Validation of the Equations Used in Determining Dry Matter Intake, and Metabolizable Protein Requirements for Finishing Lambs as used in the Sheep Companion Module to BRaNDS

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Summary and Implications

The growth equations published in the 2006 NRC "Nutrient Requirements of Small Ruminants" along with the additions added to these equations when used in the Sheep Companion Module to BRaNDS appear to provide reasonable estimations of performance of feeder lambs.

Introduction

The BRaNDS software package was developed originally to balance beef cattle rations, but companion modules have been developed to address the nutrient requirements of sheep. The sheep companion modules followed the guidelines outlined in the 2006 NRC "Nutrient Requirements of Small Ruminants" publication, however in the process of compiling the information contained in this NRC publication into a practical software application to be used for routine ration formulation, a number of biological interactions needed to be quantified to permit a reasonable degree of program robustness across a wide range of feeding programs. The 2006 NRC publication, for instance, does not go into detail in regards to how one should account for the situation where a ration low in rumen degradable protein but excessive in the fraction of rumen by-pass protein. Due to the limited detail on this matter, the methodology used in the cattle edition was applied to the sheep edition of BRaNDS. This paper focuses on the results of methods used for nitrogen recycling in the rumen as well as the validation of the dry matter intake equation used, validation of the weight gain equations and the overall validation process regarding metabolizable protein requirements observed for the feeder lambs used in this trial.

Material and Methods

One hundred and twenty, five month old, weaned, white faced, crossbred, lambs were treated for parasites, placed into groups of 10 and fed one of four ration scenarios: a ration balanced at 100% of the metabolizable protein requirement with the theoretical correct proportion of rumen degradable and by-pass protein being supplied throughout the growing phases (MP100-DIP), a ration balanced to provide 100% of the lamb's metabolizable protein requirement throughout the growing phase but using excessive rumen bypass protein in accordance to the formulas outlined below (MP100), a ration scenario was formulated at 90% of the lamb's metabolizable protein requirement (MP90) and a ration formulated at 110% of the lamb's metabolizable protein requirement (MP110). The ingredients of these rations consisted of rolled shell corn, soybean meal, corn gluten meal, a vitamin ADE supplement, a trace mineral salt, limestone and a chlortetracycline premix product. Feed grade urea was then used in ration MP100-DIP to balance the rumen degradable – rumen by pass protein fractions (see tables 1-4). No forage was provided to the lambs; however the lambs were given straw as pen bedding. It was not determined if any straw was consumed by the lambs. Three pens were assigned to each ration treatment. Lamb rations were adjusted every three weeks to maintain the treatment levels of protein in accordance to the lamb's weight. Lambs started the trial at a live weight near 67 pounds and were fed to a finished weight near 140 pounds. All lambs were fed for the same duration and processed the same day at Iowa Lamb Co. Hawarden, IA.

Growth equations from the NRC publication "The Nutrient Requirements of Small Ruminants" publication were followed with a couple exceptions and those modified equations are listed below. Validation consisted of comparing actual performance with the performance estimated by the suggested equations with the aid of the Student's T test to quantify significance between differences. Treatment differences between metabolizable protein provisions were tested using the mixed model procedure of SAS.

Formulas used to determine metabolizable protein requirements and nitrogen recycling are as follows:

NP rq = net protein requirement (grams)
NP rq = ADGe*(268-(29.4*(RE/ADGe)))

MP rq = metabolizable protein requirement (grams)
MP rq =if EQWT<301 then NP/(0.83-(EQWT *0.00114)
else NP/0.492

FWT = finished wt (kg)
FWT is considered to be mature ewe weight for this program or average mature ewe weight of flock where lamb originates.

BWt = current shrunk body weight of lamb (kg)

EQWT = equivalent shrunk weight
EQWT =((BWT)*478/ FWT)

RE = retained energy after maintenance (Mcal)

ADGe = average daily gain allowed from energy intake (kg)

MP intake = MPmic + MPfeed

MPfeed = UIP (*undegraded intake protein*) from feed that contributes to metabolizable protein (grams)
MPfeed = UIP x .8

MPmic = microbial contribution of metabolizable protein (grams)
MPmic = lower of the following two possibilities:
#1 (Ration crude protein – UIP) x .64
Or
#2 Ration TDN (*total digestible nutrients*) x eNDFadj x MicEff x .64

eNDF = effective neutral detergent fiber
eNDFadj = if ration eNDF% >20 then the adjustment = 1
Otherwise
the adjustment factor = (1 - ((20 - eNDF%) x 0.022)

MicEff = microbial efficiency
MicEff = if(ration TDN% >= 64 then the value = 0.13
Otherwise
The value = (0.29 x ration TDN% - 5.9) x 0.01)

The metabolizable protein (MP) requirement is based on net energy intake in order that weight gain allowed from protein intake is equal to weight gain allowed from energy intake. Degradable intake protein (DIP) requirement is based on ration TDN levels. When DIP is limiting in the MPmic step, the BRaNDS program will utilize excess UIP multiplied by .64 to substitute. The .64 adjustment is based on 80% utilization of excess UIP x 80% utilization of this fraction in the rumen.

Feed crude protein estimates for total protein are based on commercial feed testing laboratory analysis results given as crude protein adjusted for heat damage or excessive fiber while the UIP and DIP fractions of this feed are estimated based on tabular values given in the NRC publication for the given feedstuff.

The formula used to determine dry matter intake were taken from the 1996 Beef Cattle NRC publication rather than the Small Ruminant publication since the small ruminant publication only provided an equation for forage intake with growing lambs and on early evaluation tended to estimate dry matter intake at levels 90 percent higher than what is typically observed in a high energy grain diet. The formula used therefore is as follows:

DMI = ((BWt^0.75*(0.2435 x NE m - 0.0466 x NE m^2 - 0.1128))/ NE m) x TEMP x MUD x BC x TEX
DMI = dry matter intake (kg)

NE m = Net Energy – maintenance concentration of ration (Mcal / kg)

TEMP = air temperature (°C)
TEMP = If air temperature > 25 = 0.9,
If air temperature >15 and<=25 = 1.00
If air temperature >5 and<=15 = 1.03
If air temperature >-5 and<=5 = 1.05
If air temperature >-15and<-5 =1.07
Other wise = 1.16

MUD = If dry yard = 1.00
If muddy yard = 0.8

BC = If body condition is < 3.0 then = 1.02
If body condition is > 3.0 then = 0.95
Otherwise = 1.0

TEX = If feed texture = “pelleted ration” = 1.10
If feed texture = “Long Hay” = 0.88
If feed texture = “silage” = 0.94
Otherwise = 1.00

The formula given by the NRC Small Ruminant publication to estimate forage intake in growing lambs is as follows:

DMI as a percent of mature weight = 6.8 x (BWt / FWT) – 4 x $(BWt / FWT)^2$

The Rations provided during the trial consisted of the following:

Table 1. Rations - Treatment MP100.

Feedstuff	Period 1	Period 2	Period 3	Period 4
Corn %	83.83	86.98	88.88	90.36
Soybean meal %	6.96	5.43	4.42	3.70
Corn gluten meal %	6.96	5.43	4.42	3.70
Urea %	0	0	0	0
Vitamin-mineral %	2.25	2.25	2.25	2.25
Ration NE g	0.68	0.68	0.68	0.68
Ration Cr.Protein	13.7	12.2	11.1	10.4
UIP as % of CP	43.5	42.9	42.3	41.9
MP % of requirement	100	100	100	100
DIP % of requirement	104	93	85	79

Table 2. Rations - Treatment MP90.

Feedstuff	Period 1	Period 2	Period 3	Period 4
Corn %	86.40	88.68	90.65	92.48
Soybean meal %	5.67	4.54	3.55	3.00
Corn gluten meal %	5.67	4.54	3.55	3.00
Urea %	0	0	0	0
Vitamin-mineral %	2.25	2.25	2.25	2.25
Ration NE g	0.68	0.68	0.68	0.69
Ration Cr.Protein	12.4	11.2	10.2	9.6
UIP as %of CP	43.0	42.4	41.8	41.4
MP % of requirement	90	90	90	90
DIP % of requirement	94	86	78	74

Table 3. Rations - Treatment MP110.

Feedstuff	Period 1	Period 2	Period 3	Period 4
Corn %	79.63	84.97	87.09	88.76
Soybean meal %	9.05	6.40	5.33	4.48
Corn gluten meal %	9.05	6.40	5.33	4.48
Urea %	0	0	0	0
Vitamin-mineral %	2.25	2.25	2.25	2.25
Ration NE g	0.68	0.68	0.68	0.68
Ration Cr.Protein	15.9	13.1	12.0	11.1
UIP as %of CP	44.2	43.3	42.8	42.4
MP % of requirement	110	110	110	110
DIP % of requirement	119	99	91	85

Table 4. Rations - Treatment MP100-DIP.

Feedstuff	Period 1	Period 2	Period 3	Period 4
Corn %	83.83	88.19	91.81	94.30
Soybean meal %	6.96	4.54	2.57	1.14
Corn gluten meal %	6.96	4.54	2.57	1.14
Urea %	0	0.46	0.83	1.23
Vitamin-mineral %	2.25	2.25	2.25	2.25
Ration NE g	0.68	0.68	0.68	0.69
Ration Cr.Protein	13.7	12.5	11.5	11.1
UIP as % of CP	43.5	38	32.6	27.2
MP % of requirement	100	100	100	100
DIP % of requirement	104	103	102	105

Results and Discussion

Part 1 – Treatment Effects.

Table 5. Feedlot Performance.

Treatment	Overall ADG	ADG P> |t|	Wt Gain	Wt Gain P>|t|	DMI	DMI P>|t|
MP100	0.70	AB	63.0	A	2.9	AB
MP90	0.67	AB	59.7	AB	2.8	B
MP110	0.71	A	63.5	A	3.0	A
MP100DIP	0.65	B	58.6	B	2.8	B

Table 6. Feedlot Performance.

Treatment	Feed:Gain	F:G P> |t|	Wt. SD	Wt. SD P> |t|	Carcasses*	Carc. P>|t|
MP100	4.1	A	2.8	A	90%	A
MP90	4.2	A	3.1	A	83%	A
MP110	4.2	A	1.7	A	90%	A
MP100DIP	4.2	A	1.9	A	70%	A

*number of animals with a live sale weight over 118 pounds – referred to as “acceptable carcasses” below

Table 7. Carcass Measures (acceptable carcasses).

Treatment	Bodywall	B.wall P> |t|	REA	REA P>|t|	Fat	Fat P>|t|
MP100	0.99	A	2.4	A	0.29	AB
MP90	0.99	A	2.3	A	0.27	A
MP110	1.09	A	2.3	A	0.34	B
MP100DIP	0.99	A	2.3	A	0.30	B

Table 8. Carcass Value (acceptable carcasses).

Treatment	Carcass Wt.	Carc.Wt P> |t|	Dress %	Dress % P>|t|	Yield Grade	YG P>|t|
MP100	59.9	A	50.5	A	2.9	AB
MP90	54.4	A	50.6	A	2.7	A
MP110	60.4	A	50.8	A	3.1	B
MP100DIP	48.6	A	50.8	A	2.8	A

Table 9. Carcass Market Variation (acceptable carcasses).

Treatment	Carc. Wt. SD	SD P> |t|	Dress %	Dress % P>|t|	Yield Grade SD	YG SD P>|t|
MP100	3.5	A	0.02	A	0.51	AB
MP90	4.3	A	0.02	A	0.56	AB
MP110	3.5	A	0.01	A	0.05	C
MP100DIP	4.4	A	0.02	A	0.42	A

*Different letters indicate an expected chance of a larger “t” value of 0.05 level or less

Referring to Feedlot Performance (Tables 5 & 6), ADG (average daily gain) and overall live weight gain did show some minor treatment differences at the end of the trial. These differences were more pronounced early in the feeding period (see Figure 1-A), but lessened substantially in the last month the lambs were on feed. The MP100DIP treatment was the lowest performing treatment and did vary significantly from the MP110 treatment. This difference became apparent mid way through the trial. Early in the trial the MP90 lagged behind the other treatments in ADG, but this difference appeared to be over come during the last three weeks the lambs were fed. Much of this difference may be due to differences in dry matter intake (DMI). The ADG and DMI do seem to parallel each other to some degree, but not perfectly (Figures 1-A and 2-A). Feed dry matter intake to live weight gain conversion did not differ between treatment groups. Live weight variation in the finished pens was calculated and compared. There was a strong tendency towards less variation between pen mates with the MP110 and the MP100DIP rations, however not significant at P>|t| of 0.05, may be of merit to explore with other pens to see if this trend continues. Likewise there was another strong trend towards more acceptable carcass weights over the trial period with the MP110 and MP100 groups but as with the measure of final weight variation this difference could not be stated as significant with the number of pens measured. The carcass data in tables 7, 8 and 9 refer only to the acceptable carcasses, meaning those carcasses which were from lambs with a final live body weight at or above 118 pounds. Since this restriction was put on these carcasses a bias was subsequently applied and thus as expected to a certain degree there was no strong indication of differences in body wall thickness, rib eye area, dressing percent or carcass weight. There was however some differences in rib fat thickness with the MP110 and MP100 animals tending higher in thickness and subsequently also reflected this fatness in carcass greater yield grade values. All lambs were classified as “choice” in terms of marbling. When the degree of pen variation was observed the standard deviation in carcass weights or dressing percent standard deviations did not vary between treatment groups, however when yield grade variation was compared the MP110 treatment displayed a much reduced variation from what was seen in the other groups. If all carcasses which include those too small for evaluation could have been compared I suspect the differences would have been considerably greater. From the results of the trial there is probably not enough evidence to make any sweeping changes to the NRC small ruminant publication in terms of protein requirements, but it does appear that the equations applied by the BRaNDS Sheep Companion modules do account for the recycling of nitrogen to the rumen if the rumen does indeed require extra DIP in these rations. This trial does have limitations in making this claim without reservation since these rations were very highly digestible and did not promote the degree of rumination a higher fiber ration would. It may be because of this limited demand for rumination that the necessity of DIP was lessened and thus gave rise to the situation observed in this trial where higher levels of UIP allowed better performance than balanced DIP. However, as the trial progressed this situation subsided to some degree and it may be partially a result of the lambs adapting to the urea in the ration.

Part 2 – Equation versus Actual Results

Weight Gain data over the feeding periods was then evaluated (Figure 1, Table 10). The BRaNDS-Sheep Companion modules indicate a probable weight gain allowed from dietary energy intake and a probable weight gain from dietary MP intake with the lower of these two gains being the realized gain of the lamb. This evaluation needs to be reviewed with some degree of caution since live animals were evaluated prior to their daily feeding. Thus different degrees of gut fill need to be expected as well as different body compositions of fat and muscle brought on by treatment effects. Live weight and live weight gain are relatively important issues however in production systems so attention has been given to this topic. When comparisons were made actual pen feed dry matter intake was used to generate the estimates along with pen weight averages during the feeding periods. This note is worthy of attention since original rations were balanced at the previously described MP and DIP levels, but as lambs are fed and treatment effects begin to be realized, the estimates for allowable gain from the energy and MP intakes also shift to some degree. Overall, the actual ADG was slightly higher than what would be estimated by six hundredths of a pound per day and considered significant statistically. This difference, in practicality, is debatable.

Dry matter intake (Figure 2, Table 11) was evaluated in a similar way and when comparing the actual to estimated values there was no real difference between the overall actual feed intake and the overall estimated feed intake. Feeding periods one and three did show a difference, but no pattern was established to suggest that the equation used should be changed. It may be beneficial to use the level of UIP and DIP in the ration to assist in the estimate of feed intake since these items currently are not factored into the equation, but did seem to influence the total DMI of the lambs in this trial. In general, the use of the NRC feed intake equation which was published for use in beef cattle does seem to work well with lambs fed high energy, finishing diets. How well this equation would work for other diets was not determined here.

Figure 1-A Average Daily Gain (pounds per head per day).

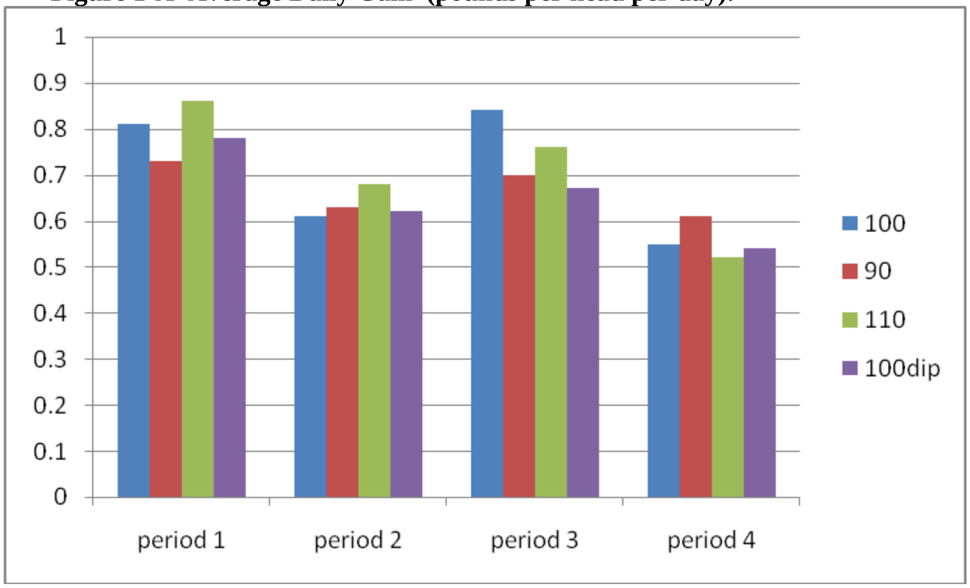

Figure 1-B Average Daily Gain Bias (pounds actual– pounds estimated).

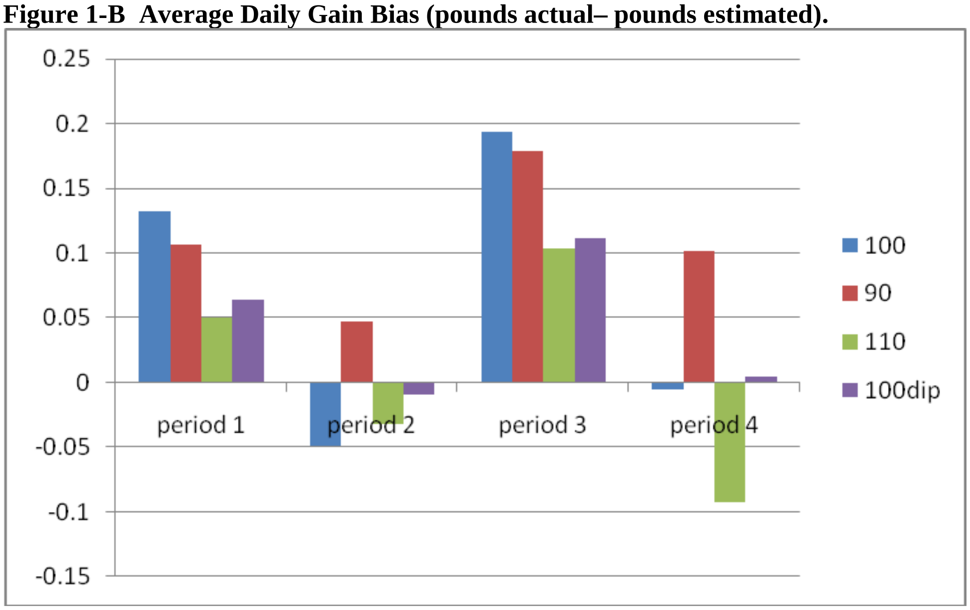

Table 10. Daily Gain Bias - Energy / MP Intake (Pounds Actual Gain – Estimated Gain).

	Period 1	Period 2	Period 3	Period 4	Overall
Avg. Bias (act – est)	0.09	-0.01	0.15	-0.00	0.06
P > t	<0.01	0.62	< 0.01	0.94	<0.01
R^2	0.37	0.13	0.28	0.17	0.53

Figure 2-A Dry Matter Intake (pounds per head per day).

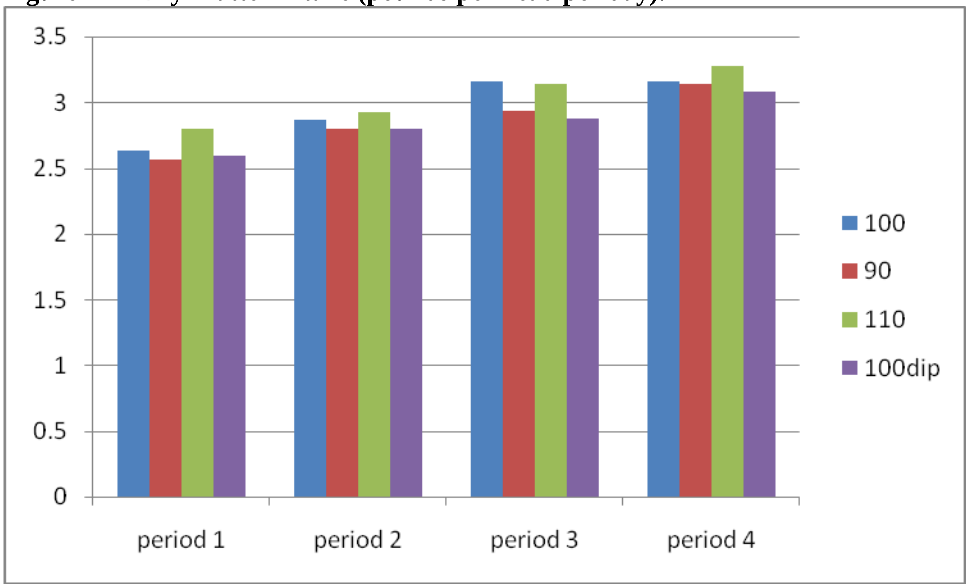

Figure 2-B Dry Matter Intake Bias (pounds actual intake – pounds estimated intake).

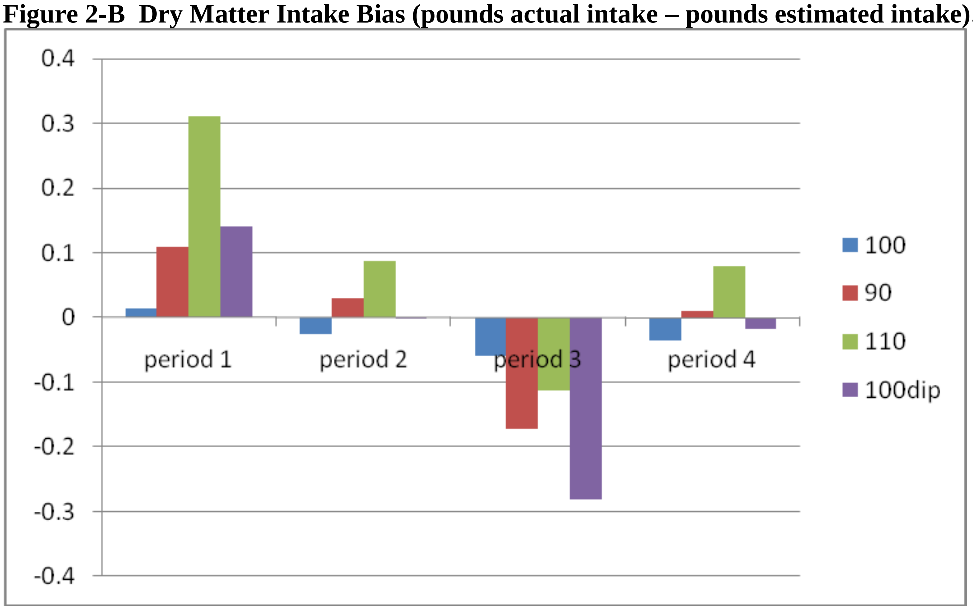

Table 11. Dry Matter Intake Bias (pounds) Actual Intake – Estimated Intake.

	Period 1	Period 2	Period 3	Period 4	Overall
Avg. Bias (act – est)	0.14	0.02	-0.16	0.01	0.005
P > t	< 0.01	0.43	< 0.01	0.73	0.66
R^2	0.52	0.70	0.65	0.69	0.75