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# Distribution of Marbling Throughout the *M. Longissimus Thoracis et Lumborum* of Beef Carcasses Using an Instrument-Grading System

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**Abstract:** Beef Loin, Strip Loins (IMPS #180; *n* = 20) with marbling scores between Modest$^{00}$ and Modest$^{30}$ at the 12th and 13th rib interface of the *M. longissimus thoracis et lumborum* (LL) were collected. Each strip loin was fabricated into 6 samples taken perpendicular to the long axis of the LL from the 13th thoracic vertebra to the fifth lumbar vertebra with the cut made on the anterior side of the respective vertebra. A Computer Vision System Cold Camera measured the LL cross-section of each sample location for USDA marbling score, marbling distribution, average marbling fleck size, LL area, LL length (distance medial to lateral), and LL width (distance dorsal to ventral). In the present study, mean LL marbling score decreased ($P < 0.05$) from the second lumbar vertebrae location to the fifth lumbar vertebrae location. Marbling size and marbling distance were the smallest ($P < 0.05$) in samples from the 13th thoracic vertebrae location. The LL area and width was largest ($P < 0.05$) for the samples from the most anterior location and thus decreased ($P < 0.05$) as the samples became more posterior. Samples from the most posterior end of the strip loin were the longest ($P < 0.05$) in length. It was observed that marbling score, distribution, and size, as well as, LL area, length, and width vary from anterior to posterior in the strip loin which can have potential marketing implications for food service distributors and retailers.

**Keywords:** beef, camera grading, marbling, *M. longissimus thoracis et lumborum*, strip loin
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## Introduction

The role of marbling in the eating experience of beef is well established. Earlier research has shown that differences in marbling can explain between 24 and 34% of the variation in sensory panel ratings for juiciness, tenderness, flavor, and overall palatability (Smith et al., 1985). Emerson et al. (2013) reported that increasing degree of marbling resulted in greater juiciness, tenderness, meaty/brothy flavor, and buttery/beef fat flavor. Emerson et al. (2013) also demonstrated that marbling accounts for 40 and 23% of the variation in tenderness as evaluated by Warner-Bratzler shear force analysis and trained sensory panels, respectively.

Numerous branded beef programs have developed their product specifications to include stringent marbling requirements in an effort to ensure their customers have an enjoyable eating experience. For a beef carcass to qualify for a United States Department of Agriculture (USDA) grade or certified USDA beef program, based on marbling, at least 1 side must have the minimum suggested marbling for that respective grade or certification. Visual evaluation of the amount and distribution of intramuscular fat (marbling) located in the cut surface at the 12th to 13th rib Longissimus muscle (LL) interface provides the means for determining marbling scores ranging from the highest amount, Abundant, to the lowest amount, Practically Devoid based on the current USDA grading standards (USDA, 2017). The 12th to 13th rib interface is the point where marbling score

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is determined, however, previous research has shown that the amount of marbling throughout a carcass can vary depending on specific anatomical location (Doty and Pierce, 1961; Lawrie, 1961; Blumer et al., 1962). The variation of marbling is of greatest concern in the high-value steak cuts from the beef rib and loin (Smith et al., 1987; Smith et al., 2008) where more precise measures of eating quality potential could improve the merchandising value of those items. Within these primals, marbling variation can lead to potential problems with eating consistency (Smith et al., 1987; Platter et al., 2005; Smith et al., 2008), especially if the marbling score at one anatomical location is significantly lower than the marbling score at the 12th–13th rib interface. Furthermore, dimension of steaks can play a role in merchandising and consumer acceptability (Dunn et al., 2000; Sweeter et al., 2005; Bass et al., 2009). In order for beef purveyors to ensure they are providing a high–quality and consistent eating experience, it is important to understand how marbling score and other quality attributes can vary based on anatomical location. There are no contemporary objective empirical data to precisely describe the potential variation of marbling in high-value beef subprimals which may influence the eating experience or possibly allow for alternative merchandising strategies of those subprimals. The objectives of this experiment were to determine, using a USDA approved camera grading system, how marbling score, texture, and distribution, as well as, loin eye area, length, and width vary in strip loin samples from different anatomical locations.

## Materials and Methods

Meat samples were obtained from a federally inspected beef processing facility; therefore, Institutional Animal Care and Use Committee approval was unnecessary.

### *Carcass selection*

Beef carcasses ($n$ = 20) were selected from a commercial packing plant in northern Colorado. A USDA-approved on-line instrument grading system (VGB2000, E+V Technology, Oranienburg, Germany) was used to identify carcasses for the project. Each carcass was selected based on a specific marbling score requirement. The marbling score (USDA, 2017) for the side of the respective carcass from which the highest degree was achieved had to be between Modest$^{00}$ and Modest$^{30}$. Additional specifications for each carcass included: 64.5- to 103.2-cm$^2$ LL area, A-maturity, less than 454 kg hot carcass weight, less than 2.54-cm fat thickness, superior muscling; practically free of capillary ruptures, no dark cutters, and no neck hump (*M. rhomboideus*) exceeding 5.08 cm (USDA, 2018). The narrow parameters for selecting carcass sides for this study were in alignment with several commercially available government certified programs and were believed to help control for additional variation that may otherwise contribute to Type-II error critical for assessing marbling and dimension of the resulting cuts from those carcass sides.

After identification, carcasses were fabricated to obtain the Beef Loin, Strip Loin (NAMP #180) from each side selected. A total of 20 strip loins were collected from the carcasses identified. After fabrication, subprimals were placed into combo bins and transported under refrigeration (0 to 2°C) to the Colorado State University (CSU) Meat Laboratory. Upon arrival, subprimals were stored in the absence of light at 0 to 2°C for 3 d (5 d postmortem).

At 5 d postmortem, six locations from each strip loin were evaluated by making cuts perpendicular to the long axis of the LL from the 13th thoracic vertebra to the fifth lumbar vertebra at the anatomical location marking the anterior side of each respective vertebra. Samples for each side were numbered one through six, starting with the most anterior sample. Following a minimum bloom period of 20 min, the exposed LL for each sample was assessed using the Computer Vision System cold camera (CVS; Research Management Systems, USA, Inc., Fort Collins, CO). The CVS cold camera, which uses proprietary software to measure data for assessment of carcasses being graded, captured the following measurements: USDA marbling score, marbling distance (mean distance between each piece of intramuscular fat appearing on the cut surface of each sample), marbling size (mean area of each piece of intramuscular fat appearing on the cut surface of each sample; mm$^2$), LL area (cm$^2$), LL length (cm; measured medial to lateral at the maximum length of the cut surface); LL width (cm; measured dorsal to ventral at the maximum width of the cut surface).

### *Statistical methods*

Individual strip loin subprimal was the experimental unit ($n$ = 20). Treatment data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). All comparisons were tested using a comparison-wise significance level of $\alpha = 0.05$. The repeated measures ANOVA model included the fixed effect of side and the random effects of location nested within side. Denominator degrees of freedom were calculated using the Kenward-Roger approximation.

**Table 1.** Least squares means ± SEM of *M. longissimus thoracis et lumborum* (LL) characteristics of six samples from the beef strip loin

| | Location[1] | | | | | |
|---|---|---|---|---|---|---|
| Item | 1 | 2 | 3 | 4 | 5 | 6 |
| USDA marbling score[2] | 565 ± 10$^{a}$ | 534 ± 10$^{b}$ | 551 ± 10$^{ab}$ | 545 ± 10$^{ab}$ | 545 ± 10$^{ab}$ | 504 ± 10$^{c}$ |
| Marbling distance[3], mm | 8.49 ± 0.18$^{b}$ | 8.02 ± 0.18$^{b}$ | 7.69 ± 0.18$^{d}$ | 7.97 ± 0.18$^{cd}$ | 8.28 ± 0.18$^{bc}$ | 9.39 ± 0.18$^{a}$ |
| Marbling size[4], mm$^2$ | 1.91 ± 0.09$^{c}$ | 2.02 ± 0.09$^{bc}$ | 2.10 ± 0.09$^{abc}$ | 2.25 ± 0.09$^{ab}$ | 2.35 ± 0.09$^{a}$ | 2.10 ± 0.09$^{abc}$ |
| LL surface area, cm$^2$ | 101.3 ± 2.2$^{a}$ | 87.0 ± 2.2$^{bc}$ | 87.4 ± 2.2$^{b}$ | 81.3 ± 2.2$^{c}$ | 83.3 ± 2.2$^{bc}$ | 83.7 ± 2.2$^{bc}$ |
| LL surface length[5], cm | 15.7 ± 0.2$^{c}$ | 15.0 ± 0.2$^{d}$ | 14.5 ± 0.2$^{d}$ | 15.0 ± 0.2$^{c}$ | 16.5 ± 0.2$^{b}$ | 17.4 ± 0.2$^{a}$ |
| LL surface width[6], cm | 8.6 ± 0.2$^{a}$ | 8.3 ± 0.2$^{ab}$ | 8.0 ± 0.2$^{b}$ | 7.4 ± 0.2$^{c}$ | 6.9 ± 0.2$^{c}$ | 6.9 ± 0.2$^{c}$ |

[a–d]Within a row, means without a common superscript letter differ ($P < 0.05$).

[1]Six samples from each strip loin were taken perpendicular to the long axis of the *Longissimus lumborum* from the 13th thoracic vertebra to the 5th lumbar vertebra at the anatomical location of the mid-point of each vertebra. Samples locations were numbered 1 through 6. Sample 1 is the most anterior piece.

[2]500 = Modest$^{00}$.

[3]Marbling distance is defined as the mean distance between each piece of intramuscular fat appearing on the cut surface of each sample.

[4]Marbling size is defined as the mean area of each piece of intramuscular fat appearing on the cut surface of each sample.

[5]Longismus length was measured as the maximum length of the cut surface in the medial to lateral direction.

[6]Longissimus width was measured at the maximum width of the cut surface measured in the dorsal to ventral direction.

Continuous data were analyzed using the REG and CORR procedures of SAS. Data significance was assessed at a level of $\alpha = 0.05$.

## Results and Discussion

Data characterizing the 6 samples from the beef strip loin are presented in Table 1. In the present study, the samples from the 13th thoracic vertebrae (location 1) and second lumbar vertebrae (location three) had the highest ($P < 0.05$) mean marbling scores. Samples from the fifth lumbar vertebrae (location six) had the lowest ($P < 0.05$) mean marbling score. Mean marbling score declined by 61 degrees from anterior (location 1) to posterior (location 6). Similarly, previous studies have shown that marbling score varies within the rib and loin depending on anatomical location; however, a consistent pattern has not been determined (Doty and Pierce, 1961; Lawrie, 1961; Blumer et al., 1962; Cook et al., 1964; Cross et al., 1975; Faucitano et al., 2004). Within the ninth to 11th rib region, Blumer et al. (1962) reported that marbling varied from 2/3 to 2 2/3 of a USDA marbling score. In contrast to the present study, Cook et al. (1964) evaluated the marbling score of samples taken from the 13th thoracic vertebra to the 5th lumbar vertebra and determined that marbling score was similar for each anatomical position with the exception of the sample from the 1st lumbar vertebra, of which had a lower marbling score. It is commonly accepted that an animal tends to deposit fat from anterior to posterior. However, it has not been previously documented how marbling score varies within the strip loin using a USDA-approved camera-grading system. Previous studies utilized human grading that would allow for more subjectivity and possibly more variation (Ockerman and Cahill, 1969; Moore et al., 2010) which may have resulted in the Cook et al. (1964) study failing to find differences between several of the different anatomical locations. With the results from this study and previous studies it is clear that marbling score does vary with anatomical location of the LL but the degree to this variation is not consistent between studies. Although carcasses were originally selected to determine how marbling score varied within the range of Modest$^{00}$ to Modest$^{30}$ to limit the variation of the marbling within the subprimals, the additional day of aging and chilling between selection and fabrication, as well as the use of 2 different cameras, led to an average marbling score of Modest$^{65}$ for the first location when evaluated in the meat laboratory environment (Table 1). It is known that as carcass chill time increases, the susceptibility for fat deposits to solidify increases thereby allowing for a greater amount of marbling to be observed (Johnson et al., 1985). Furthermore, some level of variation is allowed within camera grading systems (USDA, 2006) and therefore can possibly explain some of the variation observed in the current study.

Similar to marbling score, the texture of marbling can also vary depending on the anatomical location of the sample (Cross et al., 1975). Texture of marbling is defined as the actual size or coarseness of the intramuscular fat deposit (Cross et al., 1975). Several premium beef programs utilize marbling texture specifications (USDA, 2018) as a perceived quality measure. Moody et al. (1970) determined that a group of beef rib primals with finely textured marbling were classified by the Warner-Bratzler shear force method as more tender than the group of beef ribs with coarsely textured marbling. More recent research indicated a greater beef intensity and juiciness from beef strip loin steaks with coarser marbling (Vierck et al., 2018). In the present study, the texture of marbling was reported as marbling size ($mm^2$) as reported by the CVS cold camera (Table 1). The mean marbling size was greatest ($P < 0.05$) in samples from the third and fourth lumbar vertebrae (locations 4 and 5) and least ($P < 0.05$) in the samples from the 13th thoracic vertebrae (location 1). Cross et al. (1975) observed that samples with lower marbling scores had finer textured marbling while samples in the higher marbling groups such as "moderately abundant" or "abundant" had coarser textured marbling. In the present study there was no clear relationship between marbling size (texture) and marbling score. Although there was a significant correlation of pooled individual location for marbling score and marbling size ($P < 0.001$), however, the simple correlation coefficient of $r = 0.19$ is rather weak (Fig. 1). In addition to marbling amount, the CVS cold camera measures the size and distribution of each individual piece of marbling and is capable of reporting an average marbling size (Mafi et al., 2014). The authors postulate that extremely large pieces of marbling could have increased the average marbling size of samples measured, as was observed in the pooled data reported in Table 2, to a degree that is unrepresentative of the entire respective sample. This could explain the lack of a stronger relationship between marbling size and marbling score.

In addition to marbling score and size, the CVS camera quantified marbling distribution in terms of distance (millimeters). Marbling distance was reported as an average measurement of distance, measured by the camera system, between each fleck of marbling within a sample (Table 1). A lower numerical value for marbling distance

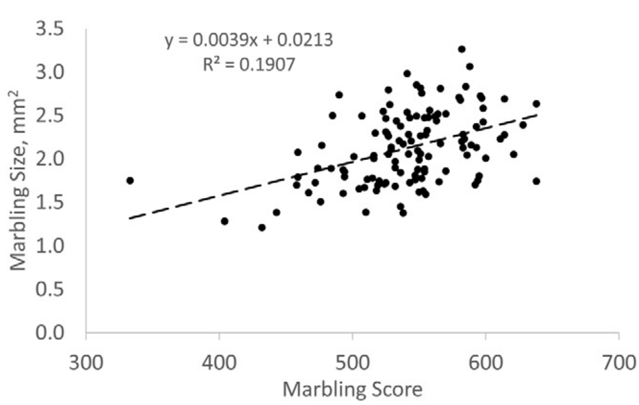


**Figure 1.** Relationship of *M. Longissimus thoracis et lumborum* marbling score, pooled locations, and concomitant strip loin anatomical location average marbling size ($mm^2$; $P < 0.001$).

**Table 2.** Correlation coefficients of digital vision system image parameters of the *M. Longissimus thoracis et lumborum* from the beef strip loin subprimal, pooled data

| Variable | Marbling score | Average marbling size |
|---|---|---|
| Marbling Score | | |
| Average Marbling Size | 0.43* | |
| *Longissimus* muscle area | 0.31* | -0.04 |

*$P < 0.01$.

indicates a smaller distance between each individual piece of marbling within a sample. Marbling distance was lowest ($P < 0.05$) for the samples from the second lumbar vertebra (location 3) and was greatest ($P < 0.05$) for the samples from the 5th lumbar vertebra (location 6). Marbling distribution was the most uniform in samples taken from the middle of the strip loin and marbling distribution became more variable in samples from the ends of the strip loin. Similar to the present study, Cook et al. (1964) noted that marbling uniformity decreased toward the muscle extremities; however, in reality, the 13th vertebra (location 1) is rather a mid-point of the full LL, yet an extremity of the thoracic portion of that muscle. In contrast, Cook et al. (1964) reported that samples from the 10th to 13th thoracic region exhibited the most uniformly distributed marbling pattern. Breidenstein et al. (1968) noted that marbling distribution score increased as marbling score increased which indicated a more uniform distribution of marbling in samples with a higher marbling score. In the current study, as marbling score increased from the sixth to third sample locations (5th to second lumbar vertebrae, respectively), marbling distance became smaller indicating a more uniform marbling distribution in samples with a higher marbling score.

Table 1 contains the means for LL steak sample surface area, length, and width for samples from each anatomical position. Muscle area and width was largest ($P < 0.05$) for the samples from the most anterior position and decreased ($P < 0.05$) as the samples became more posterior suggesting a slight conical dimensionality of the muscle. Samples from the most posterior location of the strip loin were the longest ($P < 0.05$) and had a significantly smaller area than the more anterior locations. These measurements help depict how the overall shape of samples from a strip loin change moving from anterior to posterior considering the length of the strip loin steak and surface area continued to decrease, suggesting a smaller steak dimension. Samples from the most anterior location are more circular in shape while samples from the posterior positions are more oblong or rectangular in shape. Steaks from the more posterior region would thereby need to be cut thicker to obtain the same portion weight as steaks from the anterior section. The shape of a steak from the strip loin, in addition to the amount and distribution of marbling within the LL of the strip loin, can have marketing implications for a foodservice distributor or retail meat merchandiser. Bass et al. (2009) identified that LL area between 89.7 and 102.6 $cm^2$ to have a predicted probability of acceptance of 0.80 among surveyed professional culinarians; the current research observed smaller LL areas than the Bass et al. (2009) study from location 2 through 5. Dunn et al. (2000), however, observed surface area of steaks between 77 and 97 to be ideal for cooking time and tenderness in a foodservice setting. Leick et al. (2011) observed that thickness of steak was the greatest trait of importance, of those evaluated, to consumers when selecting LL steaks. Sweeter et al. (2005) found no preferences among steaks from different LL areas but rather suggest that a retail consumer exists for the wide range of LL areas observed in the beef industry.

## Conclusions

Marbling score, size, and distribution, as well as LL area, width, and length, varies from the anterior to the posterior end of beef loin, strip loin. For branded beef programs that have developed product specifications to include marbling score and LL sizing parameters it is important to understand these variations in the product for optimizing the merchandising potential of the individual locations of the muscle for specific consumers. Areas of the beef subprimals that consistently excel in eating quality indicators, such as the more anterior end of the beef strip loin as determined by the current research, could be more precisely targeted for higher premiums when merchandised. Increased knowledge of these variations can help ensure that foodservice and retail operators and distributors can market and provide the product necessary to guarantee an enjoyable eating experience for their customers. Considering the varied understanding of previous research with what is recommended as "ideal" LL area sizes for retail and foodservice consumers, this type of research can help better understand within muscle dimensional variation to fit specific cuts to consumer preferences. Further research needs to be conducted to critically evaluate, using precision instrument grading technology, the variation of marbling score, size, and distribution, as well as LL portion cut area, width, and length in the *longissimus thoracis* portion of the *M. longissimus thoracis et lumborum*, as well as other beef subprimals, to have a more complete understanding of marbling in the entire beef carcass.

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