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Tenderness prediction in porcine *longissimus dorsi* muscles using instrumental measurements along with NIR hyperspectral and computer vision imagery

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ABSTRACT

Tenderness is an important attribute influencing consumer opinion about the eating quality of fresh meat. Manual assessment of tenderness requires lengthy procedures with tedious sample preparations. An objective, non-destructive, and rapid technique for assessing meat tenderness is required by the meat industry. In this study, the development of partial least squares (PLS) regression models to relate near-infrared (NIR) reflectance spectra and statistical features (mean, standard deviation, norm-1 energy, norm-2 energy, average residual, and entropy) from discrete wavelet transforms (DWT) of raw porcine *longissimus dorsi* muscle images, to slice shear force (SSF) instrumental measurements, was investigated. The coefficient of determination (R^2) of the PLS regression model was 0.63 when only spectral information from hyperspectral (HS) images was analyzed, while PLS models using DWT features extracted from computer vision (CV) images yielded coefficient of determination of 0.48. By combining them, the R^2 increased to 0.75. The study has shown the potential for NIR measurements combined with wavelet features from CV images to provide better correlations with muscle tenderness.

Industrial relevance: The study has shown the potential for NIR measurements combined with wavelet features from CV images to provide better correlations with muscle tenderness for the meat industry.

1. Introduction

Tenderness is a major attribute in determining overall meat quality and is often cited as the focal quality attribute of meat. In sensory panels, tenderness is highly correlated with overall acceptance comparing to other sensory properties such as flavour (Enfält, Lundström, Hansson, Lundeheim, & Nyström, 1997). Research is focused on the *longissimus dorsi* muscle, because there is more variation in tenderness among beef carcasses in *longissimus* than in other major muscles (Shackelford, Wheeler, & Koohmaraie, 1995, 1997). Tenderness varies greatly among meat samples due to the complex pre- and post-mortem biochemical changes such as collagen content, sarcomere length and degree of post-mortem proteolysis (Kazemi, Ngadi, & Gariépy, 2009; Koohmaraie, Kent, Shackelford, Veiseth, & Wheeler, 2002). Collagen content has little influence in animals of similar ages. Sarcomere length variation is an early post-mortem event, with shorter sarcomere lengths resulting in less tender meat. Post-mortem proteolysis degrades structural proteins in muscle during storage at refrigeration temperatures, resulting in increased tenderness (Koohmaraie, 1994). However, rate and extent of post-mortem tenderization are variable and difficult to predict. Hence, tenderness is often difficult to measure practically in fresh meat samples, making its prediction an even more challenging task. Compared to beef, pork quality attributes are affected by other factors such as interactions among the genotype and nutritional environment, combined with pre-mortem metabolism, rather than the post-mortem proteolyses (Purslow et al., 2008). Regions of loose and soft structure located within samples of normal pork can occur in some *longissimus dorsi* muscles (Laville et al., 2005; Voutila, Perero, Ruusunen, Jouppila, & Poulanne, 2009). The combination of all these factors makes sorting porcine carcasses or loins based on tenderness particularly complicated.

Large variations among subsamples on a single meat chop (Chan, Walker, & Mills, 2002) are a major drawback for the application of Warner–Bratzler shear force (WBSF) measurement. In this sense, an alternative to WBSF could be the measurement of the slice shear force (SSF). Shackelford, Wheeler, and Koohmaraie (1999a, 1999b) showed that SSF is more repeatable and strongly correlated with tenderness assessed by a trained taste panel, than WBSF. Unlike WBSF, SSF uses less subsamples per sample and the meat does not need to be cooled before testing, so that the SSF measurements can be obtained more quickly, which has benefits in commercial applications. Nevertheless, both methods require the removal of muscles from carcasses, cooking and slicing samples in standard sizes, and thus are not suited for rapid, online sorting.

Given that pork tenderness can be affected by the chemical composition of the samples, some studies have reported significant coefficients of correlation between the Warner–Bratzler shear force (WBSF) values and water (1400 and 1900 nm), as well as C–H molecular bonds (1300–

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