluate an existing ration for nutrient limitations or oversupply, and indicates the amount of milk or growth that is possible with the user defined rations. The Capricorn program includes a module for loading ration ingredients into a mixer for a specified number of goats, and for unloading the mixed ration to a specified number of goats. 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 Capricorn ration formulation and evaluation program has wide potential application in the goat feeding industries worldwide, and its Windows based format makes it compatible with current computer operating systems.

References