

## MONITORING OF COLOR AND PH IN MUSCLES OF PORK LEG (*M. ADDUCTOR* AND *M. SEMIMEMBRANOSUS*)

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### ABSTRACT

In order to identify PSE pork meat, pH and color testing was performed directly in a cutting plant (72 hours *post mortem*) in this research. Specifically pork leg muscles *musculi adductor* (AD) and *semimembranosus* (SM) from five selected suppliers (A, B, C, D, E) were examined. Twenty samples of meat for each muscle were examined from each supplier. The measured pH values ranged from 5.43 to 5.63, and the L\* values from 46.13 to 57.18. No statistically significant differences in pH values and color were detected among the various suppliers with the exception of the a\* and b\* parameters for two suppliers, namely A and B (p <0.01). On the contrary, a statistically significant difference (p <0.5) was recorded between individual muscles (AD/SM) across all the suppliers (A, B, C, D, E) with the exception of a\* parameter from suppliers B, C, D, E, and pH values for the E supplier. Our results revealed that individual muscles differ in values of pH and color. In comparison with literature, pH and lightness L\* values in *musculus adductor* point to PSE (pale, soft and exudative) meat, while the values of *musculus semimebranosus* to RFN (red, firm and non-exudative). Use of PSE meat in production of meat products can cause several problems. In particular, it causes light color, low water-holding capacity, poor fat emulsifying ability, lower yield, granular or crumbly texture and poor consistency of the finished product. Therefore classification of the meat directly cutting plant may be possible solution for this problem. The finished product produces from muscles of *musculi semimembranosus* can obtain better quality than the finished product from *musculi adductor*.

**Keywords:** PSE; quality; pork meat; lightness

### INTRODUCTION

In recent years, production of pork has been steadily decreasing in the Czech Republic. Meat processors import cheaper pork meat from abroad (Línková, 2013). This fact entails certain disadvantages, including a high variability in the quality of pork meat. Variations in the quality of raw materials have a negative impact on meat processors and the quality of final products.

The quality of pork meat is defined as a combination of various characteristics of raw and cooked meat (Joo et al., 2013). These characteristics relate to acceptability for consumers and technological aspects, such as color, water-holding capacity, and texture. Biochemical processes that take place in the muscle *post mortem* affect all of these characteristics. The consequence of these biochemical changes is influenced by pH value, which is considered one of the most important factors determining the quality of meat (Van der Wal, Engel and Hulsegge, 1997). Based on the pH of meat and other characteristics, pork can be divided into different quality groups: RSE (red, soft, exudative), PSE (pale, soft, exudative), DFD (dark, firm, dry), PFN (pale, firm and non-exudative), whereas normal pork meat is considered to be RFN (red, firm and non-exudative), (Kazemi et al., 2011; O'Neill et al., 2003; Van de Perre et al., 2010; Chmiel et al., 2011). For pork, the most commonly encountered defect is PSE (Lesiów and Xiong, 2012). Pale, soft and exudative (PSE) pork is a defective product resulting from both

preslaughter and postmortem factors, for example, animal genetics, nutrition, season of the year, stress during animal transportation, and carcass processing and storage conditions (Barbut et al., 2008, Lesiów and Kijowski, 2003 and Scheffler and Gerrard, 2007). Genetic selection and pre-slaughter stress cause rapid postmortem glycolysis that results in increased lactic acid production and decreased pH. Decreased pH combined with high muscle temperature causes protein denaturation that exceeds that observed in normal muscle leading to the production of pale, soft, and exudative (PSE) pork. Because of this protein denaturation, there is an increase in water loss and paleness that is detrimental to product quality (Schilling, et al., 2004). PSE meat has a huge economic impact on both, the supplier as well as meat industry. The paper by Cannon et al., 1996 indicates that 10.2 per cent of carcasses in slaughterhouses are classified as PSE. A more recent study in slaughterhouses shows that the incidence of PSE ranges from 2 to 30% (Owen, 2012). In the research Mlynek et al., (2013) report and compare incidence of PSE in three countries – Slovakia, Netherlands and Hungary. The lowest incidence PSE meat was in the group of pigs imported from the Netherlands (13.8%). The highest frequency of PSE meat in the *musculus longissimus dorsi* (MLD) was in the group of pigs imported from Slovakia (24.13%). From these results can be concluded that the incidence of PSE meat in evaluated groups is relatively high (Mlynek et al., 2013).

At present, there is a prevailing tendency to constantly reduce the incidence of PSE meat and to find reliable detection indicators (pH, color, texture, electrical conductivity, etc.), which might enable detection of this defect already before the processing itself. When PSE meat is separated from material exhibiting standard fresh meat characteristics, the final product reaches better characteristics that are acceptable for consumers (Lesiów and Xiong, 2012).

In literature, the most commonly encountered classification of PSE meat is based on drip loss, lightness value  $L^*$  and pH, e.g. drip loss >6 per cent and  $L^* >50$  for PSE (Ryu et al., 2005). In accordance with Šimek, et al. (2004), meat is considered PSE if characterized by drip loss >5 per cent, lightness  $L^* >50$  (or  $L^* >55$ ), and  $pH_{1h} <5.6$  (Šimek et al., 2004). Other authors identify PSE meat using  $pH_{45}$  (<5.7), whereas normal meat (RFN) reaches  $pH_{24}$  values within the range of 5.5 – 5.8 (O'Neill et al., 2003) and Mota-Rojas, et al., (2006) reports values 5.8 to 6.2.

Use of PSE meat in production of meat products results in several problems. In particular, it causes light color, low water-holding capacity, poor fat emulsifying ability, lower yield, granular or crumbly texture and poor consistency of the finished product (Laville et al., 2005; O'Neill et al., 2003). These issues are described in a wide range of meat products including ham, bacon, dry fermented sausages, finely minced meat products, and smoked meat (Severini et al., 1989; O'Neill et al., 2003). Young, (1996) stated that customers will not buy a gray, wet product, and that appearance of pork is the most important attribute to the consumer. The authors compared here the functional properties of finished products, using PSE and normal (RFN) meat and report that the PSE raw material produces final products of very low quality, compared with the normal raw material (RFN), (Severini et al., 1989; O'Neill et al., 2003).

The biggest problem is caused by PSE meat in processing of cooked hams. A defect in hams due to the use of this raw material occurs in 5 – 20% of cooked hams (Minvielle et al., 2001). The basic raw material for cooked hams is meat of pork hind leg composed of several anatomically different muscles. Muscles that are most affected by variations in the quality of meat, include *musculi adductor* (AD), *semimembranosus* (SM) and *biceps femoris* (BF) (Bucko et al., 2012; Hugenschmidt et al., 2010; Laville et al., 2005; Valous et al., 2010; O'Neill et al., 2003). *Musculus adductor* and *m. semimembranosus* are anatomically separated muscles of the top side of pork leg, and they may exhibit different characteristics in the production of cooked hams. Laville, et al., (2005) report that the incidence of PSE meat affects the integrity of white muscle and the so-called PSE zones are limited mainly to AD and the inner parts of SM. It is of prime importance to clearly distinguish the various kinds of PSE, because they differ in important traits such as tenderness or flavour beyond the most evident deficiencies common to all of them. Moreover, as they result from different mechanisms, they require different remedies. Visually, meat from PSE zones resembles serious cases of PSE

induced by high rates of *post mortem* pH fall, as encountered in halothane-sensitive pigs for instance. Overall, meat from PSE-zones and fast pH fall-PSE meat show numerous histological and biochemical similarities, particularly in their protein characteristics (Laville, aetal., 2005). PSE meat can be reliably detected at the slaughterhouse using  $pH_{45}$  or  $pH_1$ , but processors, who purchase the meat from slaughterhouses, do not have this opportunity because they get meat 48 hours or more after the slaughter. Thus, there must be other determination methods applied.

The aim of this study was to evaluate and compare the differences in meat quality from five foreign suppliers based on selected indicators (pH and color) in muscles of pork leg, namely *musculus adductor* (AD), *musculus semimembranosus* (SM), and to evaluate the differences between these two muscles.

## MATERIAL AND METHODOLOGY

### Samples of examined meat

Meat quality monitoring was performed directly in the cutting plant in pork legs (72 hours *post mortem*) from five different suppliers (A, B, C, D, E). Measurement of pH and color were performed in 20 samples of *m. adductor* muscles and in 20 samples of *m. semimembranosus*.

### Measurement of pH and color of meat

Measurement of pH and color of meat was performed directly in the cutting plant. The pH values were measured using a pH-meter of WTW pH 340i (WTW GmBh, Germany) with a needle probe Double Pore (Hamilton Bonaduz AG, Switzerland). The instrument was calibrated to the pH values of 4 and 7 prior to the measurement itself. The pH was determined by inserting the probe into the sample to be analyzed for each of the muscles (AD, SM) at two different points. The color was measured in the CIEL\*a\*b\* system using Minolta CM 2600d spectrophotometer (Konica Minolta, Japan). Instrument calibration was performed on black and white colors. The most commonly used value to measure the quality of color deviation of meat is  $L^*$  – lightness or the values of  $a^*$  – redness and  $b^*$  – yellowness.

Results of the color ( $L^*$ ,  $a^*$ ,  $b^*$ ) and pH measurements were statistically analyzed using Statistica CZ 7 (Statsoft, Czech Republic).

## RESULTS AND DISCUSSION

### pH

Table 1, 2 and Figure 1 shows that the pH values for individual muscles differ. In AD, the measured pH for all suppliers ranged from 5.43 to 5.46 and, in SM, it ranged from 5.56 to 5.63. When comparing the pH of pork meat, pH values for individual muscles were significantly lower in AD ( $p < 0.05$ ) than in SM for suppliers A, B, C, D, with the exception of the E supplier where there was no statistically significant difference between AD and SM. Different characteristics of AD and SM may affect the quality of final products and may cause some defects in them, as described e.g. by Hugenschmidt, et al. (2010).

**Table 1** Comparison of pH and color (L\*, a\*, b\*) of the five selected suppliers in *m. semimembranosus*

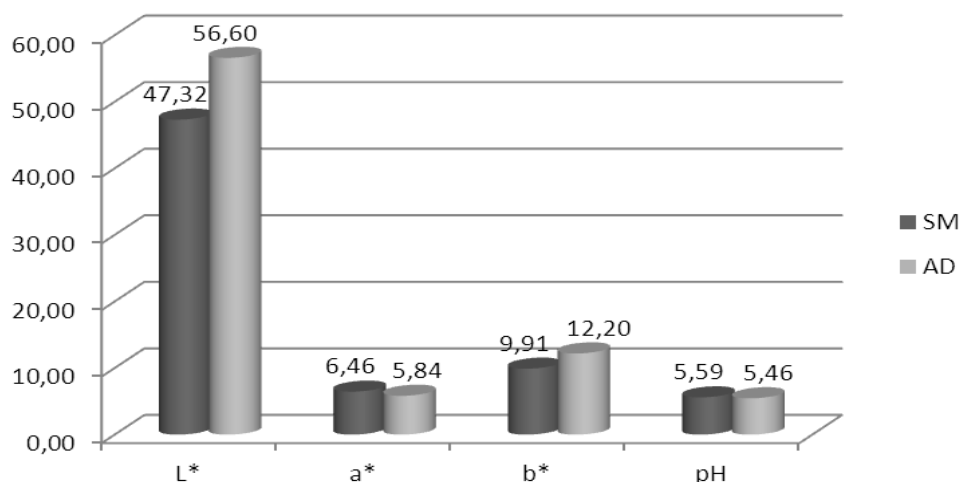
Muscle	Supplier	n = 20	L* (means ±SD)	a* (means ±SD)	b* (means ±SD)	pH (means ±SD)
SM	A	20	47.38 ±2.57 <sup>+</sup>	6.17 ±1.36 <sup>+</sup>	9.53 ±0.99 <sup>+</sup>	5.63 ±0.22 <sup>+</sup>
SM	B	20	46.13 ±3.10 <sup>+</sup>	7.02 ±1.68	9.93 ±1.83 <sup>+</sup>	5.62 ±0.20 <sup>+</sup>
SM	C	20	46.99 ±3.43 <sup>+</sup>	6.53 ±1.99	9.83 ±1.10 <sup>+</sup>	5.59 ±0.17 <sup>+</sup>
SM	D	20	47.56 ±3.59 <sup>+</sup>	6.85 ±1.68	10.12 ±2.06 <sup>+</sup>	5.56 ±0.12 <sup>+</sup>
SM	E	20	48.53 ±3.02 <sup>+</sup>	5.72 ±2.51	10.14 ±2.33 <sup>+</sup>	5.57 ±0.19 <sup>+</sup>

SM – *m. semimembranosus*, L\* – lightness, a\* – redness, b\* – yellowness, SD – standard deviation, <sup>+</sup> p <0.05 significant between AD and SM

**Table 2** Comparison of pH and color (L\*, a\*, b\*) of the five selected suppliers in *m. adductor*

Muscle	Supplier	n = 20	L* (means ±SD)	a* (means ±SD)	b* (means ±SD)	pH (means ±SD)
AD	A	20	56.02 ±3.31 <sup>+</sup>	4.11 ±1.72 <sup>++</sup>	12.26 ±1.56 <sup>++</sup>	5.47 ±0.15 <sup>+</sup>
AD	B	20	56.81 ±3.92 <sup>+</sup>	7.49 ±2.49 <sup>++</sup>	15.26 ±2.43 <sup>++</sup>	5.47 ±0.12 <sup>+</sup>
AD	C	20	57.17 ±3.71 <sup>+</sup>	5.02 ±3.10	13.21 ±2.31 <sup>+</sup>	5.45 ±0.09 <sup>+</sup>
AD	D	20	55.81 ±2.56 <sup>+</sup>	6.85 ±1.68	10.12 ±2.06 <sup>+</sup>	5.43 ±0.06 <sup>+</sup>
AD	E	20	57.18 ±1.83 <sup>+</sup>	5.72 ±2.51	10.14 ±2.33 <sup>+</sup>	5.46 ±0.11 <sup>+</sup>

AD – *m. adductor*, L\* – lightness, a\* – redness, b\* – yellowness, SD – standard deviation, <sup>+</sup> p <0.05 significant between AD and SM, <sup>++</sup> p <0.01 significant between suppliers



**Figure 1** Average value of pH and color (L\*, a\*, b\*) in *musculus semimembranosus* and *musculus adductor*

Comparison of pH values with other works in our case is limited because in focusing on our issue, monitoring of pH, e.g. pH<sub>1</sub>, pH<sub>45</sub> is impossible to be implemented. The meat is available for us 72 hours *post mortem*, so we have to work with this figure. Our results disagree with the work by **Hugenschmidt, et al. (2010)** who measured a higher pH value in AD (5.78) than in SM (5.61) after 72 hours. In the work by **Bucko et al., (2012)**, pH values of 5.72 in AD and 5.73 in SM are reached and there is no significant difference between the muscles as in our results. Values of pH as an indicator of pork meat quality differ in a number of studies and the boundaries between PSE and RFN meat is not uniform (**Chilling et al., 2004;**

**Lesiów and Xiong 2013;** **O'Neill et al., 2003**). For example, **van Laack and Kauffman, (1999)** and **Lien, et al., (2002)**, state that PSE meat has pH<sub>24</sub> below 5.32. According to these authors, we identified the examined meat as normal – RFN from all the suppliers (A, B, C, D, E) with no differences in muscles. However, in some cases muscles exhibit characteristics of PSE even when the pH is relatively high – 5.48, as shown in **Ryu, et al., (2005)**. In a study by **Nam, et al., (2001)**, the PSE meat pH<sub>24</sub> is considered below 5.47 which, compared with our results, corresponds to pH values measured for SM. **Kuo and Chu, (2003)**, on the other hand, report that the average value of pH<sub>24</sub> in PSE meat reaches 5.6 and in RFN 5.96. In

this case, we would classify all the meat, without regard to the differences between muscles, as PSE. The measured pH values for AD and SM correspond to the work by **Chilling, et al., (2004)** wherein the pH ranges from 4.9 to 6.3. These authors also state that all samples with a pH below 5.5 are PSE while samples with a pH above 5.6 are RFN. **Chmiel, et al., (2011)** classifies PSE and RFN meat using a combination of  $pH_{24}$  and lightness  $L^*$ . The average pH value of the meat is described as 5.49 for PSE meat and an average pH of 5.64 points to RFN meat. Furthermore, raw material having a low pH value is characterized by low moisture and high values of proteins as well (**Chmiel et al., 2011**). The work by **Hugenschmidt, et al., (2010)** confirms that the lower the pH, the higher the incidence of defects in the final product. It is necessary to mention that in this work we compared the results of the  $pH_{ult}$  value and the pH measured 72 hours *post mortem*. An important role in the classification of deviations in the quality of meat is also played by pH monitoring during the entire process after the slaughter ( $pH_1$ ,  $pH_{45}$  and pH after 2, 4, 8 hours). This fact is described by **Lesiów and Xiong (2013)**, where the meat was classified as PSE and RFN based on the color and pH, while the final  $pH_{ult}$  here was very similar – ranging between 5.35 and 5.38.

### Color

Color is a significant indicator of the pork quality, because it is one of the most important features influencing evaluation of meat by the consumer (**Valous et al., 2009**). Measurement and subsequent evaluation of color can be done with determining the  $L^*$ ,  $a^*$ ,  $b^*$  values in CIELAB color space and computer image analysis (**Du and Sun, 2004**). The most frequently used methods of detection of PSE meat are instrumental methods, in particular pH measurement in combination with measurement of the color of meat in the CIEL\*a\*b\* system (**van Laack and Kauffman, 1999; Lien et al., 2002; Nam et al., 2001; Kuo and Chu, 2003; Hugenschmidt et al., 2010; Lesiów and Xiong, 2013**). **Scheier et al., (2013)** state that the color ( $L^*$  - value) influences the consumer's purchasing decision more than any other quality factor. On the other hand, tenderness is deemed the most important quality parameter in determining consumer acceptance (**Damez and Clerjon, 2008**). However, tenderness is an inherent property which cannot be estimated visually and which is often replaced by shear force measurements as a physical method (**Scheier et al., 2013**). The muscles investigated in our research reached  $L^*$  values on average from 46.13 to 57.18 (Table 1, 2). No statistically significant difference in the value of  $L^*$  in both investigated muscles was determined among individual suppliers (A, B, C, D, E). A statistically significant difference ( $p < 0.01$ ) was detected in the value of  $a^*$  and  $b^*$  between suppliers A and B. When comparing the values of  $L^*$ ,  $a^*$ ,  $b^*$  between muscles, i.e. between AD and SM (Figure 1), a statistically significant difference ( $p < 0.05$ ) was detected for all suppliers (A, B, C, D, E) with the exception of the  $a^*$  parameter for suppliers A, B, C, D. The most commonly used parameter for the classification of pork meat quality groups (PSE, RFN) is  $L^*$  (**van Laack and Kauffman, 1999; Nam et al., 2001; Lien et al., 2002;**

**Kuo and Chu, 2003; Hugenschmidt et al., 2010; Lesiów and Xiong, 2013**). For SM muscle,  $L^*$  values were measured between the average values of 46.13 to 48.53 and, for AD muscle, these values were statistically significantly higher ( $p < 0.05$ ) ranging between 55.81 – 57.18. When comparing the values of lightness  $L^*$  in SM muscle with other studies, our results are similar. **Scheier, et al., (2013)** report that the average value of  $L^*$  for SM reaches the values of 48.8, **Weschenfelder, et al., (2013)** reported 49.45 and the work by **Hugenschmidt, et al., (2010)** publishes the lightness values  $L^*$  ranging from 47.1 to 48.9 depending on the pH. Our results, however, disagree with the work by **Bucko, et al., (2012)**. Here  $L^*$  for SM reaches higher values of 61.43 than for SM of 40.87, i.e. in comparison with our work, these results are the opposite. In our case, we detected higher values for AD than for SM.

Identification of PSE and RFN meat using the  $L^*$  value by a number of authors is inconsistent, as it is the case of pH values. For example,  $L^*$  values for PSE/RFN (normal) published in literature reach the following values: 55.9/45.1 (**van Laack and Kauffman, 1999**); 61.9/54.6 (**Lien et al., 2002**); 54.9/48.1 (**Nam et al., 2001**); and 51.5/44.8 (**Kuo and Chu 2003**). In accordance with the results of the work by **Chmiel, et al., (2011)**, based on the lightness  $L^*$ , we would include all the investigated SM muscles, regardless of the supplier, among the normal (RFN) and all the AD muscles among the PSE. The author states that meat with PSE characteristics reaches average values of  $L^*$  56.01 and RFN 48.44 (**Chmiel et al., 2011**). This fact is confirmed by the work by **Scheier, et al., (2013)**, which indicates the boundary between the PSE and RFN  $L^*$  50 ( $< 50$  RFN,  $> 50$  PSE) or by the work by **Lesiów, et al., (2013)**, in which the  $L^*$  value for PSE averaged at 56.5 and for RFN at 51.0. These differences demonstrated by experts in PSE meat are attacked by failing to define the PSE meat with similar qualitative characteristics, and to develop ingredients or technologies for utilization of PSE meat. Therefore, it is necessary to continue to focus on this research to generate control samples for fundamental studies (**Chilling et al., 2004**).

### CONCLUSION

During the monitoring of the pork meat quality based on the examination of pH and color, no difference among the various suppliers of pork meat was detected. A statistically significant difference was observed between the individual muscles (*m. adductor* and *m. semimembranosus*) from all suppliers in the examination of pH and color. From the above results, it can be summarized that, in terms of pH and color ( $L^*$  parameter), *musculi adductor* tend to be more PSE compared to *musculi semimembranosus*. The classification of meat based on pH and color directly in the cutting plant would help to separate the low-quality meat. The using of quality raw meat from *musculi semimembranosus* can to obtain finished products with the better properties. The results of this research show, that the quality of meat from suppliers of various Europe countries is on the low level and the detection of PSE meat after 72 hours *post mortem* is difficult. Detection of PSE meat according to pH value and color is possible, but it is

desirable and important rely on the experience of examiner.

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