RECENT ADVANCES IN BEEF CATTLE NUTRITION

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INTRODUCTION

Adequate nutrition programs are vital to optimize health and production in beef cattle systems. A predominant economic (and environmental) problem in the beef industry is how to optimize the utilization of feed resources to maximize efficiency of feed utilization and production and to minimize waste excretion. Feed costs represent the largest portion of total costs of production in cow/calf and growing and finishing cattle production systems. Therefore, optimal feeding management programs are necessary to maximize profitability. The objectives of this proceedings paper are to discuss new advances in beef cattle nutrition, including impacts of maternal nutrition on fetal and offspring performance, approaches to predict and improve our understanding of feed efficiency, approaches to alter the microbiome to improve cattle performance and reduce environmental impact, and feeding strategies to alter the healthfulness of beef.

DEVELOPMENTAL PROGRAMMING

It is well known that nutrient requirements change throughout the production cycle in breeding females. However, there are often times during pregnancy that there is limited quantity and quality of pasture or feeds and therefore cows often go through periods of nutrient and energy restriction. Nutritional guidelines have often focused on providing adequate or surplus nutrition during the last portion of gestation and early lactation as this period has the greatest effect on fertility and post-partem interval which is important so that cows remain on a yearly calving interval. However, it is now well recognized that environmental stressors, such as restricted nutrition, during fetal and post-natal development can have long-term effects on health and well-being of that individual (Barker, 2004; Neel, 1962; Reynolds and Caton, 2012). This concept is known as developmental programming.

Altered maternal nutrition in beef cows can also result in changes in growth, fertility, and meat quality of offspring (Funston and Summers, 2013). For example, protein supplementation to cows fed low quality forage has resulted in offspring with greater average daily gain, improved fertility, and greater marbling (Funston and Summers, 2013). These responses could be mediated through impacts on the hemodynamics of uterine blood flow and nutrient delivery to the fetus (Vonnahme et al., 2015) which results in changes in metabolism and tissue function that can continue through maturity. Changes in fetal development are correlated with changes in blood flow and nutrient delivery during pregnancy (Vonnahme et al., 2015). Some of the metabolic and functional changes observed in fetuses from nutrient-restricted dams may be related to differences in muscle and fat differentiation and growth, cardiovascular function, energy metabolism of visceral tissues, pancreatic endocrine and exocrine function, and likely many more cumulative effects. Research from our group has suggested that nutrient restriction during early pregnancy reduces O_2 consumption and realimentation until mid-pregnancy increases O_2 consumption in the fetal small intestine (Prezotto et al., 2015). If these changes persist during post-natal growth, this could contribute to differences in energetic efficiency as the intestine is a large contributor to overall energy use in animals (Koong et al., 1985). The fetal pancreas undergoes significant shifts of escalation and regression in endocrine and exocrine function during gestation and in response to maternal nutrient restriction. Realimentation reverses the impact of restriction, and in some cases, increases the concentration of fetal pancreatic protein and enzymatic activity compared to those fed adequate nutrition throughout gestation (Keomanivong et al., 2016). It is not known if these differences persist after parturition and into adulthood. Feeding strategies during mid- to late gestation can alter pancreatic physiology of the cow and fetal pancreatic development. In fact, in humans, data suggest that maternal nutrition influences the incidence of diabetes of the offspring later in life (Reusens and Remacle, 2006).

BETTER UNDERSTANDING AND PREDICTORS OF FEED EFFICIENCY

There has been an increased recent interest in studying approaches to select cattle that have improved feed efficiency. Unfortunately, measuring individual feed intake is difficult and expensive for large quantities of cattle. Additionally, measuring feed efficiency on pasture and in mature non-growing animals is especially challenging.

Therefore, there is a need for alternative approaches for estimating feed intake. This would allow for more efficient genetic selection programs. This also allows for the development of precision nutrition programs where cattle could be sorted and fed to more efficiently provide the adequate amount of nutrients and energy to individuals. It also will allow for a greater understanding of the physiological mechanisms influencing feed efficiency which could lead to the development of new approaches for improved feeding, genetic selection, and management.

There are multiple levels where regulation of metabolic processes can occur that influence efficiency. According to Herd et al. (2004), there are at least 5 major processes that contribute to variation in the efficiency of nutrient use. These include intake of feed, digestion of feed, metabolism, activity, and thermoregulation. Arthur et al. (2004) also suggested that growth rate, maturity pattern, lactation status, reproduction, metabolic rate, body composition, efficiency of nutrient absorption, energetic efficiency of tissue growth, disease status, activity, environment (climate), and body weight are other important factors affecting the efficiency of feed utilization. There likely are multiple other factors, and interactions of these factors, that are important in regulating the efficiency of nutrient use.

Of the more compelling recent research on potential indicator traits that could be used as a predictor of feed efficiency is the use of measuring body composition, metabolites in blood, heat production, indicators of mitochondrial function, and feeding behavior appear to have potential. Research has suggested that metabolites such as urea nitrogen, cholesterol, liver enzymes, and N15 enrichment as well as others are associated with feed efficiency traits (Montanholi et al., 2009; Richardson et al., 1996; Swanson and Miller, 2008; Wheadon et al., 2014). Another promising approach is the use of infrared imaging techniques to estimate heat loss, which is a major energy loss in animals. Research has suggested that body surface temperature, as measured using infrared imaging is associated with feed efficiency traits (Montanholi et al., 2009); however, care must be taken and more research is necessary to standardize this approach (Montanholi et al., 2015). The most appropriate approach to predict feed efficiency in individual animals is likely the use of a combination of some the above-mentioned and other factors like genetic markers and pedigree information.

METAGENOMICS AND THE MICROBIOME

The rumen is host to bacteria, archaea, protozoa, and fungi which live in symbiosis with the host animal and help to convert feed into usable products by the animal. Early research on defining the microbial ecology of the rumen was conducted using anaerobic culturing approaches of mixed or specific microbes. There have been significant improvements in laboratory procedures to sequence nucleic acids allowing for greater characterization of microbial communities such as in the rumen (Denman and McSweeney, 2015). This allows for greater characterization of microbial communities within ecosystems as many microbes are difficult or not possible to culture. This has led to the study of metagenomics of the microbiome of different microbial ecosystems, including the rumen. The microbiome is the collective DNA sequences of a mixed population of microbes in a specific ecological niche and metagenomics is the analysis of the collective genomes that are present in a defined environment or ecosystem which may give insight into functions of non-cultivated bacteria (Lepage et al., 2013).

It is becoming evident that the gut microbiome is unique to individuals and that metabolic activities within the host and the microbiome have great influence on the physiology of each other. For example, the microbiome has great influences on function within the gastrointestinal tract related to digestion and gut health, the microbiome-gut-brain axis, driving epigenetic changes which result in permanent changes in the host animal's physiology, as well as other physiological effects (Reigstad and Kashyap, 2013). In humans it appears that there is a relationship between the microbiome and long-term health outcomes resulting from altered metabolism or cellular health status. Some of these long-term health outcomes resulting from changes in the microbiome include irritable bowel syndrome, obesity, and diabetes to name a few (Lepage et al., 2013).

The early research on using metagenomic methods to better understand the rumen microbiome has focused on better understanding the diversity of the microbiome between animals and its relationship with nutrition or physiological status. The review by McCann et al. (2014) does a nice job of summarizing the initial research using the metagenomics approach to study the microbiome in the digestive tract of ruminants. For an example relative to nutrition, research has suggested that the microbiome changes during dietary adaptation and with the incidence of ruminal acidosis (Petri et al., 2013). Also, research suggests that differences in the microbiome are evident in cattle with differences in feed efficiency traits (Hernandez-Sanabria et al., 2012; Myer et al., 2015) suggesting that inherent differences in the microbiome between animals contributes to differences in feed efficiency between animals. Other interesting research (Wallace et al., 2015) has suggested that the microbiome in cattle differs in those with differing methane emission rates, which potentially could improve efficiency and decrease the environmental impact of beef production if this microbial population can be enriched. In the future, there is great potential in studying the specific physiological outcomes of the host and microbes occurring because of these shifts in microbial communities. Metabolic shifts and diversity may be as important, or more important, than community shifts (Karasov et al., 2011). Increased knowledge in the this area could be complemented by transcriptomic, proteomic, and metabolomic approaches which would expand our knowledge greatly on functional aspects of the microbiome. This potentially could lead to the better design of feed additives such as prebiotics or probiotics to alter the microbial ecology within the digestive tract, improving digestive and metabolic performance of the host, and, ultimately, improve animal performance and health.

BEEF ENRICHMENT

There has been much emphasis in different regions of the world on improving product quality of beef related to eating satisfaction by improving nutrition, breeding, and management programs. More recently, enhancing quality by improving the healthfulness of the product has also seen significant research activity. For example, this can be accomplished by feeding increased forages relative to grain or supplementing with feedstuffs containing polyunsaturated fatty acids such as fish oil or linseed meal which can enhance the omega-3 polyunsaturated and/or conjugated linoleic acid content of beef (Scollan et al., 2014). There also is potential to enrich beef through nutritional or other means with bioactive peptides, antioxidants, or specific minerals (Lafarga and Hayes, 2014; Lawler et al., 2004) that also could improve the healthfulness of beef and increase demand for beef products. It is important, however, to consider the effects relative to growth performance and marketing potential of the product.

CONCLUSIONS

Providing appropriate nutrition to cattle is key to maintaining and improving the efficiency of beef production as feed costs represent the largest portion of total costs of production. Utilizing new technologies could lead to the development of precision nutrition programs designed to provide appropriate nutrition to individual cattle and that individual's microbiome. This also could lead to the development of new feed products or feeding strategies to improve production efficiency.

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