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REVIEW: Subjective pork quality evaluation may not be indicative of instrumental pork quality measurements on a study-to-study basis

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ABSTRACT

Since adoption of National Pork Producers Council (NPPC) subjective pork quality standards almost 20 yr ago, there have been limited investigation of the correlation and relationship between subjective pork quality and instrumental measurement. The objective of this review was to investigate the correlation between subjective evaluation of color and marbling with the instrumental measurement of color and i.m. lipid composition. A database of 454 population or treatment group means from 101 peer-reviewed studies representing 30 affiliations (by corresponding author of publication) was used. This database was used to calculate summary statistics and Pearson correlation coefficients, as well as create prediction equations using simple linear regression and multiple linear regression modeling. Subjective color determined with NPPC (NPPC, 1999) color standards was weakly correlated ($r \leq |0.35|$; $P < 0.01$) with instrumental L*, a*, and b* when measured with a Minolta colorimeter. Marbling evaluated using NPPC (1999) marbling standards was moderately correlated ($r = 0.48$; $P < 0.0001$) with i.m. lipid percentage. The results of this review indicate the need for the meat science research community to acknowledge that NPPC color and marbling scores may differ significantly on a study-to-study basis when attempting to standardize with Minolta colorimeter readings and i.m. lipid percentage with various extraction procedures. In conclusion, this review focused on the correlations of subjective pork evaluation with instrumental pork measurements since the creation of the NPPC standards for subjective evaluation. This review emphasizes the need to better understand and interpret methodology when making study-to-study comparisons in regard to evaluation of pork quality.

Key words: pork, pork color, pork marbling, pork quality, subjective evaluation

INTRODUCTION

In 1999 the National Pork Producers Council (**NPPC**) adopted standards for color and marbling of pork. These standards were photographed by a group of leading meat scientists at the time (Berg, 2000) and to this day are used by the pork industry and meat scientists to determine color and marbling of pork (North American Meat Institute, 2017). The fresh cut surface of the loin is evaluated for subjective color [1 (pale pinkish gray to white) to 6 (dark purplish red); NPPC, 1999] and marbling (corresponding to 1 to 10% i.m. lipid in lean tissue; NPPC, 1999). Subjective pork quality evaluated by a trained person is typically thought to be highly correlated with instrumental evaluation of color measured with a colorimeter device, and likewise, marbling is expected to be highly correlated with extractible i.m. lipid content (Huff-Lonergan et al., 2002; Cannata et al., 2010). Previous studies (Brewer et al., 2001; Huff-Lonergan et al., 2002; Arkfeld et al., 2015) have evaluated correlations of quality parameters in pork from the same study observed by either one trained individual or a small group of trained individuals (intra-observer variation). Huff-Lonergan et al. (2002) reported $r = -0.69$ and 0.57 between subjective color and L*, and between marbling and i.m. fat, respectively. Although this study suggests subjective evaluations of color and marbling were moderately correlated with instrumental measurement, there has not been a previous review that has built a database of studies evaluating pork quality with NPPC standards and investigated the relationship of these standards with their accompanying instrumental pork quality measurements (inter-observer variation). Thus, the objective was to investigate the correlation between subjective evaluation of color and marbling with the instrumental measurement of color and i.m. lipid composition.

MATERIALS AND METHODS

Data Collection

Animal Care and Use Committee approval was not obtained for this review because no animals were used.

A total of 454 population or treatment group means from 101 peer-reviewed studies from various institutions across the world were used (Table 1). Several sorting cri-

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teria were used while building the database. All summarized data were from experiments where data were collected on the cut surface of pork loins (longissimus thoracis and lumborum). Studies had to have reported subjective evaluation of color, marbling, or both using NPPC official color and marbling standards (NPPC, 1999) or NPPC pork composition and quality assessment procedures (NPPC, 2000). Studies had to have reported instrumental color with Commission Internationale de l'Eclairage (CIE, 1978) standards using a Minolta colorimeter (Minolta Camera Co., Osaka, Japan) for instrumental L* (lightness), a* (redness), and b* (yellowness), or i.m. lipid composition measured with various methods of ether or methanol extraction. Studies reporting instrumental L* (lightness), a* (redness), and b* (yellowness) measurements using a Hunter Lab (Hunter Associates Laboratory Inc., Reston, VA) were excluded, because there were more available studies using the Minolta colorimeter than the Hunter Lab. Additionally, the NPPC (1999) specifically references Minolta colorimeter L* values to accompany color standards rather than Hunter Lab L* values. Although most researchers prefer to record data in whole numbers, some researchers have transitioned to recording data to the nearest half number to provide a more precise estimate of color, but ultimately the same scoring system is used across the meat industry and in the studies evaluated in this review. When available, additional parameters that were used in this review were firmness (measured based on the 3-point scale outlined in NPPC, 1991, or the 5-point scale outlined in NPPC, 1999), ultimate pH, moisture percentage, and drip-loss percentage (measured at 24 or 48 h).

A limitation of this database was each study varied in their experimental design and research goals. Thus, data from the studies used in this review varied in preharvest management (nutrition, genetics, age, and so on), slaughter procedures (stunning technique, time before chilling, and so on), and postmortem management (storage time, storage procedures, packaging before evaluation, and so on). Although these factors were certainly noteworthy, it is important to realize the objective of this review was to investigate the inter-observer and between-study variation present between subjective evaluation of color and marbling with the instrumental measurement of color and i.m. lipid composition, respectively. Therefore, differences caused by preharvest management, slaughter procedures, and postmortem management should have little effect on the interpretation of the data in regard to the study objectives.

Statistical Analysis

Population or treatment group means served as the experimental unit for analyses. Summary statistics for quality traits used in correlations were computed using PROC MEANS of SAS (version 9.4; SAS Institute Inc., Cary, NC). Distribution and probability for variables were plotted using PROC UNIVARIATE of SAS. Pearson correlation coefficients were calculated among all parameters using PROC CORR of SAS. Correlations were considered weak at $r < |0.35|$, moderate at $|0.36| \leq r < |0.67|$, and strong at $r \geq |0.68|$ (Taylor, 1990). Coefficients of determination (R^2) were considered weak at $R^2 < 0.12$, moderate at $0.13 \leq R^2 < 0.45$, and strong at $R^2 \geq 0.46$. Relationships between meaningful subjective evaluations and instrumental measurements were further analyzed with linear regression modeling using PROC REG of SAS. A multiple linear regression model was used with the dependent variable of NPPC color and independent variables of L*, a*, and b*. The regression coefficient, SE, probability level, and variance inflation factor were reported for the intercept and each independent variable. Simple linear regression models were used as predictions of instrumental measurements (L*, a*, b*, pH, and i.m. lipid percentage) using subjective evaluation (NPPC color, drip loss, and NPPC marbling). Equations including regression coefficients and coefficients of determination (R^2) were reported. The predictions were shown as scatter plots, which were created using PROC GPLOT of SAS.

RESULTS AND DISCUSSION

Pork in North America is typically marketed using a grid system based on cutability estimates that factor in carcass weight, instrumental measurement of fat, and instrumental measurement of muscling (Pomar and Marcoux, 2003; Johnson et al., 2004; Meyer, 2005). Given the fact that pork does not currently receive quality grades like beef, measurements of quality, such as color, marbling, and firmness, are typically not assessed for the purpose of assigning value in the commercial pork industry (North American Meat Institute, 2017). However, from a research standpoint meat scientists and the NPPC have worked together to establish industry standards for color, marbling, and firmness. The purpose of this review was to use peer-reviewed studies that have used these industry standards and investigate the amount of inter-observer and between-study variation was present.

Summary statistics are presented in Table 2 and were representative of subjective evaluation and instrumental measurements of fresh pork. Probability and distribution plots are presented in Figure 1 for the subjective evaluation of pork color and marbling, i.m. lipid percentage, and instrumental color (L*, a*, and b*).

Color

Color is used as a general indicator of pork quality, and several reviews and research studies indicate that color is a major quality characteristic affecting consumer purchase intent (Wachholz et al., 1978; Brewer and McKeith, 1999; Norman et al., 2003). Several studies (Huff-Lonergan et al., 2002; Nam et al., 2009; Boler et al., 2010; Wilson et al., 2017) have investigated the relationships between color [measured subjectively with NPPC (1999) standards