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The use of computer vision system to detect pork defects

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ABSTRACT

The aim of this study was to determine the effectiveness of computer vision system (CVS) to detect meat defects of *m. longissimus lumborum* (*LL*) in industrial settings. The material consisted of 230 muscles. Based on pH_1 (45 min) and pH_2 (24 h post-mortem) meat classification into quality groups was conducted. To give more precise characterization of the raw material (proving the defect or not) the electrical conductivity (EC), drip loss, thermal drip and water holding capacity (WHC) were determined. The color of the meat in CIEL*a*b* and by CVS was measured and the study into how the CVS can be employed in meat defect detection was done. It was found that it is possible to employ the CVS to detect PSE (pale, soft, exudative) and DFD (dark, firm, dry) and to classify meat into quality groups. It was not possible to differentiate RSE (red, soft, exudative) from RFN (red, firm, normal) meat in this study. The highest accuracy of raw material classification using the CVS method was reported for the HSL (hue, saturation, lightness) color parameters at 81.7%. Therefore, the computer vision system can be employed for rapid analysis of the quality of pork *m. longissimus lumborum* under industrial conditions.

1. Introduction

Non-standard quality of the marketed pork causes significant problems for the meat industry (Florowski, Florowska, Kur, & Pisula, 2013). The main issue associated with pork meat quality is a high PSE (pale, soft, exudative) occurrence. This phenomenon has drawn the attention of scientists and processors for many years (Barbut et al., 2008; Van De Perre, Ceustermans, Leyten, & Geers, 2010). The PSE meat when compared to the normal meat (red, firm, normal; RFN) is characterized by a lighter, unnaturally pale color with varied saturation, deteriorated WHC, an increased meat drip loss and soft consistency (Van de Perre and Permentier, 2010). The product of such quality should not be used for the culinary meat production since an excessive meat drip loss is negatively perceived by the consumers. Moreover, the utilization of PSE meat is hampered (Florowski et al., 2013), causing, inter alia, lower yield of the finished product. The biggest disadvantage is that the PSE occurs in the biggest and the most valuable muscle groups such as *m. longissimus dorsi*, *m. semimembranosus*, *m. semitendinosus* and *m. gluteus medius*. The muscles of neck, shoulder and knuckle are less vulnerable. The fat cuts of half-carcass (belly, dewlap and groin) are not affected by PSE.

Some authors (Barbut et al., 2008; Channon, Payne, & Warner, 2000; Gajana, Nkukwana, Marume, & Muchenje, 2013; Gregory, 2010) claim that the animal breeders and meat processors should give a special attention to the defect elimination through selective breeding and control of environmental factors influencing the meat quality. However, in the foreseeable future it is rather unlikely to eradicate major meat defects, including PSE, using zootechnical methods. Thus, it is important to identify these defects, classify the raw material and determine its end-use (as a raw material for processing or culinary purposes) what, will result in its more rational utilization. Unfortunately, unambiguous identification of PSE and other meat defects is extremely difficult. In industrial practice the meat quality evaluation is performed either visually being encumbered with numerous errors or by means of apertures measuring the following attributes: pH, EC and color lightness (Brewer, Novakofski, & Freise, 2006; Warris, Brown, & Paściak, 2006). The above-mentioned instrumental analyzes are the examples of contact methods, which may result in cross-contamination of the meat and besides it is difficult to use them directly on the meat dressing and fabrication line (Papadakis, Abdul-Malek, Kamdem, & Yam, 2000).

Abbreviations: CVS, computer vision system; DFD, dark, firm, dry meat; EC, electrical conductivity; HSL, hue, saturation, lightness; HSV, hue, saturation, value; PSE, pale, soft, exudative meat; RFN, red, firm, normal meat; RGB, red, green, blue; RSE, red, soft, exudative meat; WHC, water holding capacity.

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One of the proposed methods in rapid on-line evaluation of meat quality is the computer vision system (CVS). This method has been successfully used in industrial practice to classify and assess the meatiness of large animal carcasses and to classify the poultry carcasses (Craigie et al., 2012; Fortin et al., 2003; Pabiou et al., 2011). The research has been undertaken to check the possibility of the CVS employment to evaluate the meat quality and many works have been written on beef (Jackman, Sun, Allen, Brandon, & White, 2010; Sadkowski et al., 2014) and pork meat (Faucitano, Huff, Teuscher, Gariepy, & Wegner, 2005) marbling. Recently, the technology based on the image analysis involves tracking the elements on the meat dressing and fabrication line (Larsen, Hviid, Jørgensen, Larsen, & Dahl, 2014). According to Girolami, Napolitano, Faraone, and Braghieri (2013) it is possible to use the CVS to evaluate the meat color parameters. In addition to being rapid and objective, this method can be used on-line directly on the meat dressing and fabrication line. Moreover, this technique is non-invasive and, as a consequence, does not pose a health hazard for the consumers (Papadakis et al., 2000; Saldaña, Siche, Castro, Huamán, & Quevedo, 2014; Trinderup, Dahl, Jensen, Carstensen, & Conradsen, 2015).

The aim of this study was to determine the applicability of the CVS method to detect the *m. longissimus lumborum* defect in industrial settings. Additionally, the accuracy of raw material classification into quality groups by means of this method was determined.

2. Material and methods

2.1. Research material and organization

The sampling material comprised 230 *longissimus lumborum (LL)* muscles dissected from 230 different right swine half-carcasses.

The animal slaughtering was conducted in industrial environment using a two step-chilling process (1st ambient temperature: −10 °C, time 1–2 h, 2nd ambient temperature: 0–4 °C, time approx. 22 h, to reach an internal temperature no higher than 4 °C in the muscle). The samples were obtained in 9 batches on 9 various slaughter days. For the analysis the longest muscle was selected as it is one of the biggest and most histologically homogenous muscle of the pork carcass (it constitutes 10% of the carcass weight). Most works on the PSE meat concern this type of muscle owing to its high susceptibility to wateriness and color changeability (Karamucki, Jakubowska, Rybarczyk, & Gardzielewska, 2013).

At 45-min post-mortem the pH_1 of the raw material was determined at the area of thoracic vertebra. At the same location electric conductivity (EC_1) was determined at 90-min post-mortem. After the half-carcasses had been cooled for 24 h the pH_2 and EC_2 measurements were retaken at the same location. Then the muscle with a bone was dissected from half-carcasses between 1st and 4th lumbar vertebra (weighing 1000 g) and, then, the EC_3 was measured. Directly after that, using the CIE$L^*a^*b^*$ coordinates and the CVS method, the color of muscles on a freshly cut surface (after 20 min blooming time) dissected from the lumbar side was determined. The raw material classification into quality groups was conducted on the basis of pH_1 and pH_2 readings using the following criteria: RFN (normal meat) $pH_1 > 5.8$, pH_2 5.5–6.0; PSE (exudative meat) $pH_1 \leq 5.8$, $pH_2 \leq 5.5$; DFD $pH_1 > 6.0$, $pH_2 > 6.0$, RSE $pH_1 > 5.8$, $pH_2 \leq 5.5$ (Pospiech, Iwanowska, & Montowska, 2011).

At 48 h post-mortem, in order to give more precise characterization of the raw material, the selected parameters of its technological quality were determined proving the defect or not. To do so, from each sample a slice was cut off (weighing around 100 g, boneless) used for the determination of the drip loss. The remaining part of raw material was deboned and then comminuted in the meat mincer (Diana 886.8, Zelmer, Rzeszów, Poland) equipped with ø 3 mm plate and the water holding capacity (WHC) and thermal drip was measured. The raw material was also described in terms of total heme pigments and the content of basic chemical components (water, total protein, collagen and fat). The captured photos of the analyzed pork muscles underwent image analysis.

2.2. Methods

2.2.1. The pH measurement

The pH values were measured by inserting a spearhead electrode and a temperature sensor of pH-meter CP-411 (Elmetron, Zabrze, Poland) directly into the analyzed raw material. The device was calibrated with two buffers (pH 4 and 7). All measurements were analyzed in triplicates from which an average was calculated.

2.2.2. Electrical conductivity (EC) measurement

The electrical conductivity (EC) was measured using Pork Quality Meter (PQM MT-03, Zakład Techniki Mikroprocesorowej EXE, Poznań, Poland) by inserting its probe into the muscle crosswise to the myocytes. The device was calibrated using a 5 and 20 mS measurement standard provided by the producer (which also provided a PQM).

2.2.3. CIE$L^*a^*b^*$ measurements

The CIE$L^*a^*b^*$ coordinates were determined using a Konica Minolta CM2600d spectrophotometer (Minolta, Wrocław, Poland). The following settings were chosen: illuminant D65, observer 10°, aperture 8 mm, calibrated with a white plate (L^* 99.18, a^*−0.07, b^*−0.05). The measurements were taken on a freshly cut surface of the analyzed muscle samples of the loin after 20-min bloom time at 4–6 °C. All measurements were analyzed in quintuplicate from which an average was calculated. Using a Konica Minolta apparatus the parameters of C^* (Chroma) and h° (hue angle) were calculated based on the a^* and b^* values.

2.2.4. Image capture and analysis

The photos of the meat samples were taken in accordance with the procedure described by Chmiel, Słowiński, and Dasiewicz (2011) and Chmiel, Słowiński, Dasiewicz, and Florowski (2012). Briefly, after 20 min of blooming, the samples were placed in front of a black background at a measurement station and images were taken. Standard conditions for obtaining images were provided: halogen lighting (4 matt bulbs, 18 W each, color temperature of 2800 K, color rendering index of 90–100). Images were obtained using the following camera CANON EOS 350D with an EF-S 60-mm macro lens digital camera (Canon, USA), connected to the computer, vertical position at 500 mm distance between the lens and meat surface and an angle of 45° with the light source. Camera settings were as follow: manual mode with the f/4.0 aperture value, image exposure time 1/100 and ISO 200, zoom and flash off. Images were saved in RAW format. Then, the white balance was corrected and a color profile was selected (Adobe RGB) using Canon Utilities ZoomBrowser EX 5.6 (version 5.6.0.27; Canon).

The processed images were saved in TIFF format and analyzed using Image Analyzer software (developed for the Division of Meat Technology, Warsaw University of Life Sciences, Warsaw, Poland). The detailed operation of this software has been previously described (Chmiel et al., 2011). Information regarding the color and lightness of each particular pixel was acquired from images. The software calculated the average color components of the meat slices for RGB (red, green, blue), HSV (hue, saturation, value), and HSL (hue, saturation, lightness) models.