FACTORS AFFECTING INTAKE BY CATTLE ON GRAZINGLANDS: The *NUTBAL-PRO* System

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Nutritional Management Decision Techniques

A major limitation to supporting nutritional management decisions, is the inability of managers and advisors to determine diet quality under field conditions. However, recent advances in near infrared reflectance spectroscopy (NIRS) have made it possible to detect fecal by-products of digestion and relate these constituents to dietary crude protein (CP) and digestible organic matter (DOM) (Stuth et al. 1989, Lyons and Stuth 1991, Stuth et al. 1991, Lyons and Stuth 1992, Leite et al. 1992, Lyons et al. 1993, Pearce et al. 1993, Leite and Stuth 1994). Reflectance is influenced by number and type of chemical bonds in the feces. Primary wavelengths in prediction equations appear to be associated with the fiber, alkanes and microbial fractions of the feces. Prediction equations are developed from fecal samples of intact animals and extrusa of esophageal fistulated animals sharing the same landscape over a wide array of forage conditions. Lyons and Stuth (1992) developed a prediction equation that predicted dietary CP and DOM at similar levels of accuracy as standard wet chemistry lab analyses. To date, dietary prediction equations for cattle appear to be highly reliable across a broad spectrum of forage types including subtropical shrublands, temperature and tropical pastureland, temperate and sub-tropical grasslands, desert shrublands, desert grasslands, mediterranean annual grasslands, hardwood forests, coniferous forest, marshland, and mountain meadows in the USA. NIRS fecal profiling offers a mechanism to nutritionally profile free-ranging animals in large, diverse landscapes.

Information from NIRS analyses is intended for use with programs like the Nutritional Balance Analyzer (NUTBAL-PRO) decision support system which models CP and net energy (NE) status of cattle, sheep, and goats, and MP/net energy status of cattle (Ranching Systems Group 2000). This computerized decision aid lets the user describe the kind, class, and breed of animal to be monitored, characterize body condition and environmental conditions, establish weight performance targets and enter NIRS results. With this information, the program produces a nutritional balance report for protein and net energy. If a deficiency exists, the user can use NUTBAL-PRO to determine the amount of least-cost feedstuff necessary to correct the problem.

The NUTBAL-PRO system uses a combination of published systems including the NRC's 1984, 1987, 1996 basic nutrient requirements formulas, Fox et al. (1988) adjustments to the NRC (1984) equations, McCollum's (1994) rumen degradable protein thresholds and DOM/CP ratio concepts and Moore and Kunkel's (1995) concept of intake change rate and deviation of metabolizable energy due to associative effects in growing animals. Where NUTBAL-PRO deviates from other NRC or ARC systems is in the application of a quasi-metabolic fill system to predict dry matter intake of the animal. The system is based on of early work by Conrad et al. (1964), Forbes (1980, 1984) and to some extent the Danish Fill system and derivation from research performed by Kartchner (1981), Fischer (per. com.). Use of this approach allows modeling of fecal output processes, which consider more than just the digestion process. Impacts of forage availability, appetite drive and associative effects can be characterized in both fecal output as proportion of fat-corrected body weight and metabolizability of ingested forage. Much of the baseline fecal output factors are derived from literature review, expert opinion and unpublished data extrapolated from prior studies. Basal fecal output factors of mature animals are relatively less complex than growing animals in NUTBAL-PRO. Fecal output factors of growing animals reflect differences in the sexes, impact of DOM/CP ratio, threshold rumen protein degradability and associative effects.

Intake is estimated by two primary components: fecal output and the indigestible fraction of the diet and can be calculated in its simplest form:

$$\text{Voluntary Intake (kg DM/d)} = \frac{\text{Fecal Output (kg DM/d)}}{\text{Diet Indigestible Fraction (kg IDM/kg DM)}}$$

where Diet IDM = 1 - (TDN % *.01)

This voluntary intake equation is described by Ellis et al. (1988) as the "physical constraints" model of intake which assumes that fecal output is a constant percent of the fat corrected body weight of an animal in stable metabolic and physiological state (Ellis 1978, Forbes 1980, Minson 1982). The positive relationship between daily voluntary intake and digestibility and the non-significant relationships between digestibility and fecal output both suggest that increased intake with increased digestibility is attained by increasing the dry matter load within the gastrointestinal tract (Ellis et al. 1988). The indigestible fraction is determined by the reciprocal of the total digestible nutrients (TDN or DOM*1.05) in the diet selected by the animal. Other expressions of digestibility (DDM and DOM) are converted to TDN to standardized computation of IDM. As digestibility increases, intake increases as long as indigestible dry matter limits are not exceeded. Fecal output changes as capacity of the gastro-intestinal tract changes in response to morphological differences between species, breeds and individuals as well as physiological stages of the animal interacting with the environment. We submit that these fecal output levels within physiological stages and within species can be used to predict potential forage intake when expressed as a proportion of fat corrected body weight. Furthermore, these fecal output factors can be used as driving variables in simulation and decision support models.

Both NRC (1987) and ARC (1980) define intake based on animal's energy requirements and assumed feed energy content. As the Standing Committee on Agriculture (1990) stated "most of the schemes developed in other feeding standard systems are applicable only to housed or other hand-fed animals." In other words, these intake formulas estimate what animals need to consume to meet energy requirements not what they will consume ad libitum under grazingland conditions. In most instances, voluntary intake of ruminants in free-ranging conditions exceeds that predicted by NRC (1987) or ARC (1980) intake equations.

Under extensive grazing, intake is simultaneously influenced by the amount of forage on offer, the concentration of critical nutrients (energy, crude protein, minerals), ratios of of nutrients and partitioning of components within these nutrients. Fecal output is not only sensitive to animal metabolic and physiological state but the diet crude protein/energy concentration/ratio/fractions, forage availability, environmental conditions, feed supplements/additives, and metabolic modifers such as growth hormones and ionophores (NRC 1987, Fox et al. 1988, Fox et al. 1990). Concentration and ratio of critical plant nutrients is affected by photosynthetic pathway (C3 vs C4), growth habit (grass, forb browse), stage of growth, rate of growth at the time of ingestion, and level of leaching from senescent plant tissue.

The following aspects affecting ruminant intake are considered in NUTBAL-PRO when assessing the level of demand that animals will place on the forage resource and their subsequent nutrient balance.

Species

Smaller body-sized ruminants have proportionally smaller forestomachs and faster rates of digesta passage, thereby generally resulting in increased fecal output as a percentage of fat-corrected body weight. Typical baseline fecal output constants (kg dry matter intake per kg of fat-corrected body weight) for dry, open females of cattle, sheep and goats are 0.01, 0.011 and 0.012 (Ellis et al. 1988, Ranching Systems Group 1993). NUTBAL-PRO computes nutrient balance of cattle, sheep, goats, and horses. This paper only deals with cattle intake algorithms.

Breeds

All nutrient requirements and intake functions assume a medium frame, body condition score 5 *Bos taurus* cow, bull or steer. All other computations are computed as deviations from this standard (Fox et al. 1988). Dairy cattle breeds have higher gastro-intestinal capacity relative to body volume, probably as a result of milk production levels. This greater capacity results in proportionally higher intakes for equivalent fat-corrected body weights compared to *Bos taurus* breeds. Fox et al. (1988) indicated that intake would be 11% higher for Holsteins and 4% for Holstein crossbred animals. Special attention needs to be placed on many of the dual purpose breeds to determine the level of deviation from traditional beef breeds relative to fecal output relationships. Cattle breeds of tropical origin (*Bos indicus*) have been reported to adjust net basal metabolism and probably fecal output patterns according to genetically induced biological cycles which are counter to those of *Bos taurus.*

Before conducting a nutritional balance analysis in NUTBAL-PRO, animals must be matched to the proper breedtype. It may be necessary to adjust the default values for standard breeds. The first concern is frame score. The table below provides a guide for calibrating a specific herd of cattle. The values assume a body condition score of 5 (moderate fatness).

Table 1. Body Weight and Height of Cattle of Different Frame Scores (by age class)

------------------------------------Inches/Pounds Basis------------------------------------

	205 days		420 days		Mature	
Frame	Height	Weight	Height	Weight	Height	Weight
1	35.1	357.2	41.0	582.1	44.1	882.0
2	37.0	374.9	43.0	619.6	46.1	954.8
3	39.0	396.9	44.9	654.9	48.1	1029.7
4	41.0	419.0	46.9	694.6	50.0	1102.5
5	43.0	438.8	48.9	729.9	52.0	1175.3
6	44.9	458.6	50.8	767.3	54.0	1250.2
7	46.9	480.7	52.8	804.8	56.0	1323.0
8	48.9	500.5	54.8	840.1	57.9	1395.8
9	51.2	522.6	56.7	882.0	59.9	1470.7

--------------------------------Centimeters/Kilograms Basis--------------------------------

	205 days		420 days		Mature	
Frame	Height	Weight	Height	Weight	Height	Weight
1	89	162	104	264	112	400
2	94	170	109	281	117	433
3	99	180	114	297	122	467
4	104	190	119	315	127	500
5	109	199	124	331	132	533
6	114	208	129	348	137	567
7	119	218	134	365	142	600
8	124	227	139	381	147	633
9	130	237	144	400	152	667

The mathematical computations to derive the values in Table 1 are as follows:

For any mature animals of age greater than or equal to 5 years the following formula is used to calculate body weight at body condition score 5:

weight (kg) = (366.5833332+(33.35*frame score))

If the mature animal is less than 5 years of age, then the following formula is used to calculate body weight (kg) at body condition score 5:

weight = 240 + 16 * (frame score +0.5) + (22.3 + 3.25 * (frame score + 0.5)) * age(years)

If the cattle are growing or breedable growing animals and less than 18 months of age, the following body weights at condition score 5 are computed by age (months) for females. The same equations are used for intact males and castrates except a multiplier is used to reflect a larger body weight. Intact males (bulls) use a 1.25 multiplier and castrates (steers) use a 1.05 multiplier. To compute age, the months input must be converted to days in the following manner:

age (days) = age (months) * (365/12)

Then the weight at body condition score 5 is calculated as follows:

weight (kg) = 10.49736 + (13.15 * frame score) + (0.598793*age (days))

If the growing animal is older than 18 months, convert the age to years and use the frame score and age formulas for less than 5 year old mature animal. The same sex related adjustments are used as for the less than 18 month old growing or breedable growing animals.

Other animal attributes requiring adjustment may include, net basal metabolism factor, indigestible dry matter (IDM) fill factor, hide thickness, and maximum hair length. Intake is impacted directly by the IDM fill factor. An example of modification of IDM fill can be found in heritage herds that have adapted to local conditions.

Body Condition

One of the primary assumptions of nutritional requirement systems should be that the weight of the animal should be standardized to a given level of fatness. Standard reference weights for cattle, in our opinion, should be based on an observable average fatness index or body condition score 5 on a 1-9 system. This corresponds to a body fat content of 22%. Too many intake studies have been reported on a percent body weight basis without any correction for fatness, leading to a wide array of "intake relationships" in the literature that cannot be compared or contrasted. The use of a standard reference weight at an average fatness allows intake determinations across a wide array of body fatness, insuring that these determinations are more a reflection of gastro-intestinal tract size/function than animal weight. Body condition and age relationships in growing animals also emerges the issue of higher fecal output factors for animals experiencing "compensatory gain" situations (Koong et al. 1982, Abdalla et al. 1982). For example, with nutritionally stressed growing animals, failure to correct body weight for fatness would result in underestimates of intake. Gastro-intestinal tract capacity in these animals is greater than indicted by body weight alone. This particular example is also age dependent because weight per condition score increases until maturity (60 months in the case of cattle). If body condition is a five, use their current weight. The following adjustment factors need to be applied to current weights before computing potential IDM base output values (Fig. 1). The weight calculated is the weight used by the nutritional engine to determine IDM values.

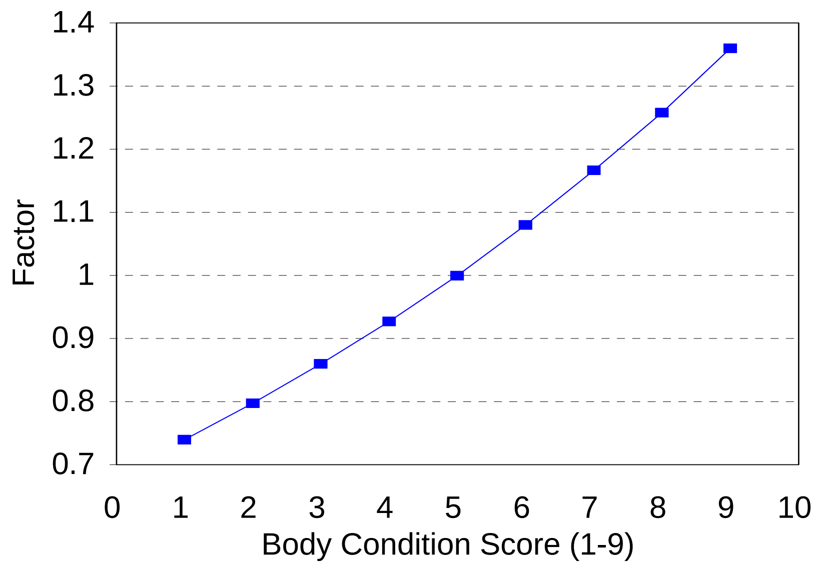
Body Condition >5

Body Weight/(.5444 + (.0898 * Body Condition Score)

Body Condition <5

Body Weight/(.6663 + (.0657 * Body Condition Score)

Figure 1. Adjustment of body weight relative to body condition score to derive a standard reference weight.



Compensatory Gain Issues

Because NUTBAL-PRO corrects body condition to an equivalent body condition, growing animals in body conditions scores less than 5 have adjusted body weights that allow proportionally more intake per unit of body weight

(Fig. 2)

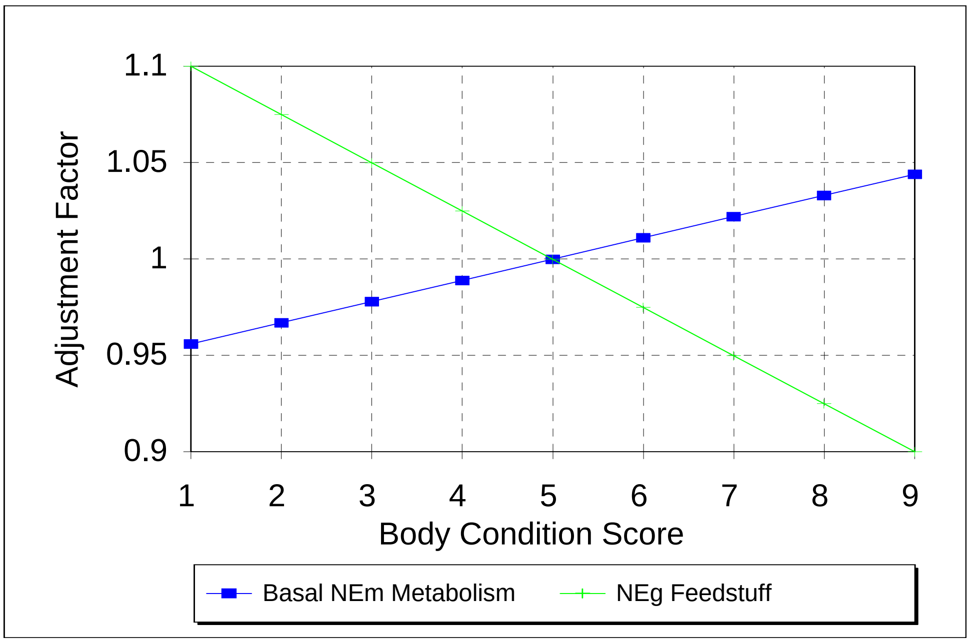
Compensatory gain is most common among young animals subjected to suboptimal nutritional regimes resulting from overstocking of the forage base, underfeeding of the lactating dam, and/or poor grazing/nutritional management of the growing animal postweaning. Compensatory gain can only occur if the animal has not been "stalled" or stunted in the development of it genetic potential to develop its skeletal frame; i.e., the animal's morphology indicates that sufficient skeletal development has occurred to allow realimentation of the soft tissue, muscle tissue and fat deposition to levels consistent with the age and size of the animal under normal conditions. Compensatory gain is the result of reduced net basal metabolism, increased efficiency in conversion of net energy of gain of forage/feedstuff consumed and proportionally greater intake.

Since maintenance energy costs are greater for soft tissue than for muscle and adipose (fat) tissue, animals with less organ mass than normal have lower net basal metabolism per unit of body weight. The largest mass of organs affecting net basal metabolism is the stomach and small and large intestines along with the liver and to a lesser degree kidneys, heart and spleen. The liver of compensatory lambs have been noted to be 45-60% less and the stomach, small/large intestines 28-48% less. Fasting heat of production was 20-22% less when compared to lambs on proper planes of nutrition. NUTBAL-PRO uses the NEm and NEg adjustments proposed by Fox et al. (1988).

Figure 2. Relationship of body condition on net basal metabolism (NEm requirements) and ability to convert NEg of consumed dry matter when expressing a compensatory gain effect.

Mature Cows

The gastro-intestinal of animals that are not carrying a fetus or that are the first two trimesters of



pregnancy is similar to that of the baseline fecal output constant for the species. However, at least with cattle, there may be as much as a 10% reduction in fecal output during the last trimester. Although, this reduction has usually been attributed to reduced rumen capacity in relation to the growing fetus, some evidence indicates that increasing estrogen levels may be at least in part responsible (Forbes 1984).

Given the profound impact of lactation on nutrient demand by the animal, special emphasis should be placed on greater understanding of fecal output dynamics associated with lactation, especially in gain/loss situations (Standing Committee on Agriculture 1990). Once lactation begins, digestive tract hypertrophy (expansion) occurs to accommodate increased gut fill, resulting in an increased capacity for nutrient absorption and increased nutrient flow into the metabolizable nutrient pool of the dam (Collier 1985). Increased gastro-intestinal capacity results in greater fecal output expressed on a fat corrected body weight (BW). Fecal output (%

BW) lags peak milk production and attains a peak value approximately 16 weeks after parturition in cattle (Standing Committee on Agriculture 1990). The degree of nutrient stress during early lactation can reduce peak milk yields and the subsequent linear decline phase of the lactation curve (Collier 1985). For example, in cattle a decrease in body condition score during the first 20 weeks of lactation can result in a 7% reduction in milk production per unit decline in condition score unit, i.e. 21% from 6 to 3 condition score (Grainger et al. 1982, Ingrastern ( ).

NUTBAL-PRO estimates the current potential milk yield, expressed as the ME value of the milk for the young, from equation 66 in the *Agric. Syst*. Paper on GrazFEED. This equation is basically a Wood's function scaled for the mature size and milking potential of the breed type and the maturity of the female. The milk yield for the breed, peak milk day, and expected duration of lactation is used in the following sequence of equations to calculate potential kg of milk per day:

V = 4 (decimal fraction of peak milk yield when duration of lactation reached)
c = -log(V) / (-peakMilkDay + duration of Lactation + peakMilkDay *
log(peakMilkDay / duration of Lactation))
b = peakMilkDay * c
a = milkYield / (peakMilkDay^b) * (-b)^exp
daily kg of milk = a * days Lactation^b * (-c*days lactation)^exp

An adjustment to milk yield is made based on the age of the cow. If the cow is 4-5 years old, or greater than 10 years old, the factor is calculated using the following equation:

milk age adj. factor = 0.996964 - (0.00118 * days Lactation) +
(0.00000314 * days Lactation * days Lactation)

If a cow is 3-4 years old, the factor is calculated using the following equation:

milk age adj. factor = 0.960179 - (0.0022 * days Lactation) +
(0.00000697 * days Lactation * days Lactation)

If a cow is 2-3 years old, the factor is calculated using the following equation:

milk age adj. factor = 0.575714 + (0.000277 * days Lactation) +
(0.00000269 * days Lactation * days Lactation)

The milk age adj. factors are multiplied by the milk parameter to obtain the kg of milk per day used to set the baseline fecal output factor for lactating cows.

daily kg milk = daily kg of milk before adj. * milk age adj. factor

Adjustments can be made to potential milk yield in NUTBAL-PRO using the response adjustment feature. If a metabolic modifier is being administered that effects potential milk yield, the adjustment will be made at this point in the calculation sequence to ensure that the base fecal output is set correctly as well as any adjustments configured in the response adjustment screen.

The baseline fecal output factor for mature cows is .01. Adjustments are made for lactation, pregnancy and other influences from this number.

Lactation is a complex sequence of calculations starting with adjustment of the stored value for peak milk yield relative to body condition. Peak milk yield estimates of cows with body condition scores less than a 5 are adjusted down 7% per score unit. The Woodsman equation (Fox et al. 1988) is used to compute milk yield for the day of lactation specified. The body condition adjusted milk yield is then adjusted for cow age decreasing from age 5 years down to 2. The following equation is used to set the base fecal output factor if days lactating is greater than 0.

fecal output = .00993848 + (.000372 * (daily kg of milk))

If lactation is less than 158 days, a lag factor is applied with the following formula (Fig. 3):

fecal output = ((.00996 + .006387 * Lactation Day) * (non-lag fecal factor -.009))+ .009

Figure 3. Simulated milk yield an fecal output of a non-supplemented lactating cow (F1 Hereford x Brahman cross) with a frame score of 5 in body condition score 5 weighing 1176 lb. and grazing a non-limiting forage resource with crude protein of 8.5% and digestible organic matter of 58.5%. The animal is in a thermal neutral situation.

An adjustment is made to fecal output if a cow is greater than 172 days pregnant. About 2/3 of fetal growth occurs during the last 1/3 of pregnancy therefore requiring an adjustment for gestation when the cow begins to enter the third stage. The gestation adjustment in NUTBAL-PRO is calculated with the following equation:

gestation adj = 1 – ((-185.94993 + 36.17768 * log(days pregnant)) * .01)

The equation effect of gestation after day 172 is shown in figure 4.

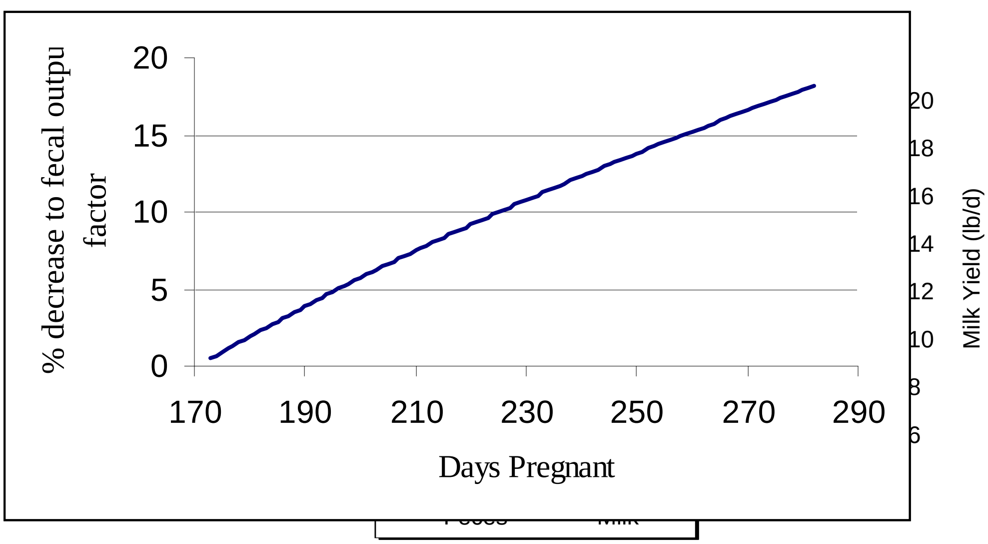


Figure 4: Percent decrease to fecal output factor based on day of gestation.

Mature Bull and Ox

Mature Bull	.0102
Mature Ox	.01

Growing Heifers

Because growing animals are sensitive to protein concentration and ratios in their diet and this level of sensitivity changes with age of the animal. Review of research reported by McCollum (1994) and Moore (1994) and Moore and Kunkel (1995) have indicated that IDM output in growing animals is influenced by DOM/CP ratio and the proportion of rumen degradable crude protein. Diets are considered imbalanced below a DOM/CP ratio of 7 with optimum levels approaching 4. Generally, DOM/CP ratios < 4 result in a suppression in IDM output if rumen degradable protein is >75%, probably a result of negative post-ingestive feedback or malaise (Provenza 1995). These baseline values are not adjusted for level of escape available crude protein or level of starch and rapidly fermentable carbohydrates (see section on feedstuffs and associative effects)

If rumen degradable protein is less than 75% as in most rangeland species, then the following formula is applied to compute the baseline IDM factor. This formula considers age of the animal and DOM/CP ratio of the diet.

((0.02344 - (0.00642 * log10 (avg_age_mo))) - ((0.015979 - (0.00711 *log10 (avg_age_mo))) * log10 (DOM/CP ratio))) * (1.15 - 0.00033 * adjusted body wt.)

If rumen degradable protein is greater than 75% as in many cool-season annuals such as ryegrass, then the following set of baseline IDM factors are used for diets greater than and less than a DOM/CP ratio of 4.

DOM/CP less than or equal to 4

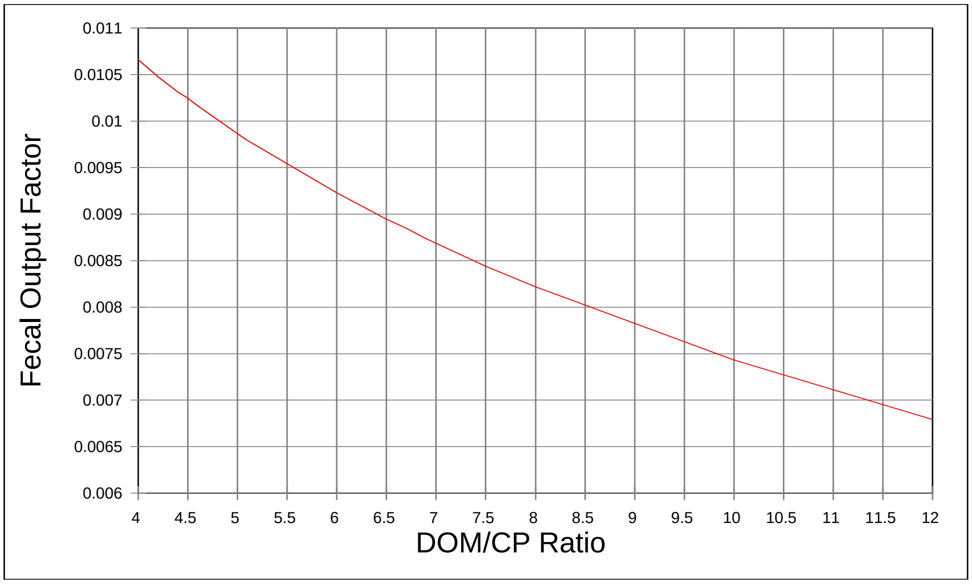
(0.03024 - (0.01749 * log10 (Total_diet_DOM%)) + (0.016252 * log10 (DOM/CP ratio))) * (1.042694 - (0.05912 * log10(avg_age_mo)))

DOM/CP greater than 4

(-0.04358 + (0.030661 * log10(Total_diet_DOM%)) - (0.00453 * log10 (DOM/CP ratio))) * (1.042694 - (0.05912 * log10(avg_age_mo)))

Growing Steers

If rumen degradable protein is less than 75% as in most rangeland species, then the following formula is applied to compute the baseline IDM factor. This formula considers age of the animal and DOM/CP ratio of the diet (Fig. 5).



(0.02344 - (0.00642 * log10 (avg_age_mo))) - ((0.015979 - (0.00711 *log10 (avg_age_mo))) * log10 (DOM/CP ratio))

If rumen degradable protein is greater than 75% as in many cool-season annuals such as ryegrass, then the following set of baseline IDM factors are used for diets greater than and less than a DOM/CP ratio of 4 (Figure 6)

DOM/CP less than or equal to 4

(0.03024 - (0.01749 * log10 (Total_diet_DOM%)) + (0.016252 * log10 (DOM/CP ratio))) * (1.042694 - (0.05912 * log10(avg_age_mo)))

DOM/CP greater than 4 (see Figure 6)

(-0.04358 + (0.030661 * log10(Total_diet_DOM%)) - (0.00453 * log10 (DOM/CP ratio))) * (1.042694 - (0.05912 * log10(avg_age_mo)))

Figure 5. Fecal output factor as influenced by DOM/CP ratio of the diet consumed by a 10-m old steer (F1 Hereford x Brahman) in body condition score 5 weighing 608 lb. grazing a non-limiting forage condition. Maximum daily temperature is 85E F with a dry coat with 5 mph windspeed and night-time cooling. No metabolic modifiers are used and rumen degradable protein is less than 75% of crude protein.

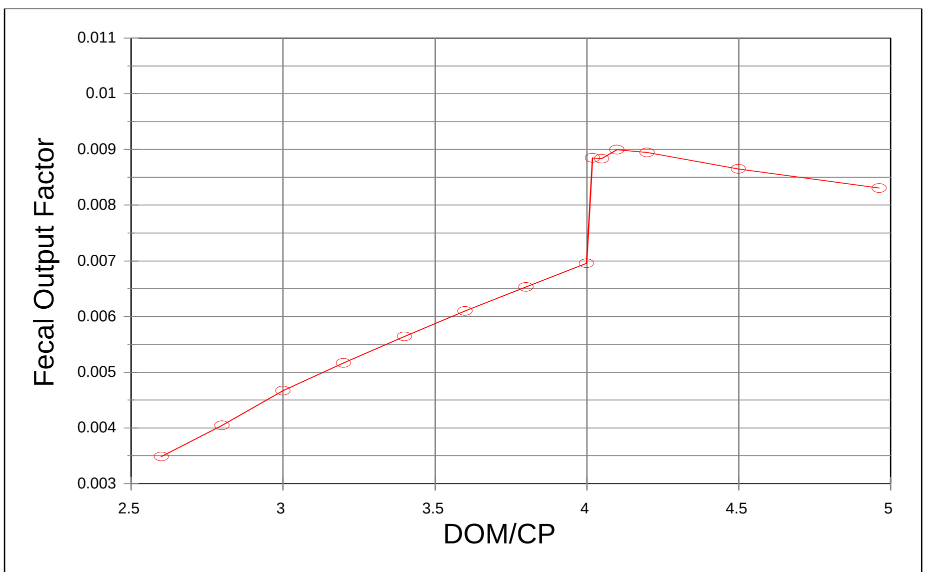
Figure 6. Fecal output factor as influenced by DOM/CP ratio of the diet consumed with rumen degradable protein greater than 75% of crude protein by a 10-m old steer (F1 Hereford x Brahman) in body condition score 5 weighing 608 lb. grazing a non-limiting forage condition. Maximum daily temperature is 85E F with a dry coat with 5 mph windspeed and night-time cooling. No metabolic modifiers are used.

Growing Bulls

If rumen degradable protein is less than 75% as in most rangeland species, then the following formula is applied to compute the baseline IDM factor. This formula considers age of the animal and DOM/CP ratio of the diet.

(0.02344 - (0.00642 * log10 (avg_age_mo))) - ((0.015979 - (0.00711 *log10 (avg_age_mo))) * log10 (DOM/CP ratio))

If rumen degradable protein is greater than 75% as in many cool-season annuals such as ryegrass, then the following set of baseline IDM factors are used for diets greater than and less than a DOM/CP ratio of 4.



DOM/CP less than or equal to 4

(0.03024 - (0.01749 * log10 (Total_diet_DOM%)) + (0.016252 * log10 (DOM/CP ratio))) * (1.042694 - (0.05912 * log10(avg_age_mo)))

DOM/CP greater than 4

(-0.04358 + (0.030661 * log10(Total_diet_DOM%)) - (0.00453 * log10 (DOM/CP ratio))) * (1.042694 - (0.05912 * log10(avg_age_mo)))

Breed Adjustment
If an adjustment to breedtype has been made in the NUTBAL-PRO system as discussed in the Breeds section above, the adjustment is applied at this point in the model. For example, a Holstein breed is configured with a fecal output adjustment of 1.08 which will increase the fecal output factor calculated thus far by 8%.

Environmental Factors

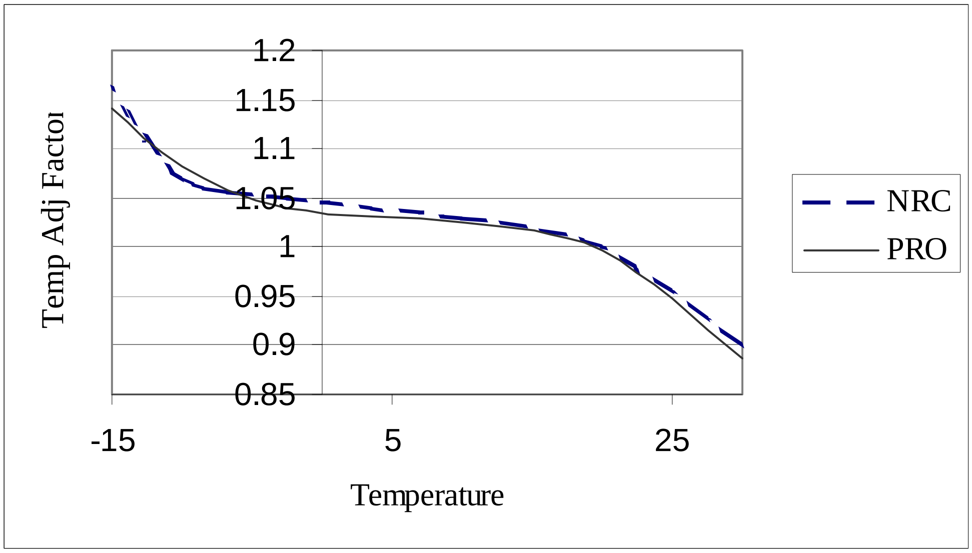
NUTBAL-PRO uses mean daily temperature to calculate the current months effective temperature index (CETI). CETI is calculated based on the Cornell Research for maintenance requirements of cattle. The equation uses the mean temperature, current relative humidity, wind speed, and hours of sunlight exposure.

CETI = 27.88 - (.456 * mean temp) + (.010754 * (mean temp^2)) –
(.4905 * cur rel humid) + (.00088 * (cur rel humid^2)) + (1.1507 * wind) –
(.126447 * (wind^2)) + (.019876 * mean temp * cur rel humid) –
(.046312 * mean temp * wind) + (.4167 * hours of sun exposure)

The temperature adjustment to fecal output is derived from NRC 1996 Errata by creating a continuous function from the adjustment factors for dry matter intake for cattle. The resulting equation applies a temperature adjustment based on CETI for all temperature ranges greater than or less than 20 degrees C.

temp adj = (-.00001*(CETI^3)) + (.0002*(CETI^2)) - (.0019*CETI) + 1.0336

If the CETI value is calculated to be 35 C or greater and night cooling is present then the temperature adjustment is set at .783. If CETI is 35 C or greater and night cooling is not present the temperature adjustment is set at .65. The lower temperature at which CETI becomes constant is –15 C. At this temperature and below, the temperature adjustment factor is set at 1.16. The calculated adjustment factor is multiplied by the fecal output factor calculated thus far in the model. The values suggest by NRC 1996 Errata and the values produced by using the equation above are graphed in Figure 7 to show the relationship established.



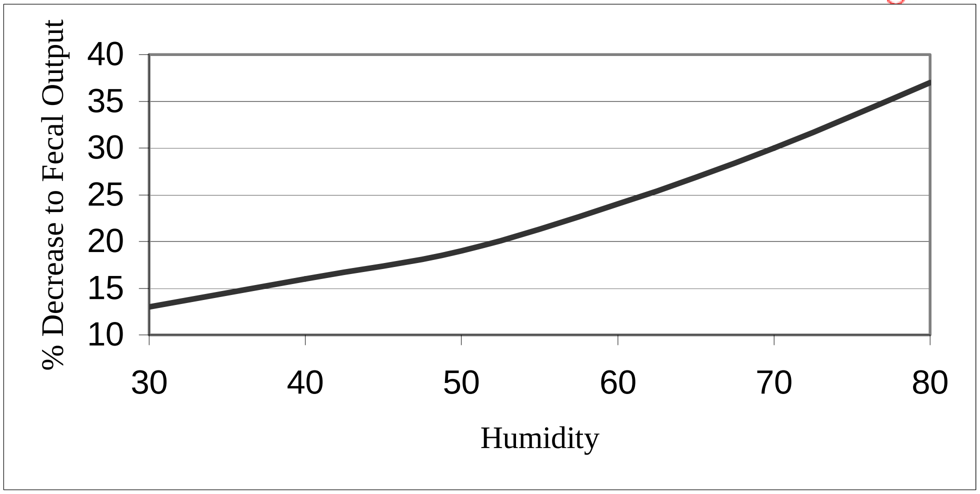


Figure 7. Relationship between NRC Errata suggested adjustment for temperature plotted with trendline for NUTBAL-PRO equation to create a continuous adjustment for temperature.

Since the CETI calculation uses a number of environmental variables to compute an effective temperature index, it is important to understand how the variables effect the overall adjustment factor calculated from the CETI equation. Relative humidity greatly increases the effect of temperature on fecal output in hot conditions. For example, a mean temperature of 85 F obtained from a maximum temperature of 96 F and a minimum temperature of 74 F will yield anywhere from a 13% decrease to a 37% decrease to fecal output based on relative humidity numbers ranging from 30% to 80% respectively. This point is illustrated in Figure 8. The calculations shown assume no wind and 8 hours of direct sunlight exposure.

Figure 8: Effect of relative humidity on CETI and temp adjustment factor with a maximum temperature of 96 F and minimum temperature of 74 F.

Obviously, inherent genetic characteristics of ruminant species and breeds, affect the upper and lower critical temperatures at which the above responses occur. Hide thickness, hair length, body surface area, and water turnover via evaporation (respiration and sweating) are key characteristics affecting voluntary intake response to heat and cold stress (Fox et al. 1988, Loza et al. 1992). Heat stress not only reduces intake but also decreases milk yield (Stephenson et al. 1980, NRC 1981). Milk yield is also reduced when temperatures fall below -5 C even though intake rises (NRC 1981).

In many arid climates, animals are trailed long distances to water sources resulting in reduced forage intake, particularly if ruminates require daily access to water (Louw 1984). Gordon (1965) observed no changes in intake during the first two days of deprivation in Merino sheep but a 46% decrease in intake was observed by the fourth day of deprivation. Weeth et al. (1967) similarly noted a 50% reduction of each preceding day's intake during four days of water deprivation in Hereford heifers.

Two IDM output adjustments are made for environment. One adjustment in IDM is condition of the animal's coat (NRC 1996). This factor also impacts energy requirements.

Coat Condition	IDM Adjustment Factor
Dry	1.00
Muddy Lower Body	0.85
Muddy Lower Body / Sides	0.85
Covered with rain, mud, or wet snow	0.65

Research suggests that an adjustment must be made to IDM for limited nighttime grazing regimes (Ayantunde. ??). The night grazing adjustment equation adjusts fecal output if the hours of grazing fall below 5.75.

night graze adj. = 1.0066 / (1 + .1080 * exp(-.4861*hour of night grazing))

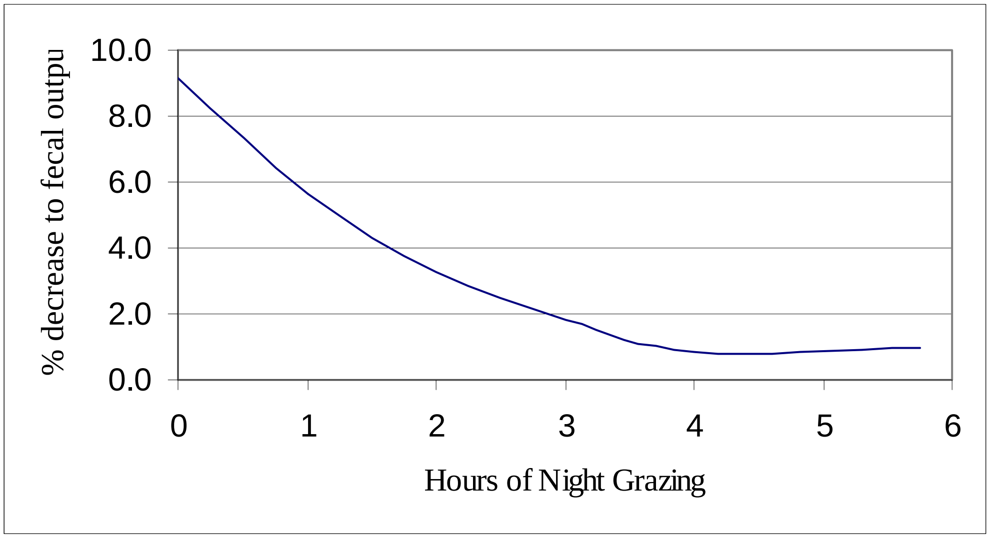


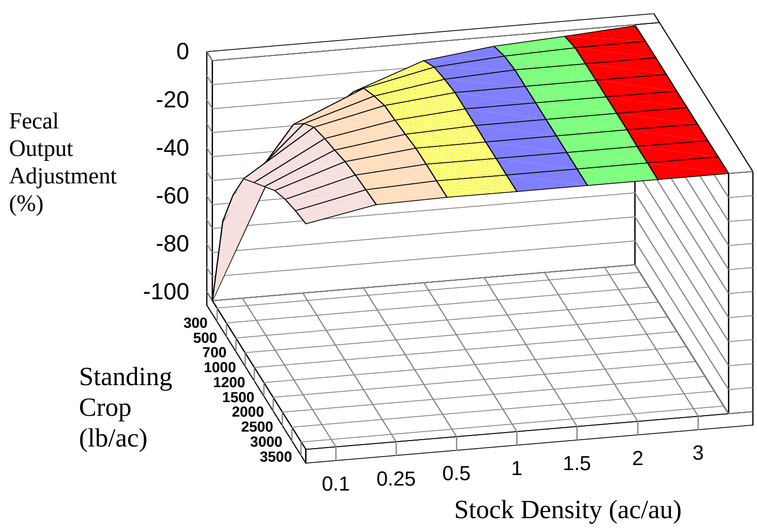
Figure 9: Relationship between % decrease to fecal output based on adjustment for hours of night grazing.

Forage Availability

An underlying assumption of voluntary intake computations is that quantity of forage on offer is not limiting ability to meet dry matter fill constraints. However, animals are often subjected to standing crops (kg/ha) that restrict forage intake. An extensive review by Huston and Pinchak (1991) indicated a wide disparity in threshold levels for restricted voluntary intake. They concluded that the intake of cattle and sheep became when standing crop on temperate grasslands was <1000 kg/ha. However, they noted that on improved temperate and tropical pastures with high stock densities, standing crops become limiting between 1000 and 4000 kg/ha. NRC (1987) and Standing Committee on Agriculture (1990) indicated that intake is restricted below 3000 kg/ha and declines linearly by 15% between 3000 and 1000 kg/ha. As standing crop declines below 1000 kg/ha the impact on intake is exponential. Further examination of this information has revealed that published relationships are derived under high stock density situations where the animal’s ability to acquire dry matter is more constrained. A major concern with NRC (1987) recommendations is that intake is impacted by physical constraints to indigestible dry matter fill (fecal output constant) and the digestibility of the diet. Most standing crop/intake studies blend or "confound" effects of forage availability along with uncorrected body weight for fatness, one possible source of the large variation reported in threshold values across studies. Although the cause of this disparity is not clear, Hendrickson and Minson (1980) suggested the source of this variation may be that total herbaceous standing crop may be an inappropriate expression of forage allowance. With heterogeneous pastures, they suggested measurement of leaf and stem yields and composition.

Launchbaugh et al. (1990) noted that fecal output of young cows subjected to a "graze out" situations did not decline as a percent of body weight until green herbage standing crop was below 400 kg/ha in a shrubland situations. In shrubland conditions subjected to high grazing pressures, total herbaceous standing crop below 900 kg/ha could result in a dietary shift to browse by cattle in an attempt to meet their indigestible dry matter fill constraint (Hanson 1987, Launchbaugh et al. 1990).

Recently, we have found that the relative decline in fecal output was similar to those reported in NRC (1987) when herbage standing crop was >1000 kg/ha. However, fecal output declined to a lesser degree than intake values reported in NRC (1987), particularly when low herbaceous standing crops are below 1000 kg/ha (Hanson 1987). This latter finding has a significant impact on intake computations in NUTBAL-PRO based on the constant fecal output model.



NUTBAL-PRO contains a built in FORAGE utility to determine the appropriate intake adjustment factor, which is entered in the Pasture Condition screen of NUTBAL PRO for the user automatically. It computes the total number of head in the herd specified by summing the number of head of each profile of animals and determines a forage adjustment factor based on standing crop, size of grazing area, growth rate, and non-harvestable forage. Figure 10 below provides a view of the range in conditions that forage availability will most likely impact the animal’s ability to meet their dry matter needs as developed with the FORAGE program.

Figure 10. Relationship of stocking density and forage standing crop on the ability of cattle to acquire their daily demand of dry matter. The graph assumes no growth, 150 lb/ac is unavailable for consumption, 25% of forage is desired for consumption and an animal unit consumes 26 lb DM/d.

External and Internal Parasite Load

External and internal parasite loads also have an effect on fecal output. Parasite load for a class of animals is selected in the herd profile screen of NUTBAL-PRO and applied after the forage adjustment in the model. The % reduction to fecal output is based on the selection made:

NONE-LOW = 0%
MODERATE = 1%
HIGH = 4%

A reduction is calculated for internal load and then for external load.

Activity

An activity adjustment to intake has been added to NUTBAL-PRO to account for limited access to water in arid climates. If a herd does not have access to daily water, fecal output is decreased in the following manner according to the selection made on the Environmental Factors screen in NUTBAL-PRO. Activity selections other than those listed do not effect intake.

HERDING WATER EVERY OTHER DAY 3-6 KM, 1.5-3.5 MI = 10%
HERDING WATER EVERY OTHER DAY > 6 KM OR 3.5 MI = 15%
HERDING WATER EVERY THREE DAYS > 6 KM OR 3.5 MI = 20%

After the fecal output factor is obtained using the above sequence of equations, the IDM value is calculated:

IDM = fecal output factor * adjusted body weight

The potential forage intake of the class of animals or "profile" is computed:

potential forage = IDM / indigestibility

where indigestibility is calculated as that part of the TDN which is indigestible by first calculating the DOM value entered in NUTBAL-PRO to a TDN value as a decimal:

TDN = (DOM * 1.05) * .01
indigestibility = 1 - TDN

Grain and Negative Associative Effects

When dietary crude protein is below 7%, use of a protein supplement can stimulate dry matter intake (Leng 1984). However, at levels above 7% CP, the role of the protein supplements is to meet protein requirements of the animal relative to desired performance level. Growing animals and to a certain extent heavy lactating cows are sensitive to balance of DOM and CP with enhance IDM output when the ratio is below 7 (Moore and Kunkel 1995). To effectively use protein supplements, there must be a good assessment of nutrient requirements relative to performance goals and projected nutrient intake. Allocation of a protein supplement then becomes a matter of feeding enough supplement in a least-cost manner to meet the imbalance. When animals exhibit both a crude protein and net energy imbalance, then the energy concentration (NEm and NEg) in the feedstuff must be considered along with the crude protein content. Often combinations of a protein supplement and high energy feedstuff (soluble sugar in molasses or highly fermentable carbohydrate of grains) or high fat containing protein supplements such as whole cottonseed are used in these situations. Associative effects can manifest themselves when feeding highly fermentable carbohydrates in two ways: (1) increases in protozoa in the rumen which can reduce microbial protein available to the animal or (2) reduction in digestibility of ingested forage due to lowering of ruminal pH which inhibits bacterial cellulolytic activity. A general rule of thumb is that grain intake should remain below 0.4 % of fat corrected body weight to minimize negative associative effects.

The NUTBAL-PRO decision support system provides a utility that uses the "intake change rate" concept developed by Moore and Kunkel (1995) to reflect changes in IDM output and forage digestible organic matter due to associative effects. In NUTBAL-PRO body weight is the fat corrected body weight. Forage values are converted to an organic matter basis assuming 10% ash content. Supplement organic matter basis is derived from stored database values of ash. Correction to IDM output is back calculated from OM intake change values. Moore and Kunkel (1995) also correct ME concentration (mcal/ kg OM) based. NUTBAL-PRO converts the "deviation in ME concentration" to NEm and NEg and corrects the forage NEm and NEg values by subtracting or adding the NEm and NEg deviation values due to associative effects. These values do not affect TDN values used in the divisor of the intake equation. Therefore, in NUTBAL-PRO intake is impacted by associative effects on IDM output while caloric concentration of the diet is impacted independent of TDN derivations. The behavior of NUTBAL-PRO will require further scrutiny in the future to determine if this logic requires modification as we better understand the "mathematics" of associative effects. The equations were developed from all data reporting negative impacts due grain as derived from the literature by Moore and Kunkel (1995).

Fecal Output (Forage Intake) Change Rate (OM, % BW)

.082733 - (.151934 * log10 (Supplement OM intake %BWT)-(.184748* log10(Supplement %CP)

R2 = .23 (related to limited range in data values)

Deviation in ME Concentration (mcal/ kg OM)

-.03626661-(3.12080924*(Supplement OM intake %BWT)^2)+(.32449636* (Supplement OM intake %BWT)^2)*(Supplement ME)^2)+(.00033648* (Forage CP%)^2)* -1

R2 = .67

Minerals

Mineral deficiencies or imbalances in soils and forages have long been associated with low production and reproductive problems in grazinglands throughout the world, especially in the tropics. Many factors affect mineral requirements of ruminants, including kind and level of production, age, level and chemical form of elements, interaction with other nutrients, mineral intake, breed and adaptation (McDowell et al. 1984). The most common mineral deficiency worldwide is lack of P. High amounts of soil Fe and Al accentuate P deficiencies by forming insoluble phosphate complexes. NUTBAL-PRO does not currently assess mineral balance of cattle and assumes mineral status of the animal does not limit animal performance. PHOSCALC, a NUTBAL-PRO utility is currently available to determine P balance of the animal.

Deficiencies of Cu can be a major problem in large areas of the tropics and subtropics. The majority of problems arise from conditioned Cu deficiency where normal amounts of Cu are inadequate because of other forage constituents such as Mo, S, and other factor that block utilization of Cu. Cobalt sub-deficiencies or borderline states are very common worldwide and are difficult to diagnose. Diagnosis is a major problem in assessing mineral status of ruminants and points to a need for better analytical techniques to determine if deficiencies exits. We defer the reader to the extensive review by McDowell (1985) on the role of minerals in ruminant nutrition and their diagnosis.

Metabolic Modifiers

Ionophores such as monensin and lasilocid are feed additives used to improve efficiency of conversion of feed/forage to liveweight gain in growing animals. Allocation of these microbial population modifiers, can affect the dry matter intake of forage, net energy for maintenance value of the forage ingested, digestibility of forage crude protein, and possibly the net basal metabolism of the animal at the tissue level (Byers 1980, Garrett 1987, NRC 1984). Ellis et al. (1988) noted that organic matter digestibility (OMD) of forages was increased by 4% with a quadratic effect on fecal output (% body weight), and a negative impact on DOM below 45% or above 65%, and a peak increase in fecal output at 55% DOM. Greater turnover and escape of ingested forage can also lead to higher propionate levels and more efficient yield of microbial protein synthesis that escapes rumen degradation thereby increasing crude protein digestibility (Garrett 1987,NRC 1984, Ellis et al. 1988). NUTBAL-PRO allows users to configure their own metabolic modifiers based on the labels and effects they feel the stimulants have on the animals.

Parameter Estimation Utilities

The NUTBAL-PRO decision support system has several small programs that enable the user to estimate critical animal and feedstuff attributes.

PKMILK

This program accepts input of calf age, calf weight at the specified age in days and the frame score of the cow to estimate peak milk yield of the cow. The program was adapted from Fox et al. (1988).

CALFWT

This program requires users to input the cows frame score and peak milk yield along with age of the calf in question. Calf weight for the specified age is then computed. Equations were derived from data provided in Fox et al. (1988).

TDNCALC

Because feed tags only provide estimates of crude protein (natural and urea), fiber, ash, moisture, and in the case of liquid feeds, total inverted sugars, it is difficult for users to input TDN values of feeds without requesting TDN values of a particular lot sold to a producer. In many cases feed representatives cannot or will not provide the information. To facilitate this process, TDN requests ingredient composition and provides default digestibility of each component. The user can modify the default digestibility values to derive an "as fed" TDN value (%) and a dry matter TDN (%) value. Entries of feedstuff values in NUTBAL-PRO are reflected on a dry matter basis, requiring computation of CP and ASH values on a dry matter basis from tag values as well.

FORAGE

Because NUTBAL-PEO adjusts intake based on standing crop of available forage, there are instances where animals are subjected to high, short duration grazing pressures where current standing crop rapidly declines. FORAGE is a utility program designed to help adjust intake for these types of situations. An intake adjustment factor is computed based on input of current standing crop, pasture size, animal numbers, average body weight, expected duration of stay in the pasture, percent harvestable forage, non-harvestable standing crop, and growth rate of forage. The user sets the available standing crop to >2300 lb/ac in NUTBAL and then inputs the intake adjustment factor computed by FORAGE if a negative intake factor is computed. Typically, stock densities must be less than 5 ac/au and standing crops less than 2000 lb/ac before negative impacts are noted.

GRAIN

Currently, NUTBAL-PRO cannot represent negative associative effects of high-starch grains without first running the GRAIN utility distributed with NUTBAL-PRO. The body condition score 5 weight and estimated fecal output from the NUTBAL-PRO balance report are input into GRAIN along with information on the diet quality value of the forage (CP, DOM derived from NIRS fecal analysis). The amount of grain fed and analysis value for dry matter (%), ash (%), crude protein (%), and metabolizable energy concentration (mcal/lb). GRAIN outputs a recommended intake adjustment factor which actually reduced fecal output of the animal, adjusted DOM value of the forage on offer and the amount of grain fed expressed as percent of body weight on an as-fed basis.

COWSCORE

COWSCORE is designed to calculate either body condition score, frame score, or weight. You must know two of the attributes to be able to compute the attribute of interest. The age, sex, and two known factors are used to predict the third factor that the user selects. The user can select the BCS system that they would like the utility to calculate on at the top of the utility. If the user is familiar with a BCS 1-5 system for dairy cattle then they would select this option and the utility would calculate based on a 1-5 system. The default for the utility is the 1-9 system. This utility only calculates BCS numbers for CATTLE. A SHEEPSCORE and GOATSCORE utility will be included in future releases.

COWSCORE is a vital utility in setting the proper frame score that consistently reflects the proper weight-body condition score relationship throughout a range of body condition. A stable frame score is essential to set the standard reference weight of the animal. Once a standard reference weight is set, all protein and energy requirements as well as fecal output values are set for determining the animals nutrient balance and weight gain/loss. The change in body condition for a given period of weight loss/gain is determined by the frame score chosen. Therefore, special care needs to be exercised in assigning frame score. The COWSCORE system is based on the National Beef Federation system in the USA and translates it to a 1-9 system. However, if we are dealing with very small frame animals, the actual frame score can be negative or if extremely large can exceed a value of 9. The breedtype profile can accept numbers outside of the 1-9 system using a continuous function.

TOTAL FEED COST CALCULATOR

The total cost of feed that should be entered into the feed screen in NUTBAL is the cost which includes waste, market value, processing cost, storage cost, delivery cost, and feeding cost. This utility is designed to calculate the cost that should be entered in order to get the least cost feed solution based on all of the contributing factors.

PHOSCALC

The PHOSCALC Utility allows you to evaluate whether the levels of excretion of phosphorus exceeds requirements of the **cattle** as computed by the NRC 1996 equations for phosphorus requirements. If the animal is excreting less than required that is the amount that should be made up by additional mineral supplementation. Use of PHOSCALC requires an understanding of pathways of excretion of phosphorus from the body. Most phosphorus is excreted in the feces and when lactating in the milk. Very small amounts of phosphorus is excreted in the urine except when the animal receives high does of phosphorus, causing a "dumping" response into the urinary system to eliminate the excess loading. Some phosphorus is lost as scurf (hair/skin) is shed by the animal. All of these sources of phosphorus loss are reflected in PHOSCALC. To use PHOSCALC, you must first run a NUTBAL PRO case for the animal kind, class and physiological group and note the level of fecal output by the animal. Also, note the concentration of phosphorus in the feces as provided by the NIRS fecal profile analysis. To standardize the requirements, note the standard reference weight of the animal as well. You will also have to specify the desired average daily gain computed in NUTBAL PRO, the days of pregnancy, the days of lactation and the predicted level of milk production. It is best to just print out the report or click back and forth between the balance report and the PHOSCALC utility. After you have run a case, you are ready for inputs into PHOSCALC. These inputs are :

Fecal Phosphorus (%) - this is the percent phosphorus in the feces and is usually in the NIRS fecal scan reports if requested or from wet chemistry conducted for the fecal sample.

Fecal Output (lb or kg per day) - expressed in lbs or kg per day can be found at the lower right side of the NUTBAL PRO balance report.

Body Weight (lb or kg) - input the standard reference weight of the animal (body condition score 5 or average fatness of the animal.)

Average Daily Gain (lb or kg per day) - input the average daily gain desired for the animal. Make sure you input the same average daily gain as specified in the balance report to properly reflect milk production, if a lactating cow.

Growing - click yes if the animal is less than the 55 to 65% of their mature body weight.

Pregnant - click yes if the animal is pregnant and a window will pop up allowing you to input the number of days of pregnancy.

Lactation - click yes if the animal is lactating. A two windows below will pop up to allow you to specify the number days of lactation and the level of milk yield (lb or kg per day) as predicted in NUTBAL PRO.

Press the "submit" button and the phosphorus balance of the animal expressed in grams per day will be computed.

Management Implications

If the balance is positive, then levels of phosphorus intake are in excess of the animal's requirements. If excessive levels are noted, this would be indicative of a high phosphorus loading level in the grazingland landscape and might have possible negative environmental implications. If the value is negative, the animal is most likely not receiving enough phosphorus to meet their needs and a mineral supplementation program should be considered.

Caution*:* There are instances where animals are eating large quantities mineral supplement and yet fecal phosphorus is low, indicating a "spillage" physiological response is occurring. The cause of this phenomena is not clear on grazing lands but other mineral interactions with such things as aluminum or iron may be the cause. Producers are encouraged to collect soil samples, water samples and plant tissue samples to try and isolate the mineral profile of the animals. To confirm spillage requires analysis of urine for phosphorus content.

LITERATURE CITED

Abdalla, H.O, D.G. Fox and M.I. Thonney. 1988. Compensatory gain by Holstein calves after underfeeding protein. J. Anim. Sci. 66:2687-2695.

Adams, D.C., T.C. Nelsen, W.L. Reynolds and B.W. Knapp. 1986. Winter grazing activity and forage intake of range cows in the Northern Great Plains. J. Anim. Sci. 62:1240-1246.

Adams, D.C., R.C. Cochran and P.O. Currie. 1987. Forage maturity effects on rumen fermentation, fluid flow, and intake in grazing steers. J. Range Manage. 40:404-408.

ARC (Argricultural Research Council). 1980. The Nutrient Requirements of Ruminant Livestock. Commonwealth Agricultural Bureaux: Surrey. The Gresham Press, Farnham Royal.

Byers, F.M. 1980. Determining effects of monensin on energy value of corn silage diets for beef cattle by linear or semi-log methods. J. Anim. Sci. 50:158-169.

Collier, R.J. 1985. Nutritional, metabolic, and environmental aspects of lactation. pp. 80-128. In: B.L. Larson (ed). Lactation. The Iowa State University Press, Ames, Iowa. 276 pp.

Collier, R.J. and D.K. Beede. 1985. Thermal stress as a factor associated with nutrient requirements and interrelationships. pp. 59-72. In: L.R. McDowell (ed) Nutrition of Grazing Ruminants in Warm Climates. Academic Press, Inc. Orlando, Florida, USA.

Conrad, H.R., A.D. Pratt and J.W. Hibbs. 1969. Regulation of food intake in dairy cows. I. Changes in importance of physical and physioiological factors with increasing digestibility. J. Dairy Sci. 42:54-62.

Ellis, W.C. 1978. Factors determining grazed forage intake and digestibility. J. Dairy Sci. 61:1828-1840.

Ellis, W.C., M.J. Wylie and J.H. Matis. 1988. Dietary-digestive interactions determining the feeding value of forages and roughages. pp. 177-229. In: E.R. Orskov (ed). Feed Science. Elsevier Sci. Publ., Amsterdam.

Finch, V.A. 1984. Heat stress as a factor in herbivores under tropical conditions . In: R.M.C. Gilcris and R.I. Mackie (eds). Herbivore Nutrition in the Subtropics and Tropics. Science Press, Craighall, S. Africa pp. 81-105.

Fischer (unpublished data). Personal communication

Forbes, J.M. 1980. A model of the short-term control of feeding in the ruminant: Effects of changing the animal or feed characteristics. Appetite 1:21-41.

Forbes, J.M. 1984. The effect of sex hormones, pregnancy, and lactation on digestion, metabolism, and voluntary food intake. pp. 420-435. In: Milligan L P, Grovum W L and Dobson A (eds). Control of Digestion and Metabolism in Ruminants. Prentice-Hall, New York.

Fox, D.G, C.J. Sniffen and J.D. O'Connor. 1988. Adjusting nutrient requirement of beef cattle for animal and environmental variations. J. Anim. Sci. 66:1475-1495.

Fox, D.G., C.J. Sniffen, J.D. O'Connor, J.B. Russell and P.J. Van Soest. 1990. The Cornell Net Carbohydrate and Protein System for evaluating attle diets. Search: Agriculture No. 34, Cornell University Ithaca, NY.

Garrett, W.N. 1987. The influence of monensin on the efficiency of energy utilization by cattle. 9th Int. Symp on Energy Metabolism. EAAP Pub. No. 29:104-107.

Gordon, J.A. 1965. The effect of water deprivation upon the rumination behavior of housed sheep. J. Agric. Sci. 64:31-35.

Grainger C., G.D. Wilhelms and A.A. McGowan. 1982. Effect of body condition at calving and level of feeding in early lactation on milk production of dairy cows. Aust. J. Exp. Agric. Anim. Husb. 22:9-17.

Hanson, D.M. 1987. Influence of contrasting Prosopis/Acacia communities on diet selection and nutrient intake of steers. M.S. Thesis. Texas A&M University, College Station. 236 p.

Hendricksen, R. and D.J. Minson. 1980. The feed intake and grazing behavior of cattle grazing a crop of Lablab purpureus cv. Rongai. J. Agric. Sci., Cambridge 95:547-554.

Huston, J.E. and W.E. Pinchak. 1991. Range animal nutrition. pp. 27-64. In: Heitschmidt R K and Stuth J W (eds). Grazing Management: An ecological perspective. Timber Press, Portland, Oregon, USA.

Ingvartsen....Danish fill system

Kartchner, R.J. 1981. Effects of protein and energy supplementation of cows grazing mature winter range forages on intake and digestibility. J. Animal Sci. 57:432.

Koong, L. J., C.L. Ferrell. and J.A. Neinaber. 1982. Effects of plane of nutrition on organ size and fasting heat production in swine and sheep. Proc. 9th Symp. on Energy Metabolism, EAAP Pub. No. 29:245-248.

Kunkel, W.E., R.S. Sand and P.Garces-Yepez. 1995. Applying new strategies for raising beef heifers. Pp. 35-47. In: 6th Annual Florida Ruminant Nutrition Symposium. Univ. Florida, Gainesville.

Launchbaugh. K .L., J.W. Stuth and J.W. Holloway. 1990. Influence of range site on diet selection and nutrient intake of cattle. J. Range Manage. 43:109-116.

Leite, E.R., J.W. Stuth, R.K. Lyons R K and J.P. Angerer. 1992. Using near infrared spectroscopy to monitor nutritional status of free-ranging goats. pp. 35-41. In: Goat, Wool & Mohair CPR, Texas Agricultural Experiment Station, College Station.

Leite, E.R. and J.W. Stuth. 1994. Influence of duration of exposure to field conditions on viability of fecal samples for NIRS analysis. J. Range Manage. 47:312-314. .

Leng, R.A. 1984. Supplementation of tropical and subtropical pastures for ruminant production. pp. 129-144. In: Gilchrist F M C and Mackie R I (eds). Herbivore Nutrition in the Subtropics and Tropics. The Science Press, Craighall, South Africa.

Louw, G.N. 1984. Water deprivation in herbivores under arid conditions. pp.106-126. In: F.M.C. Gilchrist and R.I. Mackie (eds). Herbivore Nutrition in the Subtropics and Tropics. The Science Press, Craighall, South Africa

Loza, H.J., W.E. Grant, J.W. Stuth and T.D.A. Forbes. 1992. Physiologically based landscape use model for large herbivores. Ecol. Modelling 61:227-252.

Lyons, R.K. and J.W. Stuth. 1991. Procedures for processing cattle fecal samples for NIRS analysis. Anim. Feed Sci. Technol. 35:21-36.

Lyons, R.K. and J.W. Stuth. 1992. Fecal NIRS equations predict diet quality of free-ranging cattle. J. Range Manage. 45:614-618.

Lyons, R.K., J.W. Stuth, J.E. Huston and J.P. Angerer. 1993. Predictions of the nutrient composition of the diets of supplemented versus unsupplemented grazing beef cows based on near-infrared reflectance spectroscopy of feces. J. Anim. Sci. 71:530-538.

McCollum, T. 1994....protein fractions paper

McDowell, L.R. (ed). 1985. Nutrition of Grazing Ruminants in Warm Climates. Academic Press, Inc, Orlando, Florida, USA 443 pp.

McDowell, L.R., J.H. Conrad and G.L. Ellis. 1984. Mineral deficiencies and imbalances, and their diagnosis. pp. 67-88. In: F.M.C. Gilchrist and R.I. Mackie (eds). Herbivore Nutrition in the Subtropics and Tropics. The Science Press. Craighall, South Africa.

Minson, D.J. 1982. Nutritional differences between tropical and temperate pastures. pp. 143-156. In: F.W.H. Morley (ed). World Animal Science. Subseries B, Vol. 1, Chapter 8. Elsevier, Amsterdam, Holland.

Moore, J.E. 1994. Forage quality indices:development and application. pg. 967-998. In: G.C.

Gahey (ed.) Forage Quality, Evaluation, and Utilization. ASA, CSSA, SSCA, Madison, WI.

Moore, J.E. and W.E. Kunkel. 1985. Improving forage supplementation programs for beef cattle. pp. 65-74. In: In: 6th Annual Florida Ruminant Nutrition Symposium. Univ. Florida, Gainesville.

NRC (National Research Council). 1981. Effect of Environment on Nutrient Requirements of Domestic Animals. National Academy Press, Washington, DC, USA

NRC (National Research Council). 1984. Nutrient Requirements of Beef Cattle. National Academy Press, Washington, DC, USA

NRC (National Research Council). 1987. Predicting Feed Intake of Food-Producing Animals. National Academy Press, Washington, DC, USA

Pearce, R.A, R.K. Lyons and J.W. Stuth. 1993. Influence of handling methods on fecal NIRS evaluations. J. Range Manage. 46:274-276.

Provenza, F.D. 1995. Postingestive feedback as an elementary determinant of food prefernce and intake in ruminants. J. Range Manage. 48:2-17.

Ranching Systems Group. 1993. Nutritional Balance Analyzer User's Guide. Dept. of Rangeland Ecology and Management, Texas A&M University, College Station, TX 77843-2126, USA, 148 pp.

Ranching Systems Group. 1992. NIRS Fecal Profiling. Dept. of Rangeland Ecology and Management, Texas A&M University, College Station, TX, 77843-2126, USA, Mimeo March 1992, 2 pp.

Standing Committee on Agriculture. 1990. Feeding Standards for Australian Livestock: Ruminants. CSIRO Publications, East Melbourne, Victoria, Australia

Stephenson, R.G.A, R.D. Rooley, J.K. Findley and P.S. Hopkins. 1980. Effects of heat stress on the lactation performance of ewes accustomed to tropical conditions and the total fluid intake of their lambs. Aust. J. Biol. Sci. 33:449-456.

Stuth, J.W. E.D. Kapes and Lyons R K. 1989. Use of near infrared spectroscopy to assess nutritional status of cattle diets on rangeland. pp. 889-890. In: Proc. XVI Internl. Grassl. Cong., Nice, France.

Stuth, J.W. and B.G. Lyons (eds). 1991. Proceedings of the international conference on decision support systems for resource management. Texas A&M University, College Station, TX. USA.

Stuth, J.W. and R.K. Lyons. 1995. NIRS/NUTBAL nutritional profiling system for grazingland animal management. Ann Zootech 44, Suppl, p.32.

Weeth, H.J., D.S. Sawhney and A.L. Lesperance. 1967. Changes in body fluids, excreta and kidney function of cattle deprived of water. J. Anim. Sci. 26:418-423.

Whitley, E.M. and J.W.Stuth. 1996. Fecal NIRS equations for predicting protein absorption sites of free-ranging cattle. pp. 233-237. In: La Copita Research Area: 1996 Consolidated Progress Report CPR-5047.

Young, B.A. 1986. Food intake of cattle in cold climates. pp. 328-340. In: Owens F N (ed). Proc. Feed Intake by Beef Cattle Symp, Oklahoma St. Univ., Stillwater, USA.

*** Need to add the night grazing paper, NRC 1996 stuff, and the Cornell research reference. I think that is all.