The Study of Polarization Properties of Meat

Elena Prokopyeva, Pavel Kaspar, Pavel Tománek

Brno University of Technology

mailto: xproko24@stud.feec.vutbr.cz

This work describes measurement and analysis of polarization parameters of tissue; meat samples (pork chop) of 10 mm width were used. The optical system consists of a linearly polarized laser diode (λ = 635 nm) that illuminates a sample, an analyzer and a photodetector to measure the polarization properties of the backscattered light.

1 Introduction

The study of biological tissues is a developing promising domain, primarily in optical medical technologies and food control. Biological tissues are supposed to be accidental non-homogenous and anisotropic media. Most of them are highly scattering. It comes from tissue inhomogeneities (cellular organelles, extracellular matrix, blood vessels, etc.), that cause multiple scattering which may change the direction of light propagation, phase of light and polarization. [1]

Optical methods have a great potential for many applications in biomedicine and agricultural industry because of the significant advantages: they are fast, non-toxic, non-destructive, optical apparatus can be usually portable and economical. [2]

It is important to understand the impact of anisotropic tissue structure on the optical scattering. This knowledge may help us in design, development and usage of optical methods to obtain accurate information from biological tissues.

2 Degree of polarization

State of polarization and intensity of a light beam incident on the medium is specified by the Stokes vector ***S*** in the following form:

$$\boldsymbol{S} = \begin{bmatrix} S_0 \\ S_1 \\ S_2 \\ S_3 \end{bmatrix}, \qquad (1)$$

where S_0 is a total intensity, S_1 is a polarization at 0° or 90° to the scattering plane, S_2 is a polarization at ±45° to the scattering plane, and S_3 is a left or right circular polarization.

For comparison of the polarized states of various waves, the degree of polarization DOP is used. It specifies the part of the polarized light intensity, it may refer to a linear or circular polarization. The degree of polarization can take values from zero to one, that is from a completely non-polarized radiation to a completely polarized radiation. It is defined as

$$DOP = \frac{\sqrt{S_1^2+S_2^2+S_3^2}}{S_0} = \sqrt{(DOP_L)^2 + (DOP_c)^2}\ . \qquad (2)$$

Here the degree of *linear* polarization DOP_L is defined as

$$DOP_L = \frac{\sqrt{S_1^2+S_2^2}}{S_0}. \qquad (3)$$

The degree of *circular* polarization (DOP_c,) is equal to:

$$DOP_c = \frac{S_3}{S_0}. \qquad (4)$$

3 Description of measurements

The optical system (Figure 1) consists of a linearly polarized laser diode source Thorlabs (λ = 635 nm) which illuminates the meat sample, an analyzer and a photodetector to measure the scattered light intensity and the polarization properties of the backscattered light.

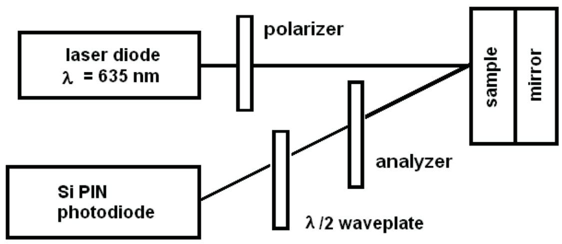

Fig. 1 *Experimental setup for the measuring of backscattered light parameters.*

Myofibers act as optical fibers passing the light more readily along, rather than across their length. The analyzer and the detector are placed at the angle 45° from the sample at the distance of 100 mm from the surface of the sample. A sample is fixed on a mirror to enhance the output signal. The analyzer (a quarter-waveplate) is attached to a rotating mount, which allows to rotate the polarization plane in the range 0 - 360°. To compensate the optical activity of the biological sample, a half-wave plate was used.

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Measurements were provided with pork chop slices of 10 mm thickness and lasted 2-3 days. Room temperature was 20-23°C during the whole period.

Figure 2 represents the results of the depolarization measurement depending on the ageing of the pork sample. Two curves correspond to a linear and circular degree of polarization. It is noticeable that with time the degradation of curves happens, back-scattered light becomes less polarized.

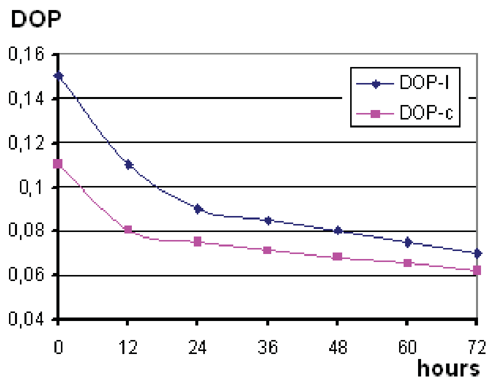

Fig. 2 *DOP dependence on meat ageing.*

For the next experiment slices were cut along or across the direction of meat fibers. Figures 3 and 4 show how polarizing and scattering properties of the sample may change with the influence of degradation. At the beginning of measurements linear polarization is dominant.

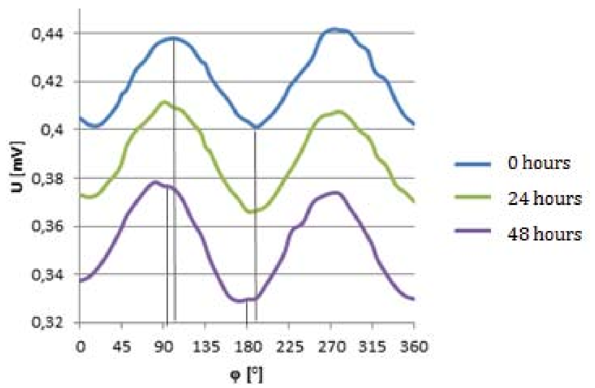

Fig. 3 *Measurements with a parallel cut.*

During the measurements when slices were cut along the fiber direction (Fig. 3), after 2 days energy values decreased, there was a polarization shift of maximums and minimums 10° to zero. Type of polarization did not change.

Figure 4 represents the results of measurement with a perpendicular cut. Here it is noticeable that after 2 days linear polarization starts to change to circular. At this stage a sample begins to dry out and it does not lead to such strong light scattering as it was in the beginning. Gradual degradation of the sample also leads to a decreasing of energy values and shifting of minimums and maximums (about 10°) from 0°. It can happen due to the change of refraction index of ageing meat and relatively rapid loss of water from it.

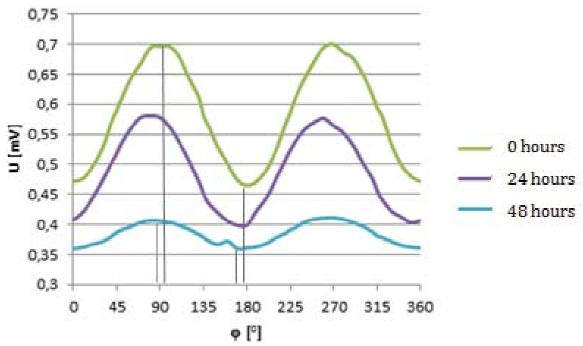

Fig. 4 *Measurements with a perpendicular cut.*

It is possible to say that optical measurements of tissues is very promising in spite of some factors necessary to respect, such as the influence of lightning, stable position of a sample, the results can also be dependent on the sample thickness. Measurements can be complicated by the loss of polarization signal due to the random multiple scattering of light in tissue.

4 Conclusion

This work presents the way of assessing meat ageing states by means of measurement of optical backscattering parameters. The results show that optical measurements have high potential to be used in the quality control of biological tissues, although they have some limitations and difficulties.

It turned out that the degree of polarization decreased with the sample ageing. Also a type of polarization may change from linear to circular. Moreover, there can occur a significant shift of polarization maximums and minimums.

Acknowledgement

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References

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