EVALUATION OF CHICKEN MEAT PHYSICAL PROPERTIES DURING FOOD PROCESSING

short running title: Chicken meat physical properties

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Food processing is designed to produce safe food and engineering calculations mainly focusing on required processing time, temperature and other technology parameters to reach desired level of safety. This treatment sometimes over process raw materials and therefore decrease sensory and nutritional value. The objective of the presented work was to monitor changes of chicken breast fillet physical properties during heating. The results are expected to help optimization of new methods such as ohmic heating. Chicken meat was acquired from retail and was processed within one day. Slices were subjected to measurement of impedance spectra, texture and near-infrared (NIR) spectra. The following instruments were used in the experiment: Hewlett-Packard LCR meter (model HP4285A) recorded impedance spectra in the range of 30 Hz – 30 MHz; Stable Micro Systems Texture Expert instrument (model TA.XT.plus) was used to measure rheological properties; MetriNIR instrument recorded reflectance in the range of 740 – 1700 nm. Heat treatment was performed using a household electric heater of 1500 W (Sencor SCP 1501 BK). Meat surface temperature was monitored with non-contact IR thermometer.

Obtained results show clear difference of physical properties during processing. Kinetics can be estimated better with more measurements but preliminary experiments already suggest nonlinear behavior.

Keywords: impedance, near-infrared, chicken fillet, cooking

Introduction

Food processing is usually investigated to meet required safety, improve product quality or save energy, materials used in technology. Thermal simulation of frying process can help in optimization of technology and save up to 10% energy (Wu et al., 2013). The quality attributes typically measured on meat are pH, drip loss, frying loss, color change, shear force, impedance (Pliquett et al., 2003). Meat cells can be simulated with two resistors (elctrolyte) and a capacitor (membrane)

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successfully. Such model could be used to follow changes in beef quality during 23 days storage and processing afterwards. Impedance readings were found to correlate significantly with other quality indices (Pliquett et al., 2003). Zhang et al. (2004) measured thermophysical properties of meat products in wide range of temperature (5-85 °C), frequency (RF, MW) and changing key ingredients. It was concluded that frequency has the major effect on dielectric properties, followed by ingredients. They also highlighted that changing ingredients, such as melting fat, may also affect interaction between meat and electric field. Pork meat dielectric properties were analyzed in 40 Hz – 4 MHz range by Castro-Giráldez et al. (2010). They introduced ageing index based on dielectric spectra. It was also observed that anisotropy decreased during post-mortem. This suggests that meat fiber structure should be considered during processing raw meat. Additionally, the study recommend frequencies of 140 Hz, 500 Hz and 300 kHz for quality assessment of meat. Ohmic heating is popular recently due to its lower energy consumption and higher effectiveness. In previous study our research group investigated heat distribution pattern in pork sausages during ohmic heating (Baranyai et al., 2017). Thermovision measurements confirmed theoretical computation results performed with COMSOL Multiphysics software. Impedance of pork meat samples was also measured during experiment and found that sausages have mainly ohmic impedance with very weak capacitive character. Engchuan and Jittanit (2013) investigated ohmic heating of meat balls. They created a model to predict electrical conductivity of food based on its recipe (starch, salt, etc. content). Literature review and preliminary research both suggest investigation of physical properties of specific product and technology due to the high number of affecting factors.

The main goal of presented work was to investigate changes in biophysical properties of chicken breast fillets during frying. The results are expected to help design ohmic heating treatment of raw chicken meat slices.

Materials and methods

Chicken breast fillets were acquired from retail store. Five regions were marked from 1 to 5 along the fillet starting at the thickest part. Slices of 8 mm thickness were cut from each region. Samples were fried using a Sencor electric heater (model SCP 1501BK) and meat slices were pressed to the pan surface with 1 kg load. A stainless steel metal plate was placed between meat and load. Slices were fried for 3 min on the first side and 2 min on the second. Measurements were performed before and after frying.

Electrical impedance measurements were carried out using precision LCR meters in the ranges of 31 Hz – 800 kHz (model HP 4284A) and 79.4 kHz – 28.2 MHz (model HP 4285A). Source was adjusted to 1 V. Parallel plane electrodes made of stainless steel (model HP 1645B1) were used during data acquisition.

Meat texture was evaluated using an SMS (Stable Micro Systems) Texture Expert instrument, model TA-XT.plus Texture Analyser. Penetration tests were performed with two probe types, a needle and a sphere of 5 mm diameter. Speed was adjusted to 0.1 mm/s during measurements until 3 mm penetration depth. Penetration work was recorded. In case of spherical probe, elasticity (E) was also calculated as ratio of unloading (W_U) and loading (W_L) works (Eq.1).

$$E=\frac{W_U}{W_L} \qquad (1)$$

The near-infrared (NIR) reflectance spectra was captured with MetriNIR spectrometer instrument (model 10-17 PR). The wavelength range of 740 – 1700 nm was used. Each set of measurement was started with calibration based on the internal standard of the instrument.

Preprocessing and statistical analysis of collected data was made with software package of R (version 3.4.1) and RStudio (1.0.153).

Results and discussion

The chicken fillets changed their surface color during processing. Color change observed by naked eye was confirmed by captured NIR spectra (Fig. 1). Fried meat obtained lower reflectance values, almost parallel to the raw one. It is in agreement in literature since primarily change in CIE L* value has been expected.

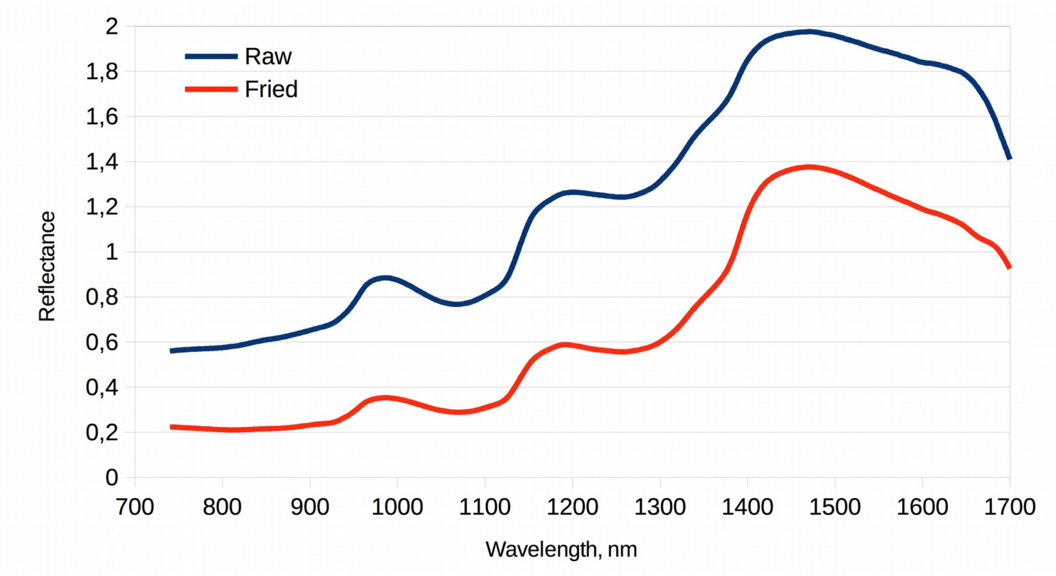

Figure 1: Average NIR spectra of raw (blue) and fried (red) chicken fillets

The standard normal variate (SNV) was calculated for both average spectra and comparison revealed that fried chicken spectra show similar change in reflectance but more rapidly in a given wavelength range (1100-1500 nm). First derivatives also show difference this region.

Figure 2: Standard normal variate of NIR spectra for raw (blue) and fried (red) samples

Impedance values are shown on Figure 3 from 39 Hz to 5.6 MHz. Before comparison of impedance spectra, they were preprocessed to correct to the same thickness of 8.2 mm and 5.87 mm for raw and fried, respectively.

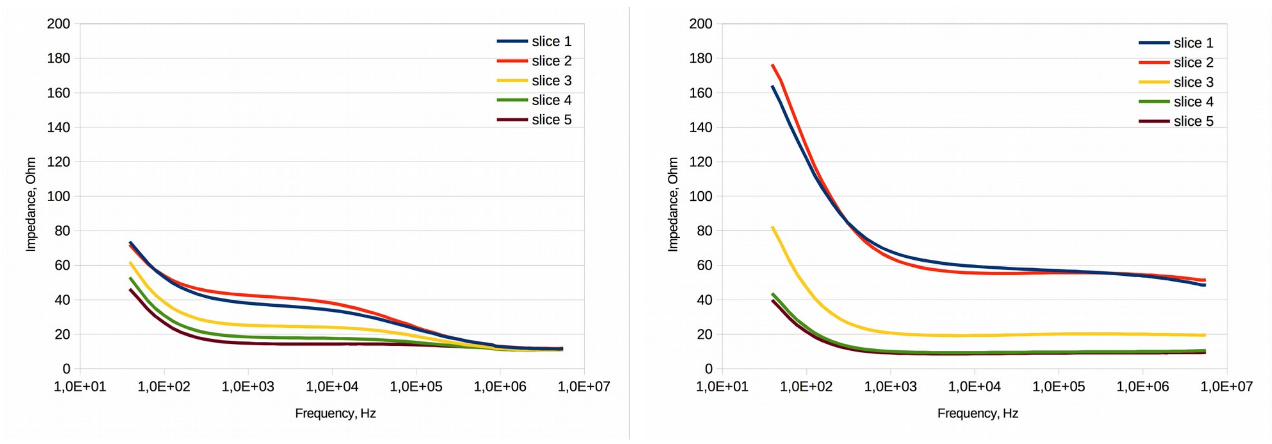

Figure 3: Impedance spectra for raw (left) and fried (right) chicken meat

The magnitude of impedance clearly changed as a result of frying. Although chicken fillet was expected to be homogeneous, slices of different position show different behavior. This is likely to be in relationship with muscle fiber structure. Similar inhomogeneity was observed for chicken breast tenderness using hyperspectral imaging technique (Jiang et al., 2018). Phase angle was also different for slices of different position in raw meat (Fig. 4). The frying process decreased differences in the range of 1 kHz – 1 MHz, but increased beyond at high frequencies. The separation of positions 1 and 2 are visible on both Fig. 3 and Fig. 4. This also suggests structural effect of chicken breast fillet.

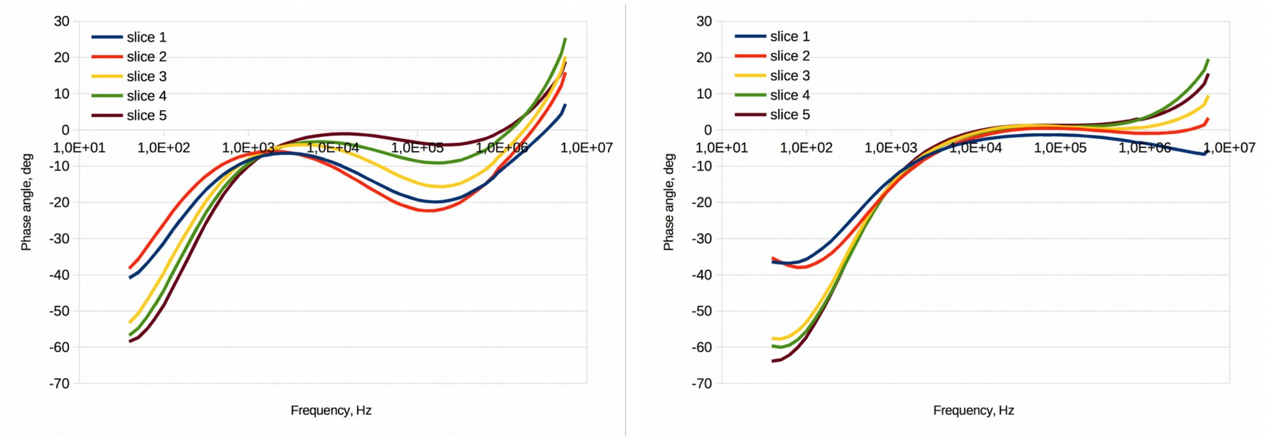

Figure 4: Phase angle spectra for raw (left) and fried (right) chicken meat

The force-deformation curves shown similar difference of positions like impedance spectra. Raw and fried chicken samples differ significantly in measured work either with sphere or needle probe. Although there is some fluctuation of data by position, this statistical effect is not significant on elasticity (Table 1). There is clear difference between raw and fried samples ($F=130.523$, $p<0.001$).

Table 1: Analysis of variances (ANOVA) of elasticity

Source	df	Sum sq.	Mean sq.	F value	Sig.
Frying	1	0.1524	0.1524	130.523	***
Position	4	0.0061	0.0015	1.299	
Residuals	4	0.0047	0.0012		

*** $p < 0.001$

Elasticity (Eq.1) mean value was 19.03% (sd=4.87%) for raw and 43.71% (sd=1.76%) for fried chicken fillet samples.

Conclusions

Biophysical measurements were performed on chicken breast fillet samples before and after frying. Observations were in agreement with literature. Clear difference was observed between raw and fried samples. The NIR spectra shown lower reflectance and changed shape as a response to frying.

The wavelength range of 1100 – 1500 nm seems to be suitable to monitor this process. Range selection was supported by standard normal variate of spectra and the first derivatives. The impedance spectra also responded sensitively to frying. In case of impedance spectra, both magnitude and shape changed. The shape of phase angle spectra also changed, frying decreased differences in the frequency range of 1 kHz – 1 MHz. Literature already suggested 300 kHz frequency for pork meat quality assessment. This value seems to be suitable for monitoring frying of chicken meat as well. There was slight variability of samples according to their position in fillet, and impedance spectra turned to be the most sensitive to it. The thick part of the fillet differ from others. Texture was also evaluated and work, elasticity parameters were calculated. Elasticity changed significantly due to frying. According to observed effect of frying, measured parameters are suitable for monitoring the process. Due to the shape changes in NIR and impedance spectra, these methods suggest non-linear kinetics of frying.

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