

kg) were blocked by weight within breed and randomly assigned to treatments. Treatments consisted of: 1) control (no supplemental B), 2) 5 mg/kg of supplemental B, 3) 50 mg/kg of supplemental B. Supplemental B was supplied from sodium borate. The control diet contained 10.2 mg/kg of B. Steers were housed in slotted floor pens with 2 animals per pen. Weights were taken at 14 d intervals. Jugular blood was obtained from steers on either d 42 or 44 for assessment of lymphocyte blastogenesis. One-half of the steers in each treatment group were sampled on each date. Supplemental B tended ( $P = 0.12$ ) to increase the blastogenic response of B lymphocytes to pokeweed mitogen, but did not affect proliferation of T lymphocytes when stimulated with concanavalin A or phytohaemagglutinin (PHA). Humoral immunity was assessed on d 49 by injecting steers IM with a

pig red blood cell (PRBC) suspension. Blood samples were collected at d 0, 7, 14, and 21 following PRBC administration for determination of antibody titers. Specific anti-PRBC IgG titers were affected by a treatment  $\times$  day interaction ( $P < 0.07$ ). Boron supplemented steers had greater ( $P < 0.05$ ) IgG titers than controls on d 7 but not on d 14 or 21 post-injection. Cell-mediated immune response was also evaluated following an intradermal injection of PHA on d 77 of the study. Skinfold thickness following PHA injection was not affected by dietary B. Performance of steers during the 77 d study was not affected by dietary B. Results of this study indicate that supplemental B did not affect the performance of growing steers, but may affect the immune response.

**Key Words:** Cattle, Boron, Immunity

## Ruminant Nutrition: Opportunities to Improve Forage Utilization and Rumen Function

**360 Utilizing fats and carbohydrates in forage-based diets for lactating cows.** M. S. Allen\*, *Michigan State University, East Lansing.*

Forages contain relatively high concentrations of fiber that is slowly and incompletely digested, limiting energy intake for high producing cows. Therefore, cows with high energy requirements are fed forage-based diets supplemented with feeds containing readily digested carbohydrates and (or) fats. However, specific fuels can have physiological effects that alter intake and utilization of dietary energy. The profile and pattern of absorption of fuels depend on the composition of the diet, including not only its chemical composition, but physical characteristics which influence ruminal fermentation and dynamics. Rapidly fermented carbohydrates and some fat sources can decrease feed intake, ruminal fiber digestibility, efficiency of microbial protein production, and increase flow of intermediates from fatty acid biohydrogenation from the rumen. Physiological effects of specific fuels might involve alteration of hormone or enzyme concentrations affecting gluconeogenesis, lipolysis and lipogenesis in tissues, fat and protein production by the mammary gland, gut motility, or feeding behavior. These physiological effects can influence energy intake, yield of milk and milk components, and body condition independent of the energy contributed by the fuel itself. Furthermore, physiological and production responses to specific fuels are dependent upon animal characteristics (e.g. glucose demand, lipolytic state, adiposity). Therefore, physiological effects of energy concentrates must be considered when formulating diets rather than formulating for energy density alone. The objective of this presentation is to discuss physiological effects of specific fuels and how these effects can be utilized to optimize diets for cows in different stages of lactation.

**Key Words:** Feed Intake, Energy Partitioning, Physiological State

**361 The role of ionophores in improving utilization of forage and forage-based diets.** V. Fellner\*, *North Carolina State University, Raleigh.*

Ionophores have been routinely added to non-lactating ruminant diets to improve animal performance and efficiency of feed utilization. Although several ionophores have received FDA approval, the most common and widely studied ionophore is monensin that is now also approved for use in lactating cow rations. Benefits of ionophores are

attributed, almost exclusively, to changes that occur in the rumen. A shift in the ruminal acetate:propionate ratio, with a concomitant decrease in methane and ammonia, are classical responses to feeding ionophores. The magnitude of change can vary, however, and is not always predictable. Preferential binding of ionophores to specific ions, level of ionophore inclusion in the diet, and dietary composition are some of the reported factors contributing to the variability in ionophore action. Managing the diet is perhaps the most critical factor in maximizing the benefit of ionophores, irrespective of type or level of inclusion. With high forage diets a lower dose of ionophore elicits maximal ruminal response. This is in contrast to high concentrate diets that typically provide for a greater ionophore response at higher doses. Generally, the fiber digesting microbes are most sensitive to ionophores whereas starch fermenters tend to be more resistant. Yet, a decrease in nutrient digestibility, specifically fiber, is more pronounced in diets having low, rather than high forage content. Changing the forage:concentrate ratio alters several factors, including intakes, passage rates and pH, all of which impact microbial shifts. Among the predominant fibrolytic bacteria, some that may even be resistant to ionophores, there is considerable difference in kinetics of microbial growth in response to ionophores. The major starch utilizing bacteria are less sensitive to ionophores but seem to alter their metabolism with source and level of starch. The driving force in ruminant production is energy whether it's from grain or forage. Varying dietary ingredients varies the substrate for the microbes as well as ruminal kinetics, both of which interact to determine the response to ionophores.

**Key Words:** Ionophore, Forage, Rumen

**362 Lactating dairy cow responses to yeast products.** P. H. Robinson\*<sup>1</sup> and L. J. Erasmus<sup>2</sup>, <sup>1</sup>*University of California, Davis,* <sup>2</sup>*University of Pretoria, Pretoria, South Africa.*

Studies with lactating Holstein cows, from peer review publications, were used to determine responses to feeding *Saccharomyces cerevisiae* yeast products (YP) from diet composition. The 21 studies reflected 6 YP, with 3 used in 6, and 3 used in 1 study. In spite of differences (i.e. NDF/starch;  $P < 0.05$ ) in diets, and milk yield, milk energy output and milk fat % ( $P < 0.05$ ) among control group cows (CGC) in studies of the 3 major YP, proportional milk, milk component, milk energy and DMI responses of cows to these YP did not differ. Thus all 21 studies were pooled and simple correlations showed that higher diet NDF or

ADF levels reduced responses to any YP, while higher diet starch had little impact. Increased milk and milk energy output of CGC reduced benefits of YP, and results suggest that YP milk yield response was absolute (~0.9 kg/cow/d) and decreased proportional to CGC milk yield as that increased. Multiple correlation analysis showed that only milk and milk protein yield responses to YP could be acceptably, but modestly ( $r^2 = .52$  and  $.45$  respectively), predicted based on milk yield of CGC and diet NDF and starch levels (both negative). Precision of predictions appeared compromised by unequal allocation of NEL between milk and BW change among studies. A reduced study set (i.e. 10), with BW and BW change reported, allowed % response in NEL output to feeding YP to be calculated. Results suggest that % increase in NEL output to YP increased modestly in diets with higher starch levels and decreased in diets with higher NDF levels, although changes were more positive as NDF fermentability increased. While findings support 2 currently proposed modes of action of *Saccharomyces cerevisiae* YP that suggest that they stimulate rumen microbes to increase fermentability of fiber and/or allow rumen microbes to more effectively metabolize end-products of ruminal starch fermentation, benefits in milk, milk energy and NEL output to YP were modest (i.e., 2.7, 3.1 and 5.3% respectively). Future studies in feeding YP should consider dose response designs at YP feeding levels higher than those in past studies, as well as report BW and BW change, in order to allow YP impacts on animal energetics to be determined.

**Key Words:** Yeast, Lactation

**363 Enzymes to improve forage utilization by ruminants: What's on the horizon.** K. A. Beauchemin\* and J. -S. Eun, *Agriculture and Agri-Food Canada, Lethbridge, AB, Canada.*

This paper reviews the research on the development of enzyme additives for ruminants and attempts to provide a rationale for enzyme

selection with emphasis on future research needs and opportunities. Ruminant feed enzyme additives are concentrated fermentation products with specific enzyme activities, primarily hemicellulases and cellulases. Enzyme additives have significant potential to improve fiber digestion in cattle, thereby enhancing feed utilization and animal performance. Enzymes help bridge the gap between actual digestibility of the feed in vivo and the potential digestibility of the feed that would occur under ideal conditions. However, in previous research, the response to enzyme additives has been variable because many of the products used were not specifically formulated for ruminants. The optimum array of enzymic activities in products designed for ruminants depends mainly on forage composition. In vitro assays that reflect conditions in the rumen and measure fiber degradability can be used to identify effective enzyme candidates and optimum dose rates. Recent studies indicate that, depending on the forage, about 50% of the improvement in in vitro fiber degradability due to added feed enzymes can be predicted from the main enzymic activities provided. Method of providing the enzyme additive to the animal must be also considered. Applying a liquid solution of enzymes to the feed allows the enzyme to bind to the target substrate, thereby increasing the resistance of the enzymes to proteolysis within the rumen and facilitating a pre-ingestive attack of the enzymes upon the plant fiber. Enzyme additives provide cattle producers the opportunity to feed higher fiber diets, thereby minimizing digestive upsets associated with feeding higher grain diets while still maintaining productive performance. The challenge is to develop a better understanding of the mode of action and the critical enzyme activities needed, such that product formulations and application methods and rates can be tailored to elicit the desired response at minimal cost.

**Key Words:** Enzymes, Fiber Digestion, Feed Additive

## Teaching/Undergraduate & Graduate Education: Enhancing the Undergraduate Learning Experience in Animal Agriculture, Through the Integration of Teaching and Research

**364 Enhancing learning through inquiry.** B. Wuetherick\*, *University of Alberta, Edmonton, Alberta, Canada.*

Almost two decades ago Ernest Boyer called on educators to "move beyond the tired old research versus teaching debate." That has resulted in several studies exploring the interrelation and integration of teaching and research in higher education in the North American, Europe and Australasia. Over a decade ago a well-known meta-analysis was conducted that explored commonly used measures of excellent teaching and research and demonstrated that there was at best only a minor positive correlation between them. The researchers concluded that it would be far more useful to investigate ways to increase the relationship than to try to insist that the status quo is acceptable. That was followed in 1998 by the well-known Boyer Commission, which criticized the current higher education system in the US and called on universities to make research-based learning the standard throughout undergraduate education. Undergraduate education is intended to furnish students with both generic and discipline specific skills, including inquiry and research skills, in preparation for a supercomplex, knowledge-based economy. Recent shifts toward a research-based curriculum have been attempting to provide this. Questions continue to

be asked, however, about what it means to bring teaching and research together effectively to benefit undergraduate student learning. Recently attempts have been made to conceptualize the integration of teaching and research in order to help shape the debate about how to move forward with making research-based learning the standard. This introduction to the symposium "Enhancing the Undergraduate Learning Experience in Animal Agriculture, Through the Integration of Teaching and Research" will explore different conceptions of the integration of teaching and research and will set the stage for further discussion by the co-presenters.

**Key Words:** Inquiry-Based Learning, Undergraduate Research, Research-Based Teaching and Learning

**365 Why should we integrate our teaching and research?** C. Colbeck\*, *The Pennsylvania State University, University Park.*

Actual synergies between teaching and research are masked by institutional evaluation practices that fragment academic roles and