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The influence of meat muscle structural properties on mechanical and texture parameters of canned ham

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ABSTRACT

The aim of this study was to determine the relationships between mechanical-rheological properties as well as muscle texture parameters and their physico-chemical and structural characteristics in the course of different production phases of canned ham. Their mechanical-rheological, texture as well as physico-chemical and structural properties were analysed at each phase of the performed experiments. Injection and plasticisation in both kinds of ham muscles caused loosening of muscle fibres and partial extraction of muscle and connective tissue proteins. It should be emphasised that musculus quadriceps was characterised by a higher dynamics of changes in the fibre structure in comparison with the semimembranosus muscle. This found its expression in the analysed mechanical-rheological and texture as well as physico-chemical parameters. However, as a result of pasteurisation, values of all the analysed texture determinants, i.e. hardness, shearing force, cohesiveness and gumminess failed to exhibit statistically significant differences between one another in the case of both of the examined muscles.

1. Introduction

Meat texture is one of the most important attribute affecting its quality and consumer acceptability (Chen and Opara, 2013; Bekhit et al., 2014). It is understood as a complex of traits associated with meat structure elements, their mutual arrangement and interactions which are perceived and registered by human sensual apparatus or by means of appropriate devices (Bourne, 1982). Texture's physical determinants include such characteristics as elasticity, hardness, viscoelasticity, viscosity, plasticity etc. The above values can change depending on temperature, moisture content and composition of analysed systems.

From physical point of view, meat constitutes a multiphase system of complex internal structures. Diversity of structural elements, abundance of various chemical constituents of varying physico-chemical properties cause that each of them separately or in combination with other components affects to a different degree meat texture properties. That is why it can be justifiably assumed that there are interrelations between chemical constituents, i.e. water content, protein, fat, salt and ash and meat physical product attributes, i.e. tenderness, hardness, springiness, cohesion, gumminess, chewiness and colour (Cheng and Sun, 2005). Two basic meat structural components, i.e. myofibrillar and connective tissue - are mainly responsible for meat texture (Purslow, 2002, 2005; Nishimura et al., 2008). Each of them, due to their physicochemical preconditioning, is involved in different ways in the development of meat quality. Meat unique properties depend on different types and the distribution of muscle fibres. They reflect their physical and chemical properties as well as their morphological composition. That is why the relationship between meat quality attribute and the type and properties of muscle fibres have been the focus of attention of numerous studies for many years. However, these investigations have been confined to the determination of correlations between the type of fibres and selected texture parameters, mainly tenderness (Chang et al., 2003; Ryu and Kim, 2005; Lorenzo et al., 2013), but so far no consistent correlations between them have been discovered. In addition, the composition, quantity and distribution of the intramuscular connective tissue affect meat quality (An et al., 2010; Nishimura, 2010; Dubost et al., 2013a).

The role of meat connective tissue continues to attract numerous researchers, especially from the point of view of its quantitative chemical composition and structural preconditioning (Torrescano et al., 2003; Dubost et al., 2013b).

The intramuscular connective tissue plays a significant role in

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determining meat toughness (Grześ et al., 1998; Nishimura et al., 2009; Christensen et al., 2013; Eskandari et al., 2013). Collagen, one of the constituents of the intramuscular connective tissue, plays a particularly important function in the creation of texture. It is responsible for the mechanical stability of the connective tissue (Oshima et al., 2007; Voutila et al., 2009) and, in addition, it is also believed to play a key role in affecting hardness (Torrescano et al., 2003). The mechanical stability of the intramuscular connective tissue depends also on the size and distribution of its fibres (Iwamoto et al., 1999; Oshima et al., 2007).

The final quality of meat product depends not only on the muscle structure used as the raw material for its production. This is particularly important in the production of smoked bacon and cooked or canned hams in which the product quality is the final effect of a number of technological processes dependent on factors associated with the raw material (kind and size of muscles) as well as the process (quantity of injection, time of massaging, temperature, rotational velocity of the massage drum, massaging cycle, construction of the device) (Gadekar et al., 2013; Patrascu et al., 2013). Each step of the technological process exerts a different impact on the structure, mechanical-rheological properties and texture of the employed raw material.

Plastification is a technological process improving the quality characteristics of cured meat (Patrascu et al., 2013; Gurikar et al., 2014). It is a procedure changing the springy-elastic properties of meat into plastic-viscous ones. As a result of plastification the tenderness, water binding capacity and yield of products obtained from plastified muscles or deboned meat raw materials are improved (Krause et al., 1978; Lachowicz et al., 2003). Generally it may be stated that during plastification the muscle tissue is subjected to the action of overpressure and partial vacuum, which modify properties of meat as a result of changes taking place in the meat proteins, primarily the myofibrillar protein fraction (Jayasooriya et al., 2007; Xu et al., 2012).

The process of pasteurisation carried out in controlled conditions of the applied thermal treatment contributed to the formation of a new physical system characterised by a complete change of initial molecular–structural parameters. Pasteurisation exerts a significant influence on values of mechanical-rheological discriminants and texture parameters of the final products (Duranton et al., 2011; Roldan et al., 2013).

The properly selection of technological process parameters make possible to obtain the final product with appropriate tenderness and juiciness.

It is evident from the above brief review how difficult an issue it is to try and determine the texture of raw materials exhibiting such a degree of complexity with their internal structure as meat. A particularly difficult problem is also the interpretation of the obtained results as well as their correlation with physicochemical and structural properties. This can be attributed to the fact that texture parameters are complex quantities referring to physical properties and, to a large extent, to mechanical-rheological properties.

Since meat raw materials, semi-finished and finished products embrace a very wide scale of such properties from plastic, visco-elastic to elastic, methods of texture instrumental analyses must be characterised by considerable methodological and interpretational versatility (Steffe, 1996). Investigations conducted for many years concerning mechanical-rheological properties of meat raw materials subjected to different technological treatments as well as products obtained from these treatments (Kerry et al., 1999; Kerr et al., 2000; Hui-Huang et al., 2008; Liu et al., 2014; Stangierski et al., 2014) confirm that oscillation rheometry belongs to one of the most universal and objective methods that can be applied in studies of this kind of systems. The oscillation rheometry expanded to the technique of dynamic-mechanical analysis (DMA) provides possibilities of determining values of elasticity coefficients, coefficients of internal friction (viscosity) as well as other mechanical-rheological parameters at any frequency of activities which do not destroy the developed system structure as well as at a wide range of temperatures. It also makes it possible to determine the relationship between changes taking place in the molecular structure of meat raw material, interaction between functional additives and meat constituents and their effect on macroscopic properties. Consequently, it allows quantitative analysis of the structure of macromolecular systems containing meat and other non-meat additives at different levels of organisation as well as at different stages of evolution of this structure. This accounts for the publication of many studies devoted to interrelationships between modifications in the molecular structure and values describing macroscopic properties of polydisperse materials of complex internal structure, which highly processed meat products are (Ahmed and Ramaswamy, 2007; Fischer and Windhab, 2011; Savadkoohi et al., 2013). On the other hand, there are few papers concerned with the analysis of structural changes taking place in the course of technological processes and their correlation with texture in products manufactured from whole muscles or their parts, e.g. maturing, cooked or canned hams (Barone et al., 2007; Benedini et al., 2012).

The aim of this study was to determine relationships between mechanical-rheological properties as well as muscle texture parameters and their physico-chemical and structural characteristics in the course of different production phases of canned ham.

2. Materials and sample preparation

2.1. Experimental material

The experimental material comprised muscles making up the pork ham: the semimembranosus muscle (*m. semimembranosus*) and the quadriceps muscle of the thigh (*m. quadriceps femoris*). Muscles for experiments were collected 24 h after slaughter and the temperature of meat did not exceed +4 °C. The pH value of the ham muscles employed in the investigations ranged from 5.68 to 5.72. After cutting the muscles out from the carcass, they were divided into two parts: one part was treated as the control, while the other was subjected to injection.

2.1.1. Injection

The process of injection with curing brine was carried out with the assistance of a low-pressure, double-head injector (“Nowicki” MH 280, Poland). In each head, there were 6 rows of needles with 20 needles in each. The injector was controlled by a microprocessor which allowed smooth regulation of parameters affecting the quality of meat injection. The injection was performed using curing brine at the temperature of +4 °C.

The applied brine contained 90.48% water 2.8% protein, including 0.60% collagen, 0.03% nitrate, 5.06% sodium chloride and 0.52% phosphates converted into P_2O_5.

The average pH value of the brine used for the injection was 6.75. The applied injection with the curing brine was 30% in relation to the muscle weight.

2.1.2. Massaging

Each of the injected samples was divided into three parts. The first part was subjected to analyses, while the other two were subjected to the massaging process in a 2000-L volume vacuum massaging machine with a cooling jacket. To prevent mutual interactions between muscles during massaging, individual muscles were placed in tight plastic bags.

The massaging machine was filled with the raw material in 60%,