Ruminant Nutrition Symposium: Time required for diet adaptation and minimization of carry-over effect in ruminants: Evidence-based decisions

342 Time required for adaptation of rumen fermentation and the rumen microbiome. Timothy Hackmann*, *University of Florida, Gainesville, FL.*

Dietary shifts disturb microbiota and fermentation of the rumen, and varying amounts of time are required for them to re-stabilize. Shifts from high-forage to high-grain diets have been studied for over 60 years. During these shifts, abundance of total and cultured bacteria generally increases and then stabilizes. For some shifts in some studies, stabilization was complete within 24 h, but in others, it was incomplete even after 3 wk. Specific groups of bacteria (cellulolytics, amylolytics, lactate-utilizers) and protozoa also require varying amounts of time to stabilize. The time required for methanogens and fungi to stabilize has seldom been studied. Stabilization of fermentation (pH, short-chain fatty acid concentration) does not necessarily coincide with stabilization of the microbiota. For diets with very high (>70%) grain, abundance of protozoa and cultured bacteria vacillates greatly and stabilizes slowly, if at all. More recent studies have employed culture-independent methods, such as qPCR and 16S rDNA sequencing, to investigate taxonomic composition of bacteria and methanogens during dietary shifts. These studies confirm that taxonomic composition does change during dietary shifts, but more frequent sampling is required to resolve at what exact point it stabilizes. Other culture-independent methods, such as whole-genome or transcriptome sequencing, need to be deployed to resolve changes in microbial function, not just taxonomic composition. Changes in microbial communities, whether assessed by culture-independent or dependent methods, need to be better related to variables of interest in feeding trials (e.g., diet intake and digestibility).

Key Words: dietary adaptation, microbiota, rumen

343 Time required for adaptation of behavior, feed intake, and dietary digestibility in cattle. Richard J. Grant*, Heather M. Dann, and Melissa E. Woolpert, *William H. Miner Agricultural Research Institute, Chazy, NY.*

Experimental designs such as Latin square, crossover, and switchback have been used extensively in nutritional studies to assess behavioral, intake, and digestibility responses to diet. A critical consideration when using these designs is the necessary length of an adaptation period to accurately measure treatment effect and to minimize potential confounding influence of carry-over from previous treatment. The objective of this review was to determine typical time required for adaptation of these responses based on research evidence primarily with dairy cattle. We focused on (1) eating, ruminating, and resting behavior, (2) dry matter intake (DMI), and (3) total-tract nutrient digestibility. Animal response to dietary treatment integrates response to physicochemical properties of the diet being studied as well as the feeding environment, and so the environment must be similar among treatments. For example, competition for feed can profoundly affect eating behavior and DMI. Response to diet for eating, ruminating, and resting behaviors usually stabilizes within 1–7 d. Consequently, DMI response to diet reflects the pattern of change in eating behavior. This time course is affected by physical and chemical attributes of the diet such as particle size, carbohydrate fermentability, and fat or protein content and characteristics. Most research indicates that ruminant total-tract digestibility ordinarily adjusts to diet within 10 to 14 d. Meta-analysis reveals that change-over designs are as accurate as continuous designs in assessing DMI. However, diets of extremely high or low digestibility may cause lingering effects on digestive and metabolic processes related to ruminal function or dynamics of body fat and protein that may confound interpretation of response to diet in subsequent experimental periods. Examples of expected time to adaptation and potential carryover in lactating dairy cattle will be illustrated using Latin square studies that evaluated diets with considerable range in forage amount and carbohydrate fermentability. In summary, adaptation periods of approximately 7–14 d are usually adequate for measuring response in eating behavior and DMI, but potential consequences of carryover effects in change-over designs are less clear.

Key Words: adaptation, carryover

344 Time required for adaptation of protein metabolism. G. I. Zanton*, *USDA, Agricultural Research Service, US Dairy Forage Research Center, Madison, WI.*

Animals that can appropriately adjust to varying environmental and nutritional conditions possess a survival advantage. Maintaining homeostasis and homeorhesis in response to changing nutritional conditions requires flexibility in nutrient partitioning and use efficiencies. This is especially the case for protein metabolism because there is no dedicated pool of amino acids held in reserve for times of changing dietary protein availability. Research on the adaptation in protein metabolism to changing dietary conditions could have potential implications on experimental design and on basic and applied ruminant nutrition. However, experiments directly evaluating the metabolic characteristics and appropriate timing of dietary adaptation are very limited. This is especially the case when compared with the number of experiments that have evaluated a response to a nutritional change after the period of adaptation is presumed to be complete, although rarely verified. Factors affecting the adaptive responses in protein metabolism in the ruminant are multiple and likely interacting, although the time required for adaptation appears to depend most on factors such as the duration and level of the previous nutritional condition, the difference from the current nutritional condition, the timing of these dietary changes with respect to the physiological state of the animal, the priority of the metabolic demand, and the productive state of the animal (i.e., the respective combinations of maintenance, growth, and/or lactation). As a consequence of these varied factors, from an experimental perspective, the time required for adaptation may depend on the response variables of interest, productive state of the animal, and the treatments under investigation. Existing literature will be reviewed to highlight time-related adaptive responses to diet changes on protein digestion, post-absorptive metabolism, and production and to emphasize areas where this understanding is incomplete.

Key Words: protein nutrition, adaptation, ruminant

345 Time required for diet adaptation and minimization of carry-over effect in ruminants: The perspective of an experimental researcher. Kevin J. Harvatine*, *Penn State University, University Park, PA.*

The ideal experimental design depends on the biological mechanisms and physiology under investigation. Classical metabolic data provides

insight into clearance of specific metabolic pools, but recent discoveries in epigenetic provide the opportunity for long-term responses to diet. Arguably, the most complete experimental design would determine the effect of a dietary treatment over entire lactations, multiple lactations, and possibly over multiple generations. However, these approaches are not practical and arguably other interactions are of greater importance. Experimentally the time course of response to a treatment is very important to provide mechanistic insight into the primary mechanism and secondary adaptations. Both primary mechanisms and secondary adaptations are biologically relevant and application of time-series analysis in experiments may provide key insight in understanding theses mechanisms. In our own work with milk fat depression we have determined the time course of rumen response to diet changes and mammary response to bioactive fatty acids. This information has been invaluable to efficient experimental design and increasing confidence in mechanisms. Lastly, a common goal is to determine the expected response to a treatment. Temporal adaptation is one factor to consider, but many other interactions such as composition of the basal diet (e.g., high vs. low fiber) and physiological state of the cow (including level of intake and production) are also extremely important factors. Arguably, testing treatments over several conditions with adequate, but not excessive, treatment durations would optimize the accuracy of the predicted response when a treatment is applied in practice.

Key Words: time-course, milk fat depression

346 The perspectives of a beef cattle nutritionist. Shawn L. Archibeque*[1] and Gerald B. Huntington[2], *[1]Department of Animal Sciences, Colorado State University, Fort Collins, CO, [2]Department of Animal Science, North Carolina State University, Raleigh, NC.*

There are numerous changes in beef cattle in both their symbiotic and physiological aspects as they are adjusted to various diets associated with varying production states and research needs. Within the beef industry, there is a need to address changes within diet types as well as across diet types (i.e., high roughage vs. high concentrate). These changes will influence our understanding of how nutrients are used during varying production states. These variations in treatments that deal with source more than daily supply will allow for minimal variation in measurements within a shorter period of time than those studies with large changes in particularly nutrients or overall plane of nutrition. In particular, these adaptations are greatly varied in the literature. This is of particular interest in studies that use a study design that minimizes animal-to-animal variation through the repeated use of animals in the study, such as a Latin square or crossover design. To highlight the significance of this issue, over 35% of the articles in the ruminant nutrition section of the *Journal of Animal Science* used these research techniques and had a range in adaptation periods from 9 to 27 d, with an average of 14.6 d. There is a need for greater understanding and homogeneity in these adaptation periods for future understanding of data, particularly those that will be happening over a fixed period of time.

Key Words: homeorhetic adaptation, ruminal adaptation, variance

347 Algae meal for ruminants: I. Nutrient digestibility in finishing lambs. Rebecca S. Stokes*, Megan L. Van Emon, Daniel D. Loy, and Stephanie L. Hansen, *Department of Animal Science, Iowa State University, Ames, IA.*

Heterotrophic microalgae combined with soyhulls forms an algae meal (ALG) which contains partially deoiled microalgae (DMA; 57% DM basis) and soyhulls (43%). Eight whiteface wethers (23.02 ± 0.54 kg) were used in a 4 × 4 Latin square design to determine the effect of the DMA portion of ALG on total-tract nutrient digestibility. Lambs received 1 of 4 isonitrogenous dietary treatments (2 sheep·diet^{-1}·period^{-1}) where ALG was added at the expense of soyhulls: a soyhulls-based control (CON; 53% soyhulls), 10% DMA from ALG (DMA10), 20% DMA from ALG (DMA20), and 30% DMA from ALG (DMA30). There were 4 periods, with 10 d of adaptation and 5 d of total fecal and urine collection. Prior to each collection period was a 14 d washout period where all lambs were fed a common diet. Data were analyzed using Proc Mixed of SAS, and pooled LSMEANS and SEM are reported. Intake of OM and fecal OM output were similar ($P \geq 0.11$) between CON and ALG-fed lambs. Urine output linearly increased ($P = 0.02$) as DMA increased in diets (0.57, 0.72, 0.77, and 0.87 ± 0.08 L/d for CON, DMA10, DMA20, and DMA30, respectively). Digestibility of OM (73.6, 72.9, 71.0, and 69.1 ± 1.01% for CON, DMA10, DMA20, and DMA30, respectively) linearly decreased ($P < 0.01$) as DMA increased in diets. Also, NDF (65.5, 61.3, 53.6, and 39.0 ± 2.36% for CON, DMA10, DMA20, and DMA30, respectively) and ADF (65.0, 60.7, 50.9, and 30.2 ± 1.94% for CON, DMA10, DMA20, and DMA30, respectively) digestibility linearly decreased ($P < 0.01$) as DMA increased in diets. Ether extract digestibility did not differ ($P = 0.24$) between CON and DMA-fed lambs. Nitrogen digestibility linearly decreased ($P = 0.05$) as DMA increased in the diet (60.2, 58.9, 58.0, and 57.2 ± 1.10% for CON, DMA10, DMA20, and DMA30, respectively). Also, N balance linearly decreased ($P < 0.01$) as DMA increased in the diet (10.1, 8.4, 8.9, and 6.8 ± 0.64 g/d for CON, DMA10, DMA20, and DMA30, respectively). These results suggest that the DMA portion of ALG may be less digestible than soyhulls, and even though the ALG had minimal effects on OM digestibility the differences in N balance may suggest an effect on growth in sheep, under the conditions of this study.

Key Words: algae, digestibility, sheep

348 Algae meal for ruminants: II. Growth and carcass characteristics of finishing steers. Rebecca S. Stokes*, Daniel D. Loy, and Stephanie L. Hansen, *Department of Animal Science, Iowa State University, Ames, IA.*

De-oiled microalgae from large-scale production of heterotrophic microalgae can be combined with soyhulls to form a novel feedstuff called algae meal (ALG). To determine the effects of replacing corn in a finishing diet with ALG on growth and carcass characteristics, crossbred steers (168) were blocked by BW (432.2 ± 30.8 kg) into pens of 6 steers (7 pens per treatment) and assigned to 1 of 4 diets: a corn-based control (CON), 14% ALG (ALG14), 28% ALG (ALG28), and 42% ALG (ALG42). Corn was replaced by ALG on a DM basis. Steer BW were taken on d 0, 1, 28, 56, 74, 101, and 102, and steers were harvested on d 103. Pen was the experimental unit and DMI, ADG, and G:F data were analyzed as repeated measures. Two steers per pen were selected for sampling of blood and liver (d −1 and 96), and collection of rib facings at harvest. Overall DMI linearly increased ($P < 0.01$) as ALG increased in the diet (12.7, 13.4, 13.8, and 14.4 ± 0.15 kg/d for CON, ALG14, ALG28, and ALG42, respectively). There was a treatment by time effect for ADG ($P < 0.01$), with ADG linearly decreasing ($P \leq 0.03$) in the first and third month, not differing ($P = 0.95$) in the second month, and linearly increasing ($P < 0.01$) in the fourth month as ALG increased in the diet. Final BW did not differ ($P = 0.74$) between CON and ALG-fed cattle. There was a treatment by time effect for G:F ($P < 0.01$), with G:F linearly decreasing ($P < 0.01$) in the first 3 mo as ALG increased in the diet, while G:F linearly increased ($P < 0.01$) in the fourth month. Yield grade linearly decreased ($P = 0.02$), and there was a tendency for dressing percent and 12th rib backfat to linearly decrease ($P \leq 0.10$) as ALG increased in the diet. Plasma Cu, Fe, and Mg concentrations were not different ($P \geq 0.31$) in CON vs. ALG cattle; however, plasma Zn concentrations linearly increased ($P = 0.03$) as ALG increased in the diet. Total lipid, SFA, MUFA, and PUFA concentrations in the longissimus thoracis did not differ ($P \geq 0.13$) between CON and ALG-fed cattle. It appears ALG has less energy than corn; however, minimal effect on carcass performance suggests ALG may serve as a potential replacement for corn in feedlot diets.

Key Words: algae, performance, cattle