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Use of the NRC Model for Evaluating Nutrient Balances of Grazing Beef Cattle

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The National Research Council Model is a useful tool for predicting nutrient balances of grazing animals when accurate estimates of digestibility, intake and protein degradability are available.

Summary

Research conducted at the Gudmundsen Sandhills Laboratory evaluated the National Research Council Beef Cattle Nutrient Requirements Model. Equations describing seasonal variability in CP, IVOMD, escape protein and degradable intake protein of native Sandhills range and subirrigated meadow were developed. Estimates of TDN and protein degradability for feedstuffs commonly used by Nebraska cow-calf producers are given. The NRC Model generally predicted nutrient balances in agreement with research trials. Microbial efficiency is lower for less-digestible forages. The NRC model is useful for evaluating grazed diets when accurate estimates of protein degradability, digestibility and intake are available.

Introduction

Recently, the National Research Council revised its Nutrient Requirements of Beef Cattle. One of the most significant changes is the move from expressing protein requirements on a crude protein (CP) basis to a system which uses degraded intake protein (DIP) and metabolizable protein (MP). Protein degraded in the rumen and available for use by the rumen microbes is referred to as DIP, while MP is the protein utilized by the host animal and is the sum of the digestible bacterial protein produced in the rumen and the digestible undegradable intake protein (UIP) from the feedstuffs consumed by the animal. The CP system assumed, inaccurately, a constant degradability for all feedstuffs.

The requirement for DIP is estimated by multiplying TDN intake by microbial efficiency. Microbial efficiency, measure of the amount of TDN which the ruminal bacteria convert to microbial protein, is important. In the NRC model, microbial efficiency determines the amount of DIP required by the ruminal bacteria, as well as the amount of MP supplied to the animal from bacterial fermentation in the rumen.

In order for the NRC model to accurately predict nutrient supply to the

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animal, accurate estimates of digestibility, intake and protein degradability are necessary. For grazing animals, estimates of protein degradability of the diet are lacking.

Our objectives were to: 1) report protein degradabilities for forages and other feedstuffs commonly used in Nebraska; 2) demonstrate the importance of microbial efficiency in determining DIP and MP supplies; 3) use research trials previously conducted at University of Nebraska's Gudmundsen Sandhills Laboratory research facilities to evaluate the NRC model; and 4) present guidelines for successful use of the NRC Model.

Procedure

Research trials previously conducted at the University of Nebraska's Gudmundsen Sandhills Laboratory were used as validation data sets. Refer to previous Nebraska Beef Reports cited in the discussion of each respective validation for complete information on supplements, cattle management and other items related to each trial. For purposes of calculating NE_m balances, in vitro organic matter digestibility (IVOMD) values for supplements and forages were assumed to be equal to TDN.

The PROC REG procedures of SAS were used to develop multiple regression equations for prediction of CP, DIP, escape protein (EP; equivalent to UIP) and IVOMD for native upland range and subirrigated meadow. Because a hierarchical model building process was used, all lower-order terms were included when a higher-order term was included in the model (e.g. if X^3 was significant, X and X^2 were included as well).

Results

Table 1 shows the means and standard deviations in nutritive value for Sandhills range and meadow diets collected with esophageally cannulated cows. The values shown are means of diets collected on native winter range, summer native range and subirrigated meadow regrowth during 1992 and 1994 at the Gudmundsen Sandhills Laboratory (1997 Nebraska Beef Report pp. 3-5). Meadow regrowth was most variable in CP, IVOMD and NDF. This may be expected, since these diets covered August through December, representing high-quality regrowth immediately following haying to dormant forage in early winter. Degraded intake protein, when expressed as a percentage of crude protein, was similar for the three forage types and averaged 84.6%.

Regression equations for relating date with CP, EP, DIP and IVOMD of native range and subirrigated meadow forages are shown in Table 2. All equations explained at least 50% of the variation in nutrient content's seasonal changes. The highest R^2 values were obtained for EP for both native range and subirrigated meadow. These equations allow forage quality variables to be predicted for any day of the year.

Table 3 shows the effect of changes in microbial efficiency on DIP and MP supplies, requirements and balances for

Table 1. Means ± standard deviations of crude protein, protein degradability, digestibility, neutral detergent fiber and acid detergent fiber of Nebraska Sandhills forages.

Forage	CP (% of OM)	DIP (% of CP)	IVOMD	NDF (% of OM)	ADF (% of OM)
Summer native range	12.5±2.39	82.3±2.49	66.4±3.37	77.0±4.81	43.6±4.45
Winter native range	6.2±0.45	84.7±2.44	54.0±2.44	84.2±1.61	54.0±1.19
Subirrigated meadow regrowth	13.2±3.89	86.9±2.65	61.7±7.12	71.9±8.80	46.2±6.46

Table 2. Regression equations to predict crude protein, escape protein, degradable intake protein and in vitro organic matter disappearance of subirrigated meadow and native range samples.

Nutrient[a]	Subirrigated meadow Equation[b]	R^2
CP (% of OM)	$1.523698 + 1.346704Z - 0.024693Z^2 + (1.77324 \times 10^{-4})Z^3 - (5.54 \times 10^{-7})Z^4 - (6.27927 \times 10^{-10})Z^5$	.651
UIP (% of OM)	$-4.98141 + 0.543179Z - 0.011468Z^2 (1.08125 \times 10^{-4})Z^3 - (5.11525 \times 10^{-7})Z^4 + (1.18228 \times 10^{-9})Z^5 - (1.06095 \times 10^{-12})Z^6$	.835
DIP (% of OM)	$2.97353 + 1.120967Z - 0.021132Z^2 + 0.00015405Z^3 - (4.860933 \times 10^{-6})Z^4 + (5.536177 \times 10^{-10})Z^5$	.633
IVOMD	$65.14141 + 0.53003Z - 0.0003067465Z^2$	.477
	Native upland range	
Nutrient[a]	**Equation[b]**	**R^2**
CP (% of OM)	$11.119 + 0.062249Z - 0.0006297Z^2 + (1.1781796 \times 10^{-6})Z^3$	.660
UIP (% of OM)	$0.292825 + 0.076754Z - 0.000852403Z^2 + (3.191545 \times 10^{-6})Z^3 - (3.90416 \times 10^{-9})Z^4$	.823
DIP (% of OM)	$9.99572 + 0.035668Z - 0.0004266766Z^2 + (8.168981 \times 10^{-7})Z^3$	.630
IVOMD	$59.54957 + 0.466131Z - 0.005775681Z^2 + (2.192993 \times 10^{-5})Z^3 - (2.665154 \times 10^{-8})Z^4$	.686

[a]CP, crude protein; UIP, undegraded intake protein; DIP, degraded intake protein; IVOMD, in vitro organic matter disappearance.
[b]Z=Day after April 1.

Table 3. Effect of microbial efficiency on degradable and metabolizable protein requirement, supply and balance for a gestating spring calving cow consuming dormant winter range.

	Microbial efficiency					
	8%	9%	10%	11%	12%	13%
DIP supply (g/d)	436	436	436	436	436	436
DIP requirement (g/d)	494	556	618	680	741	803
DIP balance (g/d)	-58	-120	-182	-244	-305	-367
MP supply (g/d)[a]	393	432	472	511	551	590
MP requirement (g/d)	459	459	459	459	459	459
MP balance (g/d)	-66	-26	13	52	92	131

[a]Microbial MP is calculated in the NRC model from TDN and is not reduced when DIP is less than the requirement.

Table 4. Effect of supplemental rumen degradable protein on DIP and MP supplies, requirements and balances for gestating spring calving cows grazing native winter range.

	Year 1 Treatment[a]			
Item	50%	75%	100%	125%
Daily gain, lb	.13	.09	.20	.14
Condition score change	-.6	-.9	-.8	-.8
NE_m supply	15.7	16.9	15.6	16.3
NE_m requirement	16.4	16.4	16.4	16.4
NE_m balance	-0.7	0.5	-0.8	-0.1
DIP supply	642	760	797	892
DIP requirement	663	716	657	689
DIP balance	-21	44	140	203
MP supply	521	557	505	525
MP requirement	455	455	455	455
MP balance	66	102	50	70

	Year 2 Treatment[a]			
Item	29%	65%	100%	139%
Daily gain, lb	.10	.39	.14	.02
Condition score change	-.2	0	-.4	-.3
NE_m supply	13.8	13.9	13.9	13.8
NE_m requirement	16.6	16.6	16.6	16.6
NE_m balance	-2.8	-2.7	-2.8	-2.8
DIP supply	491	567	648	709
DIP requirement	586	589	589	586
DIP balance	-95	-22	59	123
MP supply	463	460	455	448
MP requirement	459	459	459	459
MP balance	4	1	-4	-11

[a]Treatments based on percentage of estimated supplemental degradable intake protein requirement (1996 Nebraska Beef Report, pp. 14-16).

a gestating spring-calving cow consuming dormant winter range. As microbial efficiency changes from 8 to 13%, DIP goes from slightly deficient to highly deficient, while MP moves from deficient to adequate (model does not reduce MP if DIP is deficient). In general, less-digestible forages, which pass from the rumen at slower rates, have lower microbial efficiencies. Forages which pass slower result in slower microbial growth, lowering both the requirement for DIP and the amount of MP produced by the bacteria which ferment that forage. Forages which have higher digestibilities result in more microbial growth which increases the requirement for DIP.

For cows grazing winter range and other low quality forages, we suggest using microbial efficiencies of 9 - 10%. Data collected at the Gudmundsen Sandhills Laboratory with gestating cows grazing winter range support the use of 9-10% microbial efficiency for most dormant forages (1993 Nebraska Beef Report, pp. 8-10; 1994 Nebraska Beef Report, pp. 5-7; 1996 Nebraska Beef Report, pp. 14-16; 1997 Nebraska Beef Report, pp. 8-10). With vegetative forages and high-quality hays, we suggest using 13% efficiency. Using a too-high microbial efficiency will result in over-prediction of the DIP requirement and overestimation of the supply of MP.

Ruminants have the ability to recycle nitrogen to the rumen in the form of urea. Therefore, excess MP (or UIP) can likely substitute for DIP. However, excess DIP cannot substitute for MP or UIP. Because of this ability to recycle nitrogen, slight deficiencies in DIP may not be detrimental to performance, especially when MP supply is greater than the requirement.

Table 4 shows the effect of supplemental rumen degradable protein for gestating spring-calving cows grazing native winter range on NE_m, DIP and MP supplies, requirements and balances (1996 Nebraska Beef Report, pp. 14-16). In Year 1, cow weight and condition score changes were similar for all treatments. In Year 2, cows responded in a quadratic manner to level of supplemental DIP. Based on the cow weight change and condition score data, the rumen degradable protein requirement was not met by the 29% level in Year 2. The NRC model predicted DIP was slightly deficient at the lowest level of supplementation and was adequate for all other treatments in Year 1, indicating only small amounts of supplemental rumen degradable protein are

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required to meet the DIP requirement. In Year 2, the NRC model predicted that cows fed at 29% of the estimated supplemental rumen degradable protein requirement were deficient in DIP. In Table 4, the NRC model calculations were completed using a microbial efficiency of 9%. Model predictions were accurate when this efficiency value was used.

Table 5 shows the effect of supplemental ear corn and/or protein for gestating spring-calving cows grazing native range on cow performance, NE_m, DIP and MP supplies, requirements and balances. The NRC model predicted DIP levels were adequate for the protein treatment and deficient for the supplemental ear corn and ear corn plus protein treatments. A 9% microbial efficiency was used to calculate the DIP requirements and MP supplies in Table 5. Cow weight gains were highest for the protein supplemented treatments, intermediate for the ear corn plus protein and lowest for the ear corn treatment. Net energy for maintenance balances were negative for all treatments. It is possible the treatments containing supplemental ear corn reduced digestibility and intake of the range forage; however, no effort was made to model these possibilities as they were not measured in the trial. If intake and digestibility were reduced when supplemental ear corn was fed, NE_m balances would be more negative for the treatments containing supplemental ear corn. The NRC model does not reduce energy digestibility when DIP is deficient. This trial illustrates the importance of meeting the DIP requirement, especially when energy is supplemented.

Table 6 gives suggested values for effective NDF, CP, DIP and TDN for feedstuffs commonly used by cow-calf operations in Nebraska. When actual analysis values for a particular feedstuff are available, the values from the analysis should be used. These suggested figures serve only as guidelines.

Table 7 gives guidelines for successful use of the NRC Model with grazing cattle. As with any computer program, the output is highly dependent on the input. Critical areas in the input section which need attention are: 1) Microbial yield (efficiency); 2) the 'On Pasture' feature; and 3) the Environment section. Microbial yield impacts both DIP requirement and MP supply. We suggest using 9 - 10% for low-quality hays, winter range and similar forages. Add 1% for lactating cows. Use 13% for vegetative forages, high-quality hays and other forages > 60% TDN. For straws, corn stover and other forages < 50% TDN use 8%. The 'On Pasture' feature will automatically raise energy requirements by approximately 25% as

Table 5. Effect of supplemental ear corn, ear corn plus protein or protein on cow performance, NE_m, DIP and MP supplies, requirements and balances for gestating spring calving cows grazing native winter range.

	Treatment[a]		
Item	Ear corn	Ear corn + protein	Protein
Cow weight change, lb	-121.0[b]	-40.3[c]	14.6[d]
NE_m supply	15.2	15.3	14.6
NE_m requirement	16.4	16.4	16.5
NE_m balance	-1.2	-1.1	-1.9
DIP supply	459	569	628
DIP requirement	632	634	613
DIP balance	-173	-65	15
MP supply	543	577	537
MP requirement	458	458	458
MP balance	85	119	79

[a]Treatments were 3.5 lbs supplemental ear corn; 3 lbs supplemental ear corn plus 1 lb 40% protein cube; or 2 lbs 32% protein cube (1987 Nebraska Beef Report, pp. 36-37).
[a,b,c,d]Means in the same row with different superscripts differ, (P<.05).

Table 6. Suggested values for feedstuffs commonly used by Nebraska cattle producers.

	eNDF	TDN	CP	DIP
Protein meals				
Soybean meal	0	88	49.9	70
Sunflower meal	0	65	25.9	81
Cottonseed meal	0	75	46.1	57
Feather meal	0	88	85.8	30
Blood meal	0	88	90.5	25
Distillers solubles/steep liquor (dry milling)	0	88	28	80
Distillers solubles/steep liquor (wet milling)	0	88	36	80
Harvested forages				
Corn silage	71	75	7.4	75
Alfalfa hay	100	60	16	82
Brome hay, mid bloom	100	66	14.4	84
Alfalfa hay, early vegetative	100	74	30	93
Alfalfa hay, late vegetative	100	67	20.3	85
Meadow hay, high quality	100	67	16.2	87
Prairie hay[a]	100	49	6.8	80
Prairie hay[a]	100	53	7.7	75
Grazed forages				
Sandhills range, June diet	100	68	12.4	82
Sandhills range, July diet	100	67	10.9	82
Sandhills range, August diet	100	64	10.0	84
Sandhills range, September diet	100	59	6.6	86
Winter native range	100	54	6.2	85

[a]Match to nearest CP value.

Table 7. Suggested inputs and guidelines for use of the 1996 NRC model.

1. **Units and Levels Section.**
   Use only Level 1, unless rates of digestion of all feed fractions are known.

2. **Animal Section.**
   Remember that your choice of breed affects maintenance energy requirements.
   Bos indicus cattle have lower NE_m requirements, while dairy and dual purpose breeds have higher requirements. This is discussed in detail in the textbook accompanying the NRC Model.

3. **Management Section.**
   A. Using the '**On Pasture**' feature in the management section will increase maintenance energy requirements by approximately 25% with level terrain and 50% with hilly terrain. The value can be input as a range between 1 (level) and 2 (hilly) in 0.1 unit increments. We recommend using this feature cautiously. In many cases, maintenance energy requirement is not increased by 25% while cattle are on pasture. Requirements are calculated accurately for pasture cattle even if this 'On Pasture' feature is turned off.
   B. **Microbial Yield.** Use 13% (default) for all vegetative forages and forages above 60% digestibility. For lower quality forages such as winter range or hays below 55% TDN use a microbial efficiency of 9-10%. Values as low as 8% may be necessary when the diet consists of mainly straw, stover, or other forages below 50% TDN which have lower passage rates. After calving, intakes and passage rates increase, therefore, microbial efficiency should be increased one percentage unit above that of a gestating cow fed the same forage.

4. **Environment Section.**
   A. **Temperature.** Because of daily fluctuations in temperature, it is difficult to state a temperature which the cattle are subjected to. Interactions also exist with other environmental factors which are discussed below. We recommend using long term average temperatures for a given month or season at a given location.
   B. **Wind speed.** Caution is needed when using this feature. Because cattle behavior is impacted by wind speed, cattle are not subjected to reported wind speeds. Wind speed is generally measured by anemometers positioned 10' above ground. Cattle are seldom subjected to these wind speeds because they will find ways to minimize the effect of wind on them. We recommend using wind speeds of less than 5 miles per hour in most cases.
   C. **Hair Depth.** Use .25 inches in the summer and .5 inches for winter coats.
   D. **Hide.** Use 1 (thin hide) for Bos indicus and dairy breed types, and 2 (average) or 3 (thick) for most English and Continental breeds.

5. **Feeds Section.**
   A. Use the **Feed Library** (a feature separate from the model) to make global changes to feedstuff composition. Use the **Feed Composition** feature to make feed composition changes specific to a ration or problem (composition changes made in this manner will be specific to that input file only).
   B. When estimates of feed intake are unavailable or unknown, use the NRC estimated intake as a guideline. Use the following as **general** guidelines. Dry gestating cows will generally consume 1.8-2.0% of body weight, while lactating cows will consume 2.3-2.5% of body weight.

a way of accounting for the energy cost of grazing activity. In some cases, when hilly terrain is an entered factor, the increase in energy requirement predicted by the model will be as high as 50%. We recommend cautious use of this feature. Grazing activity does require the animal to expend energy; however the increases predicted by the model may sometimes be unrealistic. The model also is very sensitive to environmental inputs, particularly wind speed, when the animal is below its lower critical temperature. We recommend wind speeds of less than 5 mph.

The NRC model is a useful tool for evaluating grazed diets when accurate estimates of protein degradability, digestibility and intake are available. Microbial efficiency appears to be lower for less-digestible forages which have slower rates of passage. The finding that only small amounts of DIP are necessary to maintain gestating beef cows indicates that microbial efficiency is relatively low on these low quality forages. Microbial efficiency has a large impact on estimates of DIP requirement and consequently MP supply.

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