Bison meat: Characteristics, challenges, and opportunities

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Implications

- The bison industry in North America is growing and continuing to position their meat products in the premium red meat marketplace both nationally and internationally.
- Bison are an economically competitive red meat for livestock producers, due to their relatively low input costs and high market value.
- Bison meat has shown superior nutritional (high proportion of protein and excellent source of vitamins) and palatability quality traits (generally more tender and juicy) compared with beef.
- Some challenges exist, such as improving carcass assessment systems and color stability to expand into the fresh-meat retail market.

Key words: bison, carcass grading, color stability, nutrient profile, palatability

Bison are a native species to the North American plains that have adapted to local weather conditions and naturally available feeds. Bison are better suited than cattle at utilizing low quality feeds, which leads to economic advantages in cost of production (SMA, 2000). Raising bison in a way that promotes and builds on these advantages will help keep them a distinct, unique product in the marketplace. In the USA, bison are ungraded and marketed as game animals, whereas in Canada, bison are marketed through a grading system as a means to standardize carcass and quality consistency. In addition, bison offer a healthy and nutritious red meat product that meets the demands of a growing number of health-conscious consumers looking for alternatives to traditional red meats without sacrificing an excellent eating experience (SMA, 2000). There are areas for improvement in bison meat quality as the meat color is darker (Koch et al., 1995) and is less stable at retail than beef. This article shows the current state of scientific advances in bison production and meat quality improvement and how the bison meat industry may benefit from the careful application of this knowledge.

Bison Production: A Return to the Wild West?

Between 30 and 70 million Bison (*Bison bison*) roamed North America at the time of European contact in the 1800s. The herds are said to have ranged from Alaska to the northern tier of Mexican states and from New England to the West Coast (NBA/CBA, 2010). For thousands of years, they existed in North America, and hunting them was an essential source of sustenance as well as a spiritual focus in the culture of First Nations. Well-orchestrated hunts using "buffalo jumps" involved carefully setting up scenarios where a herd could be startled into stampeding and running off large cliffs. This resulted in many animal deaths, and supplied people with food, clothing, and parts for tools. To the early European settlers, the bison became a source of wealth and personal profit. Careless uninhibited slaughter of the great herds reduced numbers to no more than 1,500 in total in the 1880s (NBA/CBA, 2010). Thankfully, a handful of ranchers saw the need to save some of the remnant herds; men like Michel Pablo, C.J. "Buffalo" Jones, Charles Goodnight, and Scotty Philip (NBA/CBA 2010). It is from the animals preserved by these individuals that the present bison population is derived.

In Canada there are 140,000 ranched bison, and in the USA, there are 162,000, for a total of about 300,000 bison on farms in North America (T. Kremeniuk, Canadian Bison Association Executive Director Regina, Saskatchewan, Canada, personal communication). In Canada, there are approximately 1,200 bison farms, with 77% of the farms located in the provinces of Saskatchewan and Alberta. In the USA, there are 2,564 bison farms throughout the country (USDA, 2012).

The bison-farming industry has experienced strong pricing and high demand for its meat product for several years. In 2013, 71,600 bison were slaughtered in North America for meat, 14,400 in Canada, and 57,200 in the USA (T. Kremeniuk, Canadian Bison Association Executive Director Regina, Saskatchewan, Canada, personal communication). Meeting market demand for bison meat is a challenge. After several years of declining herd size combined with successful marketing initiatives of the meat, the bison industry is presently working to build up numbers to increase supply. Bison meat is a niche product that attracts a high value in the marketplace, and consumers are willing to pay significant premiums for bison steaks that are certified as being produced without hormones or growth-promoting agents (Torok et al., 1998; Steiner et al., 2010; McCorkell et al., 2013).

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Bison Harvest: Challenges with Modern Harvest of a Recently Domesticated Species

There are many differences between beef and bison in both the slaughter and processing operations (Mayan, 2000). Bison are more flighty and fearful of humans compared with cattle; thus, transportation and handling of bison is particularly difficult due to their relatively large flight zone, strong herd instincts, and aggressive nature (CARC, 2001). During transportation, bison will remain calmer if kept in a group during loading, unloading, and lairage. Dehorned and horned bison have to be segregated into different compartments or transported in different trucks to avoid goring as the damage to the hide and carcass results in a loss of yield and consequent loss of dollars to the producer (Mayan, 2000). Most commercial bison herds are raised with their horns. If a producer chooses to dehorn, typically the entire herd is dehorned, so that there is not a mix of dehorned and horned animals together which would negate any advantage of dehorning by continuing a goring risk in the herd (Galbraith, 2011). During the unloading process in the slaughter facility, bison tend to run in groups, so it is imperative to have pens with limited side visibility and long alleyways for the animals to exit the trailers (Mayan, 2000). Some recommendations by Lanier and Grandin (2000) can be applied in the slaughter facility. For example, bison will remain calmer if each animal is brought up individually to the stunning box from the lairage pen. Bison waiting in the single file chute often become agitated and will stay calmer if they remain in a lairage pen with their mates. The stunning box should have solid sides as well as a solid top to prevent bison from rearing and endangering workers (Lanier and Grandin, 2000). For animal welfare reasons, bison are typically stunned with a rifle (calibers from 0.22 magnum to 0.223 and larger) due to the thickness of the skull preventing proper stunning with a captive bolt (Mayan, 2000). The Canada Food Inspection Agency (CFIA, 2013) offers stunning guidelines for bison when firearms are used to control the perforation and ricochet problems.

Mobile abattoirs have been tested for use with bison to minimize the stress associated with transport (Galbraith, 2011; McCorkell et al., 2013). Although some improvements to quality traits were noted using mobile abattoirs (fewer incidences of carcasses graded as dark, less bruising, and improved meat tenderness), the stress associated with assembling and stunning animals in home facilities varied depending on the amount of pre-stunning handling. Limits on size of the mobile facility (maximum capacity was 10 bison per day) and the high cost associated with cooling the carcasses to the required temperatures before off-loading (4°C; Meat Inspection Act, 2005) made the cost per animal to the producer greater than a stationary abattoir. The study concluded that mobile abattoirs may have a place for remote bison farms with low volume, high-value sales that have the value-added attributes of zero transport, improved animal welfare, and improved quality for the discerning consumer. However, on-farm handling facilities and methods would need to be standardized to provide welfare and quality guarantees.

From the stunning station, the carcass is taken to the dressing area where the head is skinned for inspection. This process is relatively slow compared with beef cattle, as the head of a bison is very large. The carcass is then moved to the hide removal station. Hides, particularly on the anterior portion of the animal, are thick and require a change in skinning equipment to handle the extra weight. The hide on the posterior area of bison is very thin, requiring a slower pace on the rump areas so that the hide is not punctured and cross-contamination is not introduced before evisceration. Bison evisceration, similar to beef, removes the organs and contents of the abdominal and thoracic cavities, which are presented for inspection. At the carcass splitting station, bison carcasses can be too large for standard beef splitting equipment, as the thoracic vertebrae of bison are larger than beef carcasses. Once the carcass has been split, the remainder of the processing (i.e., washing, weighing, and chilling) is very similar to beef (Mayan, 2000). Conventional chilling (0 ± 2°C until 24 hours post-mortem) and other chilling technologies have been evaluated for bison, such as blast chilling (Janz et al., 2001), spray chilling (Janz and Aalhus, 2006), and elevated temperature conditioning (Janz et al., 2000), but none of these are currently used commercially. Using these technologies, the increased cooling rate helped to minimize carcass shrinkage, which was reflected in the yield (Mayan 2000; Janz et al., 2001). However, in the USA, Rinse & Chill (MPSC Inc., Hudson, WI) technology (vascular infusion with a chilled isotonic solution of sugars and salts) is being successfully used commercially to reduce the post-mortem pH and temperature earlier and more rapidly than the traditional slaughter practices and to thoroughly remove residual blood from the animal (Yancey et al., 2001). In addition, the technology is thought to contribute to improved/easier boning-out, leaving less meat on the bone.

Bison carcasses are fabricated into cuts similar to those from a beef carcass (Aalhus and Janz, 2000). The bison industry has "adopted" names, numbers, and standards that were developed for beef by both Canadian and U.S. regulatory bodies (CMC, 1988). The major subdivisions of the carcass include chuck, brisket, rib, short plate, short loin, sirloin, hip, and flank.

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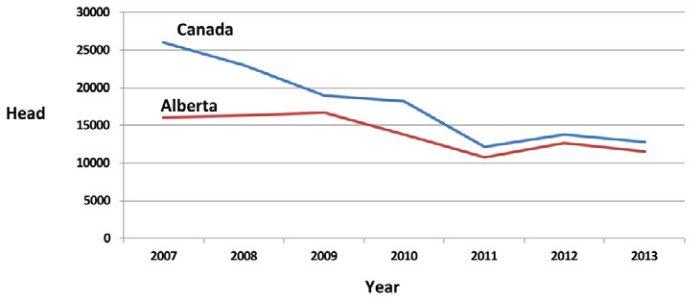

Figure 1. Seven-year trends for the total bison slaughter (no. of animals). (Source: C. Delaloye, Canadian Beef Grading Agency, General Manager, AB, Canada, personal communication.)

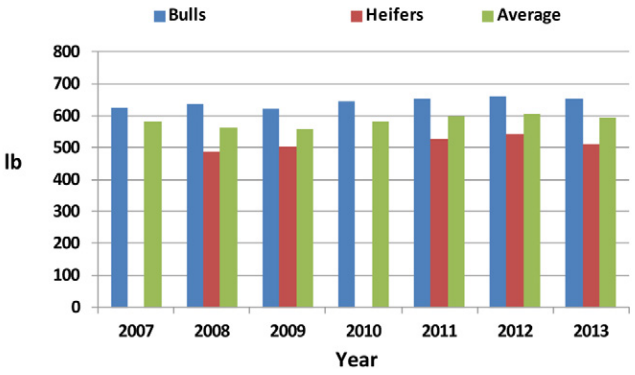

Figure 2. Seven-year trends for Canadian bison carcass weights (lb). (Source: C. Delaloye, Canadian Beef Grading Agency, General Manager, AB, Canada, personal communication.)

Bison Have Unique Carcass and Quality Attributes

Development of grading systems and their impact on production

The decade of the 1960s is considered the beginning of the modern bison business. During this period, bison production increased rapidly as private ranchers entered into this field of meat production. In the USA, bison are often marketed as "wild game" animals; however, some processors market bison in a manner similar to other red meats, while in Canada, a bison grading system was developed to provide a consistent product to the consumer, to gain a marketing advantage and to promote recognition in the international markets. The first attempt to establish a bison grading system was in the late 1950s and early 1960s. Tentative grades came into effect on 21 Mar. 1960. At this time, four grades of bison were established: Canada Choice Buffalo, Canada Good Buffalo, Canada Utility Buffalo, and Canada Manufactured Buffalo. The grade names and standards were based primarily on the beef grading system. Interestingly, these tentative grade standards were never incorporated into enforceable regulations, and hence, quality grades were never officially recognized or applied. The attempt to relate inherently different bison carcasses to regulations designed for beef grading proved to be their downfall.

After several years of evaluation, the Bison Grading System was revised and amended in 2007 to the current Canadian Bison Grading System. The present grading system comprises 10 bison grades A1, A2, A3, A4, B1, B2, B3, D1, D2, and D3 distributed in two maturity classes (Canada Gazette, 1992). Physiological maturity is determined by the degree of ossification in the cartilaginous caps located at the ends of the spinous processes of the 9th, 10th and 11th thoracic vertebrae. Youthful carcasses (Maturity Class I) are defined as having 80% or less ossification in the designated caps, and mature carcasses (Maturity Class II) are those having caps that are deemed to have greater than 80% ossification. Other grade factors include the degree of muscling on the carcass (conformation), color and quality of the fat cover, and the color and firmness of the muscle tissue. Carcasses are further classified by the amount of fat cover. Carcasses qualify for the A grades based on backfat depth at the grade site (at a point three-fourths of the length of the rib eye at the 11th rib), which includes A1 (2 to 6 mm), A2 (7 to 12 mm), A3 (12 to 18 mm), and A4 (greater than 18 mm). Carcasses that otherwise qualify for the A grades but have less than 2 mm of grade fat are given a B1 grade. Youthful carcasses having medium muscling, yellow fat, or dark cutting characteristics are graded as B2 while youthful carcasses having a deficient to emaciated muscling are given a B3 grade. Maturity Class II carcasses having excellent to medium muscling fall into the D1 (2- to 6-mm grade fat) or D2 (>6-mm grade fat) grades while mature carcasses having a muscling no greater than medium, or less than 2 mm of grade fat, are given a D3 grade. Carcasses qualifying for the D grades have no minimum requirement for fat or lean color or firmness.

The grading system assists bison meat marketers in delivering a consistent product to their customers. The grading system also provides information back to producers to correct non-desirable trends in bison production (e.g., over-finished carcasses). A review of the Canadian Bison Industry carcass-grading statistics over the last 7 years indicates trends in quality grades and performance that include a decrease in overall number of animals slaughtered, slight increase in average weights at slaughter, and an increase in over-finished carcasses (C. Delaloye, Canadian Beef Grading Agency, General Manager, AB, Canada, personal communication). There has been a decrease in the total slaughter of bison over the last 7 years. Although in 2012, there was a slight increase compared with the previous year (13,774 vs. 12,167), the total slaughtered bison were well below the 25,000 animals slaughtered in 2007 (Figure 1). The reason for the recent decline in slaughter numbers in Canada may be due to herd expansion (retention of breeding animals) at a time of fewer overall animal numbers, the movement of more live animals to slaughter plants in the USA, and further liquidation of animals for the increased prices driven by strong consumer demand (CBA, 2012). Conversely, the average weights at slaughter have only slightly increased (3%) during the same period (Figure 2), but the total of over-finished carcasses, those showing more than 12 mm of fat thickness (Canada A3 and Canada A4 together), have increased 4% (32% in 2007 vs. 36% in 2013). Over the last 2 years, carcasses with a fat thickness in the range between 2 and 6 mm (Canada A1) have decreased (35% in 2011 vs. 29% in 2013; Figure 3). The occurrence of over-finished carcasses (Figure 4) is especially remarkable in heifers (López-Campos et al., 2014), which agrees with studies in beef reporting sex influences on the fattening patterns with heifers fattening at lighter body weights than intact males (Bradley et al., 1966; Berg and Butterfield, 1968). Lean carcasses are one of the strengths in the bison industry. Over-finishing bison reduces the efficiency of bison production systems since the production of fat requires considerably more dry matter intake than the production of lean, and consequently, costs about four times more feed per unit gain (Owens et al., 1995).

Consumer appeal and nutritional characteristics

North American consumers tend to think of bison meat as an alternative to beef with strong links with their own heritage (Hobbs et al., 2006). The role of bison meat as an alternative red meat was clear after the bovine spongiform encephalopathy (BSE) crisis in 2003 when Canadian per capita consumption of bison meat increased while beef consumption decreased (Steiner et al., 2010). However, based on a study evaluating the willingness of consumers to pay for bison attributes (Hobbs et al., 2006), the bison industry needs to focus on providing a satisfactory eating experience, as the heritage and health attributes would not be enough to compete with other available meats. Furthermore, price is the most important variable for consumers, more important than attributes such as fat content, tenderness, or ease to cook (Sanderson et al., 2003).

Bison meat is usually compared with beef to portray its beneficial attributes (Rule et al., 2002). Within the bison industry itself, grain- and grass-fed bison are also compared, due to the perception of variations in quality and composition from different production systems (Marchello and Driskell, 2001). Nutritional guides from Canada (Health Canada, 2010) and the USA (USDA, 2013) show lean and ground bison as having less fat than beef (2.4 and 7.2 g of fat per 100 g of lean and ground bison meat, respectively, vs. 8.1 and 10.0 g of fat per 100 g of lean and ground beef, respectively). Cholesterol content seem to be similar for both meats, with some differences between calculations from Health Canada (~80 mg per 100 g of meat) and the USDA (~60 mg per 100 g of meat). More comprehensive studies (Rule et al., 2002) have reported low amounts of fat in lean meat from grass-fed beef and bison (~1 g per 100 g of meat), with greater fat content in grain-fed beef (~3 g per 100 g of meat) than in grain-fed bison (~2 g per 100 g of meat). Furthermore, the least concentrations of cholesterol were found in meat from grass-fed bison (~44 mg per 100 g of meat). These values usually refer to the denuded *longissimus* muscle, used as a reference for meat quality studies. Fat content from specific retail cuts from bison carcasses (Galbraith et al., 2006) can actually ranges between 1.5 g per 100 g (bottom roll) and 4.6 g per 100 g (blade). Fat composition also seems to differ between bison meat and beef from different production systems. Bison meat (*longissimus* muscle) has a greater content of polyunsaturated fatty acids than beef, from both grass- (15.5 vs. 9.5% of total intramuscular fat) and grain-fed (10.7 vs. 5.0% of total intramuscular fat) animals (Rule et al., 2002). These differences were similar in other muscles. In addition, according to Health Canada (2010), the calorie content of bison rib eye, lean only raw (116 kcal per 100 g) is less than beef (165 kcal per 100 g) and only slightly greater than raw, skinless chicken breast (112 kcal per 100 g). Finally, iron content has been reported to be greater in bison meat than in beef (3.4 vs. 3.0 mg per 100 g of lean meat; Health Canada 2010).

Therefore, nutritional facts can be used to promote bison meat as an alternative source of protein in human diets. Moreover, consumers seem to be aware of these differences and, together with its image of being a natural, safe product and its heritage as a North American icon (Steiner et al., 2010), this may be the reason for the increase in consumption of bison meat during the last decade. However, price, supply, and eating experience need to be considered to expand the market share of bison meat.

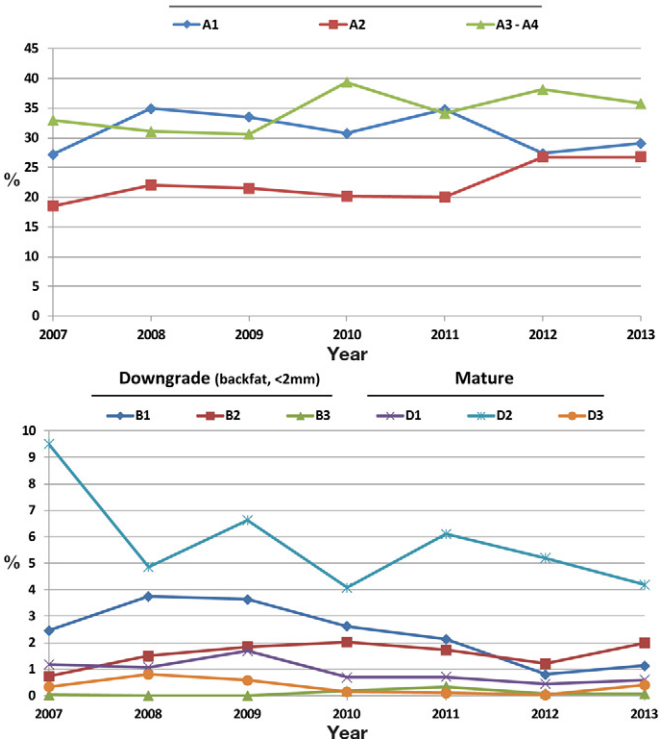

Figure 3. Seven-year trends for the Canadian bison quality grades (%). (Source: C. Delaloye, Canadian Beef Grading Agency, General Manager, AB, Canada, personal communication.)

Dark cutting/early browning: fresh meat marketing opportunities

Bison meat is darker than beef (Koch et al., 1995), and color stability is a limitation to the expansion of fresh meat marketing. Although traditional dark cutting (high ultimate pH arising from prolonged pre-slaughter stress) may occur in bison, bison do have an inherently darker meat color due to differences in muscle fiber type and resulting greater pigment content (Aalhus et al., 2009). Bison meat color is also consistently unstable (early browning) under retail aerobic packaging conditions. The rapid pigment oxidation and surface discoloration mechanisms are not well understood. In a comparative study characterizing the myoglobin protein between bison and beef, Joseph et al. (2010) determined that bison and beef had 100% amino acid sequence similarity and exhibited similar oxidation

Figure 4. Example of an over-finished carcass (8L- Grade A4) compared with an ideal carcass (1L– Grade A1). Source: Jayson Galbraith.

kinetics and thermostability; consequently, the rapid discoloration in bison meat could not be attributed to biochemistry of bison myoglobin (Joseph et al., 2010). Variations in the balance between antioxidant–prooxidant components in the sarcoplasm could induce lipid oxidation and cause meat discoloration (Ramanathan et al., 2009; Joseph et al., 2010). In addition, the greater PUFA content in bison could be susceptible to oxidation (Pietrasik et al., 2006) and generate reactive secondary oxidation products such as 4-hydroxy-2-nonenal (**HNE**), which accelerates myoglobin oxidation and subsequent meat discoloration (Schneider et al., 2001; Alderton et al., 2003; Lee et al., 2003; Suman et al., 2006; Joseph et al., 2010). However, the role of HNE on bison color has not been evaluated yet (Joseph et al., 2010).

Recently, a new packaging technology, nitrite film packaging (**NFP**; FreshCase®, Oshkosh, WI), opens the possibility for improving retail color stability if applied to bison meat. This technology has been approved by both the FDA and USDA, but does not yet have regulatory approval in Canada. The nitrite-embedded film tightly contacts the meat surface, and nitrite crystals imbedded in the film surface dissolve into the meat juices, creating a stable, bright red color at the surface of the meat without curing the meat (Siegel, 2010). This packaging can extend shelf life and eliminate retail losses due to poor color stability and early browning (i.e., stock out, markdowns, and waste due to expired display life; Siegel, 2010). Preliminary results (Rodas-González et al., 2013) indicate that bison NFP steaks and patties improved in color and showed no evidence of discoloration compared with polyvinyl chloride (**PVC**) overwrapped steaks and patties. Additionally, patties in NFP had less lipid oxidation than patties in PVC.

The Future of Bison Production

Bison have lived in North America for tens of thousands of years. Bison are a species well adapted to a wide range of environments, have hardiness and self-sufficiency unparalleled by domestic farmed species, and continue to enjoy a growing demand for their unique meat product. As a result, bison ranching has flourished across a large geographic area in North America, and their hardiness and ability to utilize marginal lands may provide expansion opportunities during changing climatic conditions. However, with increased density, their vulnerability to parasites and diseases common to cattle (e.g., malignant catarrhal fever and mycoplasma) may become a more significant issue.

Bison have traits different from cattle both in their live animal physiology and their meat characteristics. Raising and marketing bison in a way that promotes and builds on their differences from beef cattle will keep them as a distinct, unique meat product in the marketplace. Specific challenges of bison meat production include: the need to improve feeding, transport, and handling systems; ensuring that current grading systems (where they exist) provide value to both producer and consumer; and developing and implementing post-slaughter technologies that add value. The image of bison as a natural, safe product and iconic stature as a heritage animal in North America, combined with its nutritional value, all contribute to an optimistic future for bison production.

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About the Authors

Dr. Jayson Galbraith is currently the provincial bison/elk specialist for Alberta Agriculture and Rural Development. He has served in this role for more than 13 years (currently in the Livestock Business Development Branch). He works on projects that aim to help the bison, elk, and other livestock industries become more competitive. Projects cover such topics as nutrient composition of bison meat, mobile slaughter, carcass and meat quality, and stress physiology. He is enthusiastic about bison and how magnificent a species they are!
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Dr. Argenis Rodas-González is currently an Assistant Professor at the University of Manitoba. He has been working in interdisciplinary research groups in meat science and food safety in Venezuela, the USA, and in Canada. He has evaluated the meat composition and quality of domesticated (beef and pork) and exotic species (water buffalo and bison). His recent work focused on meat color stability and the application of different packaging systems (i.e., nitrite film packaging) to improve color stability in bison and beef.

Dr. Óscar López-Campos received a Ph.D. in animal production in 2007 at the University of Leon (Spain). He has undertaken intensive training in meat quality and carcass evaluation and is a certified beef and bison grader by the Canadian Beef Grading Agency. His main research focus is on objective and subjective assessments of economically important yield and muscle quality attributes, and he has participated in numerous beef, bison, sheep, and pork studies as well as several collaborations with the Canadian Cattle, Bison, and Sheep Industry Associations.

Dr. Manuel Juárez coordinates the Livestock Phenomics program at the AAFC Lacombe Research Centre, linking livestock genomics and phenotypical research focused on meat production. He applies a holistic approach to evaluate the interactions between genetic and environmental factors, being able to quantify their relative contribution on animal performance, carcass, and meat quality traits. His goal is the optimization of livestock production systems to maximize profitability.

Dr. Jennifer Aalhus initially focused her research on postmortem biochemistry and its influence on meat quality. Consequently her team developed, standardized, and streamlined a full slate of functional, organoleptic, and nutritional techniques for evaluation of meat quality in multiple species. Her program currently focuses on a value chain approach to carcass and meat quality, concentrating on understanding and manipulating ante- and post-mortem factors impacting the end product.