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ORIGINAL PAPER

Quality characteristics and chemical composition of the fatteners' meat subjected to electrical and gas stunning*

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Abstract

The study undertook to assess the effect of the method for stunning pigs, housed under equal conditions and transported to meat processing plants over similar distances, on the value of quality characteristics of pork. The experimental animals were divided into two groups that were subjected to a different stunning method, i.e. using electric current (group I) and a high CO_2 concentration (group II). During the bleeding, blood samples were collected from pigs to determine the cortisol concentration, and 45 minutes after slaughter, the pH value was assessed. After cooling the carcasses, meat samples were collected from the lumbar section of the *musculus longissimus dorsi* muscle for laboratory assessment. The most important quality characteristics, namely water-holding capacity, drip loss, thermal drip, and tenderness, were assessed. Additionally, sensory assessment of the meat was carried out. The basic chemical composition of meat was also determined. The study results indicate certain relationships between the meat quality and the selected fattener stunning method. It is worth emphasising that a more favourable colour of meat, lower drip loss, thermal drip, and better texture of meat were found in the group of pigs subjected to gas stunning ($P<0.05$, $P<0.01$). The assessment of pigs' stress based on the blood cortisol concentration did not clearly indicate any of the stunning methods as the one inducing more stress. The differences obtained in this regard were not confirmed as statistically significant. Considering the impossibility of completely eliminating animals' stress at the pre-slaughter stage, it is important to follow appropriate procedures while maintaining proper animal welfare conditions.

Keywords: pigs, stunning method, cortisol concentration, pork quality, basic chemical composition

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INTRODUCTION

When assessing the quality and value of meat, particular attention is paid to the indicators whose reduction results in great and measurable losses. Most of the meat quality distinguishing features being studied are highly interdependent. The muscle tissue before the slaughter of an animal is characterised by a neutral pH value of 7.2 and a high buffer capacity. The onset of bleeding at slaughter initiates the process of biochemical reactions resulting in the transformation of muscles into meat. The lack of oxygen inhibits the course of oxidation processes, which provide biochemically useful energy in the form of ATP within the animal's lifetime. The resulting ATP deficiency intensifies the processes of anaerobic glycolytic reactions until the glycogen stores in the muscle have been exhausted. With gradual and properly progressing *post-mortem* changes in the muscle, the quality of meat will be correct (Bocian et al. 2018). On the other hand, when the animal is exposed to short-term stress, for example during incorrectly conducted pre-slaughter handling followed by slaughter, PSE-type meat (pale, soft, exudative) may be obtained following slaughter. The colour of exudative meat is very light, turns grey quickly, and is not very attractive. In addition, due to its low water-holding capacity and poor texture, such meat is a worse raw material in processing, thus reducing the yield of a finished product (Sionek, Przybylski 2016, Borzuta et al. 2018). Modern pig breeds are characterised by very high meatiness but they are much less adaptable, for example, to environmental conditions during pre-slaughter handling, including transport (Dokmanovic et al. 2015, Goumon, Faucitano 2017). An important point in the pig slaughtering process is a slaughterhouse that is responsible for optimising the animal housing conditions (environmental control, service systems). The task of a slaughterhouse focuses on maintaining appropriate pig welfare conditions and ensuring that carcasses and meat of good and uniform quality are obtained (Faucitano 2018). As a result of long-term pre-slaughter stress in animals, the quality of meat can deteriorate, which is manifested by the occurrence of another quality deviation, i.e. DFD-type meat (dark, firm, and dry). This occurs when the glycogen depletion happens while the animals are still alive, and the resulting lactic acid is transferred from the muscles to the blood (Bocian et al. 2018). Such meat is characterised by good water binding, and with its pH_{24} value being > 6.2, which results in the surface of such meat being quite often sticky due to the easier development of microflora. Societal awareness of how slaughter products are obtained is increasing. Modern consumers demand that animals should be housed and fed under conditions as close to natural as possible, and then subjected to quick and painless slaughter (Lin-Schilstra et al. 2022). It is therefore crucial to bring the animals to the slaughter station in the most stress-free manner possible, deprive them of consciousness by means of stunning, and kill them by bleeding. For the slaughter of swine, electrical or gas slaughter is practically applied. The electronarcosis method (electrical stunning) is commonly applied in small- and medium-sized slaughterhouses. The animal is killed by bleeding (opening of larger blood vessels between the heart and the brain) or by electrocution that causes cardiac arrest. The external symptoms of the proper electronarcosis of mammals (so-called electroshock) or epileptic shock is the induction of a *grand mal* epileptic attack, i.e. a tonicoclonic seizure that occurs in three phases, namely, tonic, clonic, and return to consciousness (Prost 2006, Boniecki, Szymborski 2012, Nielsen et al. 2020). This method uses different techniques: manual using two-electrode devices; manual using three-electrode devices with an additional side electrode; and automatic using high-frequency current and belt restrainers with a two- or three-electrode stunning system (Channon et al. 2002, Channon et al. 2003, Błotnicka-Skrabka 2012). The gas stunning method using CO_2 was developed in the 1950s. It involves the bringing of an animal into a room with a high concentration of carbon dioxide (usually 80-90%), which reacts with haemoglobin contained in the blood, resulting in the formation of carboxyhaemoglobin. As a consequence, haemoglobin is not oxygenated and an oxygen deficit occurs, to which the central nervous system reacts first. The pigs lose consciousness after approx. 15 seconds, with this status is maintained for 1-2 minutes. This enables the performance of sticking and bleeding operations (Channon et al. 2002, 2003, Prost 2006). Two device types are used for pharmacological stunning: periodic or non-stop operation chambers. Bringing the animals to the slaughtering station and carrying out the stunning operation is therefore a critical point where an increased stress response of the pigs occurs. As indicated by the study results, in the muscles of pigs stunned electrically, the pH value decreases faster immediately post-slaughter than in the muscles of pigs stunned using CO_2. This reduces water absorbability of meat, even though the final pH_{24} value is the same for both stunning methods. It is assumed that electrical stunning results in more severe physiological stress in pigs by accelerating the post-slaughter energy metabolism associated with greater muscle activity. Electrical stunning also causes the formation of a larger proportion of haemorrhages and petechial haemorrhages in the meat than gas stunning (Borzuta et al. 2018).

The aspect of obtaining high quality meat while minimising the stress of animals and maintaining their welfare is becoming an important element of the modern meat industry. Hence the validity of the research and the set goal of the study, i.e. the comparison of the effect of the method of stunning pigs, housed under equal conditions and transported over similar distances to meat processing plants, on the quality of the obtained slaughter products.

MATERIALS AND METHODS

Animals and sampling

The study material was the meat of fatteners housed under the conditions of a routine production cycle typical for swine. In view of this housing and production system, the study required no approval of the Local Animal Research Ethics Committee (Directive 2010/63/EU).

The experiment involved 50 hybrid fatteners housed on a farm. The fattening was carried out under equal housing conditions in accordance with the welfare requirements (Council Directive 2008/120/EC). The animals were fed *ad libitum* with complete feed mixtures of the same composition supplied from automatic feeders according to the standard requirements (Grela and Skomiał 2020), with constant access to water provided. Once the fattening was completed, at average fatteners body weight 116 ± 8 kg, the animals were transported to two slaughterhouses using different stunning methods, located approx. 15 km from the fattening house. The animals were slaughtered in accordance with the procedures in force, following a pre-slaughter rest period (Regulation of the Minister of Agriculture and Rural Development 2004). The first group of 25 individuals was subjected to stunning by a method using electric current, while the second group of 25 individuals was subjected to stunning using a high CO_2 concentration. In the first method of stunning pigs, a microprocessor power supply for electronarcosis of animals ENZ 2010, produced by E-Projekt Bydgoszcz was used. The average value of the applied electric current was 1.35 A. In the case of gas stunning, the minimum CO_2 concentration was 85% with an application time of 120 s. A BANSS gas installation was used. The slaughter was carried out in accordance with the applicable procedures (Nielsen et al. 2020, Council Regulation 1/2005/EC 2004, Council Regulation 1099/2009/EC 2009).

Blood and meat analysis

Immediately after the application of the stunning methods, during the bleeding of pigs, blood samples were collected into test tubes and then transported under refrigerated conditions to the laboratory in order to determine the cortisol concentration. Standard laboratory assessment methods were applied. The non-anticoagulated blood was centrifuged at 3,000 rpm for 10 min to separate the serum. The serum samples were collected into microtubes and stored at −20°C until the cortisol concentration was determined by immunoassay.

The acidification of muscle tissue at 45 min post-slaughter (pH_{45}) and at 48 h post-slaughter (pH_{48h}) was determined using an Elmetron CP-401 pH-meter with a blade electrode. The equipment was calibrated using Elmetron pH 7.0 and pH 4.0 buffers.

After cooling the carcasses (24 h post-slaughter), meat samples were collected from the lumbar section of the *musculus longissimus dorsi* muscle, and then stored at a temp. of 4-6°C. After the next 24 h (48 h post-slaughter), the meat samples were subjected to laboratory assessment.

Water-holding capacity (WHC) was determined using the method developed by Grau and Hamm (Grau, Hamm 1952) with the specific procedure outlined by Szmańko and Górecka (2014). A 300 mg sample of minced meat was placed on a Whatman 1 filter paper and put between two glass plates; then an even load of 2 kg was applied to it for 5 minutes. The area of juice infiltration was used to calculate the percentage of free water content in the meat, assuming that 1 cm^2 of infiltration corresponds to 10 mg of water. The surface of meat juice infiltration was measured using a LUCIA computer analysis system (System for Image Processing and Analysis, version 4.82.2004). Drip loss was determined according to the Honikel method (1987). To this end, the slice of meat with a thickness of approx. 2.5 cm, collected during the carcass cutting, was placed along with the perimysium in a plastic bag, and weighed. An incision was made in the lower part of the bag in order to enable the outflow of meat juice. The sample was then placed in another bag, so that the leaking juice does not come into contact with a meat slice and stored in a hanging position at a temperature of +2ºC for 48 hours. Afterwards, the samples were weighed again, and the amount of juice flowed out from the muscle tissue, expressed as a percentage, was calculated from the difference in weight.

Thermal drip was determined at 48 h post-slaughter using the method developed by Walczak (1959). A sample of minced meat (20 g) was placed in a hygroscopic gauze and heated in a water bath at a temperature of 85°C for 10 min. After taking the sample out of the water bath, the gauze was removed, then the sample was cooled to a temp. of 4°C and weighed. Based on the difference in weight before and after the heat treatment, the percentage weight loss was calculated.

Shear force was measured using INSTRON 3342 strength testing equipment with a Warner-Bratzler attachment (WBSF), in accordance with the methodology provided by Szalata et al. (1999). A 120 g meat sample was heated in a water bath until the sample reached a temp. of 70°C on the inside. The heat treatment was performed in a 0.85% NaCl solution. Then, 10 mm × 10 mm bars were cut along muscle fibres, which were subsequently cut perpendicularly to the muscle fibres. The results were read as maximum shear force expressed in N.

The chemical composition of the meat, i.e. water, total protein, and intramuscular fat and collagen contents, was determined in accordance with Polish Standard (PN-A-82109:20-10) with near-infrared transmission spectroscopy (NIT) using calibration on artificial neural networks (ANN) with FOSS FoodScan equipment.

Visual and tactile evaluation was determined 48 h post-slaughter on a slice of raw meat weighing 120 g. Visual and tactile assessment of the meat was carried out by a trained 10-person team. All evaluators had 4 years of experience in assessing pork. Visual properties of the raw meat were assessed: visual colour intensity according to a 6-grade scale [PN-ISO 4121:1998) on which 1 – very light, 6 – dark purple; marbling based on Canadian and American models on a 10-grade scale (Cheng et al. 2015; NPPC 1999) where 1 – no intramuscular fat content, 10 – very high marbling. Tactile evaluation of firmness was conducted on a 7-grade scale (PN-ISO 4121:19098) where 1 – very firm, 7 – very soft.

Meat colour was also measured on a slice of raw meat at 48 h post-slaughter using a Minolta CR 310 photocolorimeter (Konica Minolta, Japan) with a measuring port diameter of 50 mm. The equipment was standardised using a CR310 white calibration plate with the following coordinates: Y = 92.80, x = 0.3175, and y = 0.3333. Colour parameters were determined by the CIE system, L*a*b* (L* – lightness, a* – participation of red, b* – participation of yellow) (CIE 1986), using illuminant D 65 and a standard 2° observer.

Statistical analysis

The results were statistically analysed. The arithmetic mean and the standard error (SEM) were calculated. Data were verified for homogeneity of variance using the Levene's test. In the absence of homogeneity of variance, statistical significance between groups was calculated using the Student's *t*-test. A probability of $P<0.05$ was considered statistically significant. The Pearson's simple correlation coefficients were calculated. Correlation coefficients were estimated based on pairs of observations: the cortisol level of pigs stunning with different methods and the meat quality parameters. All calculations were conducted using Statistica PL.13.3 data analysis software (Statistica 2019).

RESULTS AND DISCUSSION

The data regarding the concentration of cortisol in blood, technological properties and chemical composition of meat in relation to the stunning method are shown in Table 1. The livestock stress level can be determined by testing the concentration of glucocorticosteroids which include the hormones cortisol, corticosterone, and cortisone. Cortisol, produced in the adrenal cortex, is a crucial hormone that is secreted as a result of stress factor impact and it increases blood glucose levels. By increasing the glucose levels in the blood, it helps stimulate the body to action (Timmermans et al. 2019, Wiechers et al. 2021). The study demonstrated, as shown by data in Table 1, based on the cortisol content in the blood collected at the bleeding stage, that the stress levels noted in the group of pigs stunned by the electrical method

Table 1

Concentration of cortisol in blood, technological properties and chemical composition of meat in relation to the stunning method

Trait	Group – stunning method			
	I	II	SEM	$P <$
	electrical	gas		
Number (n)	25	25		
Cortisol (μg dl^{-1})	12.72	13.34	0.585	0.602
pH_{45}	6.37	6.37	0.029	0.967
pH_{48h}	5.44^{b}	5.39^{a}	0.012	0.047
WHC (% of free water)	16.97	15.41	0.045	0.080
Drip loss (%)	4.17^{B}	2.42^{A}	0.201	0.000
Thermal drip (%)	22.60^{A}	20.78^{B}	0.352	0.008
WBSF (N)	36.19	37.84	0.827	0.324
Chemical composition of meat				
Water content (%)	72.52	72.31	0.071	0.144
Total protein content (%)	25.02	24.79	0.073	0.107
Intramuscular fat (%)	1.26	1.34	0.083	0.161
Collagen (%)	1.44	1.47	0.010	0.131

$^{(a\text{-}b)}$ Row means with different superscripts differ significantly at $P<0.05$, $^{(A\text{-}B)}$ row means with different superscripts differ significantly at $P<0.01$,
pH_{45} – pH at 45 min post-slaughter, pH_{48h} – pH at 48 h post-slaughter,
WHC – water-holding capacity, WBSF – Warner Bratzler shear force (N - Newton).

(two-electrode forceps) and of pigs stunned by the gas method (using a high CO_2 concentration) were very similar (statistically insignificant). As demonstrated by Dokmanovic et al. (2015), and Koomkrong et al. (2017), stunning is a stress factor for animals, which affects, to a lesser or greater extent, the levels of the hormone in question. Electrical stunning is regarded as a more stressful method for pigs than stunning using a high carbon dioxide concentration. It causes severe physiological stress and accelerates post-slaughter energy metabolism, which results in greater activity of the muscles and increased release of catecholamines into the blood (Hambrecht et al. 2004). This study showed no differences in terms of the cortisol concentration in the blood of fatteners subjected to stunning by electrical and gas methods. Reactivity to stress is presumed to be an individual trait, with each pig having an individual, specific range of values within which the occurring stress parameters may vary (Stajković et al. 2017). They also report that there is no consistent relationship between the stress parameters and the meat quality, and emphasise that the relationships between the cortisol level and stress, and between the cortisol level and the quality parameters of meat, are not linear.

The characteristics of the technological properties of meat and its chemical composition in relation to the fattener stunning method applied are provided in Table 1. The results concerning the pH value of the meat and its capacity for holding water in its structures indicate meat of good quality, i.e. free from deviations. The meats obtained from the two groups of fatteners were characterised by equal degrees of acidification as measured 45 min post-slaughter. However, a lower pH value as measured 48 h post-slaughter was noted for the meat of fatteners stunned by the gas method ($p<0.05$). The obtained values reached a level typical of good meat quality. The effect of the pig stunning method applied on both the technological quality and that perceived by consumers is a widely discussed topic. Pork must satisfy the criteria for food that is safe for health and of high processing value. Sionek and Przybylski (2016) indicated in their study that in terms of physicochemical characteristics, stunning pigs using electric current decreased the pH value of the obtained meat. Other researchers made similar observations (Marcon et al. 2019, May et al. 2022, Zybert 2022). On the other hand, the experiment in question, involving electrical stunning, obtained a higher pH_{48} value indicating a slower rate of the glycolysis process (Sieczkowska et al. 2017). Jerez-Timaure et al. (2020) point out the identical pH value of pork 24 h post-slaughter, regardless of the stunning method selected. This confirms the results of the study by Channon et al. (2002), who observed that in the muscles of electrically stunned pigs, the pH value decreases more quickly post-slaughter, but 24 h later the level of this indicator is equalised.

The water-holding capacity, i.e. as reported by Szmańko et al. (2021), the ability of meat to hold water during the application of force and/or processing, and thermal drip are very important parameters for the meat industry. In the groups of pigs being studied, rather low and equal water-holding capacity (WHC) values of the meat were noted. This may indicate the capacity for holding meat juice in the meat structures, and the capacity for absorbing additional amounts of water. It should be noted that this is a very important characteristic in meat processing. The differences in the products obtained were observed for the drip loss and the thermal drip levels. The meat of fatteners subjected to electrical stunning was characterised by a considerably higher value of this component ($P<0.01$). Changes occurring post-slaughter affect water absorbability of fresh meat. A rapid decrease in the pH value at elevated temperatures will contribute to protein denaturation, thus causing the outflow of meat juice. It should be noted that the higher the capacity for holding the muscle juice and the lower the drip loss and thermal drip levels, the higher the pork quality will be (Kuczyńska 2022). Hambrecht et al. (2004) point out that electrical stunning reduces water absorbability of meat. The authors' own study confirmed this relationship with respect to a much greater drip loss and thermal drip from pigs' meat specifically after electrical stunning. A greater loss of meat juice in connection with this method was also noted by Channon et al. (2002) and

Marcon et al. (2019). A study described by Faucitano (2010) noted a greater drip loss when applying the electrical stunning method. Channon et al. (2003) compared the two stunning methods (electrical and gas), and additionally applied different electric current intensities. Regardless of the intensity value, the meat of pigs stunned using CO_2 led to a clearly lower drip loss level.

The tenderness of meat is determined, to a large extent, by the course of the processes occurring post-slaughter, associated with the so-called meat tenderisation, which is affected inter alia by the gradual depletion of available energy and the change from aerobic metabolism to anaerobic (Florek et al. 2016). Under this study, the assessment of meat tenderness was conducted by the sensory and instrumental method using a strength-testing device. The tenderness assessment showed that the maximum force needed to cut through the muscle fibres (Warner-Bratzler Shear Force, WBSF) was typical of the pork meat assessed at that time (48 hours post-slaughter). The values obtained in both groups were equal, ranging from 36 to 38 N.

The studies that obtained similarly equalised values for this characteristic for the groups of pigs stunned were conducted by Channon et al. (2003) and Zybert (2022). Therefore, one can expect a significant impact on the value of this parameter of post-slaughter handling of carcasses, rather than the factors resulting from the pre-slaughter handling of pigs.

Meat is a product comprising numerous chemical compounds whose amount and mutual ratios determine its nutritional value, digestibility, availability, organoleptic characteristics, and technological suitability. The basic analysis of meat focused on water, protein, fat, and collagen contents (Table 1). The water, protein, and collagen contents in the groups of fatteners subjected to a different stunning method were equal. At the same time, it is worth noting the relatively high protein content of almost 25%, and the collagen content of almost 1.5%. Slightly different results in terms of the intramuscular fat content were noted for the two groups (1.34% for group II, and 1.26% for group I), however without being confirmed as statistically significant. Pork is a source of wholesome protein, whose content ranges from 20 to 25%, with a low fat content in the *longissimus lumborum* muscle (Bodnárné Skobrák et al. 2011, Paura et al. 2019, Alam et al. 2022). Regardless of the stunning method, these values are repeatable. This is confirmed, for example, by the results of this study and the results obtained in an experiment conducted by Alam et al. (2022). The latter experiment employed three stunning methods: electrical, using carbon dioxide, and using nitrogen, and noted, in each group of pigs, equal contents of the components in question except water, whose content was the highest in the meat of pigs stunned using electricity.

An important aspect in the consumer's assessment of meat is its colour and texture (Table 2). The visual assessment of the meat, carried out by a team of assessors, indicated a similar quality in terms of colour and

Table 2

The results of visual and tactile evaluation of meat and its colour in relation to stunning method

Trait	Group – stunning method			
	I	II	SEM	$P <$
	electrical	gas		
Visual and tactile evaluation				
Visual colour intensity (1-6 scale)	3.6	3.6	0.040	0.977
Marbling (1-10 scale)	1.8	1.8	0.079	0.840
Firmness (1-7 scale)	4.1^{A}	4.4^{B}	0.061	0.010
Colour measurements				
L^*_{48}	51.57^{a}	51.20^{b}	0.253	0.040
a^*_{48}	15.21	15.17	0.110	0.877
b^*_{48}	3.24	3.12	0.107	0.588

$^{(A\text{-}B)}$ Row means with different superscripts differ significantly at $P<0.01$, $^{(a\text{-}b)}$ row means with different superscripts differ significantly at $P<0.05$,
L* value represents lightness, a* share of red, b* share of yellow.

marbling intensity, where the same scores were assigned in the two fattener groups being studied. These results imply an appropriate, eye-pleasing colour ranging from light reddish pink to reddish pink. Slight marbling was also visible, manifested by a very slight overgrowth of the fat tissue, which is typical of the meat of fast-growing fatteners. This assessment demonstrated the variation of the meat under analysis in terms of its firmness. Fatteners subjected to electrical stunning were characterised post-slaughter by very soft meat compared to the meat obtained from fatteners stunned using a high CO_2 concentration ($P<0.01$), thus falling within the limits considered to be standard.

In a further part of the assessment, the meat colour parameters were analysed following the instrumental assessment using a photocolorimeter. The lightness of colour (L^*_{48}), being one of the physicochemical characteristics of meat, is an important indicator of its quality. In this experiment, the meat obtained from both groups of animals was characterised by the lightness typical of pork. At the same time, it was demonstrated that fatteners from group II were characterised by darker, i.e. more favourable, meat ($P<0.05$). The proportion of red (a^*_{48}) and yellow colour (b^*_{48}) was appropriate and similar in both groups under assessment. Many authors dealing with this issue demonstrated that the effect of the stunning method is also evident in terms of raw meat colour parameters. It was observed that meat was lighter in colour, with a greater proportion of red and yellow colours, as a result of electrical stunning (Marcon et al. 2019, Alam et al. 2022, Zybert 2022). The current study confirmed these relationships.

The analysis of the relationship between the cortisol level in pig stunning method applied in the experiment and the technological properties of the meat samples were shown in Table 3. The results indicate significant correlations between the concentration of cortisol in the blood of electri-

Table 3

Correlation coefficients between cortisol level in pig groups stunning with different methods and technological properties of meat

Trait	Cortisol level	
	group I	group II
pH_{45}	0.229	-0.281
pH_{48h}	-0.271	-0.444*
WHC (%)	-0.093	0.296
Drip loss (%)	0.025	-0.262
Thermal drip (%)	-0.130	-0.029
WBSF (N)	0.196	-0.526**
Water content (%)	0.436*	-0.093
Total protein content (%)	-0.233	0.051
Intramuscular fat (%)	-0.140	0.136
Collagen (%)	0.101	0.014
Visual colour intensity (1-6 scale)	0.002	0.082
Marbling (1-10 scale)	-0.311	-0.165
Firmness (1-7 scale)	-0.212	0.053
L^*_{48} – value represents lightness	0.295	0.094
a^*_{48} – a proportion of red	-0.270	0.176
b^*_{48} – a proportion of yellow	0.083	-0.111

* Statistical significance at P<0.05, ** statistical significance at P<0.01,
pH_{45} – pH at 45 min post-slaughter, pH_{48h} – pH at 48 h, post-slaughter,
WHC – water-holding capacity, WBSF – Warner Bratzler shear force (N - Newton),
L* value represents lightness, a* share of red, b* share of yellow.

cally stunned pigs and the water content in the analysed meat (P<0.05). As regards other characteristics of meat quality and chemical composition, no significant relationships were noted for this pig stunning method. In turn, the assessed correlations between the cortisol concentration in the blood of gas-stunned animals and meat quality characteristics showed an impact on the degree of muscle tissue acidification measured 48 hours after slaughter, as well as on the tenderness assessed using apparatus (P<0.05 and P<0.01, respectively).

Meat is an important component of the human diet that provides inter alia proteins of high biological value. Obtaining good quality pig carcasses and meat is a guarantee of the high quality of meat products. When assessing the quality and value of meat, particular attention is paid to the indicators whose reduction results in great and measurable losses. Pre-slaughter stress of animals has a considerable effect on the carcass and meat quality, and the delivery of fatteners to meat processing plants is associated with adverse impact on numerous environmental factors. This may result in a reduced carcass value due to severe skin lesions, body weight loss, and meat quality defects resulting from abnormal post-slaughter acidification of the muscles (Faucitano 2018). Therefore, reducing stress factors at that time is becoming one of the most important measures taken in relation to pigs directed for slaughter (Goumon, Faucitano 2017). In addition to the conditions during transport or the time spent in the lairage, the use of a specific fattener stunning method can contribute to the stress level and the related quality of the obtained pork as well (Marcon 2019, Purnama et al. 2020, May et al. 2022).

CONCLUSIONS

Pre-slaughter handling of animals as well as performing proper stunning and slaughtering are important elements in achieving good quality of slaughter products. Pigs are particularly sensitive to pre-slaughter handling stress. In view of the significance of animal welfare both at the stage of production and in pre-slaughter handling, the study undertook to assess the effect of the method for stunning pigs, housed under equal conditions and transported over a short distance to meat processing plants, on the quality characteristics of pork meat. The study results show that following the application of the electrical stunning method, the meat of fatteners exhibited a considerably greater, unfavourable drip loss, thermal drip, and a worse texture. On the other hand, following the application of the stunning method using a high CO_2 concentration, a darker, and therefore a more favourable, colour of the meat was obtained. At the same time, no relationship was demonstrated between the stunning method and the stress level of pigs as measured by the cortisol level in the blood collected during bleeding. This may indicate the individual predisposition and psychophysical resistance of the individual under stress conditions. Considering the impossibility of completely eliminating animals' stress at the pre-slaughter stage, it is important to follow appropriate procedures while maintaining proper animal welfare conditions.

Author contributions

R.P. – conceptualisation, methodology, investigation, statistical analysis, resources, writing-original draft preparation, writing- review and editing; A.Z. – methodology, investigation, resources; A.C. – methodology, investigation, statistical analysis, resources, writing-review and editing; H.J. – conceptualisation, methodology, investigation, statistical analysis, resources, writing-original draft preparation, writing – review and editing, supervision.

All authors have read and agreed to the published version of the manuscript.

Conflicts of interest

The authors ensure that they have neither professional nor financial connections related to the manuscript sent to the Editorial Board

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