# Relative contribution of *ante*- and *post-mortem* factors to Canadian beef carcass and meat quality

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*Abstract*— **Numerous factors have been shown to influence economically important beef quality traits. Studies usually include 1 to 3 effects, limiting the interpretation and comparison of the results. The present study aims to investigate the relative contribution of *pre*- and *post-mortem* factors to the final quality of Canadian beef. One-hundred-and-twelve steers (4 breed-crosses) were arranged in a 2×2×2 factorial experimental including production system, growth implant and β-adrenergic agonist strategies. Carcasses were suspended by the Achilles tendon or the aitch bone and meat was aged for 2/6/13/21/27 days. Carcass and meat quality traits were measured. Statistical analyses were developed including *ante*- and *post-mortem* factors and their interactions as main effects. The adjusted multiple $R^2$ and the relative contribution of the factors to the variability observed for each measured trait were calculated. While the variability accounted by the model for fat class and estimated yield was mainly affected by production system and breed-cross, the marbling score was mainly affected by suspension and growth implant strategies. Ageing, production system and their interaction were the main factors responsible for the variability in colour. The main factor responsible for the variability in sarcomere length was the suspension method. The variability in instrumental and sensory tenderness was mainly affected by ageing time, but also suspension and their interaction. Within the production and processing conditions commonly used in Canada, the relative contribution of *pre-mortem* factors seems to be limited to carcass and colour traits, while meat tenderness is highly influenced by *post-mortem* factors.**

*Keywords*— **colour, tenderness, variance**

## I. INTRODUCTION

Numerous factors have been shown to influence economically important beef quality traits [1]. Traditionally, meat research focuses on the most important production and processing factors. However, studies usually include 1 to 3 effects, limiting the interpretation and comparison of the results and our understanding of the relative importance of each factor and their interactive effects. Knowledge of the quantitative significance of each factor is important to assess their economic value, as well as to choose the correct selection traits to improve the profitability and quality of animal products and to develop efficient integrated management strategies [2].

Traditional analyses used to evaluate the significance of fixed and random factors present limitations for use with complex models in which numerous factors are included. Moreover, the information generated indicates if the differences among groups are significant, but it does not clarify which factor/s had a larger influence on the studied traits. The approach used in the present study evaluates the relative importance of the individual factors and their interactions as parts of a complete model in which some of the most important factors of variation in the Canadian beef cattle industry have been included.

## II. MATERIAL AND METHODS

In order to evaluate the relative contribution *of pre-mortem* factors, 112 steers (4 breed-crosses: >75% Continental, 50-75% Continental, 50-75% British, >75% British) were arranged in a 2×2×2 factorial experimental including production system (12-13 months, calf-fed vs. 18-20 months, yearling-fed), implant (not implanted vs. implanted with 200 mg progesterone and 20 mg estradiol benzoate at weaning followed 120 mg of trenbolone acetate and 24 mg estradiol 83 days after first implantation) and β-adrenergic agonist (no ractopamine vs. 200 mg ractopamine/head/day for 28 days). Steers were slaughtered at a constant back fat thickness of 8 to 9 mm determined by ultrasound. For all the animals, half carcasses were suspended by the Achilles tendon or the aitch bone (pelvic bone suspension) and meat was aged for 2/6/13/21/27 days, including the suspension and ageing time as *post-mortem* effects.

At 24 h after slaughter, carcass sides were knife-ribbed and the Canada grade and fat class, estimated yield and marbling were assessed by a certified grader. The *longissimus* muscles were then removed for meat quality analyses. Sarcomere length and drip loss were measured as described by Girard [3]. The rest of the *longissimus* muscle was fabricated into steaks in order to analyze beef colour and instrumental texture at 2/6/13/21/27 days after slaughter and proximate analysis and sensory tenderness at days 2 and 27, using the methodology described by Juárez et al. [4].

Statistical analyses for carcass traits were developed using the MIXED model Covtest procedure of SAS, including the individual *ante-* and *post-mortem* factors and their interactions. For meat quality traits, the degree of fatness, nested within treatments, was used as a covariate. The adjusted multiple $R^2$ was calculated [5]. Individual factors were then removed from the model and the decrease in the $R^2$ value was used to calculate the relative contribution of that given factor on the variability observed for each measured trait. Only interactions that explained >5% of the variability for any of the variables were included in the tables.

## III. RESULTS AND DISCUSSION

The factors included in the model explained more than 80% of the variation in most carcass traits (Table 1). Within those factors, the breed-cross and the production system were responsible for ~60% of the variability in fat class. The breed-cross (47.5%) was also the main factor affecting the estimated yield value. The use of implants or β-adrenergic agonists had limited impact on these traits. The differences in carcass traits among breeds and production systems is well known [6]. However, the implant strategy (12.5%) and, especially, the suspension method (40.2%) were the greatest contributors to the variation in marbling scores. The effect of implant strategies on marbling scores has been discussed by several authors [7]. On the other hand, only few studies have reported lower amount of visible marbling in pelvic-suspended carcasses, which may be explained by the stretching of muscle fibres on the adipose tissue, resulting in less-obvious visible marbling [8].

The variability in sarcomere length explained by the model (76%) was mainly due (91.1%) to differences between suspension methods. This factor was also responsible for 44.3% of the variability in drip loss. Moreover, drip loss was also highly affected by the production system (15.3%) and β-adrenergic agonist strategy (19.5%). Pelvic suspension has been shown to increase dramatically the sarcomere length in muscles such as *longissimus lumborum* and *semimembranosus*, [9]. According to previous studies, stretching also results in a decrease in drip loss values in beef [10].

Table 1. Full model adjustment ($R^2$) and relative contribution (% within model) of individual factors to the final variation in carcass traits

| | Fat Class | Est. Yield | Marble | Sarcomere | Drip loss |
|---|---|---|---|---|---|
| $R^2$ | 0.83 | 0.80 | 0.84 | 0.76 | 0.58 |
| PS | 25.9 | 8.53 | 4.70 | 4.91 | 15.3 |
| IMP | - | - | 12.5 | - | - |
| BAG | - | - | - | - | 19.5 |
| BC | 33.3 | 47.5 | 5.21 | 2.85 | - |
| SUS | 3.39 | 9.22 | 40.2 | 91.1 | 44.3 |
| S×BC | 3.55 | 6.75 | 1.37 | - | 4.35 |
| IMP×BC | - | - | 11.0 | - | - |
| BAG×BC | 7.23 | 4.29 | - | - | 3.03 |
| Individual | 25.6 | 21.9 | 22.8 | 0.52 | 8.52 |

*PS: production system; IMP: implant; BAG: β-adrenergic agonist; BC: breed-cross; SUS: suspension*

Ageing time had a large influence on metmyoglobin (35.8%) and oxymyoglobin (36.3%) content in beef (Table 2). Metmyoglobin content was also affected by the production system (8.8%), the breed-cross (6.84%) and their interaction (12.5%). The content of myoglobin (28.6%) and the *L** (24.3%), chroma (26.0%) and hue (46.7%) values were mainly affected by the different production systems used for finishing the steers. Metmyoglobin content increases and oxymyoglobin content decreases with ageing time [11] resulting in beef discolouration. Metmyoglobin content also increases with age at slaughter, resulting in darker meat [12]. In this experiment, the production system was a combination of dietary treatment and age at slaughter, with a difference ~7 months between groups. As well, Continental breeds have been reported to have greater myoglobin concentration than British breeds [13]. The implant strategies had a relatively important contribution (9.6%) only for the variability in *L**, while the β-adrenergic agonist or the carcass suspension had a very limited impact on beef colour traits. On the other hand, the individual animal variation for colour traits, due to differences among individuals within the experimental treatments, was relatively large compared to most of the factor included in the model. These results suggest a potentially high influence of the genotype on beef colour, as reported in some recent studies [14].

Table 2. Relative contribution (% within model) of individual factors to the final variation in beef colour

| | MMB | MB | OMB | *L** | Chroma | Hue |
|---|---|---|---|---|---|---|
| $R^2$ | 0.89 | 0.57 | 0.78 | 0.56 | 0.56 | 0.72 |
| PS | 8.82 | 28.6 | 0.13 | 24.3 | 26.0 | 46.7 |
| IMP | 0.11 | 3.33 | 0.54 | 9.56 | - | 2.92 |
| BAG | - | - | 1.04 | - | - | - |
| BC | 6.84 | 1.81 | - | - | - | - |
| SUS | - | - | - | - | - | 0.96 |
| DAY | 35.8 | 2.76 | 36.3 | - | 2.19 | 6.68 |
| PS×BC | 12.5 | - | 5.34 | 1.00 | 6.02 | 5.74 |
| PS×DAY | 0.66 | - | - | 6.23 | - | 1.59 |
| BAG×BC | 0.90 | 6.67 | - | 0.66 | 4.65 | 0.36 |
| PS×BAG×DAY | - | 8.06 | 2.67 | 12.6 | 10.8 | - |
| Individual | 26.5 | 36.4 | 43.7 | 35.8 | 36.1 | 20.5 |

*MMB: metmyoglobin; MB: myoglobin; OMB: oxymyoglobin; PS: production system; IMP: implant; BAG: β-adrenergic agonist; BC: breed-cross; SUS: suspension; DAY: ageing time*

The implant strategy, ageing time and the breed-cross were the main factors affecting beef composition (Table 3). Thus, 36.6% of the variability explained by the model for fat content (84%) was due to differences among breed-crosses, while 12.9% was related to the implant strategy. Beef cattle breeds present different growth rates, resulting in different maturity levels and, therefore, different fat tissue development at similar ages [15]. Moreover, the impact of implants on fat content has been widely discussed [7]. Although intramuscular fat content has also been reported to increase with slaughter age and can be manipulated by dietary treatments [8], in the present study the production system accounted for <1% of its variability. The loss in moisture over time is likely responsible for the effect of ageing on meat composition.

The suspension method and ageing time, as well as their interaction, explained ~70% of the variability explained by the model in instrumental (76%) and sensory (66%) texture traits. Ultimate meat tenderness is highly dependent on the degree of alteration and weakening of myofibrillar structures, resulting in an increase in tenderness in aged compared to unaged meat [16]. Therefore, as indicated by our results, the greatest variation in shear force values is due to the *post-mortem* changes occurring during ageing. Moreover, several authors have reported changes in both instrumental and sensory texture of beef from pelvic suspended compared to Achilles-suspended carcasses [8, 17, 18]. In fact, pelvic suspension reduces the need for longer ageing periods and significantly reduces the variation in tenderness [8], explaining the large effect of carcass suspension and its interaction with ageing time.

Table 3. Relative contribution (% within model) of individual factors to the final variation in beef composition and tenderness

| | Moisture | Fat | Protein | Shear | Tenderness |
|---|---|---|---|---|---|
| $R^2$ | 0.81 | 0.84 | 0.48 | 0.76 | 0.66 |
| PS | - | 0.52 | - | - | - |
| IMP | 11.8 | 12.9 | 4.72 | 1.41 | 1.76 |
| BAG | - | 0.05 | - | 0.69 | - |
| BC | 16.9 | 36.6 | 52.5 | - | 2.37 |
| SUS | - | - | - | 9.90 | 28.1 |
| DAY | 13.6 | 2.07 | 3.64 | 55.8 | 11.7 |
| PS×DAY | 1.17 | - | 6.12 | 4.66 | - |
| SUS×DAY | 2.60 | 0.84 | 2.43 | 5.08 | 26.1 |
| IMP×DAY | 16.4 | 8.73 | - | 0.68 | - |
| Individual | 21.4 | 23.1 | 11.8 | 5.09 | 0.78 |

*PS: production system; IMP: implant; BAG: β-adrenergic agonist; BC: breed-cross; SUS: suspension; DAY: ageing time*

Implant strategies have been reported to decrease tenderness in beef [7]. According to previous studies, tenderness can be also affected by breed, age and production system [19]. In the present study, although some *pre-mortem* factors had an effect on beef texture, the total contribution of all of them was minimal compared to the effect of *post-mortem* factors. In this context, the individual animal variation was relatively small compared to other factors. In fact, the genetic variance in shear force for the type of breeds included in the present study has been reported to be ~8% [20]. These results confirm that an appropriate *post-mortem* handling of the carcasses is more effective on controlling beef tenderness than any *pre-mortem* strategy.

## **IV.** CONCLUSIONS

While *pre-mortem* factors had a large influence on most carcass traits, except marbling scores, their effect on meat quality is more limited. The breed-cross, production system or implant strategy, along with ageing time, need to be considered when trying to manipulate beef colour or composition. However, within the production and processing conditions used in the present study, carcass suspension and ageing time are the main factors affecting beef tenderness.

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