CALCULATING DIETARY NET ENERGY CONCENTRATIONS FROM FEEDLOT PERFORMANCE DATA

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SUMMARY

A method to calculate dietary net energy values for maintenance and gain from performance is described. Calculations are based on feed intake, mean weight, and rate of gain of cattle by solving the net energy equations in reverse based on the proposed mathematical relationships of NEm to NEg. Two mathematical solutions are presented, one being a direct quadratic solution based on the original (1968) net energy equations and the other being an iterative solution based on the 1984 NRC revision of the net energy equations. Applications and limitations are discussed.

(Key words: Net Energy, Cattle Performance.)

INTRODUCTION

Energy values of many feedstuffs for cattle were first measured in digestion-metabolism trials (TDN). Adjustments for the effect of level of feed intake on digestibility and methane loss have been added to calculate metabolizable energy (ME) in certain systems. In the California net energy (NE) system developed by Lofgreen and Garrett (1968), energy retention is measured at several levels of energy intake so that utilized energy can be divided into portions for maintenance and growth. Experiments to determine NE values for specific feedstuffs are complex and expensive to conduct, but the NE system predicts feedlot performance quite accurately. Most large feedlots project current weights of cattle fed in large pens by calculating and accumulating daily weight gains based on feed intake and net energy values of the diet being fed. Such projections are normally within 1% of measured final weights of cattle after 100 days on feed.

Feeding trials are much simpler to conduct than NE trials. Feeding trial results usually are expressed in terms of rate of weight gain and feed efficiency (feed:gain or gain:feed ratio). Gain and efficiency usually are correlated. This is because only feed consumed above maintenance can be used for gain. So efficiency of feed use increases as feed intake increases. Because the feed to gain ratio is altered both by feed intake and energy value of the diet, feed efficiency is not directly related to diet net energy value. Methods to adjust for feed intake differences and calculate NE values from performance data would help to refine NE values for specific feeding and environmental conditions. Several mathematical solutions to calculate NE values from performance data are possible. The objective of this paper is to outline two mathematical solutions, to illustrate their application and to discuss limitations of such calculated NE values.

MATERIALS AND METHODS

Equations presented by Lofgreen and Garrett (1978) and later revised (Lofgreen, 1977; NRC, 1984) for beef cattle served as the base for all calculations. To designate that the new energy values were calculated from performance and not measured in comparative slaughter trials, dietary energy values (ME, NEg, NEm) will be preceded by a C in all equations. Such designation should help avoid the confusion between measured and calculated values that currently exists in tables of feed composition.

For calculating dietary net energy values, needs for maintenance and for gain by steers and by heifers must be estimated. Equations from Lofgreen and Garrett (1968), Lofgreen (1977) or the NRC (1976, 1984) can be used as presented in Table 1. All gains and weights are in kg and are specified on an empty (E) or shrunk (S) basis. Though the initial NE equations were regressed against empty body weights and gains, they generally have been equated by the cattle industry to shrunk weights. Conversion of EBW to SBW has been described in NRC (1984).

Secondly, some relationship of dietary NEm to NEg of the diet must be employed so that a single solution, not multiple solutions relating feed intake and performance to energy values, can be found. Dietary NEm and NEg have been related to ME of the diet in both the original paper (Lofgreen and Garrett, 1968) and in a subsequent revision as presented in Table 2. These two relationships are presented in Figure 1.

Table 1. Energy requirements for gain and maintenance.[a]

	NEg (mcal/day)	Year
Calves:		
Steer:	$[(0.05272*EADG)+(0.00684*EADG^2)]EWT^{.75}$	1968
medium frame	$0.0557SWT^{.75}(SADG)^{1.097}$	1984
large frame	$0.0493SWT^{.75}(SADG)^{1.097}$	1984
Heifer:	$[(0.05603*EADG)+(0.01265*EADG^2)]EWT^{.75}$	1968
medium frame	$0.0686SWT^{.75}(SADG)^{1.119}$	1984
large frame	$0.0608SWT^{.75}(SADG)^{1.119}$	1984
Yearlings:		
Steer:	$[(0.04873*EADG)+(0.000629*EADG^2)]EWT^{.75}$	1977
large frame	$0.0437SWT^{.75}(SADG)^{1.097}$	1984
Heifer:	$[(0.05166*EADG)+(0.011684*EADG^2)]EWT^{.75}$	1977

[a] $NEm=0.077*EWT^{.75}$ (NRD, 1976)
$NEm=0.0705*SWT^{.75}$ for yearling cattle (Lofgreen, 1977).

Table 2. Relationship of dietary NEm and NEg.

Equation	Source
log F=2.2577-0.2213ME NEm=77/F NEg=2.54-0.0314F	Lofgreen and Garrett, 1968
$NEm=1.37ME-0.138ME^2+0.105ME^3-1.12$ $NEg=1.42ME-0.174ME^2+0.0122ME^3-1.65$	Garrett, 1980a

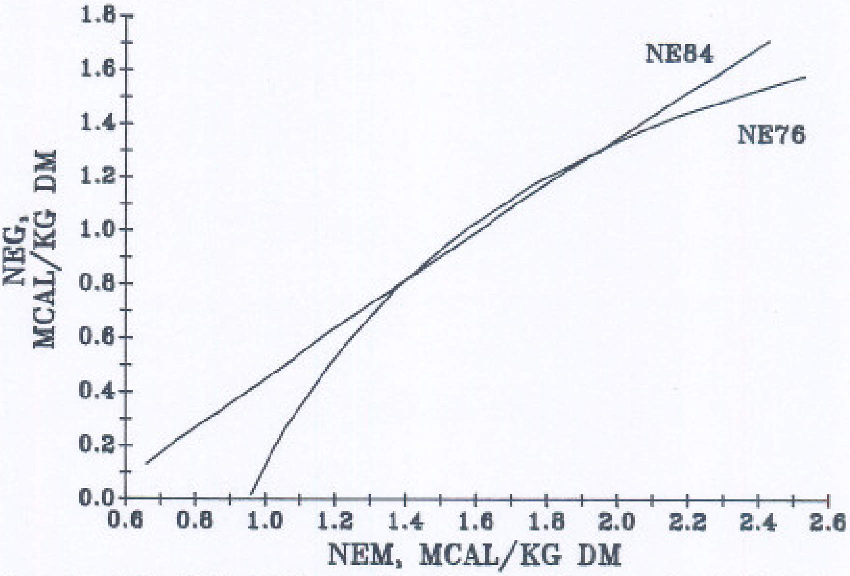

Figure 1. NRC (1976, 1984) equations illustrating the relationship of dietary NEm and NEg.

Using the relationships of Tables 1 and 2, a computer program can be employed to solve for CNEm and CNEg based on mean weight, weight gain and feed intake of cattle in a feeding trial. The 1968 equation simplifies into a quadratic equation which can be solved directly as follows:

E = 2.54 NEm + 1.098/.454 FI;
F = NEg - 1.153/.454 FI;
G = 2.4178 NEm;

where E, F and G are constants, NEm and NEg are net energy requirements for gain and maintenance in mcal/day as calculated from performance above, and FI is daily feed intake in kg per head.

Then: CNEm (mcal) = $[-E - (E^2 + 4FG)^{.5}]/2F$;
CNEg (mcal) = 115.3 - (4983/CNEm);
CME (mcal/kg) = $[2.2577 - \log_{10} (3496/CNEm)]/.2213$;
CTDN (%) = CME/.036155;

where CMEm, CNEg, CME and CTDN are calculated NEm, NEg, ME and TDN of the total diet, respectively. If the diet contains ingredients besides the test feed, one can subtract their contribution to the dietary ME from CME and divide by the fraction of the diet contributed by the test feed to determine CME of the test feed. Then CNEm and CNEg for the test feed can be calculated from CME by the equation of choice (Table 2).

The revised net energy equations (NRC, 1984) do not permit direct solution. Hence, an iterative approach must be employed. After calculating the animal's required net energy for maintenance and gain (RNEm, RNEg) one sequentially calculates the feed for maintenance (FM), the feed for gain (FG), and the calculated energy for gain (CEG) from an estimated ME (EME) value.

By comparing the CEG with RNEg, one adjusts the EME up or down and recalculates until the CEG equals the RNEg. A computer loop is included in the program (Table 3) for such iteration.

Table 3. Basic computer program for EME iteration.

```
Line        Equation

10 INPUT "IN WEIGHT";IWT
20 INPUT "FINAL WEIGHT";FWT
30 INPUT "AVERAGE DAILY GAIN";SADG
40 INPUT "AVERAGE DAILY DRTMATTER INTAKE";FI
50 EME=2.5
60 EWT=(IWT+FWT)/2
70 INPUT "CLASS OF ANIMAL, MFSC=MEDIUM FRAME STEER CALF,
LFSC=LARGE FRAME STEER CALF, LFYS=LARGE FRAME YEARLING
STEER, MFHC=MEDIUM FRAME HEIFER CALF, LFHC=LARGE FRAME
HEIFER CALF";COA$
80 IF COA$="MFSC" THEN
RNEG=.0557*(EWT^.75)*(SADG^1.097):GOTO 130
90 IF COA$="LFSC" THEN
RNEG=.0493*(EWT^.75)*(SADG^1.097):GOTO 130
100 IF COA$="LFYS" THEN
RNEG=.0437*(EWT^.75)*(SADG^1.097):GOTO 130
110 IF COA$="MFHC" THEN
RNEG=.0686*(EWT^.75)*(SADG^1.119):GOTO 130
120 IF COA$="LFHC" THEN RNEG=.0608*(EWT^.75)*(SADG^1.119)
ELSE 70
130 RNEM=.077*(EWT^.75)
140 CNEM=((1.37*EME)-(.138*EME^2)+(.0105*EME^3)-1.12)
150 FM=RNEM/CNEM
160 FG=FI-FM
170 CNEG=((1.42*EME)-(.174*EME^2)+(.0122*EME^3)-1.65)
180 CG=FG*CNEG
190 IF ABS(CG-RNEG)<.01 THEN 210 ELSE IF CG-RNEG>0 THEN
EME=EME-.01*ABS(CG-RNEG) ELSE EME=EME+.01*ABS(CG-RNEG)
200 GOTO 140
210 CME=EME
220 PRINT "INWT  OUTWT  ADG   FI     TYPE"
230 PRINT USING "#### #### ###.##  ##.##   \
\";IWT,FWT,SADG,FI,COA$
240 PRINT "REQNEM  REQNEG  CNEM  CNEG  CME"
250 PRINT USING "##.##  ##.##   ##.## ##.## ##.##
";RNEM,RNEG,CNEM,CNEG,CME
```

Using these equations, diet CME and daily CME intake can be calculated from feedlot trials. These values are more independent and potentially more useful in experiments than gain and feed efficiency values though they cannot be used as directly to calculate cost of gain.

As an example of the quadratic solution, if a 225 kg steer is fed to 475 kg at a rate of 1.05 kg per day with feed intake of 8.0 kg of dry matter per day using the quadratic solution, RNEm = 6.24 mcal/day; RNEg = 6.09 mcal/day; E = 35.20; F = -15.23; G = 15.09; CNEm = 1.74 mcal/kg; CNEg = 1.15 mcal/kg; CME = 2.76 mcal/kg, and CTDN = 76.5%. Examples illustrating the iterative solution are provided in Table 4. Note that calculated efficiency is independent of feed efficiency when gain, intake, mean weight or sex are changed.

Several contrasts from these examples are apparent. First if rate of gain is increased but feed to gain is constant (example 2 vs 1), CNEg is decreased. If gain and feed efficiency were identical but some cattle have a heavier mean weight (example 3 vs 1), CNEg must be greater for heavier animals. If more feed is required for gain (example 4 vs 1), the CNEm of the diet is lower. Finally, for heifers to have performance identical to steers (example 5 vs 1), CNEg for heifers must be greater.

These calculations are all based on the assumption that ME values of diet components are summative so that the equations relating NEm and NEg to ME are the same for mixed diets as for specific ingredients. In some publications concerning net energy calculations (NRC, 1968), net

Table 4. Examples illustrating the iterative solution.

1. Measure rate of gain, feed intake and initial and final shrunk weights from a feeding trial.

2. Calculate NEm and NEg requirements of test animals using NRC 1984 equations listed in Table 1.

3. Estimate ME of the diet and solve the computer loop (Table 3.) for final CME, CNEm, AND CNEg of the diet.

Examples:	1	2	3	4	5
Sex	steers	steers	steers	steers	heifers
Frame	medium	medium	medium	medium	medium
Initial weight, kg.	225	225	270	225	225
Final weight, kg.	475	475	520	475	475
Mean weight, kg.	350	350	395	350	350
Daily gain, kg.	1.05	1.27	1.05	1.05	1.05
Daily feed, kg DM	8.0	9.68	8.0	8.5	8.0
Feed/gain	7.62	7.62	7.62	8.10	7.62
Animal requirements:					
NEm, mcal/day	6.23	6.23	6.82	6.23	6.23
NEg, mcal/day	4.76	5.86	5.21	4.76	5.86
Diet values:					
CNEm, mcal/kg DM	1.71	1.60	1.84	1.62	1.88
CNEg, mcal/kg DM	1.09	1.00	1.21	1.02	1.25
CME, mcal/kg DM	2.61	2.50	2.77	2.52	2.82

energy, but not metabolizable energy values, are considered to be summative. This means that at a given ME, the ratio of NEg to NEm is higher if the diet consists of a mixture of two feeds containing different ME levels than if the diet consists of a single feedstuff (Table 3). This is the opposite what one might expect due to associative effects. If ME values rather than NE values are summative, a negative associative effect is automatically included in mixed diets as NEg values are not fully summative. When calculating associative effects, all energy values are often considered to be summative though critical examination of net energy relationships reveals that net energy values are related to ME in a curvilinear, not a linear, fashion.

RESULTS AND DISCUSSION

The applicability of calculated energy values is dependent on (1) the relationship of NEm to NEg, (2) the equations to estimate the requirements for NEm and NEg, and (3) the accuracy of performance data. Standard relationships of NEm and NEg were assumed. Various factors may alter this relationship. For example, monensin has been suggested to decrease the NEm requirement but not alter the NEg requirement of cattle. If the relationship of feed ME to NEm or NEg is altered or requirements change, a revised equation is needed. If a feed additive alters fecal or urinary energy loss, equations should remain valid, but if a compound changes methane loss, it would appear to change NEm of the feed more than its NEg due to the proportionally higher methane loss at lower energy intakes (Blaxter, 1962). The 1968 equations underestimate live weight gains of heavier cattle (Gill et al., 1981; Owens and Gill, 1982) though the 1984 equations often overestimates gain.

Since 1979, research reports from Oklahoma State have presented CME, CNEm or CNEg values for diets, usually listed as ME and footnoted as values calculated from animal performance and intake data. In most trials, CME values were within a few percent of ME values calculated from diet composition. Exceptions were apparent when weather stress reduced performance (Gill et al., 1984) and when steer equations were used for bulls (Gill et al., 1983). CME values were especially useful in estimating value of new feeds (Martin et al., 1984) and of feed additives for various weights of cattle (Witt et al., 1980).

Calculations also proved useful in evaluating grain or forage processing procedures which often alter feed intake. Use of these equations helps differentiate between feed efficiency changes which are attributable to feed intake versus those which are due to metabolic changes (Ferrell et al., 1983; Doran et al., 1984). CME values indicate that treatment of forage with hydroxides can increase feed intake enough to explain all of the increase in feed efficiency achieved by such treatment (Horn et al., 1981). These equations can be routinely used to adjust feed intake records for a pen when one animal in a pen dies so that records are incomplete. Calculations also help detect problem pens in an experiment and are useful to check whether performance data in the literature is reasonable or unreasonable based on diet composition and feed intake.

Weighing conditions of cattle in feedlot trials are much more variable than carcass weights and energy determinations used in net energy experiments. Dressing percents will vary with gastro-intestinal fill and degree of finish. Use of carcass weights rather than live weights should reduce this source of error as illustrated by Gill et al. (1976).

Finally, feed additives, implants, cattle type or stress may influence the energy requirement of animals and not the energy value of feeds. In such cases, it is more appropriate to adjust the energy requirements, not the energy values of feeds, even though it is simpler to adjust feed values. Certain new drugs and hormones may influence body composition. Current equations are based on an assumed body composition of hormonally implanted cattle at a specific weight. If treatments or body types alter this assumption, the determined CME values will be biased. Additional adjustments for frame size and sex as presented by Minish and Fox (1982) may be useful. Nevertheless, comparison of treatments within a study using cattle of a similar type and origin should be valid unless body composition is altered by treatment.

In conclusion net energy values for maintenance and gain can be calculated for feedlot diets from two general feedlot measurements—feed intake and rate of gain of cattle. Two mathematical solutions are outlined and their applications and limitations are discussed.

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