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Estimation of intramuscular level of marbling among Whiteheaded Mutton Sheep lambs

A. Przybylak [a], P. Boniecki [a], K. Koszela [a,*], A. Ludwiczak [b], M. Zaborowicz [a], D. Lisiak [c], M. Stanisz [b], P. Ślósarz [b]

[a] Poznań University of Life Sciences, Institute of Agricultural Engineering, Wojska Polskiego 50, 60-625 Poznań, Poland
[b] Poznań University of Life Sciences, Department of Small Mammal Breeding and Animal Origin Materials, Złotniki, Słoneczna 1, 62-002 Suchy Las, Poland
[c] Institute of Agricultural And Food Biotechnology, Division of Meat And Fat Technology, Głogowska 239, 60-111 Poznań, Poland

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ABSTRACT

The aim of this work was to develop a non-invasive method to estimate the degree of the intramuscular fat in the Whiteheaded Mutton Sheep lambs by means of the USG technology and the neural image analysis. The classification process was based on the muscles USG images acquired on the hot carcass just post slaughter in three scanning points of 63 lamb carcasses: the *longissimus* muscle – over the last rib and the 3rd lumbar vertebrae, and the leg (*musculus semimembranosus*). The total of 568 USG images were obtained. The image characteristics were used to learn the artificial neural networks to recognize and classify the level of marbling in lamb meat. From among different tested neural networks, the PNN (Probabilistic Neural Network) type with the structure 13-404-5-1 was found to have the best classifying capability.

1. Introduction

Increasing requirements of consumer market imply high value of the supplied food products. The objective is supported in developed countries by many science centers that work continuously to improve the quality of food products (Du and Sun, 2006; Qiao et al., 2007). An alarming increase numbers of cases of the so-called modern-age diseases as well as scientific research conducted in this field indicate that physical condition of consumers is immediately influenced by the quality and type of products they eat. This fact undoubtedly stimulates scientific research to search for new and genuine methods to effectively evaluate the quality of food. It applies in particular to food products of animal origin, among which the most common product is meat, being one of the basic nutrients in contemporary world. Quality characteristic are defined as factors that influence the taste and final market price of animal carcasses being sold (Sikora and Weber, 1995; Jackman et al., 2010b). Introducing stricter quality standards would prove useless if there was no possibility to perform quality control through employing several kinds of methods and verification techniques. An important parameter which constitutes basis for meat products quality assessment is the content of fat and its structural dislocation in the carcass. The amount of intramuscular fat indicates the quality of meat and its culinary and technological value which obviously influences its price significantly. The representation of the dislocation and amount of intramuscular fat on a cross-section of a muscle is defined in the meat industry with a conventional term, the so-called marbling scale (from hardly visible to very strong). Apart from tenderness and juiciness, marbling determines the most important eating quality criterion, palatability. Palatability a subjective sensory characteristic, being a sum of both taste and smell. Taste and smell precursors of meat are water-soluble and fat-soluble compounds – amino acids, reducing sugars and fatty acids. Different taste characteristics of meat from various species of animals originate from lipid elements, most of them being fats. Marble structure represents tender meat, filled with fat veins. Therefore, moderate marbling of meat is desired, because it influences its juiciness and improves the flavor of meat after thermal treatment. In order to effectively determine the nutritional value of meat, which has a direct impact on its consumption value, it is necessary to solve the problem of non-invasive quality verification, especially in the context of the aforementioned intramuscular fatting degree (Liu and Ngadi, 2014). The amount of intramuscular fat and its dislocation on a cross-section of a muscle determines its classification as a pre-defined marbling class. Nowadays, the necessary selection of carcasses is performed immediately on slaughter lines or prior to

* Corresponding author.
E-mail address: koszela@up.poznan.pl (K. Koszela).

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animal slaughter procedure. The second option is obviously more advantageous but at the same time it is more difficult to put into practice. The first option prevails within the European Union, where post-slaughter classification and assessment of beef carcasses is performed according to EUROP system in force. The EUROP system applies mostly to meat content in the carcass. Apart from the devised standards, carcass assessment also employs various types of invasive optical and needle instruments. They operate as blade probes which inserts into the layer of fat on the animal's back and then penetrates *Musculus longissimus dorsi* (loin) (Jackman et al., 2010a). It is important to stress that nowadays there is no method that would allow to perform impartial assessment and selection of meat in terms of marbling. The employed method of optical carcass assessment after cutting each muscle is obviously an invasive technique, however its precision is far from satisfactory.

Recent scientific research have indicated an opportunity to obtain satisfactory results for quality identification of meat carcasses using ultrasound technology (Ślósarz et al., 2001). USG is a non-invasive, easily automated diagnostic method that allows to obtain a cross-section image of the examined object without interfering with its structure. The method employs the phenomenon of propagation, scattering and reflection of ultrasound waves on media boundaries. USG technology allows to obtain digital images of animal tissue cross-sections and the graphic information can then be used to identify the level of marbling. Unfortunately, the nature and quality of USG images usually creates certain utility difficulties, especially in terms of proper interpretation of the information encoded in a graphic form, disturbed by noise. Therefore, correct analysis of USG images usually requires expert work. The work performed by experts is generally dissatisfactory, mainly due to small level of repetitiveness of the results, lack of unbiased assessment, being time - consuming and expensive. Currently used methods to identify intramuscular fatting degree are therefore often based on subjective evaluation from an expert, performed from a pre-defined pattern. In the pursuit of improved meatiness of domestic slaughter lambs, methodical schemes have been devised to estimate the content of intramuscular fat in *Musculus longissimus* in living lambs. The schemes include genetic characteristics and USG measurements among meat lambs and are based on digital image analysis (Ślósarz et al., 2001). Due to unique nature of USG images, it is becoming more common to analyze them using AI methods, resistant to various forms of noise or artifacts that appear on digital images (Utku and Kijksel, 1998). Modern techniques of neural image analysis become particularly significant in this context (Gon et al., 2008; Boniecki et al., 2012a,b; Fan et al., 2013). Image analysis and processing gives a very good results when used to support meat quality investigation. The combination of image analysis with the artificial neural networks is proved to be even more useful in the food industry, in general (Boniecki et al., 2012c; El Jabri et al., 2010). The mentioned computer tools increase the accuracy and reliability of the techniques commonly used for meat and carcass quality assessment like ultrasonography (Ślósarz et al., 2011), reflectance spectroscopy (Moral et al., 2009), magnetic resonance (Pérez-Palacios et al., 2010) and many others. Therefore it seems justified to explore all the merits of the novel tools for meat quality investigation. While studying the assessment of lamb carcass quality, a team led by M.N. Chandraratne compared traditional statistical methods with ANN technique. The assessment was performed by using a quality assessment method according to standards of New Zealand. One of the aspects of study was general fatting in carcasses. The study has shown the effectiveness and prevalence of a neural model over the traditional statistical method used to forecast the quality of lamb (Chandraratne et al., 2003). Analysis of available literature concerning this subject confirm inadequate knowledge in the field, thus indicating lack of a universal non-invasive method to determine the amount of intramuscular fat. An impartial estimation of intramuscular fatting degree calls for the design, creation and verification of a new and adequate identification model. Artificial neural networks are well-regarded and increasingly popular classification tools (Koszela et al., 2014; Zaborowicz et al., 2012; Nowakowski et al., 2012). Using methods of ANN in the process of marbling classification for lamb is reasonable. Therefore, the following hypothesis can be formulated: it is possible to perform neural identification of fatting degree in lamb carcasses based on graphic information obtained from USG images of intramuscular fatting degree.

The aim of the work was to examine the possibility to apply modern image analysis techniques and neural modeling methods in the process of intramuscular fatting identification among Whiteheaded Mutton Sheep lambs, based on information encoded in the form of digital USG images. In order to do this, it was necessary to identify and extract discriminating qualities (descriptors) that describe the objects represented in USG images of lamb intramuscular cross-sections.

2. Materials and methods

2.1. Materials

The study material was composed of 63 lambs of Whiteheaded Mutton Sheep. The lambs used for study had a slaughter weight of about 35 kg and were characterized by high content of intramuscular fat. The lambs were slaughtered in an experimental slaughterhouse. Immediately after the animals were slaughtered, USG images were obtained showing muscle cross-section in various parts of the carcass (the *longissimus* muscle – over the last rib and the 3rd lumbar vertebrae, and the leg (*musculus semimembranosus*). USG analysis was performed with the use of Hitachi EUB405B ultrasound scanner with a 75 mm wide linear transducer working emission frequency at 5 MHz. For each measurement spot 3 USG images were acquired, with information on the examined muscle cross-section. USG measurement spots were marked with the content of intramuscular fat, thus classifying the image with a proper marbling class.

Next step was to create cross-sections of the studies carcasses in predefined spots (where USG images were made). A series of pictures of the cross-sections were taken in laboratory conditions. The photographed cross-sections obviously corresponded to the spots probed with a USG probe.

The pictures of carcass cross-sections formed expert material to classify the material into proper marbling classes and then to link them to corresponding USG images. The total number of stored USG digital images used for study was 568. The acquired USG images were then analyzed by an expert. Using the digital photographs of proper muscle cross-sections the expert classified the acquired USG images into 5 predefined marbling classes (Fig. 1).

The aforementioned qualification patterns for fatting degree represented 5 marbling classes defined in the following manner

- **1** fatting marbling class **A**: intramuscular fat content low,
- **2** fatting marbling class **B**: intramuscular fat content small,
- **3** fatting marbling class **C**: intramuscular fat content medium,
- **4** fatting marbling class **D**: intramuscular fat content high,
- **5** fatting marbling class **E**: intramuscular fat content very high.

The acquired empirical data formed a basis to build learning sets, necessary for the process of generating neural classifiers used to identify intramuscular fatting degree among Whiteheaded Mutton Sheep lambs.