Review: Canadian beef grading – Opportunities to identify carcass and meat quality traits valued by consumers

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[1]Agriculture and Agri-Food Canada, Lacombe Research Centre, 6000 C&E Trail, Lacombe, Alberta, Canada T4L 1W1 (e-mail: Jennifer.Aalhus@agr.gc.ca); [2]Livestock Gentec, Edmonton, Alberta, Canada T6G 2C8; and [3]Department of Agricultural, Food and Nutritional Sciences, University of Alberta, Edmonton, Alberta, Canada T6G 2P5.

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Aalhus, J. L., López-Campos, Ó., Prieto, N., Rodas-González, A., Dugan, M. E. R., Uttaro, B. and Juárez, M. 2014. **Review: Canadian beef grading – Opportunities to identify carcass and meat quality traits valued by consumers**. Can. J. Anim. Sci. **94**: 545–556. Beef value is in the eye, mouth or mind of the consumer; however, currently, producers are paid on the basis of carcass grade. In general, affluent consumers are becoming more discerning and are willing to pay for both credence and measureable quality differences. The Canadian grading system for youthful carcasses identifies both lean yield and quality attributes, whereas mature carcasses are broadly categorized. Opportunities exist to improve the prediction of lean meat yield and better identify meat quality characteristics in youthful beef, and to obtain additional value from mature carcasses through muscle profiling. Individual carcass identification along with development of database systems like the Beef InfoXchange System (BIXS) will allow a paradigm shift for the industry as traits of economic value can be easily identified to improve marketing value chains. In the near future, developing technologies (e.g., grade cameras, dual energy X-ray absorptiometry, and spectroscopic methods such as near infrared spectroscopy, Raman spectroscopy and hyperspectral imaging) will be successfully implemented on-line to identify a multitude of carcass and quality traits of growing importance to segments of the consuming population.

Key words: Review, Canadian beef grading, carcass yield, meat quality, new technologies, consumer demands

Aalhus, J. L., López-Campos, Ó., Prieto, N., Rodas-González, A., Dugan, M. E. R., Uttaro, B. et Juárez, M. 2014. **Article de synthèse: Classement du boeuf canadien – occasions pour identifier les caractéristiques de qualité de carcasse et de viande appréciées par les consommateurs**. Can. J. Anim. Sci. **94**: 545–556. La valeur du bœuf demeure dans l'œil, la bouche et la tête du consommateur. Par contre, actuellement, les producteurs sont payés selon le classement de la carcasse. De façon générale, les consommateurs fortunés choisissent avec plus de discernement et sont prêts à payer pour la crédibilité et des différences mesurables de qualité. Le système canadien pour le classement des carcasses de jeunes animaux détermine à la fois le rendement en viande maigre et les attributs de qualité, tandis que les carcasses d'animaux matures sont catégorisées de façon plus sommaire. Les occasions existent pour améliorer les prévisions de rendement de viande maigre, mieux identifier les caractéristiques de qualité de la viande dans les carcasses de jeunes bæufs et obtenir une valeur supplémentaire des carcasses d'animaux matures au moyen du profilage des muscles. L'identification des carcasses individuelles de pair avec le développement des systèmes de bases de données, tel que la « Beef InfoXchange System » (BIXS) permettra un changement fondamental pour l'industrie lorsque les caractéristiques d'importance économiques peuvent être facilement identifiées pour améliorer les chaînes de valeurs marchandes. Dans un futur rapproché, les technologies en voie de développement (c.-à-d. appareils photo pour le classement, absorptiométrie bi-énergétique à rayons X et méthodes spectroscopiques telles que la spectroscopie proche infrarouge, la spectroscopie Raman et l'imagerie hyperspectrale) seront implantées en ligne avec succès pour identifier une multitude de caractéristiques de carcasse et de qualité qui sont d'importance croissante à certains segments de consommateurs.

Mots clés: Revue, classement du boeuf canadien, rendement à l'abattage, qualité de la viande, nouvelles technologies, demandes des consommateurs

Beef grading systems have been evolving over the past 25 yr as a means of classifying carcasses with similar attributes into similar classes or "grades". In Canada, beef grades form the language for trade, facilitate marketing and production decisions, and ensure that consumers are able to purchase a predictable and consistent product. Although grading is voluntary in Canada, over 90% of the total slaughter cattle are

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Abbreviations: AT, atypical; **BD**, borderline; **BIXS**, Beef InfoXchange System; **CL**, classic; **DEXA**, dual energy X-ray absorptiometry; **DPA**, docosapentaenoic acid; **NIRS**, near infrared reflectance spectroscopy graded by the Canadian Beef Grading Agency and the non-graded, "no roll" beef generally arises from the mature animal slaughter population (CanFax 2012).

The objectivity of the grading system is a fundamental pillar of beef carcass classification. For this reason, the implementation of objective methods at the grading stand has been one of the main goals pursued by the Canadian Beef Industry. There have been several attempts to develop objective technologies for assessing different beef grading traits such as marbling (Ferguson 2004) and tenderness (Wheeler et al. 2002; Vote et al. 2003) or to quantify total or saleable meat yield (Tong et al. 1997; McEvers et al. 2012) with the purpose of being implemented commercially in the grading systems.

In general, the Canadian Beef Grading system has utilized the visual assessment of certain traits to classify carcasses due to known scientific associations with quality. For example, as an animal matures physiologically, the amount of connective tissue and the degree of internal connective tissue cross-linking increases, decreasing meat tenderness (Purslow 2005). The degree of bone ossification assessed at grading is an indicator of this process (López-Campos et al. 2012). Since increases in marbling have small positive associations with improvements in flavour and juiciness, marbling has been included as a factor in both the Canadian and USA grading system (Anonymous 2009). Carcasses with lower backfat levels can chill more rapidly causing reduced tenderness (Aalhus et al. 2001); hence, carcasses with minimal backfat are downgraded in the Canadian quality grade system.

Greater control over meat quality and its assessment to enable quality control and product diversification is being sought with increasing interest in establishing methods to meet these demands. Most of the traditional techniques used for quality control purposes are time-consuming and destructive and, as a result, are unsuitable for on-line applications. Nowadays, new technologies not only result in more accurate and complete evaluation of carcass characteristics, but also in prediction of additional meat quality attributes. This information, together with complete data from the whole beef value chain, can be used to further understand which factors have the largest effect on beef yield and quality. This will allow the Canadian beef industry to improve its overall competitiveness and to take advantage of new opportunities within the changing environment of international meat trade.

CURRENT CANADIAN BEEF GRADING SYSTEM

The Canadian Beef Grading System evaluates carcass maturity, backfat thickness, muscling, meat and fat colour, as well as marbling. The current youthful carcass grades in Canada have less than 50% ossification in the spinous processes of the vertebrae, and qualify for the A or B grades (Canada Gazette 2007; Canadian Beef Grading Agency 2014). Youthful carcasses, which have >2 mm of backfat, at least traces of marbling, good to excellent muscling, a bright red meat colour and firm, white to amber-coloured fat, qualify for the A grades. Within the A grades, carcasses are assigned to either A, AA, AAA or Prime grades strictly on the basis of marbling (traces, slight, small, and slightly abundant, respectively). All "A" grade carcasses are also assessed in terms of their cutability (the estimated yield of lean meat) and are assigned a yield grade (Canada 1, Canada 2, Canada 3) according to the equation, Lean $\% = 63.65 + 1.05$ (muscle score) $- 0.76$ (grade fat) (Canadian Beef Grading Agency 2014). Estimated total lean yield is assessed with a grade ruler using fat class and muscle scores with break points at 59% or more, ≤ 58 to $\geq 54\%$ and 53% or less for Canada 1, 2 and 3 carcasses, respectively. Backfat depth is measured at the minimum point of thickness (mm), perpendicular to the outside surface, and within the fourth quarter of the longissimus thoracis (or rib-eye) at the grade site (12th–13th rib) and assigned to fat class in 2-mm increments (e.g., fat class 1 is 2 or 3 mm; fat class 2 is 4 or 5 mm, fat class 3 is 6 or 7 mm, etc.). Muscle scores (1–4) are determined on the basis of longissimus thoracis length and width measurements at the grade site. The Canadian yield algorithms in use are based on data from a Canadian National Beef cut-out in 1993.

In contrast, the USA, Canada's largest beef export market (Canfax 2013), employs yield algorithms based on the yield of closely trimmed, boneless retail cuts from four primal cuts (round, loin, rib and chuck; Murphey et al. 1960). Four prediction characteristics are used in calculating yield as follows: Yield grade $= 2.50 + (2.5 \times$ adjusted fat thickness, inches$) + (0.2 \times$ percentage kidney, pelvic and heart fat$) + (0.0038 \times$ hot carcass weight, pounds$) - (0.32 \times$ area of rib-eye, square inches$)$. The price differentials within the USA quality grading system also results in heavier emphasis on marbling than on lean meat yield. As a result overproduction of fat in other body depots has been a concern (Dikeman 1984; Cunha 1991; Sainz 1993). To fully interpret the differences in yield equations between the USA and Canada, relationships amongst total lean, primals, sub-primals and trimmed retail cuts in the current slaughter population should be established.

Under the Canadian system, carcasses that are youthful but have some deficiencies fall into the B grades. Hence, B1 carcasses are lacking in finish (less than 2 mm of backfat) or are devoid of intramuscular marbling fat. Any youthful carcass having bright red meat colour but yellow fat (generally as a result of grass finishing) will fall into the B2 grade. Youthful carcasses with bright red meat colour, white to amber fat, but which are deficient in muscling or with a soft rib-eye, fall into the B3 grade. Animals that undergo prolonged stress prior to slaughter can develop a dark red (to almost black) meat colour, which results in a downgrade to B4 (traditionally known as "dark cutters").

Over the past 10 yr, the proportion of Canadian carcasses falling in the highest estimated yield grade (Canada 1) has decreased from 63.2% in 2002 to 48.8% in 2012 (Fig. 1; CanFax 2002–2012). Over the same period, there has been a steady increase in proportions

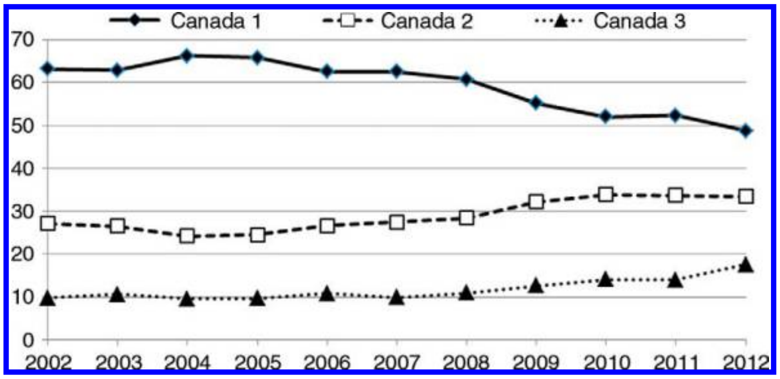

Fig. 1. Change in beef yield grades (Canada 1, Canada 2, Canada 3) over 10 yr (2002–2012; CanFax data).

of Canada 2 (27.1–33.5%) and Canada 3 (9.7–17.6%) yield grades. This likely reflects the shift in slaughter cattle types and feeding strategies that have occurred in order to qualify for the highest quality grades based on marbling (Fig. 2). Between 2002 and 2012, the proportion of carcasses with Prime and AAA marbling has increased (from 0.7 to 1.1% and from 50.5 to 55.6%, respectively), while the proportion of carcasses with lower marbling grades, AA or A, has decreased (from 46.3 to 41.2% and from 2.5 to 2.1%, respectively). The emphasis from 1958 to 1992 within the Canadian grading system rewarded carcasses for optimum backfat levels and was successful in enhancing a lean advantage; however, since 1992 the reintroduction of marbling to facilitate trade, along with price differentials for higher marbling has resulted in some losses to lean yield. The ideal for the North American market would be to ensure optimum emphasis on both lean yield to support efficient production and marbling to meet export market needs. Potentially carcasses currently meeting the Canadian Yield Grade 1, Quality Grade AAA criteria could achieve this goal; however, from 2002 to 2012 the proportion of these carcasses decreased from 25 to 19% (Canfax 2013). Updating lean yield equations using modern populations of cattle may improve the ability to place emphasis on lean yield.

Mature carcasses with greater than 50% ossification based on evaluation of the spinal processes and ribs, fall into the D grades (Canada Gazette 2007; Canadian Beef Grading Agency 2014). Carcasses from bulls or stags of any age that show pronounced masculinity fall into the E grade. To qualify for the D1 grade, mature female carcasses must have excellent muscling and be well finished with white to amber fat and <15 mm back fat. Mature carcasses with medium to excellent muscling or with yellow fat fall into the D2 grade, and those which are deficient in muscling to the point of emaciation receive a D3 grade, and over-fat carcasses with deficient to excellent muscling and >15 mm back fat receive a D4 grade.

Canadian mature cow grades (D grades) have varied significantly, from 3.88% of the total carcasses graded in 2003 to 10.09% in 2011 (Canfax 2004, 2011). Interruption of trade as a result of border closure in response to bovine spongiform encephalopathy (BSE) in 2003 created a backlog of mature cows on the farm and a potential Canadian surplus of meat from these animals (estimated annual surplus in excess of 160 000 tonnes of meat), which led the beef industry to seek opportunities to expand the domestic market and improve the carcass value of mature cows. In 2013, the demand for cows remains high, with the beef cull rate at 14.3%

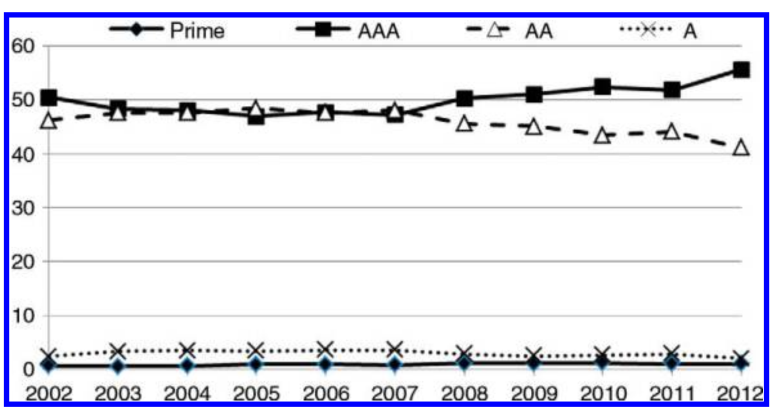

Fig. 2. Change in beef quality grades (Prime, AAA, AA, A) over 10 yr (2002–2012; CanFax data).

(well above the 20-yr average of 11%), and prices per cwt at an all-time high (Canfax 2013). Recently, Rodas-González et al. (2013) reported that D1 carcasses were comparable to youthful carcasses (Canada 1, quality grade A or AA over/under 30 mo of age) in most of the carcass traits and dissectible components (proportions of lean, bone and fat) of individual primals. Within the mature carcass grades, D1 and D4 cow carcasses have the most marbling and slightly smaller rib-eye areas; thus, meat from these carcasses may be used in value-added products with inclusion of tenderness interventions. Due to their overall low fatness resulting in high proportion of lean meat yield, the D3 carcasses have value for production of manufacturing beef.

NEW TECHNOLOGIES FOR IMPROVING BEEF GRADING IN CANADA

Camera Grading Systems

At the current time, camera/software systems have been implemented as an augmentation tool for grading in the major Canadian plants. In North America, e+v Technology GmbH (VBG 2000 camera) and Research Management Systems, Inc. (CVS beef Cam®) are the main companies developing these camera/software systems. Both technologies utilize a camera with special lighting to photograph the rib-eye at the grade site. Earlier camera models used a xenon source of lighting while the latest camera models include light-emitting diode (LED) technology. These camera systems rapidly attain and, through proprietary computer software, analyse digital images of the grade site and output additional information (e.g., marbling levels; total rib-eye area; top, middle and bottom fat depths). When combined with accurate yield prediction algorithms embedded in the software, this could be used to improve the estimates of saleable lean meat yield (retail cuts; important for marketing) and estimates of total lean meat yield (amount of total lean in the carcass; important for efficiency of production). The accuracy of prediction can also be improved through the concurrent use of camera/digital software systems that capture whole carcass conformation information (Woerner and Belk 2008).

The camera systems currently used within the Canadian Beef Grading System employ lean yield algorithms established from the earlier Canadian and USA carcass cut-outs. Thus, further calibrations and validations of new algorithms used by this system should be performed. Any changes to the yield algorithms would need to be integrated with the camera and software systems that are being used in the packing plants as grade augmentation tools. In addition, there is a need to establish the relationship between the different methods of yield assessment (e.g. percent lean yield, Canadian Beef Grading vs. percent closely trimmed retail cuts, USDA) to make the appropriate conversions at the time of trade.

Dual Energy X-ray Absorptiometry

Dual energy X-ray absorptiometry (DEXA) is a technique that has been successfully used to measure body composition in humans (Oates et al. 2006), and is based on the differential attenuation of low and high energy X-rays by fat, non-fat and bone tissues. This technique has the capability of measuring bone mineral content, bone mineral density, lean tissue mass, fat tissue mass, and percentage of fat. Recently there has been an increased interest in using DEXA technology as an indirect method to estimate carcass composition because of its low cost, speed of data collection, reliability and ease of use, compared with other technologies such as computer tomography (Scholz and Mitchell 2010).

To date, there are limited reports of the use of DEXA to predict carcass composition of market-age beef (Mitchell et al. 1997b; Ribeiro et al. 2011), though it has significant potential as a platform technology for use in routinely upgrading lean yield equations of the beef grading system. DEXA has been used successfully with poultry (Mitchell et al. 1997a), swine (Mitchell et al. 1996, 2003) and calves (Scholz et al. 2003). In Canada, DEXA is being developed as a tool for routine use in prediction of body composition in swine (Marcoux et al. 2003) and sheep (Mercier et al. 2006). The technology also has the potential to be implemented for the accurate, simple and rapid estimation of lean yield in slaughter-weight cattle (López-Campos et al. unpublished data). In the meat industry DEXA has already been implemented as a means of quality control for fat content in boxed manufacturing beef (Eagle™ FA720 PACK, Tampa, USA).

Spectroscopic Methods for Meat Quality Prediction

Various spectroscopic methods, such as near infrared, multispectral imaging and Raman spectroscopy, can provide compositional and structural information about biological samples (Schweitzer-Stenner 2006). Initially, most of these technologies were constrained for use in laboratory settings; however, robust instrumentation has been developed, which is now being tested for on-line application.

Near infrared reflectance spectroscopy (NIRS) is a sensitive, fast and non-destructive analytical technique, entailing minimal or no pre-treatment of samples and neither requiring reagents nor producing waste. Moreover, NIRS facilitates the simultaneous assessment of numerous characteristics (Prieto et al. 2009). The process involves measuring the vibrational response of chemical bonds when illuminated by NIR frequencies (from 750 to 2500 nm). These bonds have unique and characteristic absorption frequencies; hence, it is possible to build a characteristic NIR spectrum that can be used to estimate chemical composition and provide information on sample ultrastructure. Near infrared reflectance spectroscopy has been successfully applied to estimate the amount of major constituents (moisture, fat and protein) of meat and meat products. In fact, these NIRS procedures have been approved by the international committee for validating analytical procedures (Association of Official Analytical Chemists AOAC; Anderson 2007) and are currently being used in industry. Beyond this, NIRS has been successfully used to categorize meat, for example beef that is fresh or frozen and thawed, meat from different species, meat from animals fed different diets, as well as the detection of hamburger adulteration (Prieto et al. 2009; Mamani-Linares et al. 2012). Recent studies using beef backfat have shown the potential of NIRS to predict the proportion of fatty acids with important human-health-related benefits, such as omega-3, rumenic (*c*9,*t*11-CLA) and vaccenic (*t*11–18:1) acids (Prieto et al. 2012, 2013). The use on-line of a fibre-optic probe enables measurements to be made simply by placing the probe on the sample itself. With no previous sample treatment required, that probe may thus provide rapid simultaneous prediction of various meat quality criteria on-line in a commercial environment. Despite the challenging operational environment of abattoirs such as fluctuations in temperature and humidity, the fibre-optic probe could significantly improve the ability of NIRS to monitor and control meat quality at initial processing via remote on-line detection. Hence, the use of portable probes and advanced statistical software makes the application of NIRS at a commercial level more feasible.

Hyperspectral imaging is a powerful technology harnessing the power of both high spatial and spectral resolution. Both grey scale and spectrum information can be obtained for each pixel and then can be related to numerous food safety and quality traits (Kim et al. 2001). The hyperspectal imaging technology has been successfully developed to discriminate tenderness in real time at grading, where a system predicted three tenderness categories (tender, intermediate and tough) with 96.4% accuracy and, importantly, all of the tough samples were correctly identified (Naganathan et al. 2008). Likewise, Kamruzzamana et al. (2011) and Barbin et al. (2012) showed that it was possible to discriminate lamb muscles and pork of three qualities (pale, soft, exudative; red, firm, non-exudative; and dark, firm, dry) with overall accuracy of 100% and 96%, respectively, using NIR hyperspectral reflectance spectra (900–1700 nm). Applications for the meat industry are already being explored where properties of meat using hyperspectral imaging are being analysed (Subbiah et al. 2010, 2012). Indeed, Kamruzzaman et al. (2012) showed that NIR hyperspectral imaging has potential as a fast and non-invasive method for predicting quality attributes of lamb meat such as pH, colour and drip loss, and Calkins et al. (personal communication 2013) have developed a multispectral instrument for commercial application to predict tenderness in beef (US Patent #8280144 - System and Method for Analyzing Material Properties Using Hyperspectral Imaging).

Raman spectroscopy has great potential for biochemical analysis of tissue at both the macroscopic and microscopic levels. One major advantage of this technique is its ability to provide information about concentration, structure, and interaction of biochemical molecules within intact cells and tissues, non-destructively, without homogenization or extraction (Hildrum et al. 2006). Compared with other spectrometric methods, Raman spectroscopy has little sensitivity to water and therefore lends itself to making measurements in fluids and food. Raman spectra (1800–200 cm^{-1}; 5556–50 000 nm) exhibit well-resolved bands of fundamental vibrational transitions, thus providing a high content of molecular structure information of several compounds. Indeed, this technology provides information mainly about secondary and tertiary structure of proteins (Tuma 2005; Herrero 2008). Some of the components contributing to the Raman scattering in meat are certain amino acids, collagen, elastin, carotenoids, fatty acids, and cholesterols, all of which can be useful to describe meat quality. Hence, Raman spectroscopy has been strongly correlated with traditional quality methods to determine characteristics such as protein solubility, water-holding capacity, textural properties (tenderness and shear force), peroxide values, and fatty acid composition (Herrero et al. 2004, 2005; Beattie et al. 2006; Olsen et al. 2007; Lyndgaard et al. 2012). Raman spectroscopy has also been successfully used to determine quality in meat under different conditions of handling, processing and storage by monitoring the changes of proteins, water and lipids (Herrero 2008). In addition, Ellis et al. (2005) indicated that Raman spectroscopy has the ability to discriminate among meat types, aiding in meat authentication. Hence, Raman spectroscopy can be used in meat analysis since it is non-destructive and does not require any pre-treatment of samples. Further to this, only small portions of sample are required, and qualitative, quantitative and structural information about many different meat compounds can be collected simultaneously. Moreover, Raman spectroscopy is generally very well suited for on-line use since fibre-optics (up to hundreds of meters in length) enables remote analyses in difficult-to-access spots and harsh environments.

Identification and Information Flow

The competitiveness of the Canadian beef industry, both domestically and in its major exports markets, is constantly challenged by a variety of factors. Technological advances, alongside market developments, unfavourable exchange rates, and pressures to harvest productivity gains and production management efficiencies are critical. Yet, the beef sector lags behind some other sectors of the livestock industry, such as dairy, in terms of the development of tools (e.g., IT systems, alliances), which would allow a broader information exchange along the value chain from breeder to producer, feedlot, and processor. Efforts made by Australian competitors in their meat standards and grading system (e.g., Meat Standards Australia, MSA) show some of the possible benefits (and challenges) a close alignment of business partners in the industry can achieve (Polkinghorne and Thompson 2010). Another good example of industry potential is the combination of the Irish National Cattle Animal Identification and Movement system (AIM) database and the National Cattle Breeding Database (Wickham et al. 2011). Smaller initiatives have been attempted in the USA (i.e., South Dakota Certified Enrolled Cattle Program, http://www.sdcec.sd.gov/our_program_main.aspx) with variable success. A key element of such systems is the systematic collection and exchange of information among members of the supply chain. While the information alone will not adjust exchange rates or improve breeding program efforts, it provides participating stakeholders with access to data essential to improve business decision outcomes (e.g., investment, feeding, breeding, etc.) that in turn can yield efficiency gains and lead to short- as well as long-term improvements in production with substantial impacts on overall competitiveness.

Given the opportunity for efficient and effective data collection, transformation and sharing, afforded by the Canadian Cattle Identification Program (http://www.canadaid.com/) and the Beef InfoXchange System (BIXS; http://bixs.cattle.ca/), the Canadian beef industry is poised to be able to take advantage of new on-line technologies for improved grading/carcass sorting and identification of yield and quality traits valued by consumers. The Canadian Cattle Identification Program is an industry initiated and established trace-back system for Canadian cattle. As of 2010 Jul. 01, all cattle in Canada must be tagged with an approved Radio Frequency Identification (RFID) tag prior to moving from their current location. This is complemented with the voluntary Age Verification Process, which stores animal identification and birthdate information that can be used for domestic or export markets. The BIXS, hosted by the Canadian Cattlemen's Association (CCA), is a national voluntary web-based database designed to capture and exchange animal- and carcass-related data. The BIXS database builds on the Canadian Cattle Identification system by using individual animal's unique ID information to enter data all along the beef value chain. The objective is to facilitate the flow and exchange of information among industry and business partners to improve harvesting efficiencies and profitability at the ranch, feedlot and processing levels. Through the appropriate flow of information upstream to feedlot producers and breeders (seedstock and cow-calf), BIXS could contribute to medium and long-term improvements in the overall competitiveness (quality, market position) of Canadian beef, an essential condition to improve targeting of specific domestic and international market segments.

IDENTIFICATION OF ATTRIBUTES DESIRED BY CONSUMERS

Consumer demand for beef has been changing and becoming more diverse, specifically for novel products (Xue et al. 2009). In addition to the measureable product quality traits (appearance, tenderness, juiciness and flavour), there is a growing consumer demand for social or credence attributes (animal welfare, organic production, hormone-free, healthfulness, sustainability) that place additional demand for market segmentation. Like appearance, credence attributes can have a powerful influence on consumer purchasing decisions (Honeyman et al. 2006), as they are assessed prior to purchasing rather than at final consumption. Thus, the BIXS system, which will allow individual animal data entry at any stage of the production chain (cow/calf, feedlot, packer), may create the opportunity to identify, track and market some of these credence traits through the value chain.

Credence Attributes

Ecolabels are becoming dominant in Europe (EU Ecolabel 2012), identifying products that have a reduced environmental impact throughout their life cycle. Research conducted at AAFC-Lacombe (Basarab et al. 2012; López-Campos et al. 2013a) has demonstrated that calf-fed production systems and carcasses with less fat require less energy for production and produce fewer greenhouse gases. Through combining animal age identification to distinguish calf-fed animals in BIXS, along with potential use of greenhouse gas calculators based on lean meat yields, development of a Canadian ecolabel may be possible.

Humanely raised and slaughtered beef is another trend that is focused on a specific segment of consumers ready to pay a premium for meat that has been produced under prescribed standards. The problem is that, to date, there is no single definition of "humane meat". In fact, for some activists, the term itself is contradictory. However, the main idea behind this movement is that people will continue to eat meat for the foreseeable future, but farming practices deemed to be non-humane can be eliminated (Freeman 2010). Different claims focus on farming practices, animal welfare or slaughter methods.

Another claim that is increasing in popularity is the lack of use of growth promotants. Hormone-free, antibiotic-free and/or organic meats are becoming more common in retail stores and restaurants. While many organizations in North America claim there is no real benefit for the consumer, very aggressive marketing campaigns and international trade restrictions are based on the use of growth promotants in beef production. Contradictory opinions regarding the scientific evidence, commercial interests and consumer perception make this claim a very complex issue (Stephany 2001; Galbraith 2002) that can be perceived as either a challenge or an opportunity for the industry. Once again, adequate data recording and information management can result in an advantage for Canadian beef in a changing scenario like niche beef marketing.

Healthful Meat

Beef is a nutrient-rich food long recognized as a source of high-quality protein, available minerals and many vitamins. The association between saturated fat consumption and cardiovascular disease has, however, led to recommendations for limited consumption of red meats. Emerging evidence from a number of reviews and meta analyses, however, now suggest evidence linking saturated fatty acids to coronary heart disease is lacking (Nicklas et al. 2012). In addition, consumption of meat, including beef, is now being encouraged as a means to combat muscle wasting as people age (Phillips 2012). The grading (or labelling) system could and should be able to be used as a mechanism for differentiation to enable consumers to purchase what they want. Currently, carcasses graded in the B1 grade may already be appealing to consumers who are calorie conscious and looking for an ultra-lean meat, thus representing an opportunity for marketing diversification within the current grading system.

Health conscious consumers supported by a growing body of scientific information (Health Canada Trans Fat Task Force Report 2009; Mapiye et al. 2012) have also begun to discriminate based on their understanding of "healthful fats". Hence, grass-finished beef is gaining in popularity, with a resulting shift in available dietary fatty acids (from predominantly linoleic, 18:2n-6, in grains to linolenic, 18:3n-3, in forages; Daley et al. 2010). Until now, however, grass-finished animals have been imprecisely and non-verifiably identified in the grading system through the presence of yellow fat (Canada Grade B2) and the market potential is not being realized.

From a human health perspective, fatty acids with the greatest positive effects appear to be the n-3s and two of the more deeply investigated polyunsaturated fatty acid (PUFA) biohydrogenation products, vaccenic acid (*t*11–18:1) and the main natural isomer of conjugated linoleic acids (CLA; rumenic acid; *c*9,*t*11–18:2; Mapiye et al. 2012). Of the n-3s, the longer chain (i.e., ≥ 20 carbons) fatty acids have greater biological activity than linolenic acid (18:3n-3), and one, docosapentaenoic acid (DPA; 22:5n-3) naturally occurring in beef, has been recognized in Australia as an important contributor quantitatively to dietary long-chain n-3 intake (Howe et al. 2006). Furthermore, Australia and New Zealand include DPA in their recommended dietary intake of long-chain fatty acids due to mounting evidence suggesting health benefits (Kaur and Sinclair 2012). Currently, DPA is not included as a long-chain n-3 fatty acid in the Canadian dietary recommendations. However, due to their importance in human health, Canadian regulatory authorities approved a food-labelling claim for enrichment of n-3 fatty acids at ≥ 300 mg per 100 g serving (Canadian Food Inspection Agency 2003). In addition, the World Health Organization (2003) recommends a lower saturated fatty acid and a higher PUFA intake, especially of n-3 fatty acids to achieve an appropriate n-6/n-3 ratio ($<$5:1). Hence, strategies to improve the fatty acid composition of beef have been focused both on n-3 fatty acids and the natural enrichment of their beneficial biohydrogenation products while limiting total fat content and associated higher levels of saturated fatty acids.

At the same time, considerable effort is being directed to develop NIRS as a robust, on-line technology for predicting/discriminating the content of healthful fatty acids (Prieto et al. 2012, 2013). The future incorporation of this technology into automated grading and data collection systems will allow the possibility of health conscious labelling/marketing, beyond grass finishing value chains.

Colour Discrimination

Colour is the first criterion used to evaluate meat quality by the consumer in the supermarket (Cornforth 1999). Lean colour is also used as a point of discrimination within the current grading systems and the Canadian Beef Grading Agency, in consultation with industry, has developed grading colour chits to visually distinguish carcasses that have an unacceptably dark rib-eye colour (Canadian Food Inspection Agency 2010). Although classically thought to arise from preslaughter stress and depletion of muscle glycogen resulting in ultimate pH $>$6.0 (often referred to as dark, firm, dry meat), research has identified additional categories of dark cutters within the B4 grade, which include both borderline (BD) dark cutters (pH 5.8–6.1) and atypical (AT) dark cutters (pH in the normal range of 5.5–5.7). Recent research from AAFC-Lacombe (Aalhus et al. unpublished data) indicates that BD and AT carcasses can be discriminated from classic (CL) dark cutters on the basis of colour, but not from each other. AT carcasses appear to result from changes to the oxygen consumption rates during chilling (Holdstock et al., unpublished data), which results in a dark colour but other quality and tenderness characteristics are similar to normal carcasses. In contrast, BD carcasses have tougher meat that is not fully resolved through ageing. Depending on the study, AT carcasses have been observed to occur in 25–50% of the B4 population surveyed (Murray et al. 1989; Robertson et al. 2007), hence a means of distinguishing these carcasses from BD and CL dark cutters may be profitable for the industry. In 2012, the incidence of dark cutters in the Canadian population was 1.2%; appropriately identifying the AT carcasses (assuming 25% of total) could reduce the incidence level to 0.9%, which was estimated to save the Canadian beef industry $3.1 million annually (based on a discount of $0.88 per kg carcass weight on an average 372.7 kg heifer carcass; CanFax Research Services 2012).

Current research suggests NIRS has the potential to distinguish dark cutters from normal carcasses and further research would be required to determine if it can distinguish different classes of dark cutters (Prieto et al. 2014). Specific packaging strategies (López-Campos et al. 2013b) could be used to brighten the surface of dark-cutting meat such that it is almost indistinguishable from normal meat. In cubic colour measurement systems, the degree to which colours differ from one another can be calculated with Euclidean distance (ΔE). In the CIELAB colour space, whole-unit values are chosen such that the minimum discernible colour difference corresponds to a ΔE of 1 (Stijns and Thienpont 2011). However, when colours are separated by time and space, colours with a higher ΔE can be seen as either the same or very similar (Green 2002). López-Campos et al. (2013b) reported that within beef steaks of normal pH, the ΔE from the average bloomed colour can range as high as 30, and acceptable colour lasts 3–5 d at 2°C. Dark-cutting beef steaks, when packaged under 80% O_2:20% CO_2 modified atmosphere packaging at 1 atm and approximate gas to meat ratio of 3.5:1, has a ΔE from the average colour of normal pH beef of approximately 15, which can last for up to 21 d.

Tenderness

Tenderness remains the main determinant of North American consumer eating satisfaction, and significant research efforts to understand and control tenderness have taken place (Ouali 1990; Koohmaraie and Geesink 2006). In general, tenderness is a function of inherent ante-mortem factors, combined with the effects of post-slaughter processes on rigor contraction, modified by the rate and extent of post-mortem proteolysis (protein breakdown) and the effects of meat cookery on the protein and connective tissue structures (Aalhus and Price 2005). Juárez et al. (2013) demonstrated that post-mortem treatments contribute up to 70% to the variation in tenderness, with ageing having a predominant effect. The most recent Canadian Beef Tenderness Survey (Juárez et al. 2013) indicated there has been a significant improvement in tenderness at retail between 2001 and 2011, especially for strip loin and top sirloin steaks. In 2011, 99% of strip loin and 87% of top sirloin steaks at retail were considered tender, compared to 89% and 70% respectively in 2001.

However, since not all cuts have improved to this extent and since consumers have indicated they are willing to pay more for guaranteed tenderness (Miller et al. 2001), industry interest in controlling this eating characteristic remains high. Palatability critical control points have been implemented in Australia (Thompson 2002; Polkinghorne 2006), and the USA is implementing a tenderness verification program (USDA Agricultural Marketing Services 2012) based on a sampling plan for manufacturing standards (sampling and testing a small, statistically valid proportion of each lot). While this may be a valid solution when individual carcass identification is unknown, an on-line system for tenderness testing of each carcass would be of significant value in the Canadian system, where individual animal identification is known and data collection through the BIXS system is already automated. Several camera (Vote et al. 2003) or multispectral/hyperspectral (Naganathan et al. 2008; Sun et al. 2012) systems for predicting tenderness are currently under development in the USA with promising results.

Beef Flavour

As popularized by the book "Steak" by Mark Schatzker (2010), beef flavour is a sought after attribute but often remains elusive. Consumers concentrate on flavour to ultimately establish their satisfaction when beef tenderness is acceptable (Rodas-González et al. 2009); thus, flavour is a decisive sensory trait that affects consumer satisfaction in beef, and it can be used as an additional strategy for market segmentation. Diets based on grassland forages plus their interaction with local environmental factors can influence beef flavour constituents, creating a desirable and unique beef flavour for discriminating consumers. Knowledge of these influences and the strict control of the determining factors are key elements in the granting of Protected Denomination of Origin (DMO; Sheath et al. 2001) status, which is a well-applied marketing strategy in Europe and could be practical in Canada with the implementation of BIXS. The DMO promotes the diversification and valuation of specific agricultural products, due either to origin, composition or production methods, to provide the consumer with greater information and knowledge on these products (for example Parma ham from Italy). At the same time, flavour intensity increases as animals increase in age (Wood et al. 1999; Rødbotten et al. 2004) and as marbling increases (Aberle et al. 2001). Based on these considerations, the opportunity to develop a flavour niche market might be achieved utilizing cull cows due to their age and exposure to grass. Muscle profiling (Rodas-González et al. 2014, unpublished data) indicates some muscles from the D-grade carcases may have sufficient tenderness, intramuscular fat (marbling) and inherent flavour to be successfully marketed outside the ground meat trade (Gill 1998). Other muscles from D-grade carcasses that lack tenderness could be used in value-added products with inclusion of tenderness interventions (Rodas-González et al. 2013). However, in some studies (Calkins 2006; Brewer 2007), 30–40% of cow meat samples developed metallic and sour notes, and 10–20% had rancid, bloody, salty and bitter flavour notes due to a high iron content, which may need to be addressed.

CONCLUSION

Great challenges and opportunities exist for Canadian beef production. The industry is under pressure to improve production efficiency while maintaining or improving quality traits desired by consumers. At the same time, opportunities to enter new world markets are expanding and with these markets come different consumer expectations. The Canadian beef grading system has always been underpinned by scientific research and will continue to be adapted to meet changing market needs and as new technologies are developed. In the near future the combination of individual carcass identification, new on-line technologies and data exchange systems will allow a paradigm shift for the industry, leading to new grading and marketing tools to access emerging sectors of the consuming population and to obtain the maximum value from beef carcasses.

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