Version 3

CPM-Dairy

Cornell*Penn*Miner

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Contents

Overview

Introduction

Dairy cattle rations are evaluated and formulated by computer driven models. Nutrition models vary in complexity according to objectives (2). Models only need details that have significant bearing on consequences of changes arising from inputs to the system (Production Model) or as much detail as is necessary to explore the system in new and different ways (Scientific Model).

A theme for the development, refinement and deployment of production models is seen in the development and implementation of NRC (7,9,10) dairy cow models. NRC (7) was based on response equations used to predict crude protein and energy needs of the dairy cow. NRC (9) used a system of protein utilization (8) that partitioned dietary protein into rumen degradable (DIP) and rumen undegradable (UIP) fractions. Growth of microorganisms in the rumen was driven by energy intake (TDN, NEL). In 2001, NRC (10) released a new dairy cow model that contains some of the mechanistic approaches in the Cornell Net Carbohydrate Protein System (CNCPS/CPM-Dairy) that are described below.

Ration formulation tools were not provided by NRC (7,9,10). Rations were formulated by specifying details of the animal and rations were created by manual selection of ingredients to provide required nutrients. To reduce the hunting and pecking burden imposed to meet the nutrient needs of animals and incorporate cost containment in ration formulation, linear optimization was integrated into the formulation environment. At the University of Pennsylvania (5,6), NRC (7,9) was programmed into Lotus 1-2-3 with auto-balancing provided by Einfin. Spartan (16) represented an excellent effort in software development by the group at Michigan State University that was based on NRC (9) and included auto-balancing.

The need for more accurate models to define rumen bacterial and whole animal requirements, to assess feed utilization and to predict production responses lead to the development of the CNCPS (3,12,13,14,15). CNCPS contains sub-models to describe inputs (animal, environment and ration) and calculate digestion (rumen and intestine), nutrient (energy, protein and essential amino acid) metabolism and requirements, and ration evaluation. When the CNCPS was evaluated with data from individual dairy cows where the appropriate inputs were measured and changes in energy reserves were accounted for, 90% of the variation in actual milk production of individual cows was explained with a 1.3% bias. The model accounted for 76% of the variation in individual cow milk production with an 8% underprediction bias when energy was first limiting and 84% of the variation with a 1.1% overprediction bias when protein was first limiting (4).

CPM-Dairy version 1.0 was programmed in Microsoft C. Rations were evaluated and formulated according to a modified NRC model (MNRC) and to an up-dated version 3 of the CNCPS (1). Release of version 1.0 was in October 1998

CPM-Dairy version 3 is programmed in Microsoft Visual Basic and Microsoft C++. Rations are evaluated and formulated according to version 5 of the CNCPS that was updated to include expanded carbohydrate fractions and a lipid sub-model.

Table 1. Composition and digestion of carbohydrate fractions in CPM-Dairy

CNCPS v5			Digestion	
CPM-Dairy v1	CPM-Dairy v3	Composition	Rumen (%/h)	Intestine (%)[1]
A	A_1	Silage Acids	1-2	100
A	A_2	Sugars	100-300	100
B_1	B_1	Starch	10-40	75
B_1	B_2	Soluble Available Fiber Pectins B Glucans	40-60	75
B_2	B_3	Insoluble Available Fiber Cellulose Hemicellulose	2-15	20
C	C	Unavailable Fiber Lignin Fiber associated with lignin	0	0

1. Digestibility of the rumen escape fraction

Carbohydrate fractions are in Table 1. In the CNCPS version 5 and CPM-Dairy version 1, fraction A was defined as sugar but also contained silage acids. During silage fermentation, some of the soluble non-cell wall components are metabolized primarily to lactic and acetic acids. These silage acids are useful to the animal as a component of metabolizable energy but are depleted fermentable sources of ATP for microbial growth (17). Thus, ensiling has little effect on feed energy values but can affect protein nutrition substantially by decreasing bacterial protein production. In CPM-Dairy version 3, silage acids (A_1) and sugars (A_2) have been separated. In the CNCPS version 5 and CPM-Dairy version 1, fraction B_1 contained starch, pectins and *B* glucans. Grouping these carbohydrates together is not correct because they may have different rates of fermentation in the rumen (17). In CPM-Dairy version 3, starch (B_1) has been separated from pectins and *B* glucans (B_2). Insoluble available fiber, fraction B_2 in the CNCPS version 5 and CPM-Dairy version 1, is fraction B_3 in CPM-Dairy version 3. The composition of fraction C has not changed.

CPM-Dairy version 3 contains a lipid sub-model (11) to describe ruminal metabolism and digestion of LCFA. The fat model focuses on the major LCFA (C12:0, C14:0, C16:0, C16:1, C18:0, C18:1cis, C18:1trans, C18:2, C18:3). Major issues of the fat sub modelinclude: (a). intake of fatty acids, (b). ruminal lipolysis of dietary fats, (c) biohydrogenation of fatty acids in the rumen, (d) de novo production of fatty acids in the rumen. (e) effects of fat on rumen digestion and fermentation and (f) intestinal digestion of fatty acids.

References

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10. NRC. 2001. Nutrient Requirements of Dairy Cattle. Nat Res. Council, Wash., D.C.
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13. Russell, J.B., J.D. O'Connor, D.G. Fox, P.J. Van Soest and C.J. Sniffen. 1992. J. Anim. Sci.70:3551.
14. Sniffen, C.J., J.D. O'Connor, P.J. Van Soest, D.G. Fox and J.B. Russell. 1992. J. Anim. Sci. 70:3562.
15. Tylutki, T.P., D.G. Fox and R.G. Anrique. 1994. J. Anim. Sci 72:1806.
16. VandeHar, M., H. Bucholtz, R. Beverly, R. Emery, M. Allen, C. Sniffen and R. Black. 1992. Spartan Dairy Ration Evaluator/Balancer. Michigan State Univ., East Lansing.
17. Van Soest, P.J (1994) Nutritional Ecology of the Ruminant. Cornell University Press, Ithaca.

Getting Started

Introduction

If CPM-Dairy obscures the Windows Start Button and Task Bar at the bottom of the screen, click the window icon in the upper right-hand corner with the left mouse button.

CPM-Dairy is operated using the Main Menu or Toolbar icons.

To start, click File/New or File/Open with the left mouse button. This allows you to create a new Session, Feed Bank or Mix or to retrieve a previous Session, Feed Bank or Mix.

A session includes all steps involved in formulating a diet. The following sequence is suggested to create a session.

1. Set Preferences.
2. Define Farm, Animal, Environment, Feed and Ration.
3. Enter Feed Ingredient prices.
4. New rations can be formulated by manual entry of Feed Ingredient Amounts or by using the Optimizer.
5. Previous rations can be modified by manual entry of Feed Ingredient Amounts or by using the Optimizer.
6. Nutrient specifications of rations can be viewed in many of the Reports.
7. Rations can be evaluated using CNCPS Ration Guidelines.

Helpful Hint

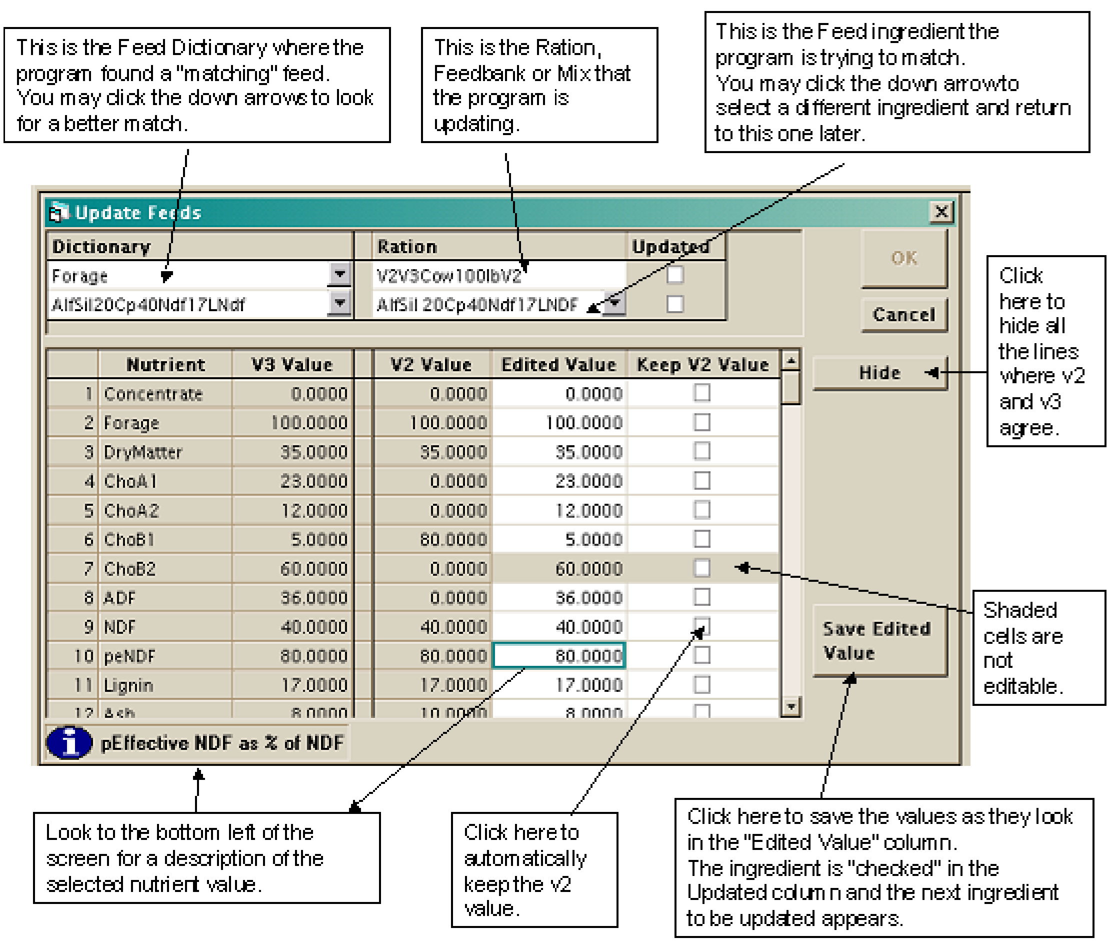
Before beginning a new session, it may be advisable to create a Feedbank for the dairy or region. Feed Ingredients from the Feed Dictionaries can be brought into the Feedbank and edited to reflect local composition. Vitamin and mineral premixes and proprietary feed ingredients can be included.

Upgrading From Previous Versions

When you try to open a session, feedbank or mix file created in a previous version of CPM-Dairy, you will see a message advising you that the feed ingredients need to be updated for the Fat Model. You may click "Cancel" and create the file by starting from scratch in version 3, or you may click "OK" to start the Upgrade Wizard.

The Upgrade Wizard will read your session, feedbank or mix file and look for any mixes that it contains. There may be mixes within mixes. The Upgrade Wizard will then show you the Update Feeds screen (see the illustration below). The Upgrade Wizard will convert the internal mixes first, then the feedbank or mix that contains them , and finally the ration. At the end of each file conversion, you will see a message telling you that all the feed ingredients in that file were updated. You may still go back and edit some more. When you are satisfied with the values, click the OK button in the upper right of the screen. This will take you to the regular CPM-Dairy program screen.

Your session, feedbank or mix file has now been updated for version 3, but it has not been saved as a version 3 file. You should save the file as you would normally do, but you may want to give it a name or a location that tells you it is now a version 3 file. **Version 3 files cannot be used in version 2.**

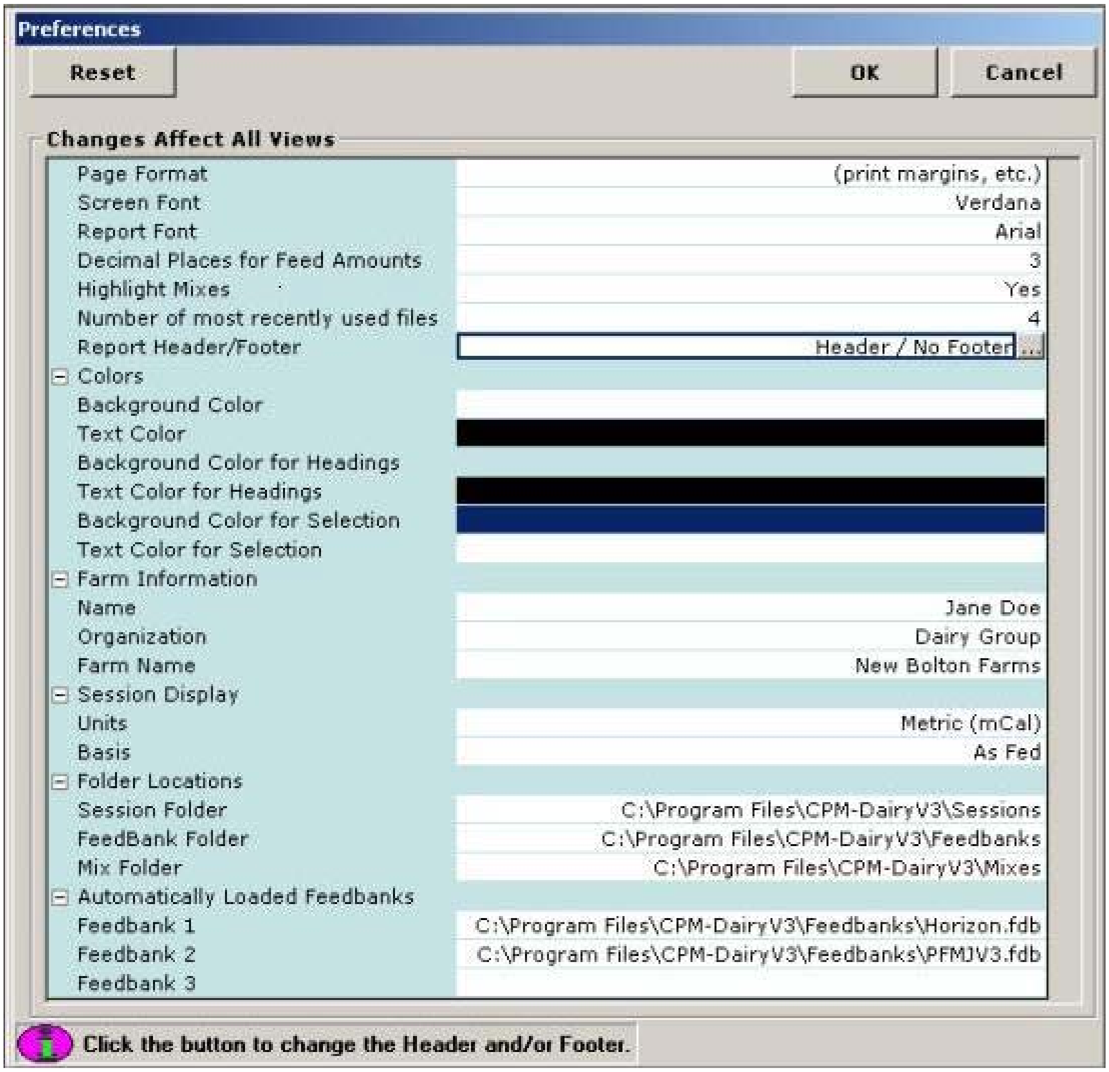


Setting Your Preferences

One of the menu options when you open the CPM-Dairy program is "Preferences."

You may change your Preferences at any time. Your Preferences are stored in your PC's registry, so they are particular to that machine.

Below is an explanation of the items on the Preferences screen.



Page Format

Select this to change printer information for the CPM-Dairy program. You may also temporarily change printer information from the Print screen.

Screen Font and Report Font

Select these to set the fonts you prefer for screens and printed output. If you are likely to create files to send to others or if you create PDF files, you should have a Report Font that is common to Windows users. Examples of common fonts are Arial and Times New Roman.

Decimal Places for Feed Amounts

Most screens will display numbers with the number of decimals you indicate here. However, there are some screens where the number of decimals is not changeable.

Highlight Mixes

Select “Yes” to have any mixes in your ration or feedbanks or mixes highlighted so you can easily distinguish them from non-mix ingredients.

Select “No” to have all ingredients look the same.

Number of Most Recently Used Files

This is the number of previously opened session files showing when you click on the File menu item.

Report Header/Footer

Select this item to set up a Header and/or a Footer that you want to appear on all your print output.

Colors

Select the Colors you prefer for your screen viewing. Make sure you have enough contrast between background and foreground (text).

Farm Information

Type in the grid your Name, your Organization and the Farm Name you want to appear on the Farm Screen whenever you create a new session. Any or all of these fields may be blank.

Session Display (Units and Basis)

Select the Units (Imperial or Metric) and Basis (As Fed or Dry Matter) that you want to use when you create a new session.

Folder Locations

Select the folders where you want CPM-Dairy to look first when you select File, Open …

Automatically Loaded Feedbanks

Select up to three Feedbanks that you want to be loaded automatically when you open the CPM-Dairy program. These feedbanks will load before the session and their ingredient values will be the ones the program will compare against any session or feedbank or mix files you open subsequently.

You will have the option to tell the program not to open them during the startup process.

Feed Dictionaries

Introduction

Feed Dictionaries provide guidelines of the feed analyses to be used for the development of rations. CPM-Dairy does not contain an exhaustive compilation of the total world assay of all feed Ingredients. Rather it provides a robust beginning for a number of feeds used in the Americas. There are a number of feeds where the analysis changes as a function of maturity and of processing. In many cases there may be only one observation within a set of ingredients. In these cases an array or surface was developed for the change that occurred within the array. Some of these estimates may be incorrect. However, the changes suggested provide the user an idea how the change might occur with changes in processing or maturity.

THE VALUES IN THE FEED DICTIONARIES IN NO WAY REPLACE GOOD FEED ANALYSIS. CPM-Dairy WAS DEVELOPED ON THE PREMISE THAT FEEDS WILL BE ANALYZED.

The user will not obtain satisfactory results with CPM-Dairy without feed analysis. It is recommended that users analyze feed ingredients, especially forages, commonly used in their region and create their own Feed Bank. This will provide a more accurate representation of the feed ingredients in the user's region. CPM-Dairy will respond in a more sensitive and accurate manner with correct composition of feed ingredients.

Some feed ingredients (i.e. corn meal) have a low variance in analysis and may not require frequent analysis. Others (i.e. forages, distillers grains) are quite variable in composition and require frequent analysis. For some components (i.e. lignin, soluble protein, NPN, amino acids), there is less variance if expressed as a percentage of another component (i.e. NDF, crude protein, soluble protein, undegraded protein) than if expressed as a percentage of dry matter. Additionally, feed fractions like lignin, NPN and amino acids may not analyzed and use of the feed dictionary values are facilitated when they are expressed on the basis of a fraction usually analyzed or calculated.

Ingredient Composition

Ingredient analyses contained in the Feed Dictionaries in version 1 were from published sources (1-14) and were also derived by extrapolation to increase the array of ingredients. Composition of the ingredients in the Commercial Dictionary was provided by the manufacturers.

The version 1 feed dictionaries have been updated and edited for version 3. Included are expanded carbohydrate fractions (silage acids, sugar, starch and soluble fiber), fatty acid composition and NRC 2002 minerals with their bioavabilities.

Edits were based on data from over 10,000 feed ingredients. Degradation rates of available NDF (carbohydrate fraction B3) were estimated from 30 hr in vitro NDF digestion. In general, degradation rates of available NDF for corn silage are lower and those for alfalfa are higher than in version 1. Fatty acid analyses conducted by Dr. Tom Jenkins were combined with published fatty acid values.

The commercial dictionary contains ingredients that were not in version 1 and some ingredients in version 1 were deleted because of incomplete data. We are in the process of verifying the nutrient profiles of the commercial ingredients with the manufacturers.

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The Custom Feedbank

Custom Feedbanks are those that you create in the program. Unlike the feedbanks that come with CPM-Dairy, custom feedbanks may be edited, saved and shared with others.

Create a Custom Feedbank

1. Click on File, then New, then Feedbank.
2. Enter a name for your feedbank, preferably one that will describe the contents to you. Then click OK.
3. Your new feedbank is ready for editing. It should appear on the left of your CPM-Dairy screen, overlaying the Ration.
4. To add feeds to your feedbank:
   a. Click the Feed Dictionaries icon to open the Feed Library
   b. If the new Feedbank screen is no longer visible, then click the down arrow under the Feed Dictionaries title. You should see all the Feedbanks with your new Feedbank listed last. Click on the new Feedbank.
   c. Click the Add/Delete Feeds button next to the down arrow. Now the new Feedbank should appear over the Ration screen on the left.
   d. Click the down arrow again to select the Feed Library from which you want to copy feeds.
   e. Copy feeds into your new Feedbank by dragging them from right to left, or by clicking Copy on the right then Paste on the left.
   f. You can copy many feeds into your Feedbank by repeating steps d and e.
   g. At any time you may change the feed name in your new Feedbank. You may also change the feed price or any other value. Edit the new Feedbank in the same way you edit a Ration. The only difference between the new Feedbank and a Ration is that the Feedbank does not have an amount for each feed as a Ration does.
   h. Please, please, please save the new Feedbank. The main purpose in creating the new Feedbank is to use it in future CPM-Dairy sessions. If you don't save it, it will disappear when the session it was created in is closed.

Save a Custom Feedbank

1. Click on File, then Save As, then Feedbank, then the new Feedbank name.
2. A screen appears titles "Save the feedbank." Select the location (folder) where you want the feedbank to reside. Remember where you put it as you will need to find it again in future sessions.

3. Click Save. The feedbank is now saved as its own file. It is still available in the current session until you remove it or close the session. Remember to save it again if you edit it after the original save.
4. The custom feedbank file is basically a text file, but only the CPM-Dairy program will be able to read it and make sense of it. You may share it with other users of CPM-Dairy just as you can share session files and mix files.

Open a Custom Feedbank

1. Click on File, then Open, then Feedbank.
2. A screen appears titled “Open the feedbank.” Select the location (folder) where the feedbank you want to open resides.
3. Click on the feedbank name and then click the Open button.
4. Your new feedbank is ready for editing. It should appear on the left of your CPM-Dairy screen, overlaying the Ration.
5. If you don’t want to edit it, you can close the screen on the left by clicking on the “X” button next to the feedbank name.

Remove a Custom Feedbank

1. Click on File, then Remove, then Feedbank…
2. A screen appears titled “Select to Remove - Feedbanks.” It lists all custom feedbanks currently opened in the program.
3. Click on the box next to the feedbank name to check or uncheck it. If any are checked then click the Remove button.

Feed Fractions

Dry Matter (DM)

Dry matter (DM) is the residue after moisture is removed by heating at 60 C or less (2). Drying at higher temperatures can produce Maillard products (Condensation of sugar residues with amino acids) that can lead to errors in carbohydrate analyses and available protein calculations. For example, drying at temperatures above 60 C reduced hemicellulose content and increased acid detergent fiber (1). Drying fermented products drives off volatile organic acids so that dry matter is underestimated. The simplest and most routine method for dry matter in fermented products is direct water measurement in toluene distillation (2). For correct analysis of fermented products, determinations should be done on the wet material (2).

Dry matter is expressed as a percentage of the feed ingredient.

References

1. Goering, H.K., P.J. Van Soest and R.W. Hemken. 1973. J. Dairy Sci. 56:137.
2. Van Soest, P.J. 1994. Nutritional Ecology of the Ruminant. Cornell University Press, Ithaca.

Crude Protein (CP)

Crude protein (CP) is 6.25 * Kjeldahl Nitrogen. The 6.25 factor is based on the assumption that proteins contain 16% N [(1/16)*100 = 6.25]. However, proteins vary in nitrogen content and all nitrogen is not protein (1).

Crude protein is expressed as a percentage of dry matter.

Reference

1. Van Soest, P.J. 1994. Nutritional Ecology of the Ruminant. Cornell University Press, Ithaca.

Soluble Protein (SP)

Soluble protein (SP) is defined as protein soluble after one hour in borate-phosphate buffer at 39 C. It contains non-protein nitrogen, amino acids and peptides (1). Soluble protein is degraded instantaneously in the rumen.

Soluble protein is expressed as a percentage of crude protein.

Reference

1. Van Soest, P.J. 1994. Nutritional Ecology of the Ruminant. Cornell University Press, Ithaca.

NPN

True protein is precipitated from borate-phosphate soluble protein (soluble protein) with tungstic acid to obtain Protein Fractions A (NPN) and B1 (true protein). Tungstic acid precipitates peptides with 2 to 3 amino acids (4).

NPN is expressed as a percentage of soluble protein.

References

1. Chalupa, W. , R. Boston, C. J. Sniffen and D. G. Fox. 1996. Practical applications with ration modeling. Proc. Bioproducts (Fairlawn OH) and Novus (St. Louis MO) International Technical Dairy Symposium. Preceding The Southwest Nutrition and Management Conf. Phoenix, AZ.
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Neutral Detergent Fiber Insoluble Protein (NDIP)

NDF not only contains lignin, cellulose and hemicellulose but NDF also contains protein, bound nitrogen, minerals and cuticle (4). In CNCPS (1,2,3), NDIP contains Protein Fractions B3 (slowly degraded) and C (not fermented or digested). ADIP contains Protein Fraction C, so B3 is estimated as the difference between NDIP and ADIP.

Protein insoluble in neutral detergent that is in the B3 Fraction has disulfide links. Adding sodium sulfite to neutral detergent will solublize part of this protein so that Protein Fraction B3 will be underestimated. For CNCPS, NDF should be analyzed without sodium sulfite in the neutral detergent.

NDIP is expressed as a percentage of crude protein.

References

1. Chalupa, W. , R. Boston, C. J. Sniffen and D. G. Fox. 1996. Practical applications with ration modeling. Proc. Bioproducts (Fairlawn OH) and Novus (St. Louis MO) International Technical Dairy Symposium. Preceding The Southwest Nutrition and Management Conf. Phoenix, AZ.
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4. Van Soest, P.J. 1994. Nutritional Ecology of the Ruminant. Cornell University Press, Ithaca.

Acid Detergent Fiber Insoluble Protein (ADIP)

Acid detergent fiber insoluble protein consists of heat damaged protein and nitrogen associated with lignin (1). This is Protein Fraction C which resists ruminal fermentation and is indigestible in the small intestine (2).

ADIP is expressed as a percentage of crude protein.

Reference

1. Van Soest, P.J. 1994. Nutritional Ecology of the Ruminant. Cornell University Press, Ithaca.

Neutral Detergent Fiber (NDF)

NDF is the insoluble residue after boiling in neutral detergent. Major components are lignin, cellulose and hemicellulose but NDF also contains protein, bound nitrogen, minerals and cuticle (1).

NDF contains carbohydrate fractions B3 (available fiber) and C (unavailable fiber; Lignin x 2.4)

NDF is expressed as a percentage of Dry Matter.

Many laboratories are now using neutral detergent with sodium sulfite. This eliminates some of the neutral detergent insoluble protein. However, this will give lower pool sizes of Protein Fraction B3. NDF for CNCPS should be without sodium sulfite in the neutral detergent.

Reference

1. Van Soest, P.J. 1994. Nutritional Ecology of the Ruminant. Cornell University Press, Ithaca.

Physically Effective NDF (peNDF)

peNDF is the application of physical particle size assessment (effectiveness of NDF) to NDF. The basic peNDF is the percent of NDF remaining on a 1.18 mm screen after dry sieving (1,2,3,4,5). This value was then adjusted for density, hydration and degree of lignfication of the NDF within classes of feeds (2,3). For all silage's except corn silage start with the coarse peNDF from Mertens (3). For grass silage, multipliers for medium and fine chop are .95 and .90, respectively. For alfalfa silage, multipliers for medium and fine chop are .90 and .82, respectively.

Theoretical length of chop (TLC) is the first but not the only determinant of corn silage particle length. TLC => than 3/4 inch usually gives coarse particle size. TLC < 3/4 inch but > 1/4 inch normally results in medium particle size corn silage. Fine particle size corn silage is obtained when TLC =< 1/4 inch. Kernel processing further reduces particle size. Corn silage particle length may be related to the Particle Size Analyzer developed at Pennsylvania State University. As a first approximation, coarse = < 20 %, medium = > 20 but < 50, and Fine = > 50 % on the bottom pan by weight.

The finer the chop the lower the effective fiber, the higher the rate of passage and the higher the rate of digestion of the fiber and starch. Kernel processing usually results in a smaller particle size of the kernel and cob.

Particle size of dry feeds is as follows: Very coarse would be equivalent to dry rolled corn. Very coarse = > 75 % being retained on a 1.59 mm (1/16") screen; Coarse = >50 but < 75 % retained on a 1.59 mm screen; Medium = >20 % but < 50 % retained on a 1.59 mm screen; Fine = < 20 % retained on a 1.59 mm screen (6).

The minimum peNDF requirement (2) should be 22 to 23 %DM. The minimum could be 20 %DM if fermentable starch is less than 20% DM. The maximum peNDF (2) is a function of body weight, age and week of lactation. Generally, peNDF maximum intake is 1.05% BW.

peNDF is expressed as a percentage of NDF

References

1. Mertens, D.R. 1985. Proc. 46th Minnesota Nutrit. Conf. St. Paul MN.
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Lignin

Lignin is the residue after treating acid detergent fiber with 72% sulfuric acid (4). In CPM-Dairy, unavailable fiber (Carbohydrate Fraction C) is lignin x 2.4 (1,2,4). It represents the material that is not fermented after 200 hr (4). Lignin does not simply impede digestion by encrusting or covering nutrients. Instead, lignin protects associated carbohydrate from digestion. The mechanism is not entirely understood (3).

Because Fraction C (unavailable Fiber) is defined as lignin x 2.4, the proportion of lignin in NDF has a great impact on ruminal fermentation of feed fiber.

Lignin is expressed as a percentage of neutral detergent fiber.

References

1. Chalupa, W. , R. Boston, C. J. Sniffen and D. G. Fox. 1996. Practical applications with ration modeling. Proc. Bioproducts (Fairlawn OH) and Novus (St. Louis MO) International Technical Dairy Symposium. Preceding The Southwest Nutrition and Management Conf. Phoenix, AZ.
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Ash

Ash is the inorganic residue remaining after combustion of organic matter.

Ash is expressed as a percentage of dry matter.

Non Fiber Carbohydrates (NFC)

NFC = 100 - (CP + Fat + Ash + NDF-NDIP). NDF contains some protein and bound nitrogen (1). In the calculation of NFC, protein insoluble in neutral detergent (without sodium sulfite) is subtracted so there is no double accounting of protein insoluble in neutral detergent.

NFC is expressed as a percentage of dry matter.

Reference

1. Van Soest, P.J. 1994. Nutritional Ecology of the Ruminant. Cornell University Press, Ithaca.

Carbohydrate A1

Carbohydrate Fraction A1 represents acids produced during silage fermentation.

Carbohydrate A1 is expressed as a percentage of NFC.

Carbohydrate A2

Carbohydrate Fraction A2 contains sugars. Sugars in the analyses used by (1) is carbohydrate extracted by water at 39 C.

Carbohydrate A2 is expressed as a percentage of NFC.

References

1. Miller-Webster, T.K., J. Grimmett and W.H. Hoover 1997. Anim. Sci. Report No. West Virginia University, Morgantown.

Carbohydrate B1

Carbohydrate Fraction B1 contains of starch.

Starch consists of two polymers (3): amylose (linear a 1-4 glucopyranosidic chains) and amylopectin (branching at the sixth carbon to form side chains of a 1-4 units). Ruminal fermentation of starch varies with feed ingredients (wheat > barley >corn >sorghum) and can be increased by processing grains to disrupt the seed coat and/or cause gelatinization and rupture of starch particles (3). Two enzymes (a and B amylases) hydrolyze starch. Values From different laboratories can vary depending upon the enzymes used and whether reported values are starch or starch plus soluble sugars.

Analyses of Feed Ingredients for starch has been pioneered by (2). This starch fraction, by virtue of the analytical method, contains starch, sucrose and fructans. Fructans ferment like starch so leaving them in the starch fraction does not create a problem. Grasses, except for corn silage, and legumes contain little true starch so what is reported as starch is mainly fructans. For feed Ingredients like beet and citrus pulp and perhaps other by-products, what is reported as starch is mainly sucrose. For corn silage, grains and most by-products, what is reported as starch is nearly all true starch.

Carbohydrate B1 is expressed as a percentage of NFC.

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Carbohydrate B2

Carbohydrate B2 is soluble fiber. It consists of pectins and beta glucans. Soluble fiber has no covalent linkage to lignin and is completely available to fermentation. It is fermented to yield acetic acid and it does not give rise to lactic acid. Its fermentation is inhibited by low pH (3).

Soluble fiber (SF) is calculated as follows:

NFC = 100 - (CP + Fat + Ash + NDF-NDIP)

NFC = (silage acids + sugars +starch + soluble fiber)

SF = NFC – (silage acids + sugars + starch)

Carbohydrate B2 is expressed as a percentage of NFC.

Reference

1. Van Soest, P.J. 1994. Nutritional Ecology of the Ruminant. Cornell University Press, Ithaca.

Carbohydrate B3

Carbohydrate B3 is insoluble available fiber (1)

It is calculated as

```
NDF – (NDIP + Lignin*2.4)
```

Reference

1. Van Soest, P.J. 1994. Nutritional Ecology of the Ruminant. Cornell University Press, Ithaca.

Carbohydrate C

Carbohydrate C is insoluble unavailable fiber. It is estimated as Lignin*2.4 (1).

Reference

1. Van Soest, P.J. 1994. Nutritional Ecology of the Ruminant. Cornell University Press, Ithaca.

Amino Acids

Ruminal fermentation can modify the intestinal amino acid profile of feeds but the extent of modification varies (10). When compared to the amino acid profile of the intact feed ingredient, the amino acid composition of the rumen escape fraction was judged to be different by some investigators (4,5,6,8,9) and similar by others (11,12,13,14). Clearly, the extent of ruminal modification depends upon the ruminal degradation of protein in feed ingredients. Animal and marine proteins have similar feed and rumen escape amino acid profiles. Amino acid profiles of feed and rumen escape fractions of ingredients like soybean meal and corn gluten feed are different.

Because there is limited data on amino acid composition, the INRA and NRC systems used feed amino acid profiles to estimate escape amino acid profiles (10,16). CPM-Dairy (3,7,15) uses amino acids insoluble in borate-phosphate buffer or in the protein fraction resistant to in vitro degradation by Strep Griseus proteolytic enzyme.

Amino acids are expressed as a percentage of the RUP.

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16. NRC. 2001. Nutrient Requirements of Dairy Cattle. Nat Res. Council, Wash., D.C.

Fat

Fatty acids and glycerol are the compounds of nutritional significance. Crude fat is normally determined by extraction with ether. Not all ether soluble materials are fatty acids (1).

Ether extract is expressed as a percentage of dry matter.

In CPM-Dairy, feed ingredients were analyzed for fatty acids (2). Routine analyses is not needed since fatty acid profiles are relatively constant within specific fats.

References

1. Van Soest, P.J. 1994. Nutritional Ecology of the Ruminant. Cornell University Press, Ithaca.
2. Sukhija, P.S. and D.L. Palmquist. 1988. J. Agric. Food Chem. 36:1202.

Fat Type

Fat type classifies feed ingredients on the basis kind of crude fat (Ether Extract) to provide an accounting of rumen active and rumen inert fat. EE 1 is fat in base feed ingredients like forages, grains and proteins. It normally accounts for 2 to 4% fat in ration dry matter. EE 2 is fat in high fat Feed Ingredients like whole oil seeds, distillers grains and tallow. EE 1 and EE 2 are considered rumen active fats and usually should be limited to 5.0 to 5.5% of ration dry matter to avoid adverse affects on ruminal fermentation (1,2,4,5,7). EE 3 is inert in the rumen due to high amounts of saturated fatty acids such as stearic and palmitic or because fat is in the form of calcium salts. EE 3 can be used to raise concentration of fat to 7.0% of ration dry matter. Because there apparently are limits to the amount of fat that can be absorbed from the small intestine (7), there is little benefit having more than 7.0% crude fat in rations. Rumen inert fats based upon high concentrations of stearic acid in the form of triglycerides have lower intestinal digestibility than rumen inert fats in the form of calcium salts (3,6).

Fat type is expressed on a categorical basis.

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Minerals

Minerals should be analyzed by wet chemistry methods.

Minerals are expressed on the basis of percentage of dry matter or as ppm.

Vitamins

Because of the uncertainty of values in feed composition tables, CPM-Dairy Feed Dictionaries do not contain vitamin values.

Vitamins are expressed as KIU/kg (vitamins A and D) and IU/kg (vitamin D).

Degradation Rate (kd)

A key component of CNCPS is recognition that feed ingredients are unique (1). The model attempts to identify feed fractions (A, B and C) that have uniform rates of digestion in the rumen. Fermentation rate (kd) is an inherent property of feed fractions. In CNCPS (2,3), fermentation rates are described by first-order kinetics (Substrate limited, enzyme excess).

Kd of protein fractions is based on literature data where feed ingredients were incubated in situ or in vitro with proteolytic enzymes. Because it is not possible to obtain reliable estimates of digestion rates for carbohydrates by enzymatic procedures, Kd of carbohydrate fractions were determined only from in situ data. Kd of fraction A was assumed to be instantaneous. Kd of fraction C was assumed to be zero. B fractions have degradation rates that are fast (200-300 %/h), intermediate (5-15 %/h) or slow (<2 %/h). Kd of the B fractions was estimated by curve peeling. Where data were not available for feed ingredients values were extrapolated based on the characteristics of the protein and carbohydrate fractions.

Cornell University has developed a calculator to determine the kd of carbohydrate B3 from either a 24 or 30 in vitro digestion of NDF (Van Amburgh; mev1@cornell.edu).

Intestinal Digestibility

Intestinal digestibility values are true digestion of rumen escape fractions in the intestines. Intestinal digestibility can be adjusted to reflect effects of maturity, processing and storage. For example, cows fed mature corn silage often excrete appreciable amounts of corn grain in feces. Reduced ruminal fermentation can be accounted for by decreasing the degradation rate of Carbohydrate Fraction B1. This will increase ruminal escape of starch. Intestinal digestion of Carbohydrate Fraction B1 can be reduced to reflect decreased digestion of starch.

Intestinal digestion is expressed as a percentage of the rumen escape fraction that disappears between the duodenum and feces.

Data (1,4,5,6) in the tables below represent an adaptation of the measurements of starch digestibility in the post ruminal tract. There are very limited data for the small intestine in the lactating dairy cow and limited data for digestion between the duodenum and feces. The current model does not have a hindgut sub model, so the database used was mostly duodenum to feces.

Effect of feed particle size on post ruminal starch digestibility (% of Starch entering the intestine)

	Particle size			
Feed Type	Very Coarse	Coarse	Medium	Fine
Corn Dry Grnd	65	75	80	85
Corn HM (% Moisture)				
32	80	85	90	95
28	78	83	85	90
24	75	80	82	85
22	73	78	80	83
Sorghum, Dry	60	70	75	80
Tapioca				52
Wheat, grnd				72

[1]Particle size of dry feeds. Very coarse would be equivalent to dry rolled corn. Very coarse = > 75 % being retained on a 1.59 mm (1/16") screen; Coarse = >50 but < 75 % retained on a 1.59 mm screen; Medium = >20 % but < 50 % retained on a 1.59 mm screen; Fine = < 20 % retained on a 1.59 mm screen (6).

Effect of Steam Flaking or Steam Rolling on Post Ruminal Starch Digestibility (% of Starch entering the intestine)

	Flaking/Rolling Density		
Feed Type	22 lb./bu. (283 g/L)[1] 34 lb./bu. (437 g/L)[2]	24 lb./bu. (309 g/L) 38 lb./bu. (489 g/L)	28 lb./bu. (360 g/L) 42 lb./bu. (540 g/L)
Corn Stm Flaked	97	95	90
Corn Stm Rolled	80	75	70
Sorghum Stm Flaked	95	93	87
Sorghum Stm Rolled	78	73	68

[1]Steam Flake densities
[2]Steam Rolled densities

Silage dry matter and kernel processing of corn silage not only affects carbohydrate fermentability in the rumen (kd), but they also impact digestibility of starch in the intestine.

Effects of Corn Silage Dry Matter and Kernal Processing on the Intes tina Digestibility of Starch (B1).			
	Forage Chop Length		
DM %	Coarse	Medium	Fine
Unprocessed			
40	60	60	60
35	70	70	70
30	80	80	80
25	90	90	90
Kernel Processed			
40	75	78	
35	80	83	
30	85	87	
25	90	90	

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Nutrients

Nutrient Requirements

The factorial system is used to calculate metabolizable energy, metabolizable protein and metabolizable essential amino acid requirements for maintenance, growth, pregnancy and milk production (1-6). Amino acid requirements are also calculated using an ideal protein method (7).

Factorial systems first estimate net requirements and then rely on efficiency factors (transfer coefficients) to transform net requirements into metabolizable (absorbable) amounts. Net requirements are based on amount of product and nutrient composition of the product. These can be measured reliably. Estimating efficiency of nutrient use is difficult. Transfer coefficients used in factorial systems are constant. This dictates that production responses are linear regardless of the amount of nutrient supplied. Factorial methods, therefore, can overestimate production responses.

References

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Nutrient Supply

Nutrients for maintenance and production are derived from rumen escape (bypass) fractions of feed ingredients, rumen bacteria and end-products (primarily volatile fatty acids) of ruminal fermentation (1,2).

Feeds entering the rumen can disappear from the rumen by digestion or by passage (7,8). In CNCPS (6), rates of passage and degradation rates of protein and carbohydrate fractions are used to calculate fermentability and rumen escape of feed ingredients. New users of CNCPS often are surprised to find that feed inputs do not include values for rumen bypass protein or for energy. The rumen sub-model calculates the former. Metabolizable energy is calculated by the rumen, intestinal and metabolic sub-models. Microbial growth is driven primarily by fermentability of carbohydrates in the rumen.

Rate of Passage

Passage rates (kp) are primarily regulated by feed intake (7). In CNCPS, kp is based on equations developed by (5).

$$kp[FORAGES] = .388 + .022*(DMIG/BWKG^{.75}) + .0002*(FORAGE\%DM^{2})$$

```
kp[CONCENTRATES] = -.424 + 1.45*(kp[FORAGE])
```

Kp of feeds is affected by particle size and density. NDF decreases density. Small particle size increases density. Effective NDF (eNDF), which is based on particle size, is used to adjust Kp calculated from equations (5) on the assumption that eNDF (%DM) of forages was 30% and eNDF (%DM) of concentrates was 10% of ration dry matter. Adjustment factors (Af) are calculated by the following equations:

```
Af[FORAGES] = 100/(eNDF + 70)

Af[CONCENTRATES] = 100/(eNDF + 90)
```

Degradation Rate

A key component of CNCPS (6) is recognition that feed ingredients are unique. The model attempts to identify feed fractions (A, B and C) that have uniform rates of digestion in the rumen. Fermentation rate (kd) is an inherent property of feed fractions. In CNCPS (4,6), fermentation rates are described by first-order kinetics (Substrate limited, enzyme excess).

Kd of protein fractions is based on literature data where feed ingredients were incubated in situ or in vitro with proteolytic enzymes. Because it is not possible to obtain reliable estimates of digestion rates for carbohydrates by enzymatic procedures, Kd of carbohydrate fractions were determined only from in situ data. Where data were not available for feed ingredients values were extrapolated based on the characteristics of the protein and carbohydrate fractions (6).

During silage fermentation, some of the soluble non-cell wall components are metabolized primarily to lactic and acetic acids. These fermentation acids are useful to the animal as a component of metabolizable energy but are depleted fermentable sources of ATP for microbial growth (7). Thus, ensiling has little effect on feed energy values but can affect protein nutrition substantially by decreasing bacterial protein production.

Degradation and Escape

Nutrients entering the rumen can only disappear from the rumen by two routes; by passage or by digestion (7,8). The proportion of feed fractions digested in the rumen or passed out of the rumen are calculated as follows:

```
Digestion = kd(/kd+kp)
```

```
   Where kd = rate of degradation (%/h)

   And   kp = rate of passage (%/h)

Passage = kp (/kd+kp)
   Where kd = rate of degradation (%/h)
   And   kp = rate of passage (%/h)
```

Extent of digestion is calculated by applying digestion percentages (kd/kd+kp) to the pools of protein and carbohydrate fractions.

The impact of passage rate on extent of ruminal fermentation depends upon whether the degradation rate of the feed fraction is of the same magnitude as passage rate. Extent of ruminal fermentation of A Fractions, because of their fast degradation rates, is not affected by rate of passage. Ruminal fermentation of protein Fraction B_3, because of its slow degradation rate is only affected modestly by passage rate. The degradation rate of protein Fraction B_2 (5-15 %/h) is close to normal passage rates (4-8 %/h) so that ruminal escape of protein in feeds that contain high proportions of Fraction B_2 will be affected by feed intake. For example ruminal escape of soybean meal protein is 36-38% at 25 kg/d DMI but only 28-30% at 15 kg/d DMI.

Escape of nutrients from ruminal fermentation can have positive or negative impacts on nutrient economy. If digested hydrolytically in the small intestine, the animal will obtain more nutrients because ruminal losses of ammonia and methane are avoided. With low intestinal digestibility, rumen escape nutrients will lower the feed's nutritional value. However, if feeds escape ruminal fermentation, they cannot provide nutrients and energy for bacterial growth so that ammonia utilization and yield of bacterial protein can be compromised.

Bacterial Growth

Only carbohydrates or products of carbohydrate fermentation provide energy (ATP) at rates sufficient for growth of most ruminal microbes (3). Thus, the amount of metabolizable protein and amino acids derived from bacteria depends primarily on the amount and ruminal fermentability of feed carbohydrate.

Bacterial growth is driven primarily by fermentability of carbohydrates in the rumen. The following equations are used to calculate the yield of bacteria that ferment sugars, starch, soluble fiber (pectins and *B*-glucans), and available fiber (1)

```
1/Y = (km/kd) + (1/Yg)

Where Y = yield efficiency (g of bacteria/g of
carbohydrate fermented)

   km = maintenance rate (g of carbohydrate fermented/g
   of bacteria/h)

   kd = growth rate of bacteria = degradation rate of
   carbohydrate (%/h)

   Yg = theoretical maximum yield of bacteria (g of
   bacteria/g of carbohydrate fermented

   Total bacteria (g/d) = Y * g of carbohydrate
   fermented
```

The dynamic approach taken recognizes that bacteria have a maintenance energy requirement. In addition, bacterial yield is adjusted for ruminal pH and the amount and type of ruminal available nitrogen.

Bacterial yield is affected by low ruminal pH in two ways. First, degradation rate of available fiber is discounted. This affects bacterial yield by decreasing fermentable carbohydrate. Second, maximum growth yield (Yg) of both fiber and non-fiber digesting bacteria is decreased.

Bacterial yield is discounted if there is insufficient ruminal available nitrogen. In addition, the form of available nitrogen is important. Fibrous fermenting bacteria only grow on ammonia. Non-fibrous fermenting bacteria also take up peptides. Whether peptides are used for bacterial protein synthesis or degraded to ammonia depends on the amount of fermentable non-fibrous carbohydrate. When fermentable non-fibrous carbohydrates allow growth, 34% of the bacterial protein comes from ammonia and 66% comes from peptides. If there is insufficient carbohydrate, peptides are converted to ammonia. In addition, as the ratio of peptides to peptides plus non-fibrous carbohydrates increases from 0 to 14%, the yield of non-fibrous fermenting bacteria can increase by as much as 18.7%.

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Metabolizable Energy

Metabolizable Energy Requirements

Maintenance

The maintenance energy requirement is determined by metabolic body size and metabolic rate with adjustments reflecting physiological state, urea cost, previous nutritional treatment, activity, and heat gain or loss required to maintain normal body temperature based on data published by Fox et al. (2,3,4) and NRC (6). The proportion of the energy available for productive functions depends on the proportion needed for maintenance. Basal maintenance requirement for dairy cows is computed as 73 kcal/kg metabolic body size, which is the ¾ power of shrunk body weight; this value is 78 kcal in dairy replacement heifers.

Growth

Requirements for growth are based upon achieving target weights. Energy and protein requirements for growth include adjustments for effects of body weight, rate of body weight gain, chemical composition of gain, and mature weight (5).

A mammogenesis requirement is included to represent growth of the mammary gland. It begins on 260 days of pregnancy and is often referred to “springing” in the field. The mammogenesis requirements added to the growth requirements are 0.94 Mcal ME and 277 g MP per day.

Lactation

Lactation energy requirements are calculated as the product of milk volume and concentrations of fat in milk (3). Net energy for milk is converted to metabolizable energy using an efficiency of 64.4% (6).

Pregnancy

Pregnancy requirements and BW gain from growth of the gravid uterus based on expected calf birth weight and day of gestation are calculated according to (1). For pregnant heifers, weight of fetal and associated uterine tissue is deducted from EqEBW to compute energy and protein requirements for growth, but conceptus growth then is added to ME and MP allowable ADG to compute target ADG for comparison with observed ADG.

Reserves

Reserves are used to meet requirements when nutrient intake is inadequate. They must be taken into account when evaluating the ability of rations to meet requirements, especially under environmental stress, feed shortage or early lactation (2). Depleted reserves also must be replaced. Body condition score can be used to assess energy balance and tissue mobilization in dairy cows with one dairy score providing about 400 Mcal (7). Equations based on body condition score for predicting energy and protein from body reserves are in (3-5).

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Metabolizable Energy Supply

Ruminal digestion rates and passage rates of carbohydrate fractions are integrated to predict metabolizable energy values of each feed ingredient. Because DMI affects rate of passage, metabolizable protein and energy values predicted are adjusted for the impacts of feed intake. Effective NDF of rations affects calculated feed values through the impacts of ruminal pH (estimated from peNDF) on degradation rate of available fiber and as a modulator of passage rate (2,3,4).

TDN, DE, ME and NEL are calculated using equations in (6-8).

Apparent digestibility (g/d) for lactating and non lactating animals is calculated as follows:

Protein = Intake Protein - Fecal Protein

Carbohydrate = Intake Carbohydrate – Fecal Carbohydrate + Digested Glycerol - De Novo Fatty Acids*2.25

Fatty Acid = Absorbed Fatty Acids

TDN for lactating and non-lactating animals is calculated as follows:

TDN (g/d) = Digested Protein + Digested Carbohydrate +Digested Fatty Acids*2.25

$TDN (\%) = (TDN_{g/d}/DMI_{g/d})*100$

Energy calculations for lactating cows are as follows:

Digestible Energy (Mcal/kg) is calculated as

$DE\ from\ Protein = (AppDigProt*0.004409)/DMI_{kg}$

$DE\ from\ Carbohydrate = (AppDigCho*0.004409)/DMI_{kg}$

$DE\ from\ Fatty\ Acid = (AppDigFA*0.004409)/DMI_{kg}$

Metabolizable Energy (Mcal/kg) is calculated as

If EE%DM <=4

then

$ME=1.01(DEConcProt+DEConcCho+DEConcFA)-.45$

else

$ME=1.01(DEConcProt+DEConcCho+1.23*DEConcFA)-.45 +.0046*(EE-3)$

Net Energy (Mcal/kg) is calculated as

$NE = ME*0.644$

Energy calculations for non-lactating animals are as follows:

Digestible Energy (Mcal/kg) is calculated as

$DE\ from\ Protein = (AppDigProt*0.004409)/DMI_{kg}$

$DE\ from\ Carbohydrate = (AppDigCho*0.004409)/DMI_{kg}$

$DE\ from\ Fatty\ Acid = (AppDigFA*0.004409)/DMI_{kg}$

Metabolizable Energy (Mcal/kg) is calculated as

If EE%DM <=4

then

$ME=(DEConcProt+DEConcCho+DEConcFA)*.82$

else

$ME=(DEConcProt+DEConcCho+1.23*DEConcFA)*.82$

Net Energy (Mcal/kg) is calculated as

$NEM=(1.37*ME-0.138*ME^2+0.0105*ME^3)-1.12$

$NEG=(1.42*ME-0.174*ME^2+0.0122*ME^3)-1.65$

For growing cattle, the efficiency of ME utilization for maintenance (NEM) and gain (NEG) are different and are affected by ration fiber (7):

These non linear equations predict efficiencies of ME utilization that vary on the basis of ME concentration (a surrogate to reflect ration fiber). At 2 Mcal/kg (all hay crop ration) efficiencies are 58% for maintenance and 30% for gain. At 3.2 Mcal/kg (all concentrate ration), efficiencies are 69% for maintenance and 47% for gain. The increased efficiencies reflect increased production of propionic acid in the rumen as fiber content decreases (3,4).

Predicted gain is estimated by calculating the DMI needed for maintenance and, by subtraction, computing the net energy available for gain (3,4).

For additional information, see Feed Dictionary and Metabolic Efficiency.

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Metabolizable Protein

Metabolizable Protein Requirements

Maintenance

Protein (amino acid) required for maintenance is a function of non-dietary protein in the intestinal tract and losses due to turnover of tissue proteins (10). These are represented as metabolic fecal, scurf and urinary protein losses. The efficiency factor used to calculate maintenance metabolizable protein requirements is 100% for metabolic fecal protein and 67% for scurf and urinary protein (4,5).

Growth

Metabolizable protein required for gain is based on composition of gain with efficiency that varies as a function of adjusted body weight (4,5).

Lactation

Lactation requirements are calculated as the product of milk volume and true protein in milk (4,5). Net protein in milk is converted to metabolizable protein using an efficiency of 65%.

Pregnancy

Pregnancy protein requirements are calculated according to (2). Metabolizable protein is calculated from net protein using an efficiency of 33%.

Feeding pre-fresh cows rations with higher dietary crude protein and rumen escape protein than calculated from (8) has increased milk yield and improved health and fertility (3,7,10,12). Postpartum responses to higher levels of metabolizable protein could be due to metabolic uses of amino acids for functions other than fetal protein accretion.

An unusual aspect of fetal metabolism is extensive use of amino acids as sources of energy. Calculations by (1) showed that 56% of fetal energy is provided by amino acids. Thus only 34% of the amino acid nitrogen extracted by the uterus is used for tissue protein deposition and 56% is lost as urea. Uteroplacental tissues rather than fetal tissue consume a major portion (60-70%) of the organic nutrients taken up by the uterus (1).

Reserves

Reserves are used to meet requirements when nutrient intake is inadequate. They must be taken into account when evaluating the ability of rations to meet requirements, especially under environmental stress, feed shortage or early lactation (20). Depleted reserves, however, must be replaced. CNCPS contains equations for predicting protein from body reserves (4,5).

Until the recent experiment of (6), ruminants were thought to have limited capacity to store protein. Ewes fed rations with 8% and 12% crude protein took protein from their peripheral tissues (skeletal muscle and skin) to meet requirements of the gravid uterus. At 16% dietary protein, there was accretion of dietary protein in peripheral tissues. Protein deposition in organs and mammary tissue was increased when ewes were fed rations with 12 and 16% crude protein. Some of the benefits of higher dietary crude protein and rumen escape protein on milk yield, animal health and fertility (3,7,10,12) may be due to greater amounts of reserve protein that can be used to sustain milk protein synthesis and hepatic gluconeogenesis during the early stages of the lactation cycle when cows are deficient in amino acids and energy (1).

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Metabolizable Protein Supply

The metabolizable protein value of a feed ingredient is the sum of metabolizable protein from rumen escape protein and from bacterial protein.

Ruminal digestion rates and passage rates of protein are integrated to predict the metabolizable protein value of each feed ingredient. Because DMI affects rate of passage, metabolizable protein is adjusted for the impacts of feed intake. Effective NDF of rations affects calculated metabolizable protein through the impacts of ruminal pH (estimated from eNDF) on degradation rate of available fiber, which in turn affects yield of fiber digesting bacteria, and the impact of ration effective NDF (as a surrogate for ruminal pH) on maximum bacterial yield (2,3).

Only carbohydrates or products of carbohydrate fermentation provide energy (ATP) at rates sufficient for growth of most ruminal Bacteria (1). Thus, the amount of metabolizable protein and amino acids derived from bacteria depends primarily on the amount and ruminal fermentability of feed carbohydrate.

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Amino Acids

Amino Acid Requirements

Requirements for metabolizable essential amino acids for synthesis of milk protein are defined using the classical factorial method (3,4,5,8) and by an ideal protein method (11,).

The factorial method requires knowledge of the amino acid content of products and the efficiency of amino acid use. Tissue amino acid composition (1) is applied to maintenance, growth and pregnancy metabolizable protein requirements (8). Amino acid composition of milk (12) is applied to the metabolizable protein required for milk production (8) Amino acid efficiency values originally were from (6) but have been updated (Overton, 2004. Unpublished data, Cornell University).

The factorial method is very sensitive to values used to describe the utilization of metabolizable amino acids for milk synthesis. This can impact predicting responses of production in two ways. First, the lactation amino acid transfer coefficients represent the utilization for milk protein synthesis of amino acids that have been extracted from blood by the mammary gland. They do not consider the efficiency of the mammary gland to extract amino acids from blood. Second, constant transfer coefficients dictate that production responses are linear regardless of amounts of metabolizable methionine and lysine. Thus, the factorial method may describe production responses correctly when amino acids are limiting but will over-estimate production responses when there are excesses of amino acids.

The ideal protein method expresses requirements of methionine and lysine as percentages of metabolizable protein (11) Optimum levels are Met/MP = 2.50% and Lys/MP = 7.20%. These levels are hard to obtain without single sources of methionine and lysine. Because milk protein yield appears to be dramatically reduced when rations provide less than 2.10 to 2.20% Met/MP or 6.5 to 6.8% Lys/MP, these levels are considered minimums. Inspection of graphs presented by (11) suggests that responses of milk protein to methionine may be negative if lysine is limiting (i.e. Lys/MP<6.57). Methionine at 150-160% of requirements, even when lysine was increased, depressed feed intake and milk yield (10). To avoid potential negative impacts of excess methionine, the lysine:methionine ratio should be 3.1:1.

The database used to calibrate the ideal protein method (11) was obtained with cows in mid or late lactation. Milk production was modest and many experiments were short-term switch-back designs. Thus, responses to increasing proportions of lysine and methionine would be expected to be low. It, therefore, is likely that production responses of early and peak lactation cows will be under-estimated by the ideal protein method.

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Amino Acid Supply

Amino acid supply is calculated by applying amino acid composition values (1,2,7) to rumen bacterial protein and rumen escape protein (8).

Ruminal fermentation can modify the intestinal amino acid profile of feeds but the extent of modification varies (10). When compared to the amino acid profile of the intact feed ingredient, the amino acid composition of the rumen escape fraction was judged to be different by some investigators (4,5,6,8,9) and similar by others (11,12,13,14). Clearly, the extent of ruminal modification depends upon the ruminal degradation of protein in feed ingredients. Animal and marine proteins have similar feed and rumen escape amino acid profiles. Amino acid profiles of feed and rumen escape fractions of ingredients like soybean meal and corn gluten feed are different.

Because there is limited data on amino acid composition, the INRA system uses feed amino acid profiles as the first guide to estimate escape amino acid profiles (10). CNCPS (3,7) uses amino acids insoluble in borate-phosphate buffer or in the protein fraction resistant to in vitro degradation by Strep Griseus proteolytic enzyme.

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Ration Guidelines

Introduction

Offered as a guide to help the user evaluate rations. No claims are made for productivity, fertility or health of animals.

Ration Guidelines										
		Pre-Fresh			Fresh			Peak		
Parameter	Units	Target	Lower	Upper	Target	Lower	Upper	Target	Lower	Upper
DMI	% Pred	100	95	105	100	95	105	100	95	105
Protein Balance	% Req	100	95	110	100	95	110	100	95	110
NP/MP		65	60	70	65	60	70	65	60	70
ME Balance	Mcal/d	1	0	4	0	-6	2	1	-1	3
BW change	lb/d	.25	0	1	0	-1.5	0.2	0	-0.5	1
Carbohydrate										
NFC	%DM	33	30	36	38	35	39	40	35	41
Sugar	%DM	4	3	6	6	5	9	6	5	9
Starch	%DM	23	20	25	24	21	27	25	21	27
Soluble Fiber	%DM	7	5	11	7	5	11	7	5	11
NDF	%DM	33	30	45	30	28	35	30	28	35
peNDF	%DM	25	23	35	23	21	28	23	21	26
Fermentability[1]										
Dry Matter	**%DM**	**43**	**41**	**44**	**43**	**41**	**44**	**43**	**41**	**44**
Sugar	**%DM**	**5**	**4**	**8**	**5**	**4**	**8**	**5**	**4**	**8**
Starch	**%DM**	**21**	**20**	**22**	**21**	**20**	**22**	**21**	**20**	**22**
Soluble Fiber	**%DM**	**6**	**4**	**9**	**6**	**4**	**9**	**6**	**4**	**9**
NDF	**%DM**	**10**	**9**	**12**	**10**	**9**	**12**	**10**	**9**	**12**
NDF	**%NDF**	**>32**	**30**	**40**	**>32**	**30**	**40**	**>32**	**30**	**40**
Fat										
EE 1	%DM		0	3		0	3		0	3
EE 2	%DM		0	3		0	3		0	3
EE 1 and 2	%DM		0	5		0	5		0	5
EE 3	%DM		0	1		0	4		0	4
EE Total	%DM		0	4.5		0	6		0	7
LCFA	%DM		1	3.5	3	2	5	3	2	6
C18:1trans	g/d				<80		100	<100		120
Rumen N Balance										
NH_3	% Req	110	105	150	110	105	150	110	105	150
Peptide	% Req	110	105	150	110	105	150	110	105	150
Soluble Protein	%CP	31	30	40	31	30	35	31	30	35
RDP	%DM	11.5	11	13	11.5	11	12	11.5	11	12
Rulquin AA Balance										
Met (%MP)	%MP				2.12	2.10	2.50	2.12	2.10	2.50
Lys (%MP)	%MP				6.57	6.50	7.30	6.57	6.50	7.30
Lys:Met					3.10:1	3.00:1	3.30:1	3.10:1	3.00: 1	3.30:1

1. The Fermentability guidelines are for 54 lb DMI (24.5 kg). Fermentability is affected by DMI; decreasing as DMI goes up; increasing as DMI goes down. To use the Fermentability guidelines, adjust DMI to 54 lb (24.5 kg) using the scaler on the CNCPS screen. Do not forget to reset DMI after evaluating fermentability.

Helpful Hints

Optimization

The objective of optimization is to return a solution. A solution is the least cost ration that is within the MINS and MAXES of By Ingredient, By Nutrient and By MinVit constraints. A solution is obtained when the message “calculation finished successfully” is returned. If a solution is not possible (i.e. the optimizer cannot find an answer at any cost that is within the MINS and MAXES of By Ingredient, By Nutrient and By MinVit constraints), the returned from dialog box gives "infeasible linear constraints" and lists the By Nutrient and By MinVit constraints that could not be met. This is a reply and not a solution. The user can accept the reply but this is not recommended. Instead, the user should relax some of the By Ingredient, By Nutrient and By MinVit constraints and optimize again.

If ammonia or peptides are among the By Nutrient constraints listed, relaxing them may yield a solution. When optimizing for the first time, it is advisable to not select peptides and ammonia as By Nutrient constraints to see if a solution at any level of peptides and ammonia is possible.

DMI

Lactating cow and dry cow intakes are calculated according to (1,3); growing dairy heifer intake is calculated according to (2). Intake of lactating cows is discounted during the early phase of the lactation cycle (3) and for environmental factors (1).

It is not possible to construct equations that will accurately predict DMI under all management, feeding and environmental conditions. The DMI predictions are intended as guidelines. If observed DMI is more than +/-5% of predicted, the user should check that that observed DMI is correct. Rations should be formulated on the basis of actual DMI. (CAUTION: Even when there are accurate records of feed delivered and unconsumed feed, actual DMI will be over-estimated because of the inability to completely account for feed wasted by cows throwing feed out of bunks, across feed alleys, into the animal area, etc.).

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Metabolizable Protein Balance

Pre-Fresh Cows

Guidelines include the requirement for mammogenesis.

Lactating Cows

The lower limit (95% of requirement) is based on the fact that (a) cows do have some reserve protein and (b) the efficiency of using metabolizable protein for milk protein synthesis (NP/MP) is not constant and can be higher than the default of 0.65. In non-ruminant animals, the efficiency of using absorbed (metabolizable) protein for productive purposes depends upon the balance of amino acids. For rations that are balanced for amino acids, we propose that NP/MP can increase to about 0.70. This means that a slight negative MP balance can probably be tolerated if NP/MP does not exceed 0.70. Formulation to a slight negative MP balance while not recommended, may be tolerated. Because amino acids are important for synthesis of glucose in fresh cows, they may be less tolerant to deficits of metabolizable protein.

Crude Protein and Rumen Undegraded Protein

The optimizer solves within a minimum and a maximum for metabolizable protein. Metabolizable protein is a function of ration crude and digestible rumen undegradable protein and digestible rumen bacterial protein. Guidelines for crude protein and rumen undegradable protein are not given. If the optimized ration calls for crude and rumen undegradable protein levels that not in the range of "comfort" to the user, these can be adjusted by changing the constraints for rumen ammonia (and sometimes peptide) nitrogen and doing another optimization. (CAUTION: only optimizations that give "successful termination" should be accepted).

Metabolizable Energy Balance

Pre-Fresh Cows

ME balance should not be negative as this will invoke mobilization of adipose tissue which increases the risk of fatty liver and ketosis.

Lactating Cows

Regardless of ration energy density, cows in the early stages of the lactation cycle usually lose body weight. How much they lose depends upon reserves at calving (i.e. fat cows eat less and lose more body condition than thin cows). The magnitude of lose can be monitored in terms of body condition score in Reports/Met E&P. When cows do not lose or even gain body condition during the early stages of the lactation cycle, this may reflect inadequate metabolizable protein, especially if milk production does not peak but is flat following parturition.

Carbohydrates

Guidelines for NFC, sugar, starch, soluble fiber, NDF and peNDF as percentages of DM are designed to avoid abnormal rumen function and thus optimize nutrients provided by the rumen system. A prime objective is to prevent ruminal acidosis and associated problems such as lameness, low fat test, protein/fat inversions, etc.

Fermentability

Fermentability depends not only upon degradation rates of carbohydrate fractions but also upon the length of time that feed ingredients are in the rumen (rumen residence time). Rumen residence time is determined by rate of passage. The main determinant of rate of passage is DMI

The Fermentability guidelines are for 54 lb DMI (24.5 kg). Fermentability is affected by DMI; decreasing as DMI goes up; increasing as DMI goes down. To use the Fermentability guidelines, adjust DMI to 54 lb (24.5 kg) using the scaler on the CNCPS screen. Do not forget to reset DMI after evaluating fermentability.

Fat

Fatty acids and glycerol are the compounds of nutritional significance. Crude fat is normally determined by extraction with ether. Not all ether soluble materials are fatty acids. The lipid sub-model in CPM-Dairy calculates EE (crude fat) and LCFA (long chain fatty acids). In TMRs, LCFA = EE –1.

Targets and lower limits for LCFA are based upon 50% of milk fatty acids being derived by extraction of LCFA by the mammary gland from blood.

Fat type classifies feed ingredients on the basis kind of crude fat (Ether Extract) to provide an accounting of rumen active and rumen inert fat. EE 1 is fat in base feed ingredients like forages, grains and proteins. It normally accounts for 2 to 4% fat in ration dry matter. EE 2 is fat in high fat Feed Ingredients like whole oil seeds, distillers grains and tallow. EE 1 and EE 2 are considered rumen active fats and usually should be limited to 5.0 to 5.5% of ration dry matter to avoid adverse affects on ruminal fermentation. EE 3 is inert in the rumen due to high amounts of saturated fatty acids such as stearic and palmitic or because fat is in the form of calcium salts. EE 3 can be used to raise concentration of fat to 7.0% of ration dry matter. Because there apparently are limits to the amount of fat that can be absorbed from the small intestine, there is little benefit having more than 7.0% EE in rations.

Rumen N Balance

Shortages

Shortages of rumen available nitrogen will compromise bacterial growth. Shortages of peptide nitrogen can decrease growth of bacteria that ferment non fiber carbohydrates (sugar, starch, pectins and beta glucans). Shortages of ammonia nitrogen will primarily decrease growth of bacteria that ferment fiber (cellulose and hemicellulose) because NFC-fermenting bacteria, as a consequence of their faster growth rates, have first priority on ammonia nitrogen. Rations low in rumen available ammonia nitrogen may result in low milk fat test even though NDF and peNDF are adequate.

Excess Rumen Available Nitrogen

Excess rumen available nitrogen requires energy (urea cost) to convert ammonia to urea and to excrete urea . Thus, rations with excess rumen available nitrogen not only contribute to environmental pollution, but they also use energy that could be channeled to productivity.

Uptake of Peptides and Ammonia

CMP-Dairy assumes that uptake of peptides and ammonia is 100% efficient. Because this is not likely, the lower limit suggested for peptide nitrogen and ammonia nitrogen is 105% of requirements. This allows a 5% safety factor.

Excess Peptides

CPM-Dairy assumes that all excess peptides are converted to ammonia. This may not always be true since some peptides resist ruminal degradation. Thus, it may be advisable to have rumen ammonia nitrogen balance 5 to 10 g/d more positive than rumen peptide nitrogen balance.

Excretion of Excess Nitrogen

The upper limit of 150% of requirements for peptide nitrogen and ammonia nitrogen is suggested to avoid excess excretion of nitrogen in urine. If rations contain feed ingredients with high soluble nitrogen (i.e. alfalfa silages), the upper limit may need to be increased (160 to 180% of requirements) in order to obtained optimized solutions.

Soluble Protein and Rumen Degradable Protein

The rumen sub-model operates on peptide and ammonia nitrogen. As a further check, guidelines for soluble protein and rumen degraded protein are presented.

Amino Acids

Pre-Fresh Cows

The ideal protein method has, so far, only been applied to lactating cows.

Lactating Cows

Requirements for metabolizable essential amino acids for synthesis of milk protein are defined using the classical factorial method (g/d) and by the Rulquin ideal protein method. The ideal protein method is recommended for lactating cows.

Optimum levels are Met/MP = 2.50% and Lys/MP = 7.30%. Because milk protein appears to be dramatically reduced when rations provide less than 2.10% methionine or 6.5% lysine, these levels are considered minimums. The suggested target is 2.12% methionine and 6.57% lysine. Where a premium is paid for concentration of protein in milk, try to formulate for 2.2% methionine and 6.8% lysine. Responses of milk protein to methionine may not occur or may be negative if lysine is limiting. To avoid this, target the lysine:methionine ratio at 3.1:1.

About CPM-Dairy

Introduction

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Heartland Lysine Inc.

Chicago IL

Novus International

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Developers

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