



**2010 Annual Meeting – Poster Session  
- Abstracts**

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# Impacts of Altered Carcass Suspension on Beef Tenderness and Grade Attributes

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Tenderness is the most important factor to the consumer in determining eating satisfaction of meat. The objective of the present study was to examine the impact of altered suspension of the carcass on beef tenderness and grade attributes. One-hundred and twelve crossbred steers (Angus X Hereford and Charolais X Red Angus) were slaughtered under simulated commercial conditions at the Lacombe Research Centre abattoir. Following dressing and splitting the left side of each carcass was hung conventionally from the Achilles tendon (CON) while the right side was suspended from the aitch bone (ALT). Following chilling at 1°C overnight, carcasses were knife-ribbed between the 12<sup>th</sup> and 13<sup>th</sup> ribs and assessed by certified graders. Five loin (*longissimus lumborum*) steaks from both carcass sides, randomized by location, were assigned to five ageing periods (2, 6, 13, 21 and 27 days) and two inside round (*semimembranosus*) steaks were assigned to two ageing periods (2 and 27 days). After ageing Warner-Bratzler shear force value was determined. Shear force values of loin steaks from ALT carcasses were lower ( $P < 0.001$ ) than CON across ageing periods. Round steaks aged 2 d from the ALT treatment required less force ( $P < 0.001$ ) to shear compared to the CON treatment, while treatment differences disappeared with further ageing. Marbling score was lower ( $P < 0.001$ ) in ALT suspended sides ( $428 \pm 49$ ) compared to conventionally suspended ( $480 \pm 65$ ). Suspension from the aitch bone causes changes to rib-eye shape and overlying fat so that ALT sides had greater measured grade fat ( $P = 0.03$ ), smaller rib eye areas ( $P = 0.01$ ) and lower grade ruler estimated lean yield ( $P = 0.0002$ ). Consequently, ALT sides received poorer quality (Chisq  $P < 0.0001$ ) and yield (Chisq  $P = 0.038$ ) grades. The data from the present study support the positive effect of altered suspension on tenderness of the *longissimus lumborum* and *semimembranosus*, in agreement with other studies in beef (Ahnström et al., 2009, 2006; Sørheim & Hildrum, 2002). However, quality grade and yield grade determining factors are affected negatively to such an extent compared to paired conventionally hung sides that it is recommended carcasses suspended by the aitch bone not be presented for grading.

# PCR-DGGE based characterization of microbial diversity in “Blown pack” spoiled vacuum packaged chill stored beef

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‘Blown pack’ spoilage is characterised by copious gas production in vacuum packs, leading to gross pack distention during chilled storage. Psychrotrophic clostridia have been reported as the causative organism. However, isolation and characterization of the microbial diversity in the blown packs have generally been unsuccessful. Differential gradient gel electrophoresis (DGGE) uses PCR and DNA sequence based characterization of dominant microbial flora in complex ecosystems and has been successfully used to characterize microbial diversity in gastro-intestinal tracts of ruminants. The present study examined the microbial diversity in the exudates of vacuum packs of primal beef cuts that had become grossly distended by gas about one month after the packs were prepared and obtained from a North American beef packaging plant using PCR-DGGE. The genomic DNA was isolated from the exudates and the V2-V3 region of the 16s rRNA gene sequence was PCR amplified. The PCR products were resolved using DGGE, and bands were eluted and further amplified using the same primers without GC clamp and then sequenced. The sequences were blasted against GenBank and the phylogenetic analysis revealed that the dominant flora include *Clostridium estertheticum*, *Clostridium estertheticum* subsp. *laramiense* and psychrophilic lactic acid bacteria like *Lactobacillus algidus*, *Leuconostoc gasicomitatum*, *Pediococcus argentinius*, and *Lactobacillus intestinalis*. Surprisingly DNA belonging to pathogens such as *Arcobacter butzleri* and a number of unculturable bacteria were part of the DNA isolated from the exudates. These findings validate our understanding that psychrotrophic clostridium are responsible for causing blown pack spoilage of chill stored vacuum packaged beef.

# Comparison of meat quality attributes of beef from credence attribute-based production systems

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Two branded beef programs based on producer-defined production systems differentiated by intangible credence attributes (Organic and Natural) were compared to Commodity beef to determine meat quality and assess consumer acceptability. In each of four slaughter periods (January, April, July and October) *Longissimus lumborum* muscle samples were collected from two industry slaughter plants; Organic n=30, 30, 27 and 31; Natural n=30, 27, 29 and 25; Commodity1 n=12 and 18 for April and July respectively; Commodity2 n=14 and 12 for April and October respectively. Samples were vacuum packaged and aged for  $16 \pm 2$  d at 2°C. Seasonal effects ( $p < 0.01$ ) were evident for mean shear force, composition, drip loss, colour and pH. While all mean shear values were classified as being tender ( $< 5.6$  kg), the most tender were Natural (5.02 kg) and Commodity (5.05 kg) with Organic (5.53 kg) the least tender (SEM=0.38;  $p < 0.01$ ). A lower proportion of steaks were classified as tender in the Organic beef compared to the Natural and Commodity beef (55.9 vs. 70.3 and 78.6 %;  $P < 0.01$ ), indicating that even after industry normal ageing times there was higher tenderness variability in the Organic beef. Fat content (SEM=0.23;  $p < 0.01$ ) was lowest for the Organic line (3.98%) with Natural (5.34%) and Commodity being intermediate (5.73%). Some statistically significant differences ( $p < 0.05$ ) in mean scores for aroma, juiciness, flavour, tenderness and overall acceptability of cooked beef steaks were observed amongst the three production systems when samples were not matched on the basis of IMF. Seasonal differences in meat quality and consumer preferences were evident but are difficult to attribute to a specific production system due to possible influences of uncontrolled pre- and post-slaughter factors. Clearly there are measureable differences in quality between “credence” based production systems and commodity beef with an overall better quality in Commodity beef. However, if the consumer is willing to pay for credence-based attributes then there is opportunity for these production systems to improve the quality of their product.

# **Effect of Carcass Pasteurization on the Detection of Hepatitis E Virus and F-RNA Coliphages on Swine Carcasses**

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The extent and role of viruses in foods, including fresh meat products, is increasingly being investigated in Asian, European and North American countries. Swine hepatitis E virus (HEV) is common in pigs and some strains are closely related to human strains. The zoonotic transmission of HEV is now well established. Cases of HEV transmission from animals to humans have been described after consumption of raw or undercooked meat. Most strains of HEV are very difficult to culture, so they can only be detected by molecular techniques. The presence of viral nucleic acid does not necessarily represent an infectious virus, which has important implications in food safety, particularly for the evaluation of inactivation treatments. F-RNA coliphage, a virus specific for coliform bacteria, is considered an attractive candidate as an indicator and as a surrogate for enteric viruses because they are similar in size, possess similar survival characteristics, and can be readily, rapidly, and economically cultured. They are a normal component of the mammalian gut flora and are commonly excreted by pigs, cattle and poultry.

The effectiveness of carcass pasteurization for reducing naturally occurring bacterial populations on swine and beef carcasses is well documented. However, there is no information on the effect of carcass pasteurization for reducing naturally occurring enteric virus numbers. Therefore, viable F-RNA coliphage counts were compared with genome copies of F-RNA coliphage and HEV from random sites of swine carcasses before and after carcass pasteurization. Most or all samples were positive for F-RNA coliphage or HEV, respectively, before pasteurization while F-RNA coliphage or HEV were detected in few or none of the samples, respectively, after pasteurization, even after enrichment. The data obtained from this limited study indicates that larger scale studies on the effectiveness of carcass pasteurization to reduce the prevalence and numbers of naturally occurring enteric virus numbers at a commercial level are warranted to address or dismiss concerns of the zoonotic transmission of enteric viruses through the meat chain. The knowledge will be valuable for the industry when concerns of the prevalence and survival of potential zoonotic viruses arise.

# Control of spoilage *Clostridium* spp. in vacuum packaged fresh beef

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Psychrotrophic *Clostridium* spp. have been isolated from vacuum packaged fresh beef produced in Canadian processing facilities. Research was done to confirm the role of *Clostridium* spp. that were previously isolated from spoiled, vacuum packaged beef as the cause of “blown pack” spoilage and to investigate the use of bacteriocin-producing cultures to inhibit their growth. Beef round was cut into steaks and inoculated with high numbers of *Clostridium* spp. that had been isolated from meat that had “blown pack spoilage.” Some of the steaks were also inoculated with *Carnobacterium maltaromaticum* UAL307, a bacteriocin-producing lactic acid bacterium that was shown to inhibit the growth of the *Clostridium* spp. *in vitro*. Beef samples were prepared as either aseptic (no background microflora) or non-aseptic (background microflora) to determine the impact of a background microflora on the growth of the *Clostridium* spp. Beef steaks were vacuum packaged and stored at 2°C for 84 days. Total aerobic, anaerobic, *Enterobacteriaceae* and lactic acid bacteria counts were completed and metabolites present in the purge of the samples were determined by HPLC. Gas production was evident in all packages inoculated with the spore-forming organisms, which confirms the role of the *Clostridium* spp. in the development of “blown pack” spoilage. Organic acids detected in samples inoculated with the *Clostridium* spp. included acetic and propionic acids. These were either not present or present in low concentrations in samples inoculated with the *Clostridium* spp. together with the *C. maltaromaticum* UAL307. The presence of a background microflora or *C. maltaromaticum* UAL307 inhibited the growth of the psychrotrophic *Clostridium* spp. and prevented gas production in the packages.

# Bacteria present in a pork processing plant

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During 3 visits to a pork processing plant, equipment surfaces were sampled by swabbing. Samples were cultured on microbiological culture media and numbers of bacteria were calculated. Biomass was removed from media and profiles of the bacteria were determined using denaturing gradient gel electrophoresis (DGGE) followed by DNA sequencing. Colonies of presumptive lactic acid bacteria, randomly picked from deMan Rogosa and Sharpe medium were differentiated using random amplification of polymorphic DNA (RAPD) and representative RAPD types were sequenced.

Predominant bacterial genera from DGGE analysis included *Pseudomonas* spp. (34%), *Acinetobacter* spp. (27%) and members of the Enterobacteriaceae family, *Escherichia coli*, *Hafnia alvei* and others (13%). Predominant presumptive lactic acid bacteria were *Enterococcus* spp. (30%), *Vagococcus fluvialis* (2%) and *Carnobacterium maltaromaticum* (2%). The remaining bacteria were comprised of various Gram positive cocci and rods and Gram negative rods. In addition to spoilage potential, some of the bacteria are potentially pathogenic and some could demonstrate resistance to multiple antibiotics. Environmental sources of these genera of bacteria are common; however, the group includes bacteria that have been associated with slime deposits on machines in paper mills (*Brevundimonas*) and persistence in hospitals on dry and moist surfaces (*Acinetobacter*). Our data shows that these organisms are associated with equipment in meat processing facilities and they may be appropriate as indicators of sanitation efficacy.

# **Towards an understanding of heat resistance in *Escherichia coli***

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*Escherichia coli* AW1.7, a strain previously isolated from a Canadian meat processing facility, exhibits an exceptionally high heat resistance compared to other strains of *E. coli*. Prior work indicated that the expression of transport proteins and the expression of outer membrane porins may contribute to the heat resistance in *E. coli* AW1.7. The objectives of this research were to investigate the survival of two strains of *E. coli* (heat resistant and non-heat resistant) under consumer cooking conditions; to compare the impact of osmotic stress and culture aeration on the heat resistance of the two strains; and to determine if *nmpC* plays a role in conferring heat resistance.

To determine the ability of the strains to survive grilling, ground beef patties were inoculated and grilled to an internal temperature of 71°C. The influence of osmotic stress on heat resistance was determined by exposure to 0 to 4% NaCl and heating broth cultures at 60°C for up to 30 min. The heat resistance of cultures grown in LB broth with different aeration conditions were also determined. Clones of *E. coli* GGG10 (low heat resistance) with *nmpC* gene from AW1.7 were evaluated for their heat resistance.

Grilling of burger patties to 71°C resulted in a 4 and >9 log reduction in *E. coli* AW1.7 and *E. coli* GGG10, respectively. Addition of 1% NaCl increased the heat resistance of AW1.7 but not of GGG10, whereas 4% NaCl increased the survival of both strains at 60°C by up to 4 logs. Decreasing the rate of aeration during culture growth led to an increase in heat resistance of both strains of *E. coli*. Expression of *nmpC* gene in *E. coli* GGG10 increased the heat resistance of this strain.

Heat resistance can be influenced by a number of parameters found in meat products. The effects of salt, aeration and osmo-regulated outer membrane porins point to a role of compatible solutes in the heat resistance of *E. coli* AW1.7.

# Heat resistance of multiple strains of *Escherichia coli* and *Listeria monocytogenes* in ground beef slurry

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With the increase in non-intact beef products, mechanically tenderized and brine injected, that are available to consumers in today's market, concern about the potential for heat resistant pathogenic bacteria surviving the cooking process is great. This is especially true for whole muscle products, such as roasts, that could be consumed rare, and which could still contain pathogenic bacteria, such as *Escherichia coli* or *Listeria monocytogenes*. The objective of this study was to determine the heat resistance of 18 strains of *E. coli* (6 strains were isolated from a commercial beef processing plant, 8 strains were verocytotoxigenic, and 4 strains were O157:H7 with the shiga-toxin producing gene knocked out) and 15 strains of *L. monocytogenes*. Each strain was inoculated into a ground beef slurry and placed in a 60°C water bath for 30 min. Recovery of *E. coli* strains post heat treatment (initial inoculation 8 log CFU/ml) was 1.5 to 4 log CFU/ml from strains isolated in processing plant, 1 to 3 log CFU/ml from VTEC strains, and 1.5 to 2.5 log CFU/ml from *E. coli* O157:H7 (non-shiga) strains. Recovery of *L. monocytogenes* strains post heat treatment (initial inoculation 7.5 log CFU/ml) was 1.0 to 4.0 log CFU/ml. These findings suggest that strains of *E. coli* and *L. monocytogenes* are heat resistant in ground beef slurry and the potential for either of these bacteria to survive in deep muscle tissue of non-intact beef may be a health threat to consumers and needs further study.

# Potential for using Lentil Flour as a Binder in Low-Fat Beef Burgers

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Saskatchewan is a top producer and exporter of lentils worldwide. To increase domestic utilization of this crop, use of lentil as an ingredient in product development was considered. Lentil flour is low in fat (0.9 – 1.9%), high in protein (26.0 – 29.0%) and carbohydrates (59.0 – 64.5%), therefore, has potential applications as a meat binder or replacer in low-fat beef burgers.

The objective of this study was to investigate the influence of lentil flour addition (6% or 12% levels) and heat treatment (micronization at 135°C) on cooking properties (cook yield and shrinkage), texture (shear force, texture profile analysis), colour (Hunter L\*, a\*, b\*), and sensory properties of low-fat beef burgers. The effects of the treatments were compared to burgers containing no binder (control) and a commercial wheat-based binder (toasted wheat crumb).

Overall, addition of binders to beef burgers increased cooking yield (up to 86% yield at 12% use level) and minimized shrinkage upon cooking. According to a trained sensory panel, these additions resulted in higher burger juiciness and tenderness at the 6% level but these values were decreased at the 12% level. Burgers containing micronized lentil had higher redness in the raw burgers when stored at 4°C over 5 days under soft white light conditions compared to burgers containing non-micronized lentil. Addition of non-micronized lentil gave burgers an off-flavour note; however micronized lentil flour did not. Moreover, burgers containing micronized lentil flour (6%) received the highest acceptability scores according to a consumer panel (n = 107). Therefore, these results demonstrate that use of micronized lentil flour as a meat binder at the 6% level can improve cooking and sensory properties. Seventy-four percent of consumers also perceived lentils as a very healthy food. Such information could be useful in marketing of meat products with an added lentil-based ingredient.

# Effect of Antemortem Acute Cold Stress, Age, Sex, and Lairage on Broiler Breast Meat Quality

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Effect of acute cold exposure was assessed on welfare (body temperature), breast meat quality and muscle metabolites of 360 male and female birds at 5 and 6 weeks of age. Temperatures from -18 to +20°C were tested in a simulated transport system for 3 h followed by 0 or 2 h of lairage prior to processing. Temperature and relative humidity (RH) near each bird was monitored along with core body temperature (CBT). Apparent equivalent temperature (AET) calculated based on the temperature and RH surrounding individual birds was used to classify birds into 5 groupings with average AETs of -14, -11, -8, 0 and 30°C.

CBT of birds dropped significantly ( $P < 0.05$ ) during the 3 h exposure time as AET decreased. Breast meat of birds at 5 and 6 wk was significantly ( $P < 0.05$ ) higher in ultimate pH ( $pH_u$ ), darker and redder in color with lower cook loss and higher water binding capacity (WBC) when exposed to AET below -8 and -11°C respectively. Breast meat drip loss, thaw loss and texture parameters did not show any significant trend based on exposure temperature. Moreover, males showed greater drop in CBT and higher breast meat  $pH_u$  compared to females. Glycolytic potential and lactate concentrations (measured 30 h post-mortem), were lower for birds exposed to average AETs below -11°C, showing that such birds had lower energy reserve at the time of slaughter. Two h lairage caused a significant increase in  $pH_u$  and WBC of meat at AET values below -11°C. Both ages showed a very high (>57%) incidence of dark, firm, dry (DFD  $pH > 6.1$  and  $L^* < 46$ ) breast meat when the average AET dropped below -14°C. Results of this study showed that older birds (heavier bird with more feather coverage) could cope better with extreme cold conditions compared to younger birds. Furthermore, contrary to a common belief, it might be beneficial to limit the length of lairage prior to processing following acute cold stress during transportation to improve welfare and reduce meat quality defects.

# Modification of steer growth, age at slaughter and meat quality through nutrition and exogenous bio-stimulants

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Exogenous growth promotants such as hormonal growth implants and  $\beta$ -agonist feed supplements are options producers use to increase growth of beef cattle that may interact with breed and age at slaughter to affect beef quality. One hundred and twelve crossbred calves (Hereford x Aberdeen Angus (HAA) or Charolais x Red Angus (CRA)) were used in a 2<sup>3</sup> factorial and finished either on grain at 12-13 months (calf-fed) or on forage at 18-20 months (yearling-fed), treated with hormonal growth implants (IMP) or not (NOIMP), and fed ractopamine hydrochloride (Optaflexx 45) (RAC) or not (NORAC). The m. *semitendinosus* (ST) and m. *gluteus medius* (GM) were assessed at 1 or 7 days post mortem for individual muscle weight, color, muscle pH and temperature, sarcomere length, fibre type and areas, purge loss, cooking loss, shear force, and proximate analysis. Data were analyzed using PROC MIXED (P<0.05) (SAS Version 9.2, SAS institute Inc., Cary, North Carolina) and included finish time, implant,  $\beta$ -agonist, and breed cross as sources of variation. Both ST and GM weights increased with age, IMP and CRA genetics but were not affected by RAC. Mean shear force increased in GM and ST with age depending on genetics and muscles, with toughness increasing more in HAA than in CRA ST muscles. Also, mean shear force of the ST was increased by IMP, but was decreased in the GM by HAA genetics. IMP increased the percentage of red muscle fibres and decreased the percentage of intermediate muscle fibres of the GM but RAC reduced the percentage red muscle fibres and increased the percentage of white muscle fibre. Yearling-fed CRA GM had a greater percentage of white muscle fibres than yearling-fed HAA GM. In ST, IMP decreased the percentage of white muscle fibres in HAA genetics but increased its percentage of intermediate muscle fibres. Overall, increased toughness appeared most associated with connective tissue and changes in muscles fibre type, while RAC had little effect on meat quality.

# **Discrimination of live and dead *Escherichia coli* by treatment with propidium monoazide and PCR**

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The DNA of microorganisms can be rapidly detected by PCR, but the usefulness of PCR for detecting pathogens in foods is limited because it does not discriminate between DNA from live and dead cells. PCR can then give false positive, misleading results if the organisms that are detected are dead. DNA can be rendered inactive in PCR systems by treatment with propidium monoazide (PMA) followed by exposure to strong light. PMA is reported to be excluded by live but not dead cells, so treatment of samples with PMA can leave only DNA from live cells available for PCR. *Escherichia coli* killed by incubation at 75°C for 20 min were mixed with live cells in various proportions, and the mixtures were treated with PMA. DNA from the mixtures was quantified using SYBR green dye based real-time PCR. Relationships of Ct values to log numbers of viable cells were linear in the presence of dead cells at numbers corresponding to 6.5 log cfu with live cells numbers in the range of 3 to 6 log cfu. However, when *E. coli* were progressively killed by incubation at 52°C for 5 h (D=40 min.), Ct values obtained for DNA from samples treated or not treated with PMA were the same and remained unchanged even when no viable cells remained. Treatment of samples with 0.5% sodium deoxycholate before treatment with PMA restored the differential effect of PMA on DNA in live and dead cells. Thus, treatment with PMA alone is not a reliable means of distinguishing by PCR between DNA from live and dead cells, but it may be possible to improve the reliability of PMA treatment for that purpose by subjecting samples to supplementary treatments that render dead but not live cells permeable to PMA.

# Characterization antimicrobial resistance in *Enterococcus* spp. recovered from retail meat samples collected from Alberta

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Antimicrobial use during animal production can select for antimicrobial resistant *Enterococcus* spp. which can be transferred from animals during slaughter and processing to retail meats. Therefore the objective of this study was to assess the prevalence of antimicrobial resistance (AMR), genes responsible for AMR and virulence in *Enterococcus* spp. isolated from retail meats. The sampling plan used by the Canadian Integrated Program for Antimicrobial Resistance Surveillance was followed. A total of 564 samples comprising raw chicken (n=206), beef (n=134), pork (n=133) and turkey (n=91) meats were collected. Enterococci were isolated and confirmed using standard cultural and biochemical methods. About 530 enterococci isolates from positive samples of four meat types were analyzed. Antimicrobial susceptibility for 17 antimicrobials was tested using an automated broth dilution method with the Sensititre system® and results interpreted according to the Clinical Laboratory Standard Institute guidelines. A microarray assay was used to detect 18 virulence and 170 AMR genes in enterococci. All chicken and turkey samples were positive for enterococci whereas 99% and 89% of beef and pork samples respectively, were positive. Preliminary analysis showed that >93% of chicken and turkey derived enterococci were *E. faecalis* whereas 73% of beef and 89% of pork enterococci were *E. faecalis*. *Enterococcus faecium* was found in 4% of chicken samples and 2% of beef and pork samples. In beef samples 20% enterococci were *E. hirae*. Seven out of nine *E. faecium* isolates from chicken (78%) meat and one out of two *E. faecium* isolate from pork (50%) meat were resistant to quinupristin-dalfopristin (QDA), a category I antimicrobial of importance to human medicine. All of the resistant *E. faecium* from chicken meat were positive for *satG/vat8* genes for QDA resistance. Resistance to other category I antimicrobials ciprofloxacin, daptomycin, linezolid, and vancomycin was not found in any enterococci. A higher percentage of enterococci from chicken were resistant to erythromycin (ERY, 46%) and tylosin (TYL, 47%), category II antimicrobials of importance to human medicine. Fewer enterococci from beef (ERY 4%; TYL 5%), pork (ERY 7%; TYL 8%) or turkey (ERY 26%; TYL 27%) were resistant to these antimicrobials. Resistance to ERY and TYL was concurrently present in all enterococci. Gentamicin resistance was higher in enterococci (11%) from turkey meat. The most common AMR genes found in the majority of enterococci were *tet(L)*, *tet(M)*, and *ermB*, consistent with the

phenotypic resistance to tetracycline and erythromycin, respectively. Consistent with the higher AMR found in enterococci isolated from chicken meat, the percentage of enterococci positive for AMR genes was also higher in these isolates. Enterococci isolated from beef had the smallest percentage of isolates with AMR genes. More than 90% of enterococci from all meat types were positive for at least one of the virulence genes tested and enterococci from chicken were positive for more virulence genes than enterococci from beef or pork. These results suggest that the prevalence of AMR, and AMR and virulence genes was higher in chicken than other meat types. This higher AMR in chicken meat may reflect the excessive antimicrobial use during poultry production.

# **Marination process optimization for beef semitendinosus muscles**

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To determine the optimum combination of injection level, sodium chloride (NaCl), and sodium tripolyphosphate (STPP) to maximize quality of injection-marinated semitendinosus (ST; eye of round) beef steaks from over-thirty-month carcasses, a response surface methodology experiment was designed to investigate the following variable ranges for whole muscle processing: injection level 105-115%, NaCl to deliver 0.3-0.9%, and STPP to deliver 0.1-0.5% in the final product. At 24 h post-processing, the muscles were prepared as 2.54 cm steaks and subject to instrumental measurements (cooking loss, Warner-Bratzler shear, Texture Profile Analysis, colour, pH, expressible moisture) and consumer product testing (acceptability of tenderness, juiciness, saltiness, flavour, and overall acceptability).

Increased injection level produced steaks with decreased water binding properties; however, the loss in functionality due to increased water addition was overcome by increasing STPP content. Increased NaCl and STPP concentrations yielded lower purge and cooking losses, and higher water holding capacity. As STPP content increased, steak colour became darker but there was no significant difference in  $a^*$  and  $b^*$  values amongst injection treatments. A highly positive linear relationship was observed between consumer acceptance scores and NaCl, STPP, and injection levels. Consumer panellists also showed greater willingness to purchase steaks injected at 115% with brine delivering 0.9% NaCl and 0.5% STPP.

Despite current concern about sodium content in processed foods, a peak in consumer acceptance was not reached in the first experiment, indicating that even higher levels of processing factors could further enhance product acceptability. A second iteration of the design was applied with the variable ranges: injection level 113-130%, 0.8-2% salt, and 0.5% STPP (regulated maximum). Again, higher injection and salt levels yielded greater consumer acceptance and a quadratic relationship term indicated an optimum variable combination was realized. Consumer acceptance of injection-marinated ST steak was maximized at 120-122% injection with brine formulated to deliver 0.9-1.1% salt and 0.5% STPP.

# **Impact of commercially available modified sea salt ingredients on the quality of low-salt injection-marinated beef steak**

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Canadian Community Health Survey findings indicate Canadian sodium consumption is almost double the recommended level. The majority of sodium in average diets is from sodium chloride (NaCl, salt) in processed foods, not from salt added at the table by consumers. Consumer demand has many meat processors looking to reduce salt content in their products; however, sodium reduction can be much more complex than simply reducing salt in the formulation since salt contributes to many aspects of product functionality and flavour. Following market cues, salt-replacer ingredients can now be found in abundance. This study is the first in a series aimed at examining the impact of selected salt-replacer ingredients on the quality of processed meat products.

Ocean's Flavor proprietary sea salt blends (OF-45LSN & OF-60LSB) are advertised as clean-label, sodium-reduced, direct replacers of salt. To assess their effects on the functionality and eating quality of injection-marinated beef their use was compared to a typical salt/phosphate brine (0.75% NaCl, 0.3% STP) at 115% injection level and to an uninjected control.

While OF60 was easy to use in a direct, 1:1 replacement of salt in the brine, an uncharacterized reaction occurred with OF45 in the phosphate/water solution causing formation of a gelatinous precipitate leading to processing difficulties, brine retention variability, and lower than expected sodium content indicating incomplete ingredient injection.

The hydration properties and instrumental tenderness of steaks from all of the injection treatments were increased over the control, with minimal differences observed amongst the processing formulations. Consumer acceptance of injection-marinated steak was significantly greater than that of the uninjected product, and there was no difference amongst injection treatments. OF45 and OF60 delivered eating quality acceptability equivalent to the salt/phosphate formulation, but with nearly 50% less sodium. Both salt-replacer ingredients delivered products with sodium contents (292 mg/serving) less than the Health Check Program maximum (360 mg/serving) for cooked, seasoned beef available to retail consumers.

# **Omega-3 fatty acids in pork products from animals fed different levels of flax**

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The consumption of omega-3 fatty acids (FA) and its health benefits have been widely reported and it is the only class of fatty acids with regulatory label claim status for meat and meat products in Canada ( $\geq 300$  mg omega-3 per 100 g serving). Feeding animals with digestible and enriched sources of  $\alpha$ -linolenic acid, like flaxseed co-extruded with peas, improves the availability and the deposition of omega-3 fatty acids in pork. In this study, the enrichment of omega-3 FA in different pork cuts was evaluated. Ninety-six pigs (48 gilts, 48 barrows) with an initial body weight of  $48 \pm 2$  kg were fed three levels of flaxseed (0, 5 and 10%) co-extruded with peas for 11 weeks and then slaughtered. The loin, picnic and butt were then taken down to  $\frac{1}{4}$  inch subcutaneous fat (i.e. commercial cut) and then lean, intermuscular and subcutaneous fat were dissected and analyzed to allow calculation of omega-3 FA amounts in primal and commercial cuts. Only lean was analyzed in the ham. As expected, increasing the level of dietary flax increased the level of total omega-3 FA in all tissues analyzed ( $p < 0.01$ ). Feeding 10% flax for 11 weeks only yielded an average of 197 mg omega-3 FA per 100 g of pure loin muscle which is less than the 300 mg required for an enrichment claim in Canada. Feeding 5% flax yielded 335, 364, 417 mg omega-3 FA/100g in loin, picnic, and butt primal cuts, respectively. Feeding 10% flax was needed to increase ham primal to  $> 300$  mg/100g. Total omega-3 in commercial cuts when feeding 5% flax provided in excess of 4x the omega-3 FA levels required for labelling in Canada. Depending on how portions are defined, less than 5% flax or 11 weeks of feeding would be required to reach 300 mg omega-3 fatty acids per 100 g serving of pork.

# Effects of dietary flax and vitamin E on beef quality in feedlot cattle

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The present study was undertaken to analyze the ability of vitamin E to overcome any shelf-life related problems associated with elevated levels of polyunsaturated fatty acids (PUFA) from flax-based diets. For 90 days, 80 feedlot steers (20 animals per treatment) were fed diets consisting of: 1) 80 % barley, 8 % grass hay and a standard level of vitamin E (451 IU per head per day), 2) elevated vitamin E (1051 IU per head per day), 3) ground flaxseed (12%) substituted for barley and standard vitamin E, and 4) ground flaxseed substitution and elevated vitamin E levels. Meat and fat composition,  $\alpha$ -tocopherol, oxidative stability (TBAR), objective colour and texture, and subjective sensory attributes were determined on *longissimus* muscle. Retail evaluations were conducted on *longissimus* muscle and ground beef (20% fat). Feeding flaxseed increased PUFA levels compared to barley-based diets (8.2 vs 6.3% of total fatty acids), and vitamin E supplementation increased  $\alpha$ -tocopherol levels (3.2 vs 2.1  $\mu\text{g/g}$  meat). Flax had no effect on meat moisture, crude fat, protein, objective colour, texture or TBAR values. However, vitamin E decreased drip loss, chroma, hue and TBAR values at 72h. Most sensory traits were not affected by dietary treatments. Nevertheless, the lowest percentage of panellists reporting off-sour flavour was for steaks from flax-fed steers with elevated vitamin E. On the other hand, while no effects were observed for lean muscle retail evaluation, the dietary inclusion of flaxseed led to lower scores for appearance and higher scores for discolouration in ground beef, possibly due to the higher fat content. Vitamin E supplementation improved ground beef retail traits compared to the control, but it was not enough to overcome the changes from the increase in PUFA levels in flax-based diets.

# **The effect of feeding omega-3 DHA on liver, muscle and fat tissue gene expression.**

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The essential dietary fats required by humans are linoleic (C18: omega-6) and linolenic (C18: omega-3). The recommended diet is a ratio of ~2: 1 omega-6: omega-3. Modern western diets are generally deficient in omega-3 fats with ratios greater than 15:1. Omega-3 fats can be obtained by eating plants to give C18 linolenic acid or by eating fish which additionally give C20 and C22 omega3 fats. Human nutrition studies suggest that the longer chain C20 and C22 omega-3 fatty acid may provide extra health benefits in eye and brain development, reducing inflammation and preventing heart disease. Fortified food products such as DHA enriched fruit juices, eggs, and bread products are recently being offered to consumers. At AAFC-Lacombe we developed DHA enriched bacon by feeding microalgae generated DHA and are currently improving its' flavour characteristics for the market. Part of this research was to test the DHA fed animals in a nutrigenomic model to assess some of the health benefit claims made by DHA suppliers.

Pigs were fed a daily dose of approximately 330, 3600 and 9400 mg of DHA per day for the last 30days before slaughter. This increased their belly fat and muscle content of DHA ~8X from 0.43 mg/g to 3.4 mg/g. Samples of blood, liver, longissimus muscle and subcutaneous backfat were collected from the animals at the time of slaughter and examined for gene expression patterns by RNA analysis and triglyceride (TG) content in blood. In adult humans, DHA supplements are proven to reduce those with high TG but in the actively growing pigs, no difference was detected and only a minor non-significant increase was observed in the TG microsomal triglyceride transport protein (MTTP). DHA is also reported to improve fat oxidation and reduce de novo synthesis, however, we observed an increase in fatty acid synthase (FASN) and steroyl coA desaturase (SCD1) and only a minor increase in acyl coA oxidase (ACO) indicating an overall increase in gene expression of de novo fat activity. This may suggest that since the polyunsaturated fatty acid DHA was increased by the diets, the animals tried to maintain saturated fat levels through internal synthesis.

