RUMINANT NUTRITION: THE GLEN BRODERICK SYMPOSIUM – IMPROVING NITROGEN UTILIZATION IN DAIRY COWS

0695 Opening remarks and overall impact of Dr. Glen Broderick on research around the world.
A. Faciola*, *University of Nevada, Reno, NV.*

Dr. Glen Broderick has been an ADSA member since 1968. Glen has been an ad hoc reviewer for JDS since 1975 and is currently a collaborator with the USDA-ARS and emeritus professor at UW-Madison. Glen received his B.S., M.S., and Ph.D. degrees from UW–Madison. Glen served as an assistant and associate professor of animal science at Texas A&M University from 1972 to 1980. In 1981, he returned to Madison to work at the USDFRC and was appointed as professor of dairy science at UW–Madison. His research focused on protein nutrition of the lactating cow, with emphasis on enhancing utilization of feed nitrogen for milk production and reducing nitrogen excretion. This work involved developing strategies to minimize dietary CP without losing milk or protein yield, identifying factors influencing microbial protein synthesis in the rumen, and perfecting methodologies for quantifying ruminal protein degradation both in vivo and in vitro. Glen's research has generated more than 135 peer-reviewed publications, of which over 100 are in JDS and JAS alone. Glen's major contributions to dairy science include: 1) understanding ruminal microbial metabolism utilizing isotope marker techniques, 2) improvements of in vitro methodologies for assessing ruminal microbial growth and ruminal protein degradation, 3) in vivo quantification of ruminal nitrogen metabolism, and 4) improving overall nitrogen utilization and reducing the environmental impact of milk production. According to the Web of Science, Glen's research articles have been cited more than 4580 times, with an average of at least 105 citations per year. According to the same source, Glen's most cited article is Broderick and Kang. 1980. J. Dairy Sci. 63: 64–75, which has been cited over 600 times. Moreover, in addition to teaching and mentoring of graduate students at UW–Madison and other universities around the world, he has served on the editorial boards of several journals, including JDS, JAS (1981–1993), and Animal Feed Science & Technology (1999–2013), among others. Glen presented a number of invited papers at meetings in more than 25 different countries and mentored over 50 graduate students, postdocs, and visiting scientists. He did sabbaticals at the Rowett Research Institute (1985–1986) in Aberdeen, Scotland, and the Swedish Agricultural University in Uppsala (1997–1998 and 2013). Glen was named a "highly-cited researcher" by the Web of Knowledge in 2005 and received the Nutrition Research Award of the American Feed Industry Association presented by the American Dairy Science Association (1997).

Key Words: dairy cow nutrition

0696 Conundrums of protein and peptide metabolism in the rumen.
R. J. Wallace*, *Rowett Institute of Nutrition and Health, Aberdeen, UK.*

Nitrogen retention in ruminants is inefficient due to rumen microbial activity. Protein in forages is particularly vulnerable, because a high proportion of forage carbohydrate comprises cellulose or hemicellulose, which are slowly degraded, in contrast to the soluble protein, which degrades rapidly. The release of energy-yielding sugars, which enables ruminant microbes to trap the forage protein N, therefore does not match the availability of amino acids, which are degraded excessively, leading to high N emissions by the animal. Protein supplements are almost as vulnerable. The problem with supplements is that they tend to be variable in their degradation rate; thus, diet formulation relies on knowledge of their rate of degradation in the rumen. How to assess protein degradation and the chemistry and microbiology of the process have long been interests of Glen Broderick. It was therefore natural that Glen might want to spend time at the Rowett Research Institute, where Bob Orskov and I shared this interest. Malt whiskies and old Scottish castles also had their part to play! Bob was a committed advocate of the nylon-bag method, a technique that Glen abhorred. I sat on the fence on that one. It might seem like a trivial thing to do, to develop a method to assess the rate and extent of protein degradation. Many have tried to develop in vitro incubations that enable the determination of those characteristics, soon finding that something simple, like the release of ammonia, was vastly in error. Protein supplements are not comprised entirely of protein, indeed starchy carbohydrate even exceeds protein in some supplements. Thus, an enzyme system is fraught with difficulty. The physical form of the supplement is an issue: to grind or not to grind? Furthermore, when ruminal digesta is used as an inoculum for protein degradation assays hydrolyses in vitro, microbes mop up the released amino acids and ammonia as they ferment the carbohydrate. Glen and his colleagues devised an in vitro system that overcame these problems and at the same time revealed some fundamental properties of ruminal protein metabolism. Peptides as an intermediate of the proteolysis cascade were a contentious topic when Glen first arrived on Scottish shores. He and I had great fun in establishing the sequence characteristics that dictate microbial degradation rates of peptides— particularly the importance of the N-terminal amino acids and whether the peptide was basic or acidic.

Key Words: proteolysis, peptide metabolism, rumen

0697 Dr. Glen Broderick's contributions to in vivo quantification of ruminal nitrogen metabolism using the omasal sampling technique. P. Huhtanen*, *Swedish University of Agricultural Sciences (SLU), Umea, Sweden.*

Dr. Glen Broderick has made a significant contribution to improve understanding of protein and amino acid nutrition of dairy cows with the aim of improving overall nitrogen utilization and reducing the environmental impact of milk production. Development of in vitro method to determine ruminal protein degradability was one of his main contributions at earlier stages of career. More recently, he has focused on studying ruminal N metabolism in lactating dairy cows, with the main emphasis in optimizing the efficiency of microbial N synthesis. In these studies Dr. Broderick and his PhD students have applied and developed omasal sampling technique. The method is now widely replaced more invasive duodenal sampling technique, but it also allows studying ruminal N metabolism in more detail as sampling takes places before hydrolysis in the abomasum and endogenous contribution is less. Applying omasal sampling technique Dr. Brodrick demonstrated that the flow of soluble NAN fractions has an important contribution to feed N flow from the rumen. Soluble feed amino acid (AA) flow accounted approximately 10% of omasal total AA flow indicating substantial escape of dietary soluble AA from ruminal degradation. This calls into question the use of in situ estimations of protein degradation to predict RUP flow. Oligopeptides had the greatest contribution of soluble feed AA flow. The study investigating gradual replacement of solvent extracted soybean meal (SBM) with lignosulfonate-treated SBM concluded that NRC (2001) overestimated the supply of RUP from treated SBM. The other important conclusion from this study was decreased microbial protein synthesis with increased proportion of RUP in dietary protein. Consistently with this, replacement of solvent extracted SBM with urea and lignosulfonate-treated SBM decreased NAN and microbial N flow at the omasum demonstrating that microbial protein synthesis is stimulated by true protein RDP compared with NPN. Comparison of red clover and alfalfa silages supported the conclusions from previous studies; increased RUP supply from red clover was counteracted by reduced microbial protein synthesis. Meta-analysis of the data from omasal sampling studies indicated usually smaller residual variance of digesta flow estimates compared with studies applying duodenal sampling, probably reflecting more the marker system applied to estimate digesta flow than sampling site per se. The results suggested that the NRC (2001) system underestimates microbial N flow and overestimates the supply of RUP. The contributions Dr. Broderick emphasize the need for re-evaluation of the feed protein systems.

Key Words: Dr. Broderick, omasal sampling, dairy cow

0698 Glen Broderick's contributions to improving in vitro methodologies for assessing ruminal microbial growth and ruminal protein degradation. P. Udén*, *Swedish University of Agricultural Sciences, Uppsala, Sweden.*

Dr. Broderick has supervised numerous graduate students during his career, been a very active contributor to scientific meetings throughout the world, and also published 126 full papers in refereed journals (Web of Knowledge, Jan. 16, 2014) of which 28 have "in vitro" in the title. The most cited (707) paper of them is so far Broderick and Kang (J. Dairy Sci. 63:64–75, 1980), describing an automated method to analyze ruminal ammonia and amino acids. This method was essential for enabling use of the inhibited in vitro (IIV) system, previously developed by Broderick (J. Nutr. 108:181–190, 1978), to measure release of ammonia and amino acids. He subsequently compared the IIV method with solubility estimates (Broderick and Craig, J. Nutr. 110:2381–89, 1980) and against in sacco estimates (Broderick et al., J. Anim. Sci. 66:1739–45, 1988). In sacco rates were only 36% of those of IIV due to an immediate loss of more rapidly degradable protein in soluble and fine particle forms. This, however, did not prevent adoption of the in sacco method as a standard method for protein evaluation, at least in Europe. The theory of the IIV method is elegant: to inhibit microbial protein synthesis without affecting protein hydrolysis and to estimate degradation as the sum of microbial extra- and intracellular metabolism. The latter feature is attractive as casein data from Broderick and Craig (J. Dairy Sci. 72:2540–48,1989) suggested that uptake of amino acids and peptides is too slow to be ignored. So far, this methodological feature is only shared with the gas-in vitro method of Raab et al., Br. J. Nutr. 50:569–82, 1983). However, the use of inhibitors has limited the use of long incubation times ($> \sim 4$ h) due to a concomitant loss of microbial activity. Nevertheless, the IIV method seems to give biologically sensible degradation rates for sufficiently rapidly degrading proteins. Dr. Broderick has also been involved in developing a 15N based in vitro method to estimate microbial growth (Hristov and Broderick, J. Dairy Sci. 79:1627–37, 1994). An important finding of this study was that microbial protein synthesis is positively related to protein degradation which implies a compensatory effect of low-escape proteins by an increased supply of microbial amino acids to the duodenum.

Key Words: in vitro, protein, dairy cow

0699 Dr. Glen Broderick's contributions to protein and amino acid nutrition of the dairy cow. A. N. Hristov*, *Dep. of Animal Science, The Pennsylvania State University, University Park.*

Dr. Broderick's interest in amino acid (AA) nutrition of the dairy cow started as early as the 1970s, stemming from his

M.S. and Ph.D. studies at the University of Wisconsin under the supervision of the late Dr. Larry Satter. In these early experiments, Dr. Broderick demonstrated that abomasal infusion of casein plus Met in cows fed a 16% crude protein diet increased milk protein content and yield. In his thesis work, Dr. Broderick utilized the concept that an essential AA will not accumulate in plasma, if it is limiting, but will start to accumulate once demands for it in the tissues are met. Using this approach, he concluded that Met, Val, and Lys were most likely limiting AA for milk production in dairy cows. Dr. Broderick's interest in Met continued throughout his career resulting in a number of key publications on production responses to rumen-protected Met (RPMet) products. These experiments demonstrated that, under some circumstances, supplemental RPMet may alleviate the negative impact of decreased dietary protein on milk production and composition with the additional benefit of drastically reducing N excretion in urine and manure. His protein and AA research branched into investigating sources of rumen-undegraded protein (RUP) for the high-producing dairy cow. Early experiments in this challenging area showed increased milk production with roasted soybeans compared with solvent-extracted soybean meal. By comparing forages in the basal diet, it was concluded that resistant protein sources may have a greater value with diets containing alfalfa silage than corn silage-based diets. Working at the U.S. Dairy Forage Research Center, Dr. Broderick's research was focused exclusively on the nutritional aspects of feeding forages, specifically alfalfa, to dairy cows. A series of studies was conducted to assess the feeding value of alfalfa silage vs. hay, with or without preservatives, and the benefit of protein supplementation of alfalfa silage-based diets. This work confirmed that alfalfa silage-based diets may benefit from RUP supplementation and identified the effectiveness of various protein feeds as RUP sources supplying limiting AA postruminally. Other forages, including tanniferous plants, were also investigated as dairy feeds. Research on urea vs. true protein sources established maximum urea supplementation levels. Studies on the interaction of fat and RUP challenged the concept that fat-supplemented diets would benefit from RUP supplementation. These numerous contributions have made Dr. Broderick one of the world's foremost experts in protein nutrition of the dairy cow.

Key Words: Glen Broderick, amino acid, dairy cow

0700 Exploring milk urea-N excretion as a nutritional and environmental management tool for the dairy industry. M. A. Wattiaux* and P. M. Crump, *University of Wisconsin–Madison, Madison.*

In controlled experiments, concentration of urea-N in milk, commonly referred to as milk urea-N (MUN), has been highly correlated with dietary CP level, N use efficiency (NUE, milk-N/intake-N) and urinary urea-N excretion (UUNE). However, under field conditions, variations due to non-nutritional factors (e.g., sampling type, frequency of milking, milk production) and lack of information about N intake the day of DHI testing have lessened the value of MUN as a management tool. This study explored the use of milk urea-N excretion (MUNE) as a UUNE predictor, and the use of MUNE per unit of milk protein yield (PY) as an indicator of NUE. Using DHI (AgSource-CRI) records from 2005 to 2013, we determined the association between PY and MUN or MUNE (calculated as MUN x milk production, regardless of sampling type). Then, we studied the relationship between MUNE/PY and NUE, and between MUNE and UUNE with data of a 128-cow nutritional study. Finally, we compared the MUNE/PY of DHI herds to the values obtained from the nutritional study. Regression analysis of approximately 1.5 million test-day MUN records of 529 DHI herds indicated no linear ($P = 0.08$) relationship between PY and herd-level MUN, but the relationship between PY (g/d) and MUNE (mg/d) was described as: PY = 0.173 + 4.19xMUNE ($r^2 = 0.995$, $P < 0.001$) for PY in the range of 600 to 1300 g/d. In the nutritional study, MUNE was calculated as average morning and evening MUN weighted by milk production at each milking. The relationship between UUNE and MUNE was described as: UUNE (g/d) = 26.8xMUNE ($r^2 = 0.991$, $P < 0.001$) for UUNE in the range of 40 to 125 g/d. Furthermore, MUNE/PY increased from (mean ± SE) 1.1 ± 0.3, to 2.2 ± 0.3, 3.6 ± 0.5, and 4.3 ± 0.3 mg/g as NUE decreased linearly ($P < 0.01$) when mid- to late-lactation cows were fed diets of 11.8, 13.1, 14.6, and 16.2% CP (DM basis), respectively. In the DHI database, however, MUNE/PY averaged 4.6 ± 0.01 mg/g, but ranged from 2.5 to 6.7 mg/g for the 47 herds for which MUNE could be calculated as in the nutritional study. In conclusion, MUNE may be used as a reliable predictor of UUNE and indicator of NUE. Comparing MUNE/PY of the nutritional study to MUNE/PY of selected Wisconsin dairy herds suggested that producers could feed cows to increase NUE and lower UUNE simultaneously across a wide range of PY. Additional research is needed to ascertain the usefulness of MUNE and MUNE/PY as management tools.

Key Words: protein nutrition, nitrogen, environment.