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Angular absorption of light used for evaluation of structural damage to porcine meat caused by aging, drying and freezing

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ABSTRACT

Meat as a rich source of protein is sought after by people from all over the world. It is also very susceptible to decay because of many internal and external processes affecting it. In this work an easy and quick method of detection of structural damage caused by decay or mishandling the meat is attempted by the method of angular absorption of light. The difference between structural changes due to aging, drying and freezing is explored and the resulting changes in light absorption in meat samples are presented. This work demonstrates that the measurement of optical angular dependency of absorption in relation to the muscle fibers in muscle tissue has the potential of detecting structural damage to the sample for meat quality control purposes.

1. Introduction

Consumption of pork is widely spread and an important part of human diet. It is therefore natural that the safety and quality control of such an article is paid increasingly more attention by consumers and manufacturers alike, especially in the light of some of the recorded incidents (Trienekens & Zuurbier, 2008). The farther away the production is situated from the consumers, the more likely it is that the natural processes in the meat and the environmental influences will cause the meat to spoil (Nychas, Skandamis, Tassou, & Koutsoumanis, 2008; Huang, Zhao, Chen, & Zhang, 2014). For that reason it is important to be able to evaluate the freshness and safety of the meat before consumption.

As a part of quality control meat tenderness can be evaluated, correlating to many possible factors, like species or age of the animal. A usual method of pork tenderness evaluation is the Warner-Bratzler Shear Force, performed by texture meters or compression devices (Xiong et al., 2006). Water holding capacity, also often discussed feature of meat, has been measured by many different procedures gauging the speed of fluid loss during freezing, cooking, or aging (Tejerina, García-Torres, & Cava, 2012). This however causes damage to the sample and lately fell out of use in benefit of non-destructive methods. One of the most prominent of these is Near Infrared Spectroscopy (NIR), able to measure chemical properties and characteristics of the meat (Pedersen, Morel, Andersen, & Balling, 2003; Prevolnik, Čandek-Potokar, & Škorjanc, 2010; Fowler, Schmidt, van de Ven, Wynn, & Hopkins, 2014). A drawback to this method is the fact that NIR captures data only from a single point, which makes it less usable for the quality classification of the whole bulk muscle tissue. Another approach to the quality measurement is the fact that the internal chemical processes are often accompanied by external changes, like color, odorous releases and texture. Collection of all of this data is being used for food quality analysis as Hyperspectral Imaging (HSI) (Cluff, Naganathan, Subbiah, Samal, & Calkins, 2013; ElMasry, Sun, & Allen, 2012). An improved version, which is less demanding on the price and the amount of data absorbed making it usable for real-time application, has also emerged in the form of Multispectral Imaging (MSI) (Sun et al., 2012; Panadou, Papadopoulou, Carstensen, & Nychas, 2014). A number of variants on MSI and HSI methods are being paid more attention as well, like improving the efficiency of the MSI algorithm for near-infrared wavelengths (Huang, Li, Zhao, Huang, & Chen, 2015), or specifically for detection of total volatile basic nitrogen content as one of the indicators of pork freshness (Huang, Chen, Li, Huang, Ouyang, & Zhao, 2015). Another of the very closely monitored properties of the meat is pH, changes in which follow very closely natural decay of the tissue (Damez, Clerjon, Abouelkaram, & Lepetit, 2008). One of the more recent methods is based on measuring the meat freshness by the use of light scattering inside of the bulk meat, taking into account specific structures inside the sample, like sarcomere lengths and collagen content (Li et al., 2016). The interaction of light with the anatomical forms inside of the pork was also used as a basis of our method.

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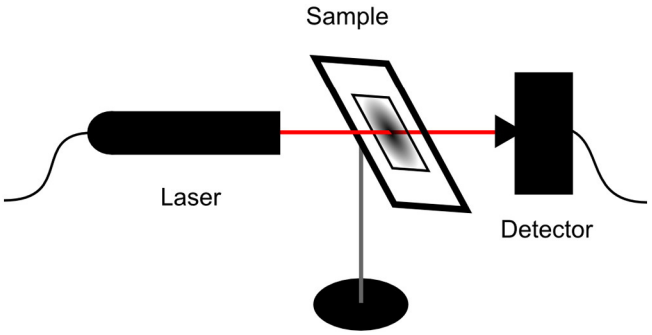

Fig. 1. The basic sketch of the acquisition system.

The main objective of this work was to create a method of measuring the internal damage done to a bulk meat sample, caused by internal processes during aging, by drying and by freezing the muscle tissue. This system focuses on values and distribution of differences of light absorption in transmission of unaltered and altered samples (aging, drying and freezing) under varying angles of illumination in relation to the muscle fiber direction in the sample. By comparing the results of the angular dependence of absorption we are able to differentiate between not only unaltered and altered sample but also the type of alteration it underwent. It provides reagent-less, technologically undemanding and fairly user friendly means of distinguishing between the causes of damage, and in conjuncture with other methods is able to detect damage to meat structure as a part of multispectral evaluation, or reveal information normally unavailable to human senses.

2. Materials and methods

2.1. Acquisition system

A simple system for light absorption measurement in transmission was created to allow rotation of the sample and detection of the light that passed through. Fig. 1 presents a basic sketch of the system, composed of three main parts: a 5 mW He-Ne laser, $\lambda = 633$ nm with a collimated beam size of 2 mm in diameter as a source of the light (this wavelength was selected because of its ability to penetrate deep through the muscle tissue (Jacques, 2013; Niemz, 2013)), a rotable sample holder aligned to the laser source with angle measure and a switchable gain detector, ranging from 350 to 1100 nm to measure the amount of light remaining after the absorption in the sample, with a voltage signal output. The distance of the source and the sample was set at 10 cm, and the distance between sample and detector was 5 cm (as close as it was possible with still allowing the sample table an unhindered rotational capacity) and the distances were kept constant during each of the measurements. The decrease of signal yield due to scattering outside of the detector was investigated and deemed below the detection threshold for the laser wavelength, power and sample thickness. The acquisition system was enclosed in a container with light absorbing paint on the inside to prevent reflected light and possible outside illumination into the system. This in combination with a reduced lighting inside of the laboratory and spot illumination for the displays prevented any detectable outside contamination of the signal.

2.2. Sample details and preparation

Thirty bulks of fresh pork were purchased on different days at a local store and were transported into the laboratory under refrigeration within 30 min. Samples of different thickness were then cut from each bulk in order to minimize the influence of sampling location, and maximize the variety of the sample sizes. While sampling, locations with least amount of inclusions, like fat or ligament, were prioritized. Purchase, cutting and first measurement were done in ten different days over the course of two months to avoid any bias in the material due to the source of the meat. All of the cutting was done manually and the samples were then sorted by their thickness with tolerance of 0.1 mm, cutting angle with tolerance of 5° and any of the samples that did not meet the tolerance or where the cut was uneven or damaging to the measured area were discarded.

The samples were split into groups one, two and three, with ten different values of thickness and each thickness numbering ten samples from ten different bulks, numbering 300 samples in total. The three main groups differed by cutting angle in relation to the muscle fibers in order to better illustrate the influence of the muscle fiber angle on the light absorption, with the cutting angle of muscle fibers being 77°, 103° and 120° respectively. As every thickness of every cutting angle was measured on 10 different samples, the resulting measured values

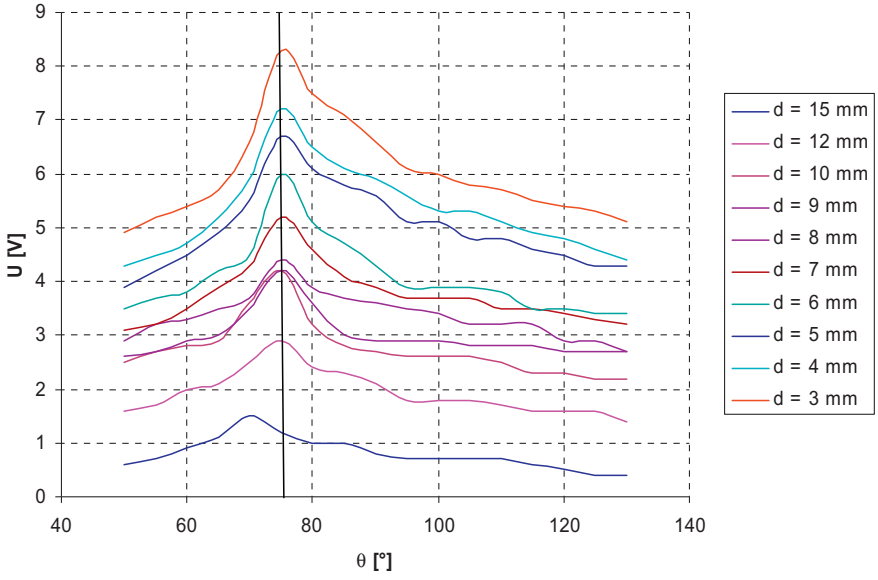

Fig. 2. Angular distribution of light transmitted through the first group of fresh samples of different thickness with marked angle of the muscle fibers. Light signal is converted into voltage on the detector. Cutting angle of 77°.