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Pre-slaughter rectal temperature as an indicator of pork meat quality

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ABSTRACT

This study investigates whether rectal temperature of pigs, prior to slaughter, can give an indication of the risk of developing pork with PSE characteristics. A total of 1203 pigs were examined, measuring the rectal temperature just before stunning, of which 794 rectal temperatures were measured immediately after stunning. pH_{30LT} (*M. Longissimus thoracis*) and temperature of the ham ($Temp_{30Ham}$) were collected from about 530 carcasses, 30 min after sticking. The results present a significant positive linear correlation between rectal temperature just before and after slaughter, and $Temp_{30Ham}$. Moreover, pH_{30LT} is negatively correlated with rectal temperature and $Temp_{30Ham}$. Finally, a linear mixed model for pH_{30LT} was established with the rectal temperature of the pigs just before stunning and the lairage time. This model defines that measuring rectal temperature of pigs just before slaughter allows discovery of pork with PSE traits, taking into account pre-slaughter conditions.

1. Introduction

It is generally accepted that the higher the temperature of the muscle, the higher the lactate production after slaughter (Monin, Lambooy, & Klont, 1995; Kylä-Puhju, Ruusunen, & Puolanne, 2005; Ritter et al., 2009; Weschenfelder et al., 2014), but muscles with type IIB fibers are more affected (Choe et al., 2008), which is also the case for pigs carrying the so-called halothane gene (Guàrdia et al., 2004; Weschenfelder et al., 2014). Thereby, the muscle temperature is influenced by the pre-slaughter handling of pigs (Adzitey & Nurul, 2011; Van de Perre, Ceustermans, Leyten, & Geers, 2010a; Vermeulen et al., 2015a,b). When pigs are acutely stressed just before slaughter, muscles use more energy reserves, metabolism is exothermic, and muscle and body temperature increase. A lower muscle pH, while the carcass temperature is still high, increases protein denaturation and hence, this might result in PSE meat (Adzitey & Nurul, 2011; Bendall & Swatland, 1988; Bertol, Ellis, Ritter, & McKeith, 2005; Garrido, Pedauyk, Bacon, Lopez, & Laencina, 1995; Van der Wal, Engel, & Reimert, 1999). An increased pH decline due to the production of lactic acid can also originate from the ATP hydrolysis, which produces free protons and heat (Scheffler & Gerrard, 2007; Scheffler, Park, & Gerrard, 2011). In literature, the pH was measured 30 min after slaughter in the *M. Longissimus thoracis* (pH_{30LT}) (Van de Perre et al., 2010a). It is a so-called white or glycolytic muscle, which is supplied by blood to a lesser extent than other muscles, making it a reference muscle for measuring the carcass quality as being more sensitive to PSE traits (Estrade, Ayoub, Talmant, & Monin, 1994; Hambrecht et al., 2005). Still, measuring the pH of meat is a very intensive process, as Van de Perre et al. (2010a) and Van de Perre, Permentier, De Bie, Verbeke, and Geers (2010b) indicated. Therefore, it could be appropriate to investigate if meat temperature or body temperature can be used as a possible PSE indicator among other indicators, as Guàrdia et al. (2009, 2012) described.

The variability of deep body temperature in slaughter pigs immediately after transport might range between 38.85 and 39.42 °C (rectal, Ritter et al., 2009), or between 38.7 and 40.6 °C (gastrointestinal tract, Goumon et al., 2013). Interactions with environmental temperature during transport (Fox et al., 2014) or stocking density (Gajana, Nkukwana, Marume, & Muchenje, 2013) were included. Also, the pig's surface temperature was measured with IR-thermography or ear tags, is considered more practical. Brown-Brandl, Eigenberg, and Purswell (2013) reported an average trunk temperature ranging from 32 to 40 °C, with interactions from dry air temperature, but with an intra class variability of 4 °C. The temperature of the ear skin, measured by an ear tag, ranged from 30.6 to 34.2 °C, but also with interactions from the dry air temperature (Andersen, Jørgensen, Dybkjær, & Jørgensen, 2008; Geers et al., 1987). However, the surface temperature of the ocular region, measured just before slaughter with an IR device, was weakly correlated with pH_{30LT} of pork meat, i.e. about −0.18 (Weschenfelder et al., 2014). This means that only 4% of the variability within pH_{30LT} was explained by the variability in the surface temperature of the ocular region. The variability of the color of the *M. Longissimus thoracis* and *M. Semimembranosus* was declared up to 36.34% by the variability in the temperature of these muscles, but was measured 45 min after slaughter.

However, these studies were dealing with a limited number of pigs and mainly in controlled environmental conditions. Hence, it is interesting to know whether or not the association between body temperature,

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muscle temperature and lactate production can be established in a complex real slaughter environment. Developing a method based on a simple measurement of body temperature, can contribute for the meat industry as feed-back information to improve the handling of pigs, and so, their welfare, but also their final meat quality. Estimating the risk of an impaired meat quality, before pigs are slaughtered, makes it possible to anticipate. For example, by adjusting several environmental factors, such as showering or lairage time after arrival at the slaughterhouse, pigs have the ability to recover from stressors (Guàrdia et al., 2012; Santos et al., 1997; Vermeulen et al., 2015a). Thus, improving meat quality could also be very helpful for the pork industry, which is still a growing industry but is subjected to enhanced competition between export countries, e.g., the European level of PSE meat is still 8%. Therefore, further investigations to improve the meat quality are required.

2. Material and methods

2.1. Experimental design

The measurements took place from February 2012 to May 2012, in one Belgian slaughterhouse, using electrical stunning, during 25 days of measurements. The day was randomly selected during the week. The pigs were heterozygous for the halothane or ryanodine receptor gene (Piétrain boar × homozygous negative sow).

2.2. Pre-slaughter measurements

Pigs were unloaded in the lairage pen and were kept in the same group as they were transported. The day of measurement was recorded. The animals were randomly selected during the entire slaughter day and at the end of lairage ($Temp_{RLairage}$), just before stunning, rectal temperature was measured (Thermoval rapid flex, Hartmann, Sint-Renelde, Belgium). Each observed pig was identified on their back with a unique number, by using a spray. Hence, pigs could be individually observed during further pre-slaughter phases. To minimize the stress of the pigs before slaughter, all measurements were carried out according to the following procedure: as soon as the pigs arrived in the lairage pen, people stood in the middle of the pen while remaining immobile until the pigs calmed down. In this manner pigs could adapt to the presence of humans. Vaseline was used to insert the thermometer in order to make the measurements more comfortable for the pigs.

The moment of unloading the pigs, as well as the starting and ending time of the rectal temperature measurements at the end of lairage, and the moment when the pigs were stunned, were recorded. As Guàrdia et al. (2012) established, lairage time is the most influential pre-slaughter handling practice. During lairage, pigs can recover from stress depending on lairage time and environmental stressors during lairage through which their body temperature might change (Guàrdia et al., 2012; Van de Perre et al., 2010b). Consequently, lairage time ($Time_{Lairage}$) and the time used to perform the measurements ($Time_M$) could be calculated. Subsequently, the pigs were moved to the stunning, first in groups, then driven in a row of two pigs and next individually, where pigs were fixed on a conveyor.

2.3. Post-slaughter measurements

Finally, pigs were stunned by a head-to-back electrical stunning and were sticked on an average slaughter speed of 450 pigs per hour. Immediately after sticking, again rectal temperatures ($Temp_R$) of the previous examined pigs, were measured and the pigs were now marked with an ear-tag since the painted unique number did not resist the burning and brushing of the carcasses, whereby each pig was traceable during the post-slaughter process (Table 1).

Due to the speed of the slaughter process, it was not feasible to simultaneously measure the pH and temperature of the same muscles. Hence, 30 min after slaughter, pH (Hanna HI99163, Hanna Instruments, Temse, Belgium) of the *M. Longissimus thoracis* (pH_{30LT}), proposed as reference muscle to detect PSE meat, was measured between the second and the last rib (Estrade et al., 1994; Hambrecht et al., 2005). The pH_{30LT} was measured by using a pH electrode of glass (FC232D, Hanna Instruments). To facilitate the measurements in the muscle, the electrode was enclosed with an unbreakable stainless steel knife. The apparatus was equipped with a built-in temperature sensor to compensate the pH for a change of temperature. Moreover, to obtain accurate pH measurements, a referential method was recommended by Hanna Instruments. At the start of the measurements and after every 20 measurements, the pH electrode was treated with a cleaning solution for oils (HI 7077, Hanna Instruments, Temse, Belgium) and a cleaning solution for proteins (HI7073L, Hanna Instruments, Temse, Belgium). Further, the pH electrode was calibrated by using two standard solutions of pH 7 and pH 4. The electrode was recalibrated if the pH had a deviation of more than 0.01 units. All measurements were performed by the same person, using the identical type of pH electrode and thermometer. When the pH_{30LT} was less than 6.0, the meat was defined as having a risk for PSE traits (Van de Perre et al., 2010b).

The temperature, 30 min after slaughter ($Temp_{30}$) (Testo 105, Testo, Ternat, Belgium) was measured in the ham, as Nanni Costa, Fiego, Dall'Olio, Davoli, and Russo (2002) reported. To standardize the measurements, the site along the slaughter line, which corresponds to 30 min after slaughter, was determined.

2.4. Statistical analysis

Statistical analysis was conducted with SAS (version 9.3, SAS Inst., Inc., USA). First, the data was checked for normality and univariate analysis was performed (means and standard deviations).

The correlations between the $Temp_{RLairage}$ and $Temp_R$ (X, know matrix and β, the unknown vector of the fixed effects) for $Temp_{30Ham}$ (Y, the known vector of observations) and the correlation between $Temp_{30Ham}$, $Temp_{RLairage}$, $Temp_R$, $Time_{Lairage}$ (X) for pH_{30LT} (Y) were examined separately, by using linear mixed models ($Y = X\beta + Zu + \varepsilon$). $Temp_{30Ham}$, $Temp_{RLairage}$, $Temp_R$, and $Time_{Lairage}$ were included in the model as fixed factors (X). The day of measurement was included in

Table 1
Observed continuous pre- and post-stunning variables for each observed pig (N[a]), the mean and the standard deviation (SD).

Phase	Variable		N	Mean ± SD
Pre-stunning	Environmental temperature during lairage in the lairage room (°C)	$Temp_{Lairage}$	1187	8.21 ± 2.23
	Rectal temperature during lairage (°C)	$Temp_{RLairage}$	1203	38.76 ± 0.54
	Time between start and end of the measurement during lairage (min)	$Time_M$	1011	30 ± 9
	Lairage time (min)	$Time_{Lairage}$	1022	135 ± 100
Post-stunning	Rectal temperature just after sticking (°C)	TempR	794	39.05 ± 0.57
	pH of *M. Longissimus thoracis* 30 min after sticking	pH_{30LT}	538	6.16 ± 0.24
	Internal temperature of the ham 30 min after sticking (°C)	$Temp_{30Ham}$	535	40.59 ± 0.71

[a] Number of measured pig carcasses.