GUEST AUTHOR

Use of BUN and MUN as Guides for Protein and Energy Supplementation in Cattle

Andrew C. Hammond[1]

RESUMEN

Título: **Uso de niveles de nitrógeno uréico en sangre (BUN) y leche (MUN) como guía para la suplementación protéica y energética en bovinos**

Además de las mediciones tradicionales de cambios en el peso y la condición corporal, los niveles de nitrógeno uréico en sangre (BUN) o en leche (MUN) pueden utilizarse como herramientas para estimar el estado de la nutrición energético-proteínica del ganado. En vacas y novillos sanos, las concentraciones de nitrógeno uréico por debajo de 7 mg/dL indican deficiencias de proteína (nitrógeno) en la dieta con relación al consumo de energía digestible. En el ganado vacuno de rápido crecimiento o las vacas lecheras de alta producción, las concentraciones de nitrógeno uréico menores de 15 mg/dL señalan una deficiencia relativa de proteína en la dieta. Las concentraciones de nitrógeno uréico mayores de 19 a 20 mg/dL, se han asociado con una reducción de las tasas de concepción y preñez en vacas lecheras.

Palabras claves: ganado vacuno, nutrición, proteína, nitrógeno uréico en sangre, nitrógeno uréico en leche.

ABSTRACT

As an adjunct to monitoring body weight changes and body condition score, blood or milk urea nitrogen (BUN or MUN) can be a useful tool for monitoring the protein-energy status of cattle. In healthy beef cows or finishing steers, urea nitrogen concentrations of less than about 7 mg/dL would indicate a deficiency of dietary protein (nitrogen) relative to the intake of digestible energy. In rapidly growing cattle or high producing dairy cows, urea nitrogen concentrations of less than about 15mg/dL indicate a relative deficiency of dietary protein. Urea nitrogen concentrations of greater than 19 to 20 mg/dL have been associated with reduced conception and pregnancy rates in dairy cows.

Key words: cattle, nutrition, protein, blood urea nitrogen, milk urea nitrogen.

INTRODUCTION

Monitoring of BUN or MUN is a technique that can be used for measuring protein and energy status in cattle from biological samples obtained at strategic times relative to production cycles, feeding changes, and seasonal availability of forage. These indicators should be used as an adjunct to other measures such as body weight and body condition score that reflect the integrated effects of nutrition over time. On the other hand, metabolic indicators such as BUN or MUN, are used to assess short-term or real-time changes in nutritional status. The focus of this review will be on protein and energy, and will attempt to provide information on assessing which of these two nutrients are limiting particularly when cattle are consuming tropical forages of varying quality.

When forage quality is low, a deficiency in protein (nitrogen) can limit dry matter utilization and intake. However, providing supplemental protein to cattle consuming low quality forage (low protein and low energy content) may or may not increase forage dry matter intake depending on the energy to protein ratio of the forage. Expressed as digestible organic matter:crude protein (DOM:CP) the optimum ratio is about 7:1 (Moore et al.,1995). Under grazing conditions, where forage quality is changing with time, it is difficult to assess the DOM:CP ratio of the consumed forage or determine the precise intake of forage. Therefore, management decisions are most often made without this information. Body weight and body condition score may indicate that over time nutrient intake has been deficient, but without knowledge of forage composition and intake the response to supplementation or changing the forage components of the diet can not be predicted with certainty.

How BUN and MUN Work

Digestible protein in the diet of ruminants is either degraded in the rumen or escapes to the abomasum and small intestine where it is degraded to amino acids and small peptides then absorbed into the portal blood system. Nitrogen from protein that is degraded in the rumen is used for microbial protein synthesis either by incorporation of free amino acids or small peptides liberated by the process of proteolysis or by incorporation of ammonia nitrogen that arises from deamination of amino acids. Nonprotein nitrogen (NPN) such as urea also can be made into ruminal microbial protein following enzymatic conversion or breakdown of the NPN to ammonia in the rumen. Yield of microbial protein produced in the rumen is maximized when the ratio of available energy (fermentable organic matter) to protein (nitrogen) is optimized.

When there is an excess of nitrogen re-

1. USDA, ARS, Subtropical Agricultural Research Station, Brooksville (Florida), 34601-4672, U.S.A.

lative to energy in the rumen, ruminal ammonia concentration increases. Unused ruminal ammonia enters the portal blood through the rumen wall and is transported to the liver where it is detoxified by conversion to urea. The liver also produces urea from ammonia derived from deamination of amino acids arising from postruminal digestion and systemic protein turnover. Urea then circulates in the blood to the kidneys and is excreted with the urine or it can diffuse from the blood back into the rumen, into saliva and back into the rumen, or diffuse from the blood into milk in the case of lactating females. When there is a deficiency of dietary protein, ruminal ammonia concentrations are relatively low and the proportion of nitrogen recycled back to the rumen as urea is increased. As a result of these metabolic transactions, BUN is highly correlated with ruminal ammonia (Thornton, 1970; Hammond, 1983a; Hennessy and Nolan, 1988), and MUN is highly correlated with BUN (Roseler et al., 1993; Baker et al., 1995; Butler et al., 1996). Therefore, in healthy ruminants BUN and MUN concentrations are indicative of the protein to energy ratio in the diet (i.e., DOM:CP ratio), and factors that are reported to affect BUN concentrations can be taken to have a similar effect on MUN concentrations.

Dietary and Nutritional Factors Affecting BUN and MUN in Cattle under Controlled Feeding Situations

When energy intake is held constant, increasing dietary protein increases BUN concentrations. Isocaloric semipurified diets with three levels of CP were fed to steers at equal intakes of 5 kg/day (Hammond, 1983ab). Mean BUN concentrations increased from 2.6 mg/dL to 11.1 mg/dL as dietary CP increased from 6 to 18% of the diet. For growing steers, BUN levels between 11 and 15 mg/dL were associated with maximum rates of gain (Byers and Moxon, 1980). With finishing steers, maximum performance was associated with BUN concentrations of 7 to 8 mg/dL (Preston et al., 1978). Balanced diets for lactating dairy cows were associated with average BUN concentrations of 15 mg/dL (Roseler et al., 1993) and average MUN concentrations of 15 to 16 mg/dL (Baker et al., 1995).

Increased solubility or degradability of dietary protein can lead to increased ruminal ammonia concentrations resulting in increased BUN concentrations. In steers fed isocaloric diets that differed widely in nitrogen solubility, there was an average difference in BUN of over 6 mg/dL (Hammond, 1983ab). Also, steers fed corn-cottonseed hull diets had higher BUN concentrations when supplemented with urea than when supplemented with soybean meal (Burris et al., 1975). In lactating dairy cows, an imbalance of degradable and undegradable intake protein increased BUN and MUN (Roseler et al., 1993). Similarly, an imbalance of ruminally degradable and ruminally undegradable protein increased BUN and MUN in lactating dairy cows, but this increase was not as great as an increase in BUN and MUN caused by excess CP (Baker et al., 1995). However, varying dietary nitrogen solubility by varying source of dietary nitrogen has not always resulted in altered concentrations of BUN. In a study with yearling steers fed corn silage diets and supplemented with soybean meal or urea to meet 85 or 100% of requirements for CP, BUN concentrations did not differ between sources of protein (Cross et al., 1974). Likewise, feeding lactating dairy cows 16% CP diets containing soybean meal or formaldehyde-treated soybean meal did not significantly affect BUN concentrations (Folman et al., 1981).

Increasing dietary energy intake while holding protein intake constant would be expected to decrease BUN. This was demonstrated in an experiment with bulls where diets were formulated and rationed to provide 75 or 150% of maintenance energy requirement but equal CP intake (Chase et al., 1993). At the high level of energy intake BUN averaged 5.6 mg/dL and at the low level of energy intake BUN averaged 19.7 mg/dL.

The effect of increased level of intake on BUN concentration appears to be similar to the effect associated with increased energy intake. Steers on both high quality (legume hay, 24% CP) and low quality (grass hay, 4.5% CP) forage diets had decreased BUN with increased intake (Vercoe, 1967). Increased frequency of feeding has been associated with lower BUN (Thomas and Kelly, 1976), probably due to more efficient use of nitrogen in the rumen.

Dietary and Nutritional Factors Affecting BUN and MUN in Cattle under Grazing Conditions or Fed Ad Libitum Amounts of Forage

Less work has been reported with regard to BUN and MUN in grazing cattle than in cattle under controlled feeding situations. Predicting response to protein or energy supplementation in grazing cattle using BUN as a guide is complicated by the fact that forage intake is not known and varies among animals. Although neither energy nor protein intake is known in free-grazing cattle, the protein to energy ratio of the diet should be reflected in BUN concentrations.

To determine whether BUN could predict the biological response (change in average daily body weight gain, ADG) to protein and/or energy supplementation in steers and heifers grazing warm season grass pastures, data from eight grazing trials in Florida were summarized (Hammond et al., 1993). Pasture grass species grazed were bahiagrass (*Paspalum notatum*) and limpograss (*Hemarthria altissima*). Fourteen comparisons between protein supplement treatments and various controls were evaluated. Change in ADG (-.05 to .30 kg/day) due to protein supplementation was linearly related to BUN concentration (6.2 to 15.5 mg/dL) in control cattle ($r = .69$). Concentrations of BUN between 9 and 12 mg/dL were a transition range below which ADG response to protein supplementation was greater and above which ADG response was lesser than the response within this range . Seven comparisons between energy supplement treatments and controls were analyzed. Positive responses in ADG to energy supplementation were obtained within the entire range of control BUN (9.6 to 17.6 mg/dL). These relatively high concentrations of BUN would be indicative of excess dietary protein (nitrogen) relative to digestible energy intake so the positive response to energy supplementation was as expected.

A similar trial was conducted in Australia (Hennessy and Williamson, 1990) using steers and heifers fed hay from a pasture that was predominantly carpetgrass (*Axonopus affinus*). The basal hay diet (5.3% CP) resulted in an average BUN concentration of 2.1 mg/dL that was increased to 10.5 mg/dL with urea supplementation or 8.5 mg/dL with protected casein supplementation. These increases in BUN were associated with significant increases in ADG (from .1 kg/day on hay alone to .3 kg/day on hay supplemented with urea, and to .6 kg/day on hay supplemented with protected casein). These data suggest that the nitrogen supplemented in the less degradable form of protected casein was more efficiently used, resulting in a grater increase in ADG and a lesser increase in BUN compared to supplementation with urea.

Nitrogen fertilization of pasture can

affect BUN in grazing cattle due to the increase in forage nitrogen content. Nitrogen fertilization (0 to 448 kg N•ha^{-1}•year^{-1}) of 'Midland' bermudagrass (*Cynodon dactylon*) pastures resulted in a linear increase in BUN of steers (Carver et al., 1978). Actual body weight gains of these steers were not reported, but when these data were combined with those obtained on common bermudagrass or orchardgrass-ladino (*Dactylis glomerata-Trifolium repens*) pastures, BUN was positively correlated with ADG (r = .53). Increasing nitrogen fertilization of limpograss from 50 to 150 kg/ha increased BUN in yearling heifers from 4.2 to 9.2 mg/dL and increased average daily gain from .06 to .36 kg/d (Lima et al., 1994; Lima, 1995).

Incorporation of a legume can be an effective way of increasing the protein content of forage diets. We found higher BUN and ADG in steers continuously grazing rhizoma peanut (*Arachis glabrata*)-grass pastures compared with steers grazing bahiagrass only (Williams et al., 1991). Due to a difference in percentage of legume in the sward between years (26% vs. 45%), there was a significant treatment per year interaction for BUN and ADG (legume-grass: 16.6 and 23.5 mg/dL, .7 and .9 kg/day; bahiagrass: 9.7 and 8.5 mg/dL, .5 and .5 kg/day; respectively). Also, steers grazing limpograss-aeschynomene (*Aeschynomene americana*) pastures in Florida had higher ADG (1.15 kg/d) and BUN (11.0 mg/dL) than steers grazing pure stands of limpograss (.64 kg/d and 6.0 mg/dL, respectively; Holderbaum et al., 1991).

Other Factors Affecting BUN and MUN

Other dietary factors that affect the efficiency of protein utilization also can affect BUN concentrations. Addition of sulfur to diets of sheep and cattle deficient in sulfur resulted in decreased BUN concentrations associated with increased animal performance (Kennedy and Siebert, 1972). Factors not already discussed that may affect BUN concentrations other than diet include health of the animal, physiological state, use of growth promotants, and breed. The magnitude of differences caused by these factors, except for certain disease conditions, is generally less than the dietary factors presented above, but the differences can be significant. Severe nutritional depletion as a result of prolonged under nutrition (Ward et al., 1992; Hayden et al., 1993) or disease can cause catabolism of tissue protein and result in high concentrations of BUN. Renal disease can interfere with excretion of urea and also result in high BUN concentrations. In dairy cows, BUN increased as cows progressed from the dry stage through early lactation and the lactating pregnant period, and BUN increased with increasing age (Peterson and Waldern, 1981). In beef cattle, the use of growth promotants generally decreases concentrations of BUN (Preston et al., 1978; Galbraith, 1980; Eisemann et al., 1989). Use of feed additives such as monensin to increase feed efficiency has resulted in no change (Steen et al., 1978) or small increases in BUN (Raun et al., 1976; Thompson and Riley, 1980). We have observed lower concentrations of BUN in Hereford cows compared to Senepol cows (Hammond et al., 1992) and lower concentrations of BUN in Angus bulls compared to Senepol bulls (Chase et al., 1993) suggesting differences in protein utilization between breeds. Higher BUN in Shorthorn x Hereford cattle compared to Africander cattle was associated with a trend toward lower nitrogen balance in the Shorthorn x Hereford (Vercoe and Frisch, 1970). Others have observed lower concentrations of BUN in Hereford compared to Brahman cattle (Hunter and Siebert, 1985), lower BUN in Angus compared to Brahman (Olbrich, 1996), and lower BUN in Angus x Hereford cattle compared to Brahman crosses (Coleman and Frahm, 1987).

Approaches and Applications for Using BUN and MUN

The most common application of the use of BUN and MUN is as a retrospective diagnostic tool to analyze biological responses to protein or energy supplementation, change in pasture or forage on offer, or change in pasture management. In a two year study (Hammond et al., 1992), we monitored BUN in cows and heifers wintered on bahiagrass hay and supplemented with molasses and rhizoma peanut-grass hay or molasses and a 20% crude protein (CP) range cube. Rhizoma peanut-grass hay fed at the rate of 2.3 kg/day or feeding .9 Kg/day of the range cubes resulted in similar BUN concentrations and performance. More importantly, BUN concentrations indicated that we did not initiate protein supplementation early enough in the winter (average BUN of 3.7 mg/dL in early January) and that we supplemented with protein longer in the spring than necessary (average BUN of 16.3 mg/dL in late April). Appropriate strategic changes in our winter supplementation program have subsequently increased the efficiency with which we use winter supplements.

Another possible approach to using BUN or MUN is to make real-time adjustments in feeding or grazing management. We tested this approach on a commercial ranch in Florida (Hammond et al., 1994) by comparing performance of cows wintered using a predetermined standard supplementation program with cows wintered under similar conditions but where level and timing of protein supplementation was guided by monitoring BUN concentrations in a subset of cows every three weeks throughout the winter feeding period. The control treatment consisted of feeding a cottonseed meal based cube (33% CP) and molasses according to standard ranch protocol. The BUN guided treatment was the same as the control except that time and amount of cube feeding was guided by results of BUN analyses. The criteria for initiation of increase of cube feeding was a herd sample mean BUN of < 7 mg/dL or 25% of the sampled cows having BUN concentrations of < 6 mg/dL. Less cube was fed to BUN guided cows than to control cows (41.2 vs. 51.5 kg/cow) without affecting overall herd weaning weights or percentage of cows rebreeding.

Increasing concern over the environment may create yet another application particularly for MUN. As producers are encouraged to increase efficiency of nitrogen utilization from the perspective of minimizing release of excess nitrogen into the environment, measuring average herd MUN by sampling from the bulk tank may be a way of monitoring efficiency of nitrogen utilization on a whole farm basis.

Technical Notes

Often, BUN is used as a generic term for plasma, serum or whole blood urea nitrogen, although small differences in values can occur depending on the sample matrix (Hammond, 1983b; Hammond, 1992). Urea in milk can be measured with typical analytical procedures used for BUN. In our laboratory, we use an automated colorimetric procedure based on the diacetyl monoxime method (Marsh et al., 1965) that includes a dialysis step to remove proteins for the analytical stream. If a manual method of this colorimetric procedure is used, a deproteinization step is required. Alternatively, urea can be measured by analyzing ammonia concentration before and after incubation with urease. Ammonia can be quantified by titration or colorimetrically. With milk samples, it is also necessary to remove fat by centrifugation.

Currently, preservatives are used in milk

samples but this may not be necessary if samples are kept cool or frozen (Miettinen and Juvonen, 1990; Butler et al,. 1996). A commercial dipstick (Azotest™, Compagnie Chimique d'Aquitaine, Lalande de Pomerol, France) has been evaluated and shown to give only semiquantitative results (Butler et al., 1996). Milk testing laboratories in the U.S. and some other countries are beginning to offer MUN analysis along with other routine milk tests. For laboratories such as these with large numbers of samples analyzed daily, automated infrared instrumentation is available.

Sampling time is an important consideration for BUN and MUN. Peak BUN concentrations occur several hours after feeding (Thomas and Kelly, 1976; Hammond 1983b; Elrod and Butler, 1993; Gustafsson and Palmquist, 1993), and changes in MUN lag behind changes in BUN by about 1 to 2 hours (Gustafsson and Palmquist, 1993). In beef cows that were supplemented with cottonseed meal twice a week (Monday and Thursday), BUN ranged from a high of 14 mg/dL in the afternoon after supplementation to a low of 7 mg/dL 2 days after supplementation (Hammond and Chase, 1996). With frequent feeding, however, there is little diurnal (Folman et al., 1981) or prandial (Thomas and Kelly, 1976) variation in BUN. To control diurnal and prandial variation, sample just prior to feeding in fed or supplemented cattle or early in the morning in cattle on pasture. When this is not possible, it is important to be consistent with regard to sampling time if results are to be compared. When sampling milk, strip samples from a single quarter and composite samples have given similar results (Gustafsson and Palmquist, 1993; Butler et al., 1996), and strip samples before and after milking are also similar. Milk samples from a bulk tank can give a generalized indication of the entire herd weighted by the production contributed by each cow.

High BUN or MUN and Decreased Reproductive Efficiency

High dietary protein (nitrogen) intake resulting in BUN or MUN of greater than 19 to 20 mg/dL has been associated with an altered uterine environment and decreased fertility (reduced conception rate, decreased pregnancy rate) in lactating dairy cows and heifers (Elrod and Butler, 1993; Elrod et al., 1993; Ferguson et al., 1993; Butler et al., 1996). However, high protein intake and high BUN have not always been associated with reduced reproductive efficiency (Caroll et al., 1988) and is therefore not pathognomonic. Also, there is an energy cost associated with the conversion of excess ammonia to urea by the liver, and this is at the expense of energy use for other productive purposes.

ACKNOWLEDGEMENTS

Portions of this review were presented at the Tropileche Workshop, CIAT, Cali, Colombia (Hammond and Chase, 1996) and the 8th Annual Florida Ruminant Nutrition Symposium (Hammond, 1997); the research conducted at USDA, ARS, Subtropical Agricultural Research Station was in cooperation with the University of Florida, Institute of Food and Agricultural Sciences.

BIBLIOGRAPHY

Baker, L.D., Ferguson, J.D. and Chalupa W. 1995. Responses in urea and true protein of milk to different protein feeding schemes for dairy cows. J. Dairy Sci. 78:2424-2434.

Burris, W.R., Bradley, N.W. and Boling, J.A. 1975. Growth and plasma amino acids of steers fed different nitrogen sources at restricted intake. J. Anim. Sci. 40: 714-719.

Butler, W.R., Calaman, J.J. and Beam, S. W. 1996. Plasma and milk urea nitrogen in relation to pregnancy rate in lactating dairy cattle. J. Anim. Sci. 74: 858-865.

Butler, W.R., Cherney, D.J.R. and Elrod, C.C. 1995. Milk urea nitrogen (MUN) analysis: Field trial results on conception rates and dietary inputs. In: Proceedings, Cornell Nutrition Conference, pp. 89-95. Cornell University, Ithaca, NY.

Byers, F.M. and Moxon, A.L. 1980. Protein and selenium levels for growing and finishing beef cattle. J. Anim. Sci. 50: 1136-1144.

Caroll, D.J., Barton, B.A., Anderson, G.W. and Smith, R.D. 1988. Influence of protein intake and feeding strategy on reproductive performance of dairy cows. J. Dairy. Sci. 71: 3470-3481.

Carver, L.A., Barth, K.M., McLaren, J.B., Fribourg, H.A., Connell, J.T. and Bryan, J.M. 1978. Plasma urea nitrogen levels in beef steers grazing nitrogen-fertilized bermudagrass and orchardgrass-ladino pastures. J. Anim. Sci. 47: 927-934.

Chase, C.C. Jr., Larsen, R.E., Hammond, A.C. and Randel, R.D. 1993. Effect of dietary energy on growth and reproductive characteristics of Angus and Senepol bulls during summer in Florida. Theriogenology 40: 43-61.

Coleman, S.W. and Frahm, R.R. 1987. Nitrogen metabolism in corssbred steers with varying levels of Brahman using a nitrogen depletion-repletion regimen. J. Anim. Sci. 65: 1077-1093.

Cross, D.L., Ludwick, R.L., Boling, J.A. and Bradley, N.W. 1974. Plasma and rumen fluid components of steers fed two sources and levels of nitrogen. J. Anim. Sci. 38: 404-409.

Eisemann, J.H., Hammond, A.C., Rumsey, T.S. and Bauman, D.E. 1989. Nitrogen and protein metabolism and metabolites in plasma and urine of beef steers treated with somatotropin. J. Anim. Sci. 67: 105-115.

Elrod, C.C. and Butler, W.R. 1993. Reduction of fertility and alteration of uterine pH in heifers fed excess ruminally degradable protein. J. Anim. Sci. 71: 694-701.

Elrod, C.C., Van Amburg, M. and Butler, W.E. 1993. Alterations of pH in response to increased dietary protein in cattle are unique to the uterus. J. Anim. Sci. 71: 702-706.

Ferguson, J.D., Galligan, D.T., Blanchard, T. and Reevs, M. 1993. Serum urea nitrogen and conception rate: The usefulness of test information. J. Anim. Sci. 76: 3742-3746.

Folman, Y., Neumark, H., Kaim, M. and Kaufmann, W. 1981. Performance, rumen and blood metabolites in high-yielding cows fed varying protein percents and protected soybean . J. Dairy Sci. 64: 759-768.

Galbraith, H. 1980. The effect of trenbolone acetate on growth, blood hormones and metabolites, and nitrogen balance of beef heifers. Anim. Prod. 30: 389-394.

Gustafsson, A.H. and Palmquist, D.L. 1993. Diurnal variation of rumen ammonia, serum urea, and milk urea in dairy cows at high and low yields. J. Dairy Sci. 76: 475-484.

Hammond, A. C. 1983a. Effect of dietary protein level, ruminal protein solubility and time after feeding on plasma urea nitrogen and the relationship of plasma urea nitrogen to other ruminal and plasma parameters. J. Anim. Sci. 57 (Suppl. 1): 435.

Hammond, A.C. 1983b. The use of blood urea nitrogen concentration as an indicator of protein status in cattle. Bovine Practitioner 18:114-118.

Hammond, A. C. 1992. Use of blood urea nitrogen concentration to guide protein supplementation in cattle. In: 3rd Annual Florida Ruminant Nutrition Symposium, pp.9-18. University of Florida, Gainesville, FL.

Hammond, A. C. 1997. Update on BUN and MUN as a guide for protein supplementation in cattle. In: 8th Annual Florida Ruminant Nutrition Symposium, pp. 45-54. University of Florida, Gainesville, FL.

Hammond, A.C., Bowers, E.J. Kunkle, W.E., Genho, P.C., Moore, S.A., Crosby, C. E. and Ramsay, K. H. 1994. Use of blood urea nitrogen concentration to determine time and level of protein supplementation in wintering cows. Prof. Anim. Scientist 10: 24-31.

Hammond, A.C. and Chase Jr., C.C. 1996. Cattle nutritional and reproductive

status through blood and milk indicators. In: Proceedings, Tropileche Workshop. CIAT, Cali, Colombia. (In press).

Hammond, A. C., Kunkle, W.E., Bates, D.B. and Sollenberger, L.E. 1993. Use of blood urea nitrogen concentration to predict response to protein or energy supplementation in grazing cattle. In: Proc. of the XVll International Grassland Congress, pp. 1989-1991. Rockhampton, Australia.

Hammond, A.C., Padgett, L.J., Williams, M.J. and Kunkle, W.E. 1992. Relative feeding value of rhizoma perennial peanut hay as a supplement to bahiagrass hay for wintering cows and heifers. Prof. Anim. Scientist 8: 48-54.

Hayden, J.M., Williams, J.E. and Collier, R.J. 1993. Plasma growth hormonne, insulin-like growth factor, insulin, and thyroid hormone association with body protein and fat accretion in steers undergoing compensatory gain after dietary energy restriction. J. Anim. Sci. 71: 3327-3338.

Hennessy, D.W. and Nolan, J.V. 1988. Nitrogen kinetics in cattle fed a mature subtropical grass hay with and without protein meal supplementation. Aust. J. Agric. Res. 39: 1135-1150.

Hennesey, D.W. and Williamson, P.J. 1990. Feed intake and liveweight of cattle on subtropical native pasture hays. II. The effect of urea and maize flour, or protected-casein. Aust. J. Agric. Res. 41: 1179-1185.

Holderbaum, J.F., Sollenberger, L.E., Moore, J.E., Kunkle, W.E., Bates, D. B. and Hammond, A.C. 1991. Protein supplementation of steers grazing limpograss pasture. J. Prod. Agric. 4: 437-441.

Hunter, R.A. and Siebert, B. D. 1985. Utilization of low-quality roughage by *Bos taurus* and *Bos indicus* cattle. 2. The effect of rumen-degradable nitrogen and sulphur on voluntary food intake and rumen characteristics. Br. J. Nutr. 53: 649-656.

Kennedy, P. M. and Siebert, B.D. 1972. The utilization of spear grass (*Heteropogon contortus).* II. The influence of sulphur on energy intake and rumen and blood parameters in cattle and sheep. Aust. J. Agric. Res. 23: 45-56.

Lima, G.F. da C. 1995. Nitrogen fertilization, and supplementation effects on limpograss chemical characteristics and utilization by cattle. Ph.D. Dissertation. Univ. Florida, Gainesville.

Lima, G.F. da C., Sollenberger, L.E., Kunkle, W.E., Moore, J.E. and Hammond, A.C. 1994. Improving limpograss forage quality and utilization using nitrogen fertilization and supplementation. In: National Conference on Forage Quality, Evaluation and Utilization. p 90. Univ. Nebraska, Lincoln.

Marsh, W. H., Fingerhut, B. and Miller, H. 1965. Automated and manual direct methods for the determination of blood urea. J. Clin. Chem. 11: 624-627.

Miettinen, P.V.A. and Juvonen, R.O. 1990. Diurnal variations of serum and milk urea levels in dairy cows. Acta Agric. Scand. 40: 289-296.

Moore, J.E., Bowman, J.G.P. and Kunkle, W.E. 1995. Effects of dry and liquid supplements on forage utilization by cattle. In: Proceedings, AFIA Liquid Feed Symposium, pp81-95. AFIA, Arlington, VA.

Olbrich Jr., J.F. 1996. The effect of corn particle size and corn silage level on the performance of Angus (*Bos taurus*) and Brahman (*Bos indicus*) steers. Ph.D. Dissertation. Univ. Florida, Gainesville.

Peterson, R.G. and Waldern, D.E. 1981. Repeatabilities of serum constituents in Holstein-Friesians affected by feeding, age, lactation, and pregnancy. J. Dairy Sci. 64: 822-831.

Preston, R. L., Byers, F. and Stevens, K.R. 1978. Estrogenic activity and growth stimulation in steers fed varying protein levels. J. Anim. Sci. 46: 541-546.

Raun, A.P., Cooley, C.O., Potter, E.L., Rathmacher, R.P. and Richardson, L.F. 1976. Effect of monensin on feed efficiency of feedlot cattle. J. Anim. Sci. 43: 670-677.

Roseler, D.K., Ferguson, J.D., Sniffen, C.J. and Herrema, J. 1993. Dietary protein degradability effects on plasma and milk urea nitrogen and milk nonprotein nitrogen in Holstein cows. J. Dairy Sci. 76: 525-534.

Steen, W.W., Gay, N., Boling, J.A., Bradley, N.W., McCormick, J.W. and Pendlum, L.C. 1978. Effect of monensin on performance and plasma metabolites in growing-finishing steers. J. Anim. Sci. 46: 350-355.

Thomas, P.C. and Kelly, M.E. 1976. The effect of frequency of feeding on milk secretion in the Ayrshire cow. J. Dairy Res. 43: 1-7.

Thompson, W.R. and Riley, J.G. 1980. Protein levels with and without monensin for finishing steers. J. Anim. Sci. 50: 563-571.

Thornton, R.F. 1970. Factors affecting the urinary excretion of urea nitrogen in cattle. II. The plasma urea nitrogen concentration. Aust. J. Agric. Res. 21: 145-152.

Vercoe, J.E. 1976. Breed and nutritional effects on the composition of faeces, urine, and plasma from Hereford and Brahman x Hereford steers fed on high and low quality diets. Aust. J. Agric. Res. 18: 1003- 1013.

Vercoe, J.E. and Frisch, J.E. 1970. Digestibility and nitrogen metabolism in Brahman, Africander and Shorthorn x Hereford cattle fed lucerne hay. Proc. Aust. Soc. Anim. Prod. 8: 131-135.

Ward, J.R., Henricks, D.M., Jenkins, T.C. and Bridges, W.C. 1992. Serum hormone and metabolite concentrations in fasted young bulls and steers. Domestic Anim. Endo. 9: 97-103.

Williams, M.J., Hammond, A.C., Kunkle, W.E. and Spreen, T.H. 1991. Stocker performance on continuously grazed mixed grass-rhizoma peanut and bahiagrass pastures. J. Prod. Agric. 4: 19-24. November 7, 1996.