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Novel ultrasound approach for measuring marbling in pork☆

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A B S T R A C T

An ultrasound examination was done on the *m. longissimus lumborum*, between the 10th and the 11th thoracic vertebra, on two sides (inside and outside the thoracic cavity) of the left half-carcasses of 162 fatteners. The carcasses were classified for lean meat percentage using the SEUROP system. The R pig carcasses (47.7% lean) had the thickest backfat (30.6 mm; $P \leq 0.01$) and the highest content of intramuscular fat (IMF = 2.28%; $P \leq 0.01$). More artifacts-free images were collected from the inside compared to the outside of the pig carcasses (90.1% vs. 58.6%; $P \leq 0.01$). The percent of bright pixels (PBP) was the highest for the inside, for all the lean-meat-content classes ($P \leq 0.01$). The correlation between the PBP and the IMF was higher for the images of the inside compared to the outside ($r = 0.811$; $P = 0.001$ vs. $r = 0.523$; $P = 0.009$). The ultrasound images of the inside of the carcasses proved to be the most useful for making an assessment of the marbling.

1. Introduction

The meatiness (lean meat content) assessment of animals raised for meat production is an important element of the meat industry. Among the methods used for quickly assessing the lean meat percentage in animal carcasses is the popular SEUROP system commonly used in the European Union (Kongsro, Røe, Kvaal, Aastveit, & Egelandsdal, 2009; Russo, Preziuso, & Verità, 2003; Stanisz, Ślósarz, & Steppa, 2012). Pig carcasses are classified according to the percentage of lean meat: S (≥ 60% lean meat), E (55–59.9%), U (50–54.9%), R (45–49.9%), O (40–44.9%), P (< 40%) (Pisuła & Pospiech, 2011). According to this system, those carcasses with a high per cent of lean meat are the most valued. It is commonly known, however, that a high meat yield of pigs does not necessarily mean that the pork is of a high eating quality. A pork quality trait very negatively affected by selection of pigs for increased meatiness, is the content of intramuscular fat (IMF). As a result, commercially produced pigs are characterised as having a very low IMF content of about 1% (Franci et al., 2005). According to the literature, the optimal IMF content, in pork required for well-developed palatability traits, ranges from 1.5% to 3.5% (Barton-Gade, Warris, Brown, & Lambooij, 1995; Cannata et al., 2010; Fortin, Robertson, & Tong, 2005). Therefore, in order to increase the sensory traits of commercial pork, it is important that the IMF content be included in carcass quality grading systems.

Meat marbling and the IMF content are strongly related. Marbling is a visual meat characteristic defined as white particles visible on the cross-section of the muscle (Albrech, Wegner, & Ender, 1996; Garcia, Casal, Olsen, & Berra, 1968; Essen-Gustavson, Karlsson, Lundstrom, & Enfalt, 1994). Meat marbling is mostly composed of IMF, therefore the correlation between the content of IMF and the level of meat marbling is significant (Czarnecka-Skubina et al., 2007; Ślósarz, Stanisz & Gut, 2001, Ślósarz, Gut, Stanisz, Steppa, Wójtowski & Danków, 2001; Young, Bain, McLean, Campbell, & Johnson, 2009). A popular, non-invasive method used for the measurement of marbling is ultrasonography. The application of this method in the production of meat animals, for a long time dealt mainly with the estimation of the tissue composition (Berg, Neary, Forrest, Thomas, & Kauffman, 1996; Cisneros et al., 1996; Shepard et al., 1996). The increased popularity of ultrasonography is related to the high correlation between the ultrasonic measurements made on live animals and the anatomical, post-slaughter measurements (Cross & Belle, 1994; Griffin, Savell, Recio, Garrett, & Cross, 1999; Hosseini Vardanjani, Miraei Ashiani, Pakdel, & Moradi Shahrebabak, 2014; Lo, McLaren, McKeith, Fernando, & Novakofski, 1992; Smith, Oltjen, Dolezal, Gill, & Behrens, 1992; Terry, Savell, Recio, & Cross, 1989). Very good results were found when using ultrasonography for the measurement of the level and distribution of meat marbling in meat cattle (Aass, Gresham, & Klemetsdal, 2006; Brethour, 1994; Hassen, Wilson, Amin, Rouse, & Hays, 2001; Ribeiro, Tedeschi, Stouffer, & Carstens, 2007). The development of ultrasonic devices also allowed this method to be used with other livestock species, such as pigs (Fortin et al., 2005; Mörlein,

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Rosner, Brand, Jenderka, & Wicke, 2005; Newcom, Baas, & Lampe, 2002; Ville et al., 1997). Unfortunately, this kind of research must deal with the fact that there is a much lower level of pork marbling compared to beef, and that thick backfat is typical for fatteners. The subcutaneous fat has a negative impact on the quality of ultrasound images. Such an impact is the result of the physical traits of the acoustic waves and the strong reflective properties of the fat tissue. Only a part of the acoustic signal passes the barrier of the backfat, and the image of the muscle located below is incomplete. The fact that the backfat in pigs is often composed of layers, generates additional artifacts called reverberations (Czyrny, 2012; Ludwiczak, Ślósarz, & Stanisz, 2011).

The backfat layer makes it difficult to acquire good quality ultrasound images of the *m. longissimus lumborum* of pig carcasses. Our research is meant to overcome this difficulty. The goal of this trial was to analyse a novel method of ultrasound image acquisition; we placed the ultrasonic transducer inside the thoracic cavity of the pig half-carcass, between the 10th and 11th thoracic vertebrae. The research hypothesis assumed that for marbling assessment, the images obtained from the inside of pig carcasses were more useful than the images obtained by application of the ultrasonic probe on the outside. To define the usefulness of ultrasonic muscle cross-sections for marbling level assessment, two image parameters were used: brightness, and the percent of bright pixels. The brightness of the image, in the case of the defined parameters of the ultrasound wave emission, is the first of the image quality indicators and is dependent on the proper contact between the probe and the carcass surface and the degree of ultrasound signal attenuation in different tissues. According to previous research, the brightness of the muscle-display might also be useful for estimating meat marbling (Ślósarz, Stanisz & Gut, 2001; Ślósarz, Gut, Stanisz, Steppa, Wójtowski & Danków, 2001). The percentage of bright pixels (PBP) was obtained in the process of segmentation, allowing us to separate the marbling pattern which was visible as bright particles (the foreground), from the muscle tissue (the background). This parameter defines the percentage of these bright particles in the muscle area. According to the research conducted by Ślósarz, Gut, Stanisz, Steppa, Wójtowski and Danków (2001) the described parameter allows for proper recognition of fat particles on the muscle cross-section.

2. Material and methods

2.1. Acquisition of m. longissimus lumborum ultrasonic cross-sections

The research was conducted at a commercial slaughterhouse in the western part of Poland. The analysed material included 162 randomly selected pig carcasses classified according to the SEUROP system. The carcasses were obtained from fatteners raised under intensive farming conditions. The ultrasound examination was made on the left pig half-carcasses which were still hot and hanging on metal hooks on a rail. The scanning probe was applied on the *m. longissimus lumborum* area, between the 10th and the 11th thoracic vertebra (10T), outside and inside of the pig half-carcass. Ultrasound examination of the inside of the carcass was achieved by applying the ultrasonic probe between the 10th and the 11th rib. The selected scanning point was also the point of the lean meat percentage evaluation made at the slaughterhouse with a hand-held Capteur Gras/Maigre apparatus by Sydel (CGM). The CGM device is equipped with an optical probe which is inserted into the carcass. The apparatus measures the lightness of the loin muscle and the backfat. The colour difference between tissues determines the thickness of the loin muscle and the fat layer. The apparatus converts it into lean meat percent and the SEUROP class of the pig carcass (Szostak, 2013).

The examined muscle area was covered with water to make sure there was good contact between the probe and the surface of the carcass. The ultrasound examination was made with the Hitachi EUB405B ultrasound system equipped with a linear-array probe (5 MHz; 85 mm scanning depth; applied on outside of the pig carcass) and a convex-array probe (5 MHz; 110 mm scanning depth; applied on the inside of the carcass). Both probes were positioned transversely to the spine. The ultrasound images were recorded in real-time B-mode (Fig. 1). The Avidemux software ver. 2.5 was used to obtain frames and save them in bmp format. All together, 324 ultrasonic muscle cross-sections were analysed (each of the 162 carcasses were examined from the outside and the inside). The ultrasound images were analysed by means of ImageJ ver. 1.50f 3 (2015). Brightness distribution and the percentage of bright pixels in the muscle area were noted.

2.2. Laboratory analysis

Forty-eight hour post-mortem, *m. longissimus lumborum* was cut from the left pig half-carcasses in the area of the ultrasonic measurement. The laboratory analysis included the measurement of pH and colour (L*), a chemical composition analysis, and a visual evaluation of marbling and colour.

2.2.1. Meat pH

For calibration of the pH equipment, buffers of pH 7.0 and 4.0 were used. Forty-eight hour post-mortem, acidity in the *m. longissimus lumborum* was measured by inserting a glass calomel electrode (ERH-11X1) attached to a portable, temperature compensated pH meter (Handylab 2, SCHOTT) into the muscle (Prost, 1955).

2.2.2. Colour

Triplicate colour measurements were taken 48 hour post-slaughter,

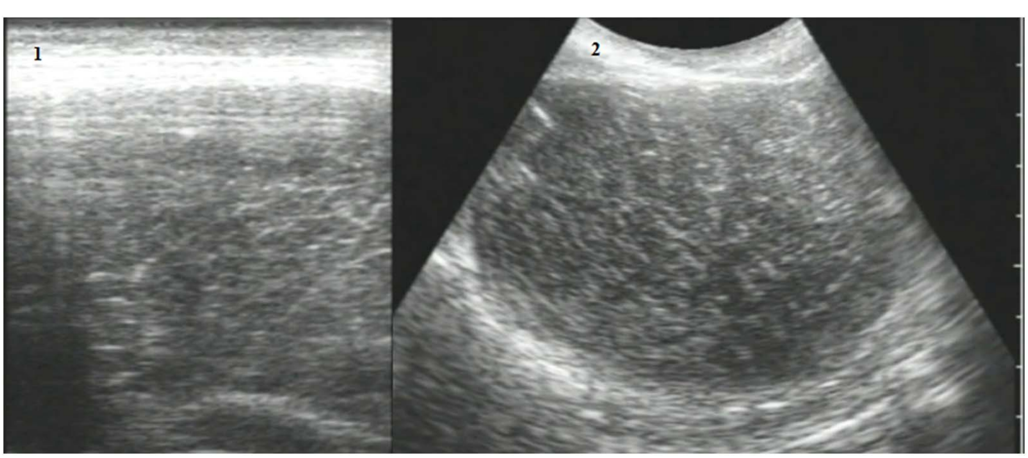

Fig. 1. The ultrasound images of the *m. longissimus* lumborum made on the same pig half-carcass behind the 10 T. Image obtained on the outside – 1; and on the inside of the pig half-carcass – 2.