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PREDICTING BEEF TENDERNESS USING OPTICAL SCATTERING

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Introduction

Beef tenderness is an important beef quality attribute. In beef industry, an accurate, non-invasive, fast and economic method is favorable for beef tenderness prediction. NIR/VIS spectra analysis is one of the most promising techniques that could be possibly used to evaluate beef tenderness non-destructively.

Optical spectrum reflects both the chemical composition and the microstructure characteristic of meat. When light transports in meat, different chemical compositions absorb the light, and meanwhile, light is scattered by sample micro structural components. In general, meat microstructures such as myofibril and collagen are considered the main factors determining meat tenderness. Thus the meat scattering properties would be a better physical parameter that could reflect the tenderness of meat.

The measured NIR reflection or transmission spectra are the combined results of light absorption and scattering in meat. In order to improve the measurement sensitivity and accuracy, it is necessary to separate scattering from absorption. Birth et al. (1978) and Macdougall (1970) measured scattering coefficients of pork samples using Kubeka-Munk model. However, in their methods, the sample need to be cut into slices for layered transmission measurement, which is impractical for the on-line application. A practical and accurate method for measuring meat scattering coefficients is still desirable.

Objectives

In this study, a fiber optic scanner was built to measure the spatially resolved diffuse reflectance distribution above meat sample surface. Scattering coefficients were calculated by fitting the measured data with light diffuse equation. Our objective is to investigate the potential of using optical scattering properties for beef tenderness prediction.

Methodology

The experimental apparatus was shown in Fig.1. A 20W broadband halogen light (Ocean Optics Inc., HL-2000-FHSA-HP) was used as the light source. A fixed optical fiber with an oblique angle 56^{o} relative to the vertical direction was used to deliver incident light. A scanning optical fiber was used to collect the spatial-resolved diffuse reflectance light at different positions. The scanning optical fiber was connected to a spectrometer (Ocean Optics Inc., USB2000) to record the diffuse reflectance spectra. The acquired spectra were then processed by a personal computer. The scanning fiber was controlled by a translation stage and scanned above the sample. The sample scattering coefficients were derived using methods proposed by Wang et al., 1995.

Beef samples were acquired from the meat laboratory at the University of Missouri-Columbia. Each sample was from a different animal and had been aged for at least 14 days. Samples were stored at 2ºC –3ºC before each measurement. Warner-Bratzler Shear Force Tests were performed on the same sample after the optical measurement. Samples were then cooked on a Farberware electric broiler (Farberware Inc., Bronx, NY). During cooking, sample was turned over as the internal temperature reached 41^{o}C; then was continued to cook to the final temperature 71^{o}C. Internal temperature was monitored using a thermocouple thermometer (MODEL 8112-20, Cole-Parmer Instrument Company, Vernon Hills, Illinois). Two cores (diameter =1.27cm) were removed from each sample for shear force test. Each core was sheared for three times perpendicular to the longitudinal orientation of the muscle fiber using TA.XT2 Texture Analyzers (Texture Technologies, Corp., Scarsdale, NY) with WB shear force attachment. The crosshead speed was set at 3.3 mm/sec. The average of six peak shear values represented the WB shear force value for each sample.

Results & Discussion

In order to have the largest variance in tenderness, extreme cuts were chosen as our test samples according to the US National Beef Tenderness Survey 1991 (Morgan et al., 1991). Scattering coefficients at 721nm of six top round steaks and five tenderloin steaks were measured and shown in Fig. 2. Tenderloin steaks had smaller scattering coefficients than top round steaks except two samples. Tenderloin steaks are from middle parts and top round steaks are from end parts in an animal body. In general, top round steak is tough and tenderloin steak is tender. According to previous research, muscles at end parts, which mainly support animal movements, have lower oxidative capacity and contain thicker muscle fibers; while muscles at middle parts, which mainly involved in posture, have higher oxidative capacity and contain thinner muscle fibers (Klont, 1998; Totland and Kryvi, 1991). Thicker muscle fibers increase light scattering cross section and have higher scattering coefficients, while thinner fibers reduce light scattering cross section and have smaller scattering coefficients. Meanwhile, thicker muscle fibers need more force to chew, bite and mince them, and are tougher, while thinner muscle fibers are easier to be chewed, minced and taste tender.

However, variations existed among different animals, and the final tenderness is also affected by many factors such as slaughter handling and post-mortem processing. For the two exceptions in tenderloin, we measured their raw beef Warner-Bratzler shear force. The results showed that the two tenderloin samples with higher scattering coefficients also had higher WB shear force than the rest tenderloin samples. The WB shear forces were 26.85N and 27.15N respectively for the two higher scattering tenderloin samples, while all other tenderloin steaks had shear force smaller than 20.58N.

Scattering coefficients at 721nm wavelength of USDA Utility and USDA Select rib eye steaks were also compared in this study (Fig. 3). Scattering coefficients of three Utility steaks were larger than all Select steaks and one Utility steak had lower scattering coefficient than the Select steaks. According to USDA meat quality grade standards, Utility beef are usually from older animals, and generally are tougher than USDA Select beef. As animal gets older, the amount of connective tissues (collagen) and the degree of interconnectivity of the collagen in muscles increase and meat becomes tougher (Sinex, 1968; Fang et al., 1999). The increased amount of connective tissues and the interconnectivity of collagen also increase the light scattering cross section and result in higher scattering in meat. However, exceptions also existed among different grades because of the natural variations among different animals and post-mortem development.

The exceptional Utility sample with lower scattering coefficient also had lower WB shear force (17.44N) than the Select sample (23.52N).

A more comprehensive investigation on the correlation between scattering coefficients and beef tenderness was also conducted in this study. A total 32 samples including bottom round, top round, tenderloin, and ribeye steaks were used. The scattering coefficients at 721nm wavelength were measured. A linear correlation plot was plotted in Fig. 4. The linear regression results indicated that the shear force value of cooked beef was significantly ($P<0.05$) correlated to the reduced scattering coefficient with a coefficient of determination of 0.59. ($R^2 = 0.59$). These results indicated that the optical scattering coefficients do reflect meat mechanical properties.

Conclusions

Our preliminary results indicated that the scattering coefficients of beef are significantly ($p<0.05$) correlated with the Warner-Bratzler shear force. The tougher beef has higher scattering coefficients and the tender beef has smaller scattering coefficients.

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Tables and Figures

Figure 1.

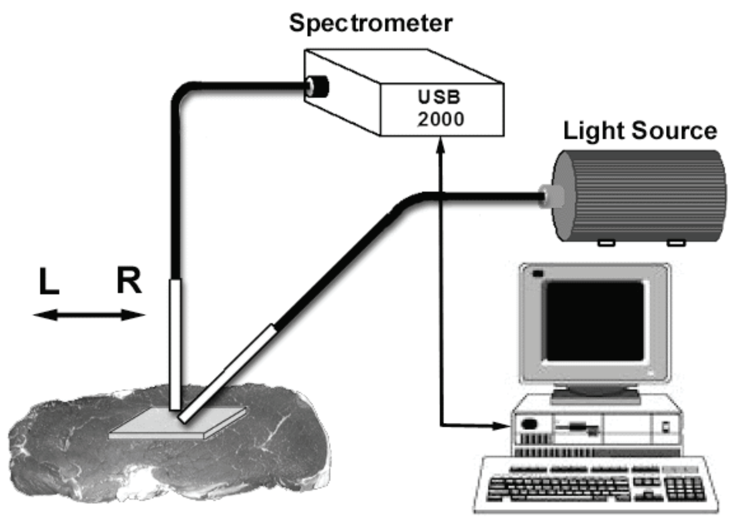

Figure 1.The schematic diagram of the experimental setup.

Figure. 2.

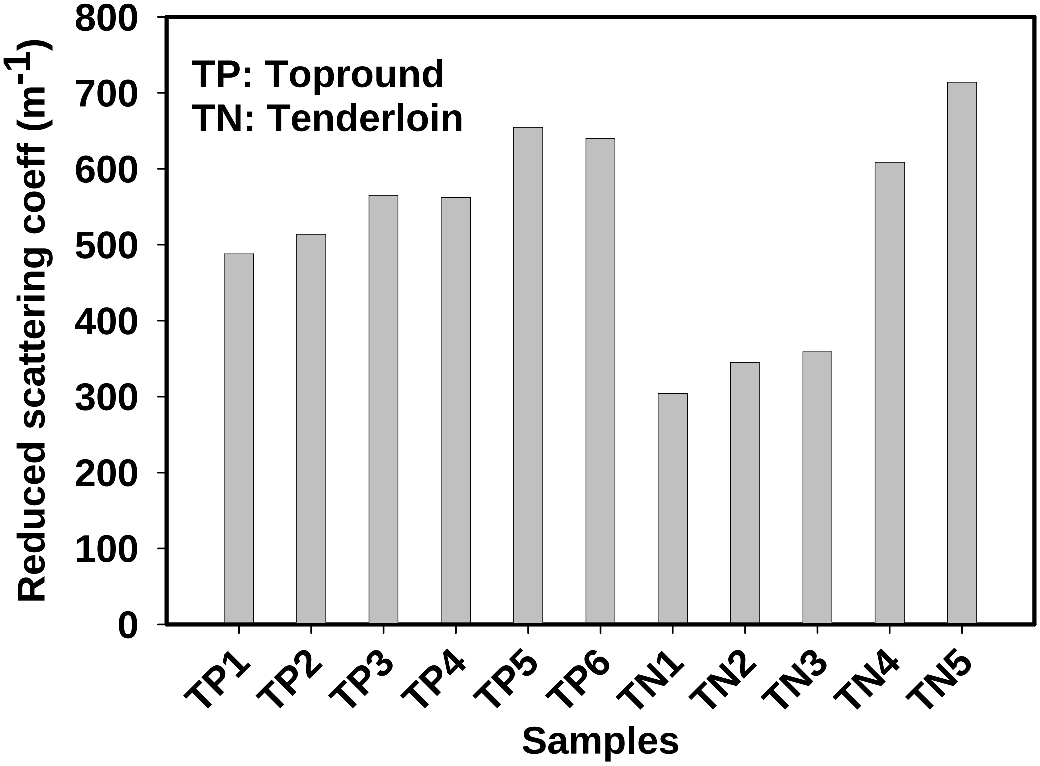

Figure 2. The reduced scattering coefficients at 721nm wavelength of tenderloin and top round steaks.

Figure. 3.

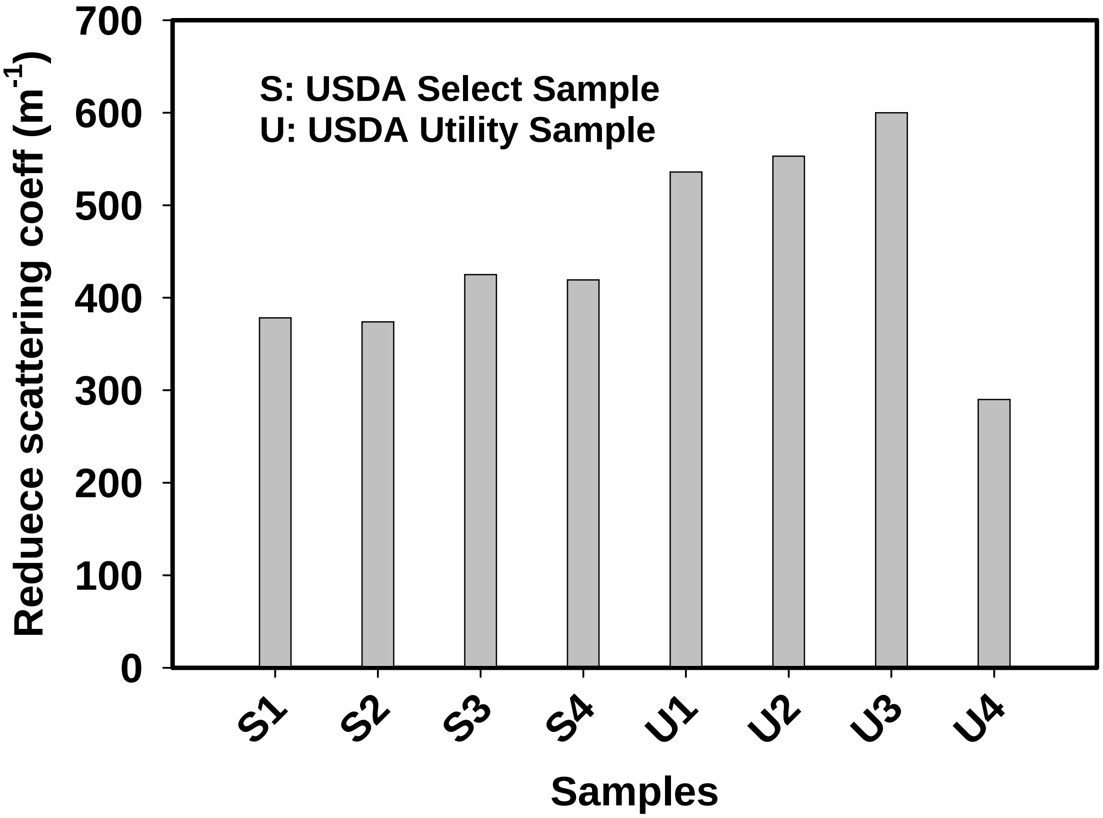

Figure 3. The reduced scattering coefficients at 721nm wavelength of USDA Utility and USDA Select steaks.

Figure 4.

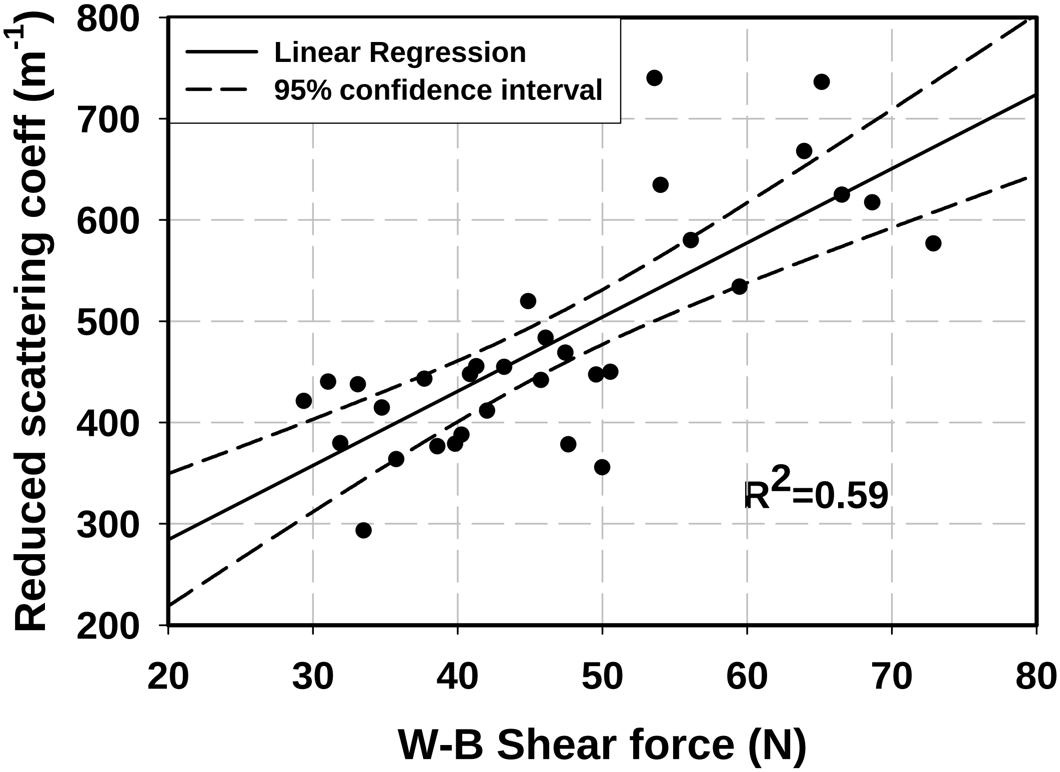

Figure 4. The correlation between WB shear forces of cooked beef and reduced scattering coefficients at 721nm.