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A modified ultrasonic method for determining the chemical composition of meat products

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ABSTRACT

In this study, an attempt was made to modify the existing ultrasound method (two-velocities method, TVM) for estimating the proximate chemical composition of meat products by replacing one of the two sound velocity measurements with a measurement of product density at the same temperature (velocity-density method, VDM). Both methods were used to determine the chemical composition of the same five batches of three selected meat products made in Poland: pork canned ham, pork 'Krakowska' sausage and pork 'Podwawelska' sausage. In all three products, the mass percentage of every ingredient determined by TVM differed significantly from the results of chemical analysis, whereas the mass percentage estimated by VDM did not differ significantly from the results of chemical analysis in any of the tested products. The study proposes a new, more accurate method for determining the proximate chemical composition of meat products. The method relies on measurements of product density, but it eliminates the need for measuring sound velocity at two different temperatures.

1. Introduction

The proximate chemical composition of meat products has to be determined during processing and distribution to guarantee that raw materials, the production process and the end product meet stringent quality requirements. In an industrial setting, the speed at which information about the chemical composition of semi-processed goods or products can be obtained during quality control is a very important consideration. Quality inspections are performed to detect and eliminate any processing defects before a product reaches the consumer. Conventional food composition tests rely on chemical analyses which are laborious, complicated, costly, destructive and sometimes harmful to the environment (Barbin et al., 2013). For this reason, they are used only to examine small samples collected from a larger batch of products.

The described drawbacks of laboratory analyses call for the development of rapid and non-destructive methods for evaluating the chemical composition of food products that can be effectively used in evaluations of large product batches (Damez and Clerjon, 2013). Such methods include near infrared spectroscopy (NIR) for evaluating the chemical composition of fish, meat, poultry and fruit (Isaksson et al., 1995; Xiccatoa et al., 2004; Barbin et al., 2013), ultrasound methods for analyzing the chemical composition of fish, meat and cheese (Ghaedian et al., 1997; Simal et al., 2003), as well as methods that rely on the electrical parameters of the analyzed material (Jin et al., 2015; Sharifi andYoung, 2012).

Ultrasound methods are rapid and non-destructive, and the applied equipment is relatively cheap and suitable for mobile applications due to its small size. Ultrasound methods support rapid quality tests in production plants and distribution outlets.

The existing ultrasound methods for analyzing the chemical composition of food products rely on equation (1) described by Ghaedian et al. (1997), where the speed with which sound penetrates a material is determined by the product's chemical composition:

$$\frac{1}{c^2} = \sum_{i=1}^{n} \frac{x_i}{c_i^2} \tag{1}$$

Symbols and abbreviations: c, sound velocity, m/s; d, distance between transducers or sample thickness, m; t, temperature, °C; PKCH, pork canned ham; PKKS, pork 'Krakowska' sausage; PKPS, pork 'Podwawelska' sausage; TVM, two-velocities method; VDM, velocity-density method; x, mass percentage of ingredient; t, temperature, °C; ρ, density, kg/m^3; τ, time of flight, μs; A,F,P,O,W, index for: ash, fat, protein, the others, water.

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The equation can be effectively applied only to homogeneous products and products characterized by negligibly low sound attenuation and dispersion coefficients. Simal et al. (2003) used this equation to determine the proximate chemical composition of sobrassada, a raw, cured pork sausage from Mallorca (Spain). The cited authors estimated the content of water, fat, protein and other ingredients (referred to as the 'protein + others' fraction) with a system of equation (2), where the first two equations expand equation (1) for measurements of sound velocity at different temperatures, and the third equation (2) describes the proportions of a product's ingredients.

$$\begin{cases} \dfrac{1}{c_1^2} = \dfrac{x_W}{c_{W1}^2} + \dfrac{x_F}{c_{F1}^2} + \dfrac{x_{P+O}}{c_{P+O1}^2} \\ \dfrac{1}{c_2^2} = \dfrac{x_W}{c_{W2}^2} + \dfrac{x_F}{c_{F2}^2} + \dfrac{x_{P+O}}{c_{P+O2}^2} \\ 100 = x_W + x_F + x_{P+O} \end{cases} \quad (2)$$

The same approach was used by Fulladosa et al. (2015) who compared and combined this technique with X-ray technology in a study of raw salted and dried (dry-cured) ham. We are not familiar with any published studies where the 'two-velocities method' (TVM) proposed by Benedito et al. (2001) and Simal et al. (2003) has been used to determine the chemical composition of other meat products, including thermally processed products. The above observation led to an experiment whose results are described in this paper. A preliminary examination revealed that TVM requires some modification to be used for other products because its outcomes considerably differed from the results of chemical analysis (negative values were obtained for some components).

The objective of this study was to expand our knowledge of ultrasound measuring methods, in particular to: 1) evaluate the applicability of TVM for determining the proximate chemical composition of selected pork products, 2) develop a new method for evaluating the proximate chemical composition of meat products, 3) compare the results of ultrasonic methods for estimating the proximate chemical composition of meat products with the results of chemical analysis, and to identify the more accurate method.

2. Materials and methods

2.1. Materials

The experiment was performed on three types of pork-based products that differed in their composition, production method and degree of coarseness: canned ham (PKCH), 'Krakowska' sausage (PKKS) and 'Podwawelska' sausage (PKPS). The products were manufactured during a normal production cycle in an industrial meat processing plant. Product composition declared by the producer was presented by Nowak et al. (2015). The study covered a period of eight months during which eight batches of every product were analyzed. Samples collected from all eight batches were subjected to chemical analysis and ultrasound measurements. The batches were then divided into two series of products. The first three batches constituted series 1 and were used to determine sound velocity in the protein + others fraction. The remaining five batches constituted series 2, and their proximate chemical composition was determined by two ultrasound methods. The findings were compared with the results of chemical analysis.

2.2. Chemical analysis

A proximate analysis of meat products involved the determination of dry matter content, total protein content by the Kjeldahl method, fat content by Soxhlet extraction (diethyl ether solvent) and ash content (AOAC, 1990).

2.3. Ultrasound measurements

All products were subjected to ultrasound measurements of sound velocity using the through-transmission technique (TT). A diagram of the test stand is presented in Fig. 1. The OPBOX 2.0 (PBP Optel, Polska) ultrasound device and two transducers (PBP Optel, Poland) with nominal frequency of 2 MHz (PBP Optel, Poland) were used to generate and receive electroacoustic signals. The bottom transducer was positioned in a fixed platform, and the top transducer was mounted to a movable arm (in the same axis) that moved up and down. The distance between transducers was measured to the nearest 0.01 mm with an electronic caliper. One jaw of the caliper was mounted to the fixed platform, and the other – to the movable arm. The amplitude of the registered acoustic signal was determined with a precision of ±4 mV, and time was measured to the nearest 0.01 μs.

In all product samples, electroacoustic signals were acquired at storage temperature (5 ± 1 °C) and at room temperature (20 ± 1 °C). Temperature was measured with the EMT-50 electronic thermometer (Czaki Thermo-Product, Poland).

The electroacoustic signals registered during measurements of samples from every product batch were processed to determine the velocity of sound in 20 replications. Sound velocity was calculated

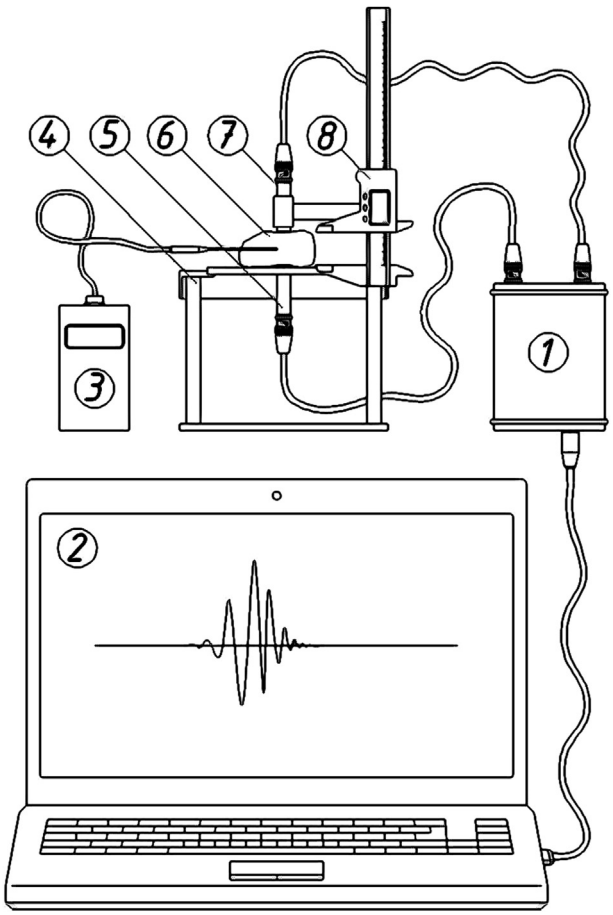

Fig. 1. Test stand: 1 – OPBOX 2.0, 2 – PC, 3 – electronic thermometer, 4 – platform, 5 – fixed acoustic transducer, 6 – sample, 7 – acoustic transducer on movable arm, 8 – electronic caliper (Nowak and Markowski, 2013).