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Contents

Detection of Virulence Genes in *Escherichia coli* Isolated from Retail Poultry Meats

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Background: Extraintestinal pathogenic *Escherichia coli* (ExPEC) strains are distinct from intestinal pathogenic and commensal strains. The ExPEC including avian pathogenic *E. coli* that cause colibacillosis in poultry are responsible for serious public health concerns and cause important economic losses for the poultry industry. The objective of this study was to investigate the prevalence of ExPEC related genes isolated from retail poultry meats purchased in Alberta. **Methods**: Multiplex PCRs followed by agarose gel electrophoresis were used to detect 25 *E. coli* virulence genes in *E. coli* isolated from retail meats (469 isolates). These retail meat isolates were then compared to 12 *E. coli* isolates recovered from clinical cases of human infections (stool, blood and urinary tract infections). **Results**: Human isolates were found to harbour 3 to 16 virulence genes while these numbers in the retail meat isolates varied from 1 to 14. The *fimH* (type I fimbriae, 98%), *traT* (serum resistant, 74%) and *ironEC* (siderophore receptor, 48%) genes were prevalent in retail poultry meat isolates, while *fimH* (100%), *fyuA* (yersinabactin, 92%), and *traT* (83%) were prevalent in human isolates. No *concnf* (cytotoxic necrotizing factor) gene was found in poultry meat isolates while no *K15* (polysialic acid transport), *bmaE* (M fimbriae), *gafD* (G fimbriae) and *cdts* (cytolethal distending toxin) were found in human isolates. The pathogenicity-associated island (*PAI*) marker was found in 33 (7%) and 2 (17%) of the retail meat and the human isolates, respectively. All retail meat isolates positive for *PAI* harboured *fimH* whereas 82% and 64% of them carried *traT* and *ironEC*, respectively. The two *PAI*-positive human isolates harboured *fimH*, *vat* (vacolating autotransporter toxin), *fyuA*, and *clbB* (peptide-polyketide synthase). A retail meat isolate was found to carry the genes-pattern *PAI-papA-fimH-vat-ireA-fyuA-ironec-clbB-sfa-iutA-K5-cdts-focG-allele II* suggesting its ExPEC potential. **Conclusion**: Comparing the virulence factors of *E. coli* isolated from humans with those from retail poultry meats provide insights into their ExPEC potential that may represent serious food safety concerns. Our results showed that further characterization of retail meat-associated *E. coli* isolates are warranted to determine their relationship with *E. coli* strains causing infections in humans.

Characterization of antimicrobial resistance in *E. coli* isolated from a commercial pork processing plant

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This study assessed the prevalence of antimicrobial resistance (AMR) and resistance genes in *E. coli* isolated from a commercial pork processing plant. Samples for isolation of generic *E. coli* were collected during multiple visits to a commercial pork plant. Sample sources were pig carcasses after bleeding (BC; 55 samples), pasteurized carcasses (PC; 100 samples) and retail pork (RP; 55 samples). A total of 68 *E. coli* isolates comprising 55, 12 and one isolate from each of BC, RP, and PC samples, respectively were analyzed. Antimicrobial susceptibility for 15 antimicrobials was tested and PCR was used to detect genes for β-lactamase (*blaCMY-2*, *blaTEM, blaSHV, CTX-M*), tetracycline (*tet*(A), *tet*(B), *tet*(C)), sulfonamides (*sul1, sul2, sul3*), and aminoglycosides (*strA/strB*, *aadA*). *E. coli* recovery rate was 100%, 22% and 1% for BC, RP and PC samples, respectively. The AMR varied by the sample types and single *E. coli* recovered from PC samples showed resistance to tetracycline. *E. coli* isolates from BC samples did not show resistance to amikacin, ciprofloxacin, gentamicin, kanamycin, sulfisoxazole and nalidixic acid. Only one isolate was resistant to amoxicillin/clavulanic acid (AMC), ceftiofur (TIO), ceftriaxone (CRO) and cefoxitin (FOX), antimicrobials important in human medicine. About 16% of isolates from RP samples were resistant to AMC only and no resistance was found to TIO and CRO. Prevalence of resistant genes in *E. coli* isolated from BC and RP samples varied. More *E. coli* from RP samples were positive for bla_{CTX-M} and bla_{TEM} genes, important from human health point of view, than *E. coli* recovered from BC samples. The $_{blaCMY-2}$ and *sul3* genes were found only in 27% and 13% of *E. coli*, respectively, from BC samples. *E. coli* with phenotypic AMR mostly carried corresponding AMR genes; however, a number of susceptible *E. coli* were also positive for AMR genes. These data suggest that incoming pigs carried antimicrobial resistant *E. coli* that are essentially eliminated from the carcasses after pasteurization, however, the retail pork can be re-contaminated with resistant *E. coli.* This study would help understanding the epidemiology of AMR in a pork processing plant.

Visible and Near-Infrared Light Transmission: A hybrid Imaging Method for Intramuscular Fat Evaluation

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Abstract: Marbling (intramuscular fat) is one of the most important criteria for attributing the quality of meat. On a processing line, it is determined by visual inspection (of fat and muscle) of the surface of the meat sample and charts are used to assign the meat quality grading level. However, this observation of the meat surface provides no information about the quantity of the actual marbling or its distribution content inside the meat sample. In this work, a new visible (VIS) and near-infrared (NIR) light method is used to evaluate the quantity of marbling in beef meat samples. It is demonstrated that using NIR light in transmission mode (NIR light crosses through the meat sample without damaging it), it is possible to detect the fat not only on the surface of the meat sample, as for visual grading, but also underneath the surface of the meat sample. Moreover, by combining the analysis of the two sides of the meat sample (5~7 mm), it is possible to estimate the volumetric marbling which is not accessible when observing only the surface. The scientific and experimental studies demonstrate the applicability of the proposed method.

A simple and accurate Computed Tomography approach for measuring the lean meat percentage of pig carcasses

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Objectives

The global challenge was to develop a robust, unbiased, accurate and simple method for measuring the lean meat weight and percentage (in live animals, carcasses, cuts and meat pieces). The aim of this study was to test on pig carcasses such a method, which was developed on pig cuts.

Materials and methods

Twenty-nine left sides, as a representative sample of the French pig slaughtering, were scanned by spiral Computed Tomography (CT). The slice thickness was 3 mm, giving about 450 axial images for a side (1.50 m length) Muscle volume was measured by automatic thresholding, using 0 and 120 Hounsfield values (HU). LMP (Lean Meat percentage) was calculated applying a constant muscle density. After scanning the sides were fully dissected according to the EU standard.

Results

Correlation between CT and dissection was 0.98. The regression of dissection on CT gave a Residual Standard Deviation (RSD) of 384 g muscle weight and 0.81 % LMP.

Conclusions

This CT procedure is a rather accurate method to measure the lean meat percentage of the pig carcasses. Among the CT procedures proposed in the EU, it is the simplest one. Furthermore, it is independent of the population, as there is no prior calibration against dissection, leading to the assumption of good robustness property. It is therefore a good candidate for a starting point to build a harmonised international CT procedure.

It will be used in France for composition studies until future noticeable improvement. Variability of muscle density is under investigation to assess the robustness of this approach. The detection of the different tissues, especially in the belly and in the less valuable cuts, could deserve further improvement.

Temperature Dependent Effect of Cinnamaldehyde on Cell Viability and Morphology of *Escherichia coli* O157:H7

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Many spice essential oils are useful sources of antimicrobial compounds and have the potential to be used as natural alternatives to chemical preservatives for improving safety and shelf-life of perishable foods. One such compound, cinnamaldehyde, is active against many food-borne pathogens including *Escherichia coli* O157:H7; however, understanding how cinnamaldehyde acts on microorganisms is key for its application in food preservation. The objective of the present study was to examine changes in viability and cell morphology of *E. coli* O157:H7 during exposure to sub-lethal concentrations of cinnamaldehyde at 37 ºC or 6 ºC. Log phase *E. coli* O157:H7 (02/0627) cells were treated with cinnamaldehyde at less than its minimal inhibitory concentration of 400 mg/L (100, 200 or 300 mg/L) at 37ºC for 24 h or at 6 ºC for 7 d. Growth was monitored by hourly plate count at 37 ºC and daily at 6 ºC, while filament formation was monitored by photomicroscopy. At 37 ºC, ≤ 200 mg/L cinnamaldehyde significantly ($p < 0.05$) delayed *E. coli* O157:H7 for 2 h while 300 mg/L prevented growth for 5 h. The greatest extent of filamentation (87.3% of cells) and greatest mean cell length (6.4 µm) occurred at 2 h exposure to 200 mg/L, whereas only 61.7% of cells were filamentous and mean cell length was 5.6 µm after 5 h at 300 mg/L cinnamaldehyde. After 2 h at 200 mg/L and 5 h at 300 mg/L, cell morphology and growth rate approached control values. At 6 ºC, a > 5 log reduction occurred at 3 d exposure to 300 mg/L and numbers were less than the detection limit during the next 3 d, but 200 mg/L caused only a 4 log reduction at 7 d. At ≤ 300 mg/L, the mean cell length and filamentation remained unchanged (≤ 4 µm and ≤ 30%, respectively) during 7 d period while for the control at 7 d the filamentation increased to 77.7% with a mean cell length of 7.5 µm. These findings suggest that at sub-lethal concentrations, cinnamaldehyde caused a delay in *E. coli* O157:H7 replication because of filament induction which was reversible at 37 ºC, but it did not cause filamentation and was lethal at 6 ºC. The greater potential of this natural antimicrobial at low temperature suggests that it may be useful in perishable foods for *E. coli* O157:H7 control.

Filamentation of *Listeria monocytogenes*

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Filaments of bacterial cells could have major implications for food safety as they may result in an underestimation of viable cell counts in foods. Filamentation occurs when cell division is inhibited but cellular components continue to increase. Filamentation occurs when bacterial cells are exposed to harsh conditions, which interrupt cellular processes, including cell division. Conditions that induce filamentation include low temperature, high salt, acidic environments and modified atmosphere, all of which can be found in meat plant environments.

The objective of this research was to compare the degree of filamentation and growth of 16 strains of *Listeria monocytogenes* at 3, 3.5, 4, 4.5 and 5°C in tryptic soy broth to gain a better understanding of the potential significance of filamentation to the meat industry.

Optical density, plate counts and flow cytometry analyses were performed on day 0, 7 and 10. All 16 strains were capable of growth at temperatures as low as 3°C. Using flow cytometry, the size of the 10% longest cells in the sample was compared to the 10% longest cells in the control (cells grown at 15°C) using fold change of cell size, where a higher fold change indicates filamentation. Filamentation was highest at 4.5°C. Data showed that the fold change correlates with the shift of size in the entire population. Flow cytometry data also revealed an increase in the size of the cells in the population that correlated with fold change data. Microscopic analysis revealed the highest degree of filamentation in *L. monocytogenes* CDC7762, a medium degree in FS2 and very little filamentation in FS12, at all temperatures. The large degree of strain variation suggests that the impact of filamentation on enumeration by plate counts will be variable. During enumeration each filament would be detected as a single colony with subsequent underestimation of the potential numbers of bacteria to which consumers could be exposed.

Understanding cryptic growth of *Escherichia coli* at chill temperature

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E. coli and related pathogens have been reported to produce filamentous cells at < 7 °C. This may result in underestimation of microbiological risks if filaments yield multiple daughter cells upon temperature increase. The objective of the study was to determine the changes in colony count, cell size distribution, cell division pattern of filamentous and normal sized cells when chilled *E. coli* were exposed to the optimum growth temperature (37 ºC). Log phase *E. coli* ATTC 23739 were incubated at 6 ºC for 8 d. On day 0, 4, 6, and 8, samples were collected and were incubated at 37 ºC for 4 h. Growth was monitored by plate count at 30 min intervals while changes in cell size distribution were monitored hourly by photomicroscopy. On day 5, the cell multiplication patterns of filamentous and non-filamentous cells were monitored for 1.5 h at the single cell level using a heated stage microscope. After 8 d at 6 ºC, the proportion of filaments (> 4 µm) reached 95% with a mean cell length of 12 µm. On day 0 and 6 at 37 °C, cells multiplied at a rate of 2.2 and 1.8 generations/h, respectively, after a 30 min apparent lag period while on day 4 and 8, the rate of increase was ≥ 2.5 generations/h after a 1 h apparent lag. On day 5, each cell measuring > 10 µm produced > 13 daughter cells, whereas those that measured ≤ 4 µm or 4 -10 µm produced < 5 daughter cells after 1.5 h. Results of this study suggest that chilled, filamentous *E. coli* form multiple daughter cells when shifted to higher temperatures which yields faster growth. Therefore, direct enumeration of *E coli* and other mesophilic pathogens by plate counting of refrigerated foods may underestimate the numbers of organisms to which consumers might be exposed.

Effect of oil source and refrigerated storage on colour and oxidative stability of *biceps femoris* muscle steaks

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The objective of this study was to enhance *biceps femoris* (BF) muscles from over-thirty-month carcasses with omega-3 fatty acids by incorporation of flaxseed or canola oil and to determine colour and oxidative stability of the injected steaks during refrigerated storage.

BF muscles were injected with brine to achieve 20% extension by weight and 0.4% salt, 0.3% sodium tripolyphosphate (STPP) and 1% flaxseed or 5% canola oil levels in the injected product. Non-injected muscles and muscles injected with brine containing only STPP and salt served as controls. At 24 h post-processing, muscles were cut into as 2.54 cm steaks which were vacuum packaged and stored overnight or for 2 weeks at 4°C for instrumental evaluation. Color (CIE L*a*b*) and oxidative (TBARS values) stability of BF steaks during 6 days of display at 4°C were evaluated. Omega-3 fatty acids content in raw injected muscles and cooked steaks was determined.

Non-injected beef steaks and those injected with 20% of canola oil emulsion were significantly lighter (higher *L** values) than those injected with salt/phosphate brine and flaxseed oil emulsion. Holding vacuum-packaged samples for 14 d at 4°C resulted in a decrease in a* and b* and saturation index values in all but the salt/phosphate injected samples. There was a general decline in *L**, *a**, *b**, saturation index, and an increase in hue angle values as the duration of display increased but the colour change was unaffected by injection treatment. Steaks injected with salt/phosphate solution and canola oil emulsion maintained better oxidative stability during the 6 days of retail display compared to non-injected steaks and those injected with flaxseed oil emulsion. Targeted levels of omega-3 (300 mg/100 g) can be achieved by the inclusion of omega-3 containing marinades/emulsions at levels sufficient to retain omega-3 fatty acids in the cooked product. Injection treatment had no effect ($P>0.05$) on the cooking loss. Good retention of fatty acids after cooking indicated that emulsion injection is a viable option for enhancing whole muscle beef with essential fatty acids to meet nutrition claims.

Predicting the content of polyunsaturated fatty acids and biohydrogenation products in subcutaneous fat of beef cows fed flaxseed by near infrared reflectance spectroscopy

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Today, consumers are interested in fat composition as scientific evidence suggests that diets high in saturated fat are associated with an increased risk of cardiovascular disease. Techniques to quantify fatty acids (FA) in meat are costly and time-consuming. Near infrared reflectance spectroscopy (NIRS) is a rapid and non destructive method. The aim of this study was to examine the ability of NIRS to estimate the concentration of polyunsaturated FA and their biohydrogenation products in subcutaneous fat from cows fed flaxseed. Subcutaneous fat samples at the 12th rib of 62 cows were collected and stored at -80ºC. After thawing, 32 spectra from each intact sample were collected, then averaged, over a NIR spectral range from 400 to 2498 nm at 31ºC (warm samples) and 2ºC (cold samples), and then analyzed for FA profiles. NIRS calibrations on warm samples, tested by cross-validation, showed high predictability for most of the n-3 (R^2: 0.81-0.86; RMSECV: 0.11-1.56 mg·g^{-1} fat) and linolenic acid biohydrogenation products such as conjugated linolenic acids, conjugated linoleic acids (CLA), non-CLA dienes and *trans*-monounsaturated FA with R^2 (RMSECV, mg·g^{-1} fat) of 0.85-0.85 (0.16-0.37), 0.84-0.90 (0.21-2.58), 0.90 (5.49) and 0.84-0.90 (4.24-8.83), respectively. When spectra were obtained from cold samples NIRS predictability was lower than that for warm samples, probably due to a less homogeneous distribution of fat throughout the cells and more air bubbles, or to reduced molecular vibration due to the cooler temperature. NIRS could discriminate 100% of subcutaneous fat samples from cows fed different diets (with or without flaxseed). These data support that NIRS has the potential to be used as a fast and accurate predictor of content of linolenic acid and its biohydrogenation products in subcutaneous fat of beef cows. Nevertheless, further studies are required to test its ability during on-line operations in an abattoir.

Sensory characterization of omega-3 enriched pork meat using free choice profiling following addition of sugars

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The greatest challenge presented by n-3 enrichment of pork meat is the reduced oxidative stability of n-3 fatty acids, which may lead to the generation of off flavours during cooking and decreased consumer eating satisfaction. Addition of sugars may improve the sensory characteristics of these meat products due to their involvement in the Maillard reaction. Free choice profiling and Generalized Procrustes analysis were used to assess differences in aroma, texture and flavour of omega-3 enriched pork meat patties. Pork trim was collected from the carcasses of pigs fed either a control diet (no flax) or 10% flax diet for 6 weeks with vitamin E at either 40 mg/kg feed (control) or 400 mg/kg feed in a 2×2 factorial design. Food grade sugars sucrose, glucose, xylose or no sugar (control) were added at a 2% level to pork grinds from each dietary treatment in a split plot design. A sensory panel of eight panellists was used to identify aroma, texture and flavour characteristics of the pork patty products. Sample presentation order was randomized using a Williams Latin Square with 8 treatments presented to eight panellists over 6 blocks in an incomplete block design. Cooked and reheated patties were assessed by panellists in triplicate separately in 4 sessions per week. Sample attributes chosen by each assessor were scored on 15 cm line scales, anchored at the ends by the terms “none” and “extreme”. Data were analyzed using XLSTAT 2010 (Addinsoft, Inc. NY, USA). Aroma and flavour in control (no sugar) meat patties were described as cardboard, warmed over, stale and descriptors rated as more intense for re-heated patties than for those freshly cooked. The aroma of meat patties that contained glucose and sucrose were described as pork meaty, roasted pork, browned and oily, while patties that contained sucrose and glucose were described as moist, juicy and soft. Sweet and caramelized flavour notes apart from pork meaty and roasted pork flavours were detected in patties that contained sucrose. Patties that contained glucose were described as having roasted pork, fishy and umami flavour. Meat patties that contained xylose were described as hard, spongy and fibrous with chemical, burnt and oily flavors and burnt, rancid, fishy and warmed over aromas. Addition of sugars modified product descriptors and produced distinct sensory characteristics irrespective of the source grind fatty acid or Vitamin E composition.

Potential application of genomics for improving the quality of Canadian pork

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The availability of high-density Single Nucleotide Polymorphism (SNP) panels for the swine industry has created an opportunity to use genomic information to improve the quality of Canadian pork. A commercial test for over 64,000 genetic markers (64K SNP panel) has been available since January 2009 and has been used in several swine research projects in Canada. In order to develop practical applications for use in industry, there is a need to collect phenotypes for traits of interest on many animals, genotype these pigs and then determine associations between the 64K SNP genotypes and phenotypes. The resulting associations can be used to predict genetic values for other animals in the population based on a genetic test without having to measure the phenotypes. This has an important practical advantage for meat quality traits which are expensive to measure and since they are measured post-mortem, the animals being measured cannot be selected for breeding. A DNA based test focused on meat quality traits offers an opportunity to develop genomic evaluation methods for selecting breeding animals early in life to improve meat quality.

In this study, 700 purebred pigs from herds across Canada were tested at the Deschambault station in Quebec. Of these, 620 pigs were evaluated post-slaughter for carcass and meat quality traits. The averages ± standard deviations for ultimate pH, luminosity, color (Japanese scale), marbling (NPPC) and drip loss percentage measured in the *longissimus dorsi* muscle were 5.62±0.13, 51.63±2.99, 3.47±0.51, 2.77±0.81 and 3.50±2.30, respectively. The traits measured on *gluteus medius* were ultimate pH, luminosity and subjective color with averages ± standard deviations of 5.61±0.12, 51.77±3.06 and 3.80±0.57, respectively. The quality of 64K SNP genotypes on about 3000 pigs from this and other recent studies in the same Canadian breeds was evaluated. Analyses revealed a calling rate greater than 0.96, less than 0.01 error rates, an average minor allele frequency greater than 0.24, Hardy-Weinberg equilibrium in more than 0.96 of SNPs and a good level of average linkage disequilibrium within breed (r^2 of 0.31-0.33). These preliminary results indicate a good potential for use of genomics to improve meat quality.

Use of loin intramuscular fat content predicted with ultrasound technology in the Canadian Swine Improvement Program

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Pork marbling is an important meat quality trait for some international and domestic markets, and a main component influencing sensory quality. The Canadian swine industry has a strong reputation of high quality and standards. Improving or differentiating Canadian products will be vital in the coming years. Moreover, pigs have been selected very efficiently for leanness in the past decades to address market requirements, and this has probably resulted in a slow decrease in intramuscular fat (IMF) levels. The Canadian Centre for Swine Improvement (CCSI) has been working for several years on the development of methods to predict loin marbling levels in live pigs in order to include it in selection programs and stabilize or increase it in Canadian pig populations.

Intramuscular fat predicted on live pigs has been recently included in the Canadian accreditation program for ultrasonic technicians. A large research project involving 6,000 Duroc pigs scanned across Canada was designed to enlarge the live IMF database and confirm genetic parameters estimated in a previous study. Data collected in the project are also used for genetic evaluation and selection of boars with either low or high IMF EBVs and to produce commercial pigs fed with standard or specific feeding programs formulated to increase marbling. The field tests will provide valuable information about the effect of genetics and management (especially feeding) on the marbling level in pork loins.

As part of the project, CCSI has developed genetic evaluations on live intramuscular fat for Canadian Durocs. Breeding values for loin IMF are now available for breeders and producers across Canada, through participating AI centres.

Understanding the Formation of Grade B4 Beef in Alberta

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Canadian grade B4 beef carcasses are penalized by $0.77 per Kg because the *longissimus lumborum* is dark, firm and dry (DFD). The number of DFD carcasses has dramatically increased in Alberta and has almost doubled since 2004. Classical DFD beef is caused by stress and insufficient muscle glycogen prior to slaughter, which causes an abnormally high post mortem muscle pH of 6.0. Past Research has identified a portion of DFD carcasses that have a pH of 6.0 or less, suggesting glycogen sufficiency may not be the causative mechanism. Grading site muscle pH values were used to identify sub-classes within the DFD population ($pH > 6.0$, $5.8 < pH < 6.0$, $pH < 5.8$). About 7% of the DFD carcasses exhibited muscles with normal muscle pH but dark colour ($P < 0.05$). Muscle metabolic measurements showed no differences in glucidic potential suggesting some DFD animals are not caused by the same mechanism as traditional DFD carcasses. All B4 carcasses weighed less than normal carcasses, indicating that light weight animals may be at risk of DFD ($P < 0.05$). This study will provide insight of cost recovery of B4 carcasses for the beef industry.

Exploring the Biochemical Basis of DFD in Broiler Breast and Thigh Meat

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The effect of acute cold exposure on muscle energy reserves at slaughter and its relation to post-mortem glycolysis and the incidence of dark, firm and dry (DFD) breast and thigh meat were investigated. Male broilers (160) were exposed to temperatures of -9 to -15, or +20 °C (control) for 3 h prior to slaughter. Glycolytic potential (GP) and pH of thigh (*illiotibialis*) muscles was determined at 5 min, 6 h and 24 h post-mortem and that of breast *pectoralis* major muscle at 0 and 20 min, 1h, 6h and 24 h post-mortem from selected birds. Activity of adenosine monophosphate-activated protein kinase (AMPK) in breast meat was assessed at 0 min post-mortem. Color, water binding capacity (WBC) and processing cook yield (PCY) were measured. Breast and thigh meats were classified based on ultimate pH (pH_u) and lightness (L*) to normal breast (pH_u < 6.1, L* > 46) and thigh (pH_u < 6.4, L* > 44) and DFD breast (pH_u > 6.1, L* < 46) and thigh (pH_u > 6.4, L* < 44).

The total amount of AMPK was similar for normal and DFD breast samples, but phosphorylated AMPK, indicative of its activity, could not be detected in this study. Within the cold-stressed birds 85% and 42% showed DFD in thigh and breast meat, respectively. This contrasts to DFD incidence of 0 and 20% for thigh and breast meat, respectively, for the control birds. Energy reserves were completely exhausted in DFD thigh meat (14.8 µmol/g of lactate), suggesting that the lack of substrate availability resulted in DFD in thigh meat, whereas in white glycolytic breast muscle energy reserves at slaughter were limiting only in cold-stressed birds with DFD meat (67.0 µmol/g of lactate). Incomplete post-mortem glycolysis rather than lack of substrate availability seemed to be the main cause of DFD breast meat, particularly in control birds (86.8 µmol/g of lactate). GP for breast meat, but not for thigh meat, was time sensitive and showed some fluctuations over time post-mortem. In addition, GP was more highly correlated to changes in meat quality of thigh than breast meat. Therefore, development of DFD meat was observed to be different in glycolytic breast and oxidative thigh muscles.

Improvement of microbial quality of fresh pork loin using dietary oregano oil and cranberry pulp

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An oregano oil (Regano® C500, Ralco Nutrition, Inc.) and ground cranberry pulp (Fruit d'Or, Notre-Dame-de-Lourde, Qc) supplement was added to the ration of finishing pigs to determine their antioxidant and antimicrobial effect on the microbial quality of fresh pork loin during storage at < 4°C under aerobic and anaerobic conditions. Two levels of oil (250 and 500 µg/kg) and three levels of cranberry (5, 10 and 20 g/kg) were tested according to a factorial experimental design. The control group did not receive any supplement. A total of six samples per treatment were tested at each sampling time. Meat was vacuum packed and analysed after 0, 23, 45 and 60 days of storage. Samples were re-packaged under aerobic conditions after 0 or 23 days of anaerobic storage and analysed after 4, 8 and 12 days at < 4°C. The pH was determined in the *longissimus dorsi* muscle at the ¾ last rib level 45 min and 24h after slaughter in a federally inspected abattoir. Total aerobic mesophilic (TAM), presumptive lactic acid bacteria, presumptive *Pseudomonas*, *Escherichia coli* and coliforms counts were determined on each sample in duplicate. Color and drip loss were also measured on each sample. With respect to TAM counts, no significant difference was observed between treatments except for samples packaged at day 0 under aerobic conditions after 12 days of storage. During storage, TAM counts increased by 1.39 log cfu/g for the control whereas treatments were between 0.25 to 0.95 log cfu/g. Coliform counts were not significantly different for any treatment in both storage conditions and no *E. coli* was detected on any sample. Under anaerobic conditions, lactic acid bacteria were not affected and remained a predominant microflora despite the antimicrobial treatments.

Defining Carcass and Meat Quality Standards for Canadian Pork

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The development of Canadian standards for the measurement of pork meat and carcass quality is required to provide the Canadian pork industry with a mechanism to establish quantifiable points of differentiation. Enhanced pork quality standards will improve the competitive advantage of innovative producers and meat processors choosing to differentiate their products based on specific meat quality attributes for the most discerning domestic and export markets. The project aims at developing standard methods for evaluation of various carcass and meat quality characteristics, using a science-based approach to develop two-tier evaluation systems involving both objective and subjective methods. New technologies based on computer vision and hyperspectral analysis are explored as new avenues for potential reference methods.

As part of this initiative, visual charts for meat color and marbling are under development, based on a photo bank constituted in 2010 on a total of 631 pigs tested at the Deschambault test station. A large number of carcass and meat quality traits were measured on these pigs, for which high quality pictures of the 4th last chop are available. Based on computer vision and laboratory results, and after color calibration was standardized, visual charts were developed for colour and marbling. These charts will need to be validated and fine-tuned by specialists in meat quality assessment, in slaughter plant conditions.

The scoring methods and charts developed as 'Canadian standards' will be made available to the Canadian swine industry for various purposes such as benchmarking, marketing, carcass grading, research and genetic improvement. This project is supported by Canada Pork International though the International Pork Marketing Fund.

Effect of production system and implant strategies on steer performance and carcass traits

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Numerous cattle management strategies have been developed to improve efficiency, reduce input cost and enable producers to access differentiated beef products to satisfy consumer needs. A common practice in North America is to use hormonal growth implants which may compromise beef quality. The aim was to determine the effects of different management strategies on performance and carcass traits. Over a 2 year period 222 crossbred steers were allotted to a 2x2x2 factorial arrangement of treatments to determine the effect of the production system (**Calf-fed**, 13-14 months of age, grain finished *vs*. **Yearling-fed**, 20-22 months of age, grower period followed by grain finishing), growth implant strategy (not implanted, **NOIMP** *vs*. implanted, **IMP**) and *β*-agonist supplementation (**RAC**: ractopamine *vs.* **NORAC**: no ractopamine). Animals were slaughtered at the Lacombe Research Centre. Following chilling at 1 ^{o}C overnight, left sides of carcasses were broken down into primals and subsequently dissected into principal tissues. Live weight (Calf-fed, 556.1 ± 13.26 kg; Yearling-fed, 716.1 ± 12.83 kg: NOIMP, 614.1 ± 14.25 kg; IMP: 658.1 ± 12.30 kg) and commercial carcass weight were affected by the production system and implant strategy ($P < 0.001$). Intermuscular fat, body cavity fat and lean were affected ($P < 0.05$) by the implanting. IMP were leaner than NOIMP (57.8 ± 0.62 %; 55.6 ± 0.89 % carcass weight, respectively) resulting in concomitantly higher fat in the NOIMP (30.0 ± 1.02 %; IMP: 28.0 ± 0.73 % carcass weight). No differences ($P > 0.1$) were noted across treatments for lean yield grade. Implanting affected quality grade in Calf-fed ($P < 0.06$) and Yearling-fed ($P < 0.01$). In the Yearling-fed, 21.6 % NOIMP and 7.2 % IMP carcasses were graded AAA. Calf-fed showed a higher AAA grade frequency in the NOIMP (18.0 %) than in the IMP (8.11 %). The results indicate that the production systems and implant strategies studied could affect the carcass quality of steers. The interaction between both strategies could affect quality grade. It should be noted that in this study factors determining yield grade were not affected by the different management strategies.

Effect of production system and implant strategies on steer maturity and carcass characteristics

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There are numerous beef production systems in North America that use anabolic growth promotants to improve performance and profitability. However, growth implants could compromise beef carcass quality. The aim was to examine the effect of different beef production systems on physiological maturity and carcass characteristics. Over a 2 year period 222 crossbred steers were allotted to a 2x2x2 factorial arrangement of treatments to determine the effect of the production system (**Calf-fed**, 13-14 months of age, grain finished *vs*. **Yearling-fed**, 20-22 months of age, grower period followed by grain finishing), growth implant strategy (not implanted, **NOIMP** *vs*. implanted, **IMP**) and *β*-agonist supplementation (**RAC**: ractopamine *vs.* **NORAC**: no ractopamine). Animals were slaughtered under simulated commercial conditions at the Lacombe Research Centre. Dentition, physiological maturity, and "blue-tag" data were collected by experienced evaluators. All (100 %) Calf-fed NOIMP and only 21.6 % of Calf-fed IMP steers had no islands of ossification in the lumbar vertebrae ($P < 0.001$). Ossification of thoracic vertebrae was affected ($P < 0.001$) by the production system and implant, and sacral vertebrae of the Calf-fed was affected ($P < 0.001$) by implanting. Calf-fed were affected ($P < 0.05$) by implant treatment showing a trend where dentition scores were highest, otherwise as expected, dentition scores were lowest (level 4 & 5) for Calf-fed, and spread across the full range for Yearling-fed. Apart from a production system by implant interaction ($P < 0.05$) for rib-eye length, values for "blue-tag" were always lower for Calf-fed ($P < 0.001$), as expected. Carcass maturity was affected by production system and implant strategy ($P < 0.001$). Marbling score was higher ($P < 0.01$) for NOIMP (498 ± 23.6) compared to IMP (443 ± 20.8). The data indicate that combining production systems and implant management strategies affects both ossification and carcass characteristics such as marbling. Growth implants accelerate the ossification process in younger animals thus having a dramatic effect on numbers of animals eligible for under 21 months of age based on physiological maturity evaluation.

Improving the safety and competitiveness of lean, low sodium meat products

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Canadians are becoming much more aware of the nutritional quality of the foods they eat and are seeking lower sodium alternatives. Addition of sodium chloride to meat products is very important for technological reasons, but the meat industry must overcome many challenges to expand their offerings of low-sodium meat products and meet the new Health Check Program levels for sodium. Processors need alternative ingredients and processing strategies to provide consumers with flavourful processed meat products with a long storage life and assured safety.

The objective of this research was to determine the microbial profile of commercial products to establish a benchmark for further research on storage life and safety. "Lower salt" sausages and their conventional counterparts were obtained from a processor and stored at 2°C for 120 d. At regular sampling times, products were removed from storage and subjected to both culture-dependent and culture-independent analysis of the microbial community. On day 0, 35, 70 and 120 of storage, the culturable microflora were identified by partial 16SrDNA sequencing. The numbers of culturable bacteria recovered from these products at all sampling times were extremely low. Sequence analysis of the culturable microflora revealed that the regular salt sausages contained strains of *Lactobacillus sakei, Lactobacillus curvatus/graminis* and *Pediococcus acidilactici*, while the lower salt sausages contained wider spectra of bacteria, including many strains of *Carnobacterium maltaromaticum, L. sakei/curvatus,* and *L. curvatus/graminis*. Using culture-independent techniques (denaturing gradient gel electrophoresis analysis and partial 16S rDNA sequencing), *Lactobacillus* spp. were recovered from the surface microflora of the regular salt product while the surface microflora of product formulated with reduced sodium included *Carnobacterium* spp. and *Lactobacillus* spp. The difference in microbial species composition between regular and salt- reduced products may be due to different formulations, with possible impacts on the product shelf-life and safety.

A Comparison of Wheat and Corn-Based Distillers Grains Plus Solubles and their Combination on the Quality of Beef *Longissimus*

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This study investigated the effect of feeding crossbred beef steers diets with barley (control) or with 40% wheat or corn dried distillers grains plus solubles (DDGS) or their combination on *Longissimus* muscle quality attributes. Six-bone rib sections (7th to 12th ribs) from 80 steers (20 per diet) were aged for 14d.

No differences ($P>0.05$) were observed in meat composition, pH, drip loss or shear values due to dietary regime. Steaks from steers fed wheat DDGS were lighter (higher L* value; $P<0.05$) than steaks from steers fed the other treatments. Similarly, retail display panel results showed wheat DDGS steaks had a lighter ($P<0.001$) lean colour score than steaks from the other diets. It was also observed that steaks from animals fed any DDGS diet lost redness faster over time (lower a* values) and had a less desirable retail appearance than control steaks ($P<0.001$). Differences between diets were also observed in both the subcutaneous and intramuscular fatty acid profiles, especially in regards to *trans*-monounsaturated fatty acids, branched-chain fatty acids (BCFA), and conjugated linoleic acid. Specifically, fat from steers fed wheat DDGS had higher levels of BCFA, while fat from steers fed corn DDGS had higher levels of *trans*-monounsaturated fatty acids. In addition, the fat from steers fed DDGS diets had higher levels of conjugated linoleic acid. Although the fatty acid composition from cattle fed a DDGS diet had higher concentrations of PUFA, no differences were observed in regards to the oxidative stability of raw or cooked meat. Overall, feeding 40% wheat DDGS, 40% corn DDGS or their blend did not significantly affect meat quality; however, wheat DDGS did offer enhanced colour stability and a more desirable fatty acid profile over corn DDGS.

Effect of packaging on the shelf life of pork in industrial consumer sale units (UVCI)

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Objectives: This study examines the impact of packaging on the microbiological shelf life (*Durée de vie microbiologique* - DVM) of pork packaged in industrial consumer sale units (UVCI).

Materials and methods: The evolution of spoilage flora in three batches of ribs in industrial consumer sale units packaged under air or modified atmosphere (70% O_2 – 30% $C0_2$) and stored at 8°C during their shelf-life (7 days for air packaging and 11 days under modified atmosphere packaging) was studied. These results allowed for the estimation of growth parameters of spoilage flora, in each of the three batches of pork packaged in UVCI and for the two types of gaseous environments using predictive microbiology models and the Sym'Previus software (http://www.symprevius.net). These parameters allowed to simulate the growth of *Pseudomonas*, the main type of bacteria responsible for spoilage in meat, when wrapped in film or modified atmosphere packaging for four different storage conditions. Bacterial growth rates that were obtained were compared to threshold levels recommended by the Guide for Good Hygiene Practices and Application of HACCP Principles.

Results and Discussion: The estimation of growth parameters shows that the latency period and growth rate of flora studied vary according to the batch, the gaseous composition and the flora. With regards to the maximum population density, it is difficult to conclude. The average growth parameters were used to simulate the growth of *Pseudomonas.* The simulation showed that the growth of *Pseudomonas* is systematically greater under air packaging (DVM=7days) compared to modified atmosphere packaging (DVM=11days), which is explained by the inhibitive power of the gaseous environment composition. It acts by increasing the latency phase and reducing the growth rate of spoilage flora in carbon dioxide environments.

Conclusions: This work allowed to demonstrate the effect of gaseous environment and storage conditions of industrial consumer sale units (UVCI) of pork ribs on the microbiological qualities based on one spoilage bacterium – *Pseudomonas*. The simulation results compared to threshold levels recommended by the Guide for Good Hygiene Practices and Application of HACCP Principles demonstrated that increasing microbiological shelf life by four days was acceptable for pork in UVCI by using modified atmosphere packaging.

Joint Technology Network on the « expertise of determining microbiological shelf life of food »

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Joint technology networks (*Réseau Mixte Technologique* - RMT) are a scientific and technical partnership implemented and supported by the Ministry of Agriculture in France. The agri-food joint technology networks are coordinated by the Technical Coordination Association for the Agri-Food Industry (*Association de Coordination Technique pour l'Industrie Agro-alimentaire* - ACTIA France, www.actia-asso.eu). Their goal is to create work between research, training and development stakeholders in concert with public authorities and professionals. The joint technology network on the « expertise of determining microbiological shelf life of food » has been approved by the Ministry for five years, until late 2012.This RMT is made up of important stakeholders in the food safety and quality field working towards the development and transfer of tools among agri-food professionals, which assist in determining microbiological shelf life.

The objective of the RMT is to provide expertise to businesses and public authorities concerning the impact of processes and conservation on the microbiological quality of foods. Some studies were started to optimize tools for determining the microbiological shelf life as part of European regulation (CE) n° 2073/2005 pertaining to food microbiological criteria and to better understand the evolution in micro-organisms during food processing and storage . The RMT is also involved in the recognition of these tools through the participation in standardization bodies, planning of workshops and round table meetings and the publication of technical and scientific papers.

The effect of corn DDGS in hog diets on pork breakfast sausages and ham quality

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Increased demand for ethanol-based bio-fuels has resulted in increased feedstock grain prices and a market flood of the Dried Distiller's Grains with Solubles (DDGS). The objective of this study was to evaluate how inclusion of corn DDGS in hog diets affected the quality and consumer acceptance of pork breakfast sausages and ham.

Pork was harvested from hogs fed no DDGS (T1, Control), 30% corn DDGS throughout all feeding phases (T2), or 30% DDGS during the grower phases followed by 20% in the first finisher phase and 0% in the second finisher phase (T3). Both breakfast sausages (15% and 25% fat levels) and ham (7% fat) were manufactured from each pork source, and functionality (texture profile analysis [TPA], colour, pH, cooking loss, and expressible moisture) and consumer sensory evaluation of the products were assessed.

Evaluation of ham indicated that neither functionality nor consumer acceptance was affected by dietary DDGS inclusion. High fat (25%) breakfast sausages made with pork from DDGS-fed hogs (T2 and T3) were softer (lower TPA hardness) than sausages made from control pork. Both DDGS treatments resulted in breakfast sausages with higher pH ($p<0.01$) while T2 was less red ($p<0.05$) compared to the sausages made from control pork. Generally, the T2 diet resulted in the lowest consumer acceptance ($p<0.01$) of appearance, colour, flavour and overall liking. T2 treatment reduced texture acceptability ($p<0.01$) of the high fat breakfast sausages whereas there was no difference in acceptability among the dietary treatments in the 15% fat sausages. Overall, the breakfast sausages from hogs that underwent DDGS withdrawal during the finisher phases of feeding (T3) had consumer acceptance scores comparable to sausages made from control pork.

Results suggest that dietary inclusion of 30% corn DDGS throughout hog feeding can result in lower fat pork products with functionality and consumer acceptance equivalent to products made from control pork. DDGS withdrawal during the finisher phases of hog feeding may mitigate the effect of DDGS dietary inclusion on consumer acceptance of pork products with higher fat content.

The effect of hydrostatic pressure and boning method on quality and functional properties of the fresh beef *semimembranosus* muscle

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High pressure processing (HPP) has potential as a decontamination strategy for inactivating microbial in ready-to-eat meats, but has also been shown to influence meat quality attributes in fresh meat. Hence, the effects of HPP on quality and functional properties of hot and cold boned beef were studied using 24 paired *semimembranosus* (SM) muscles. On each of 3 processing days, SM muscles from right sides of 8 carcasses were removed by hot boning at 50 min post-mortem, cut into half perpendicular to the muscle fibre and separately vacuum packaged. The packaged muscle pieces were packed in ice and immediately transported from the abattoir to the Food Processing Development Centre for HPP processing (~ 1 h transport). One piece of each SM muscle was assigned for HPP processing (120 MPa for 5 min) while the other piece of SM served as the control. After 24 h of chilling, contralateral SM muscles from the left side of the carcasses were cold boned (conventional method) and processed the same as the right side muscles. Following HPP, drip loss was recorded and SM muscles were cut into 2.5 cm thick steaks. Steaks designated for pH, water binding capacity (WBC), total protein solubility (TPS), and Warner Bratzler shear force (WBSF) were vacuum packaged, frozen and thawed prior to analyses. Steaks designated for evaluation of colour and oxidative stability (thiobarbituric acid reactive substances, TBARS), were overwrapped in oxygen permeable film and displayed in a retail display case prior to analyses. Hot boning significantly ($p < 0.001$) reduced the drip loss of whole muscle, while HPP did not affect the drip loss. Both hot boning and HPP resulted in a darker colour steak ($p < 0.01$). TPS increased, indicating higher protein solubility, in both hot boning and HPP ($p < 0.001$) steaks. In the hot-boned muscle, HPP tended to lower WBSF compared to the control (51.8 vs. 61.5 N; $p < 0.08$). Boning methods and HPP treatment did not affect the pH or WBC of steaks. Hot boned HPP steaks had the lower TBARS values, compared to cold boned HPP steaks, whereas the boning method did not affect oxidative stability in control steaks. Thus, HPP of hot boned beef resulted in superior meat quality in terms of drip loss, oxidative stability and TPS. HPP may thus have potential for use in improving quality attributes of fresh meats.