Ciência Rural, Santa Maria, v.53:12, e20220678, 2023 http://doi.org/10.1590/0103-8478cr20220678
ISSNe 1678-4596
ANIMAL PRODUCTION

Pre slaughter factors in pigs on initial pH and temperature: a case study

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ABSTRACT: This study evaluated factors associated with the pre-slaughter handling of pigs in a commercial slaughterhouse located in Minas Gerais and evaluated the influence of these factors on the initial pH and temperature of the carcasses. In all, 4449 carcasses were evaluated. The factors evaluated were transport distance, transport duration, loading density, fasting duration, resting duration, average weight of the animals, average temperature in the resting area, and maximum temperature in the resting area. The effects of these factors on the initial (i.e., at 45 minutes after slaughter) temperature and pH (pH_{45}) were measured. The pH_{45} values were used to determine the occurrence of PSE; the carcasses were classified as PSE when they presented a $pH_{45} < 5.90$. Results showed that animals fasted for more than 24 hours were more likely to result in PSE meat (1.41 times more likely), as did animals that were exposed to an average temperature above 24 °C (1.52 times more likely). Except for the average weight of the animals, which did not affect the initial temperature values, all other pre-slaughter factors have influenced both pH_{45} and the initial temperature values, and the difference of fasting duration and the temperature in the resting area increase the incidence of PSE meat.
Key words: preslaughter management, pH, PSE.

Influência de fatores do pré-abate de suínos sobre o pH e temperatura inicial: estudo de caso

RESUMO: O estudo foi realizado com o objetivo de avaliar fatores associados ao manejo pré-abate de suínos em um abatedouro comercial localizado em Minas Gerais e sua influência sobre o pH inicial e temperatura das carcaças. Ao todo, foram avaliadas 4449 carcaças. Os fatores considerados na avaliação foram: distância de transporte, tempo de transporte, densidade da carga, tempo de jejum, tempo de descanso, peso médio dos animais, temperatura média na área de descanso e temperatura máxima na área de descanso. Para avaliar os efeitos desses fatores foram mensurados a temperatura e o pH inicial aos 45 minutos (pH_{45}). Os valores de pH_{45} foram considerados para determinar o índice de predisposição para ocorrência de PSE já que as carcaças foram classificadas como PSE quando apresentaram valor de $pH_{45} < 5,90$. Os resultados encontrados mostraram que os animais com tempo de jejum acima de 24 horas, apresentaram maior probabilidade para ocorrência de carne PSE (1,41 vezes), assim como, aqueles que foram expostos a temperatura média acima de 24°C na área de descanso com probabilidade de 1,52 vezes. Em relação a temperatura inicial e pH_{45}, com exceção do peso médio dos animais, os demais fatores pré-abate analisados influenciaram os valores destes parâmetros, sendo que o tempo de jejum dos animais e a temperatura média da área de descanso promoveram aumento na incidência de carne PSE.
Palavras-chave: manejo pré-abate, pH, PSE.

INTRODUCTION

Pork is the most consumed animal protein worldwide, and Brazil ranks fourth in pork production and exports. The quality of pork has multifactorial aspects, including sensory quality, nutritional value and technological quality. The development of technological solutions related to the management, feeding and nutrition of animals, combined with their genetic characteristics, directly influences the composition of the meat and the biochemical changes inherent to the transformation of muscle into meat, which impact the sensory characteristics, nutritional value, losses during preparation or industrialization and the stability of products during shelf life (EMBRAPA, 2022; RAMOS & GOMIDE, 2017).

Pre-slaughter handling stands out as a major influence in the quality of meat (DOKMANOVIC et al., 2014; DRISSEN et al., 2020; SALMI et al., 2012) and several authors have noted that stressful factors trigger changes in muscle biochemistry, which manifest as quality defects,

Received 12.15.22 Approved 02.25.23 Returned by the author 04.19.23
CR-2022-0678.R1
Editors: Rudi Weiblen Gabriel Augusto Marques Rossi

resulting in a product with altered physical, chemical and sensory properties (GARCÍA-CELDRÁN et al., 2012; LAWRIE, 2005; RAMOS & GOMIDE, 2017; SALMI et al., 2012; SANTIAGO et al., 2012). This management begins on the farm with the separation of animals for slaughter, followed by fasting, loading, transport, unloading at the slaughterhouse, resting duration, and movement until stunning and bleeding (COBANOVIC et al., 2020; DALLA COSTA et al., 2010; LUDTKE et al., 2010; MARZOQUE et al., 2020; SANTIAGO et al., 2012; SILVA et al., 2014).

One of the main challenges of the meat industry (especially the pork industry) is the occurrence of Pale, Soft and Exudative (PSE) meat (TREVISAN & BRUM, 2020); such meat is undesirable because, in addition to being rejected by consumers, it impairs the industrial manufacturing processes, causing considerable economic losses (CALDARA et al., 2012; MOURA et al., 2015; RAMOS & GOMIDE, 2017). The measurement of the initial temperature and pH (at 45 minutes after slaughter – pH_{45}) are an important tool for predicting defects that can compromise the quality of meat because they can be linked to changes in color, texture (tenderness and juiciness, for example) and water retention capacity; these factors related to PSE meat, in addition to industrial yield, shelf life and nutritional value, emphasize the importance of these parameters being monitored and controlled in the meat industry (LIMONI et al., 2017; RAMOS & GOMIDE, 2017; SILVA et al., 2014).

Although, parameters previously described in the literature (initial temperature and pH_{45}) and their importance have been emphasized, there is still a lack of awareness of the potential of using these parameters as a tool for establishing management plans and directions, especially since these factors happen together and they can contribute more or less to specific problems depending on the region.

Thus, this study evaluated the temperature and pH of pig carcasses at 45 minutes after slaughter (pH_{45}) and to estimate the occurrence of PSE carcasses as a function of factors related to the pre-slaughter handling of pigs in a commercial slaughterhouse.

MATERIALS AND METHODS

The study was conducted in a commercial swine slaughterhouse with a daily slaughter capacity of 700 animals under supervision of the Federal Inspection Service (SIF), located in the municipality of Lavras, Minas Gerais. Data collection occurred from December 2021 to February 2022.

Site characterization, adopted practices, and data collection

The data collected and analyzed came from the routine activities developed in the processing plant during the summer, and the initial pH and temperature evaluations were performed on the pig carcasses *post mortem*. In the slaughterhouse, the animals were kept in covered resting pens with a density of 0.6 m^2/animal and variable resting duration with free access to water, ensuring that at least 15% of the animals in each pen could drink water simultaneously, as recommended by Decrees 711 and 365 (BRASIL, 1995; BRASIL, 2021).

The animals came from commercial farms and were submitted to a fasting period with free access to water; this information was stated in the health bulletins that accompanied the batches. The animals were loaded into compartmentalized trucks (cage-type trucks) and transported to the slaughterhouse, traveling from 3.5 to 419 km.

The resting and fasting duration were defined according to the time of feed withdrawal stated in the health booklet and the time the animals arrived at the slaughterhouse. In the resting pens, lot separation was maintained according to the origin of the animals.

At the time of slaughter, the animals were led in batches to the spray shower with hyper-chlorinated water (minimum 5 ppm), where they remained for at least 3 minutes and were then individually led to the stunning box that used a syringe. In the stunning box, the pigs were stunned using the electrical stunning method (electronarcosis) and then bled on the bleeding table, with no more than 15 seconds between stunning and bleeding, according to Decrees No. 365 (BRASIL, 2021).

The information of each lot was obtained through a structured form that was previously sent to all producers to assess the following: distance from the farm to the slaughterhouse, date and time of feed withdrawal at the farm, truck specifications, date and time of the start and end of loading, time of farm departure and arrival at the slaughterhouse, and date and time of the start and end of unloading. The forms were returned to the slaughterhouse along with the corresponding load of pigs.

The temperature in the resting pens was collected using a temperature data logger (USB Data Logger Series JDL 11, Faytech Technology Comércio de Serviços Ltda, resolution 0.1 °C/accuracy ± 0.5 °C/temperature: -35 to 80 °C, São Paulo, Brazil).

Analyzed variables and sample size

The following independent variables were assessed:

A - Transport distance between the farm and slaughterhouse, which was divided into four levels:

up to 100 km (n= 765), between 100 and 200 km (n=1936), between 201 and 300 km (n=1340) and over 300 km (n=408);
B - Animal transport duration from the farm to the slaughterhouse, which was divided into five levels: up to 3 hours (n=109), between 3 and 6 hours (n=808), between 6.1 and 9 hours (n=2120), between 9.1 and 12 hours (n=1372) and over 12 hours (n=40);
C - Loading density of pigs in the truck, which was divided into four levels: below 0.35 kg/m^2 (n = 1391), between 0.35 and 0.40 kg/m^2 (n = 1510) between 0.41 and 0.45 kg/m^2 (n = 1065) and above 0.45 kg/m^2 (n = 483);
D - Total fasting duration of the animals until slaughter, which was divided into two levels: up to 24 hours (n=2561) and over 24 hours (n=1888);
E - Resting duration of the animals until slaughter, which was divided into five levels: up to 3 hours (n=168), between 3 and 6 hours (n=863), between 6.1 and 9 hours (n=1420), between 9.1 and 12 hours (n=1552) and over 12 hours (n=446);
F - Average weight of live pigs, which was divided into four levels: below 100 kg (n=454), between 100 and 110 kg (n=1830), between 110.1 and 120 kg (n=1886) and above 120 kg (n=279);
G - Average temperature in the resting stalls, which was divided into two levels: up to 24 °C (n= 2159) and above 24 °C (n=2290);
H - Maximum temperature in the resting stalls, which was divided into four levels: below 24 °C (n=190), between 24 and 28 °C (n=1774), between 28.1 and 32 °C (n=1854) and above 32 °C (n= 631).

The initial pH, carcass temperature, and occurrence of PSE were the dependent variables and were obtained by measuring a total of 4449 pig carcasses, which had an average live weight of 109.09 ± 7.19 kg and came from 138 lots of animals.

Analysis of pH and carcass temperature and estimation of PSE occurrence

Measurements of the pH (pH_{45}) and temperature of the carcasses were performed 45 minutes after slaughter. For the measurement of pH and temperature of the carcasses, a portable measuring instrument with a pH measuring tip combined with a temperature probe (Testo 205, Testo AG, Lenzkirch, Germany) was used, inserted at a depth of 3 cm, perpendicular to the muscle. The measurement was performed in the *semimembranosus* muscle of the right half of the carcass.

Statistical analysis

Statistical analyses were performed using the *Statistical Package for the Social Sciences* (SPSS) software, version 20.0. The quantitative dependent variables (pH and carcass temperature) were compared between the levels of the independent variables (transport distance, transport duration, loading density, fasting duration, resting duration, average weight, average temperature in the resting area and maximum temperature in the resting area) with Kruskal–Wallis and Mann–Whitney tests, as the nonnormal distribution of these variables was checked with the Kolmogorov–Smirnov test.

An evaluation of the relationship between the qualitative dependent variable (occurrence of PSE meat) and the independent variables (transportation distance, transportation duration, loading density, fasting duration, resting duration, average weight, average temperature in the resting area and maximum temperature in the resting area) was performed via univariate analysis with the chi-square (χ^2) test. Variables that showed a significant association (with $P < 0.02$) by the χ^2 test were selected for inclusion in the combined model. The risk was calculated by means of the adjusted odds ratio and its 95% confidence interval for each variable that showed a significant association ($P < 0.05$) in the logistic regression.

Based on the pH_{45} values obtained in this study, the carcasses were classified as normal or PSE. The carcasses were classified as normal when they presented a pH_{45} higher than or equal to 5.90 and PSE when they presented a pH_{45} lower than 5.90 (BARTON-GADE, 1978; ROSSI, 2022).

RESULTS

The initial (i.e., at 45 minutes) pH (pH_{45}) and temperature values for the carcasses in this study are shown in figure 1. The predominant range of pH_{45} values for the carcasses was 6.18 to 6.49 (n=2215), representing 49.78% of the carcasses, while temperatures between 38.08 °C and 40.96 °C corresponded to 64.64% of the carcasses evaluated.

Of all the carcasses evaluated, 306 presented a predisposition to developing PSE meat according to pH_{45} values (< 5.90); this number corresponded to an incidence of 6.87% in this study. Table 1 shows the results regarding the effects of the variables on the temperature and initial pH in the *semimembranosus* muscle of the carcasses. Carcass temperature at 45 minutes varied as a function of distance, and transport duration, loading density, fasting duration, resting duration, and average and maximum temperature of the resting area. There was no difference according to the average weight of the animals. pH_{45} values varied as a function of all independent variables studied.

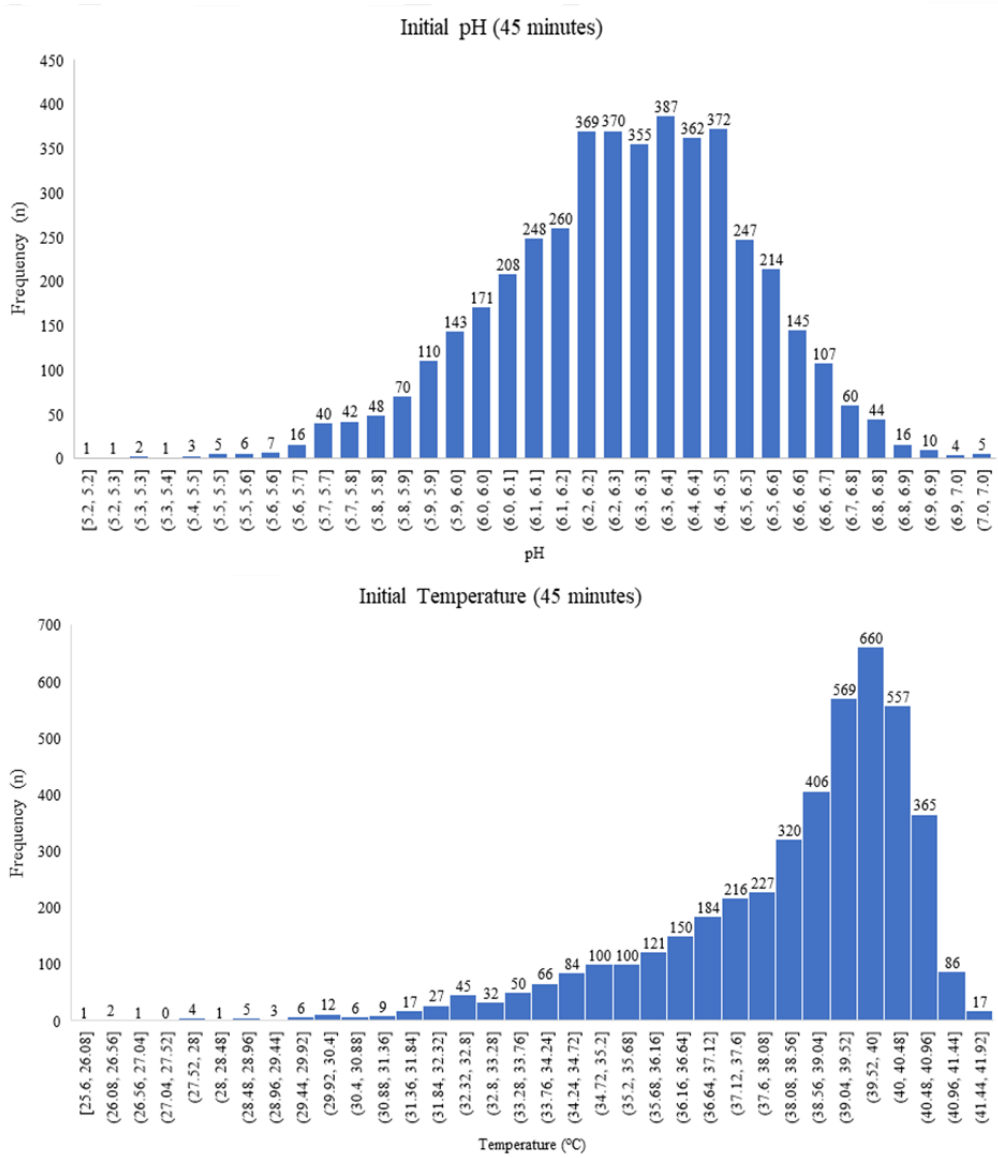

Figure 1 - Histograms of pig carcasses (measured from the *semimembranosus* muscle) at 45 minutes: (A) initial pH values (pH_{45}) and (B) initial temperature values.

Animals transported between 201 and 300 km presented higher carcass temperatures and lower pH_{45} values. Regarding the transport duration, the lowest pH_{45} were obtained from animals transported for up to 6 hours, and the highest temperatures were obtained from animals transported up to 3 hours. Loading densities lower than 0.35 kg/m² led to higher carcass temperatures and loading densities higher than 0.45 kg/m² led to lower pH_{45} values. Regarding the average weight of animals, the lowest pH_{45} values occurred in carcasses from animals above 120 kg. Higher temperatures and lower pH_{45} values were associated with fasting duration longer than 24 hours. Animals with resting duration up to 6 hours showed lower values for $pH_{45,}$ while higher temperatures were obtained from the carcasses of animals with resting durations over 12 hours. The average temperature of the resting area also influenced the dependent variables: temperatures up to 24 °C promoted higher carcass temperatures, while temperatures above 24 °C caused lower values of $pH_{45.}$

Figure 2 shows the occurrence of meats with different pH_{45} values within the same temperature range, indicating that, as an isolated factor, temperature does not determine the predisposition for the PSE.

Table 1 - Effects of independent variables on carcass temperature and initial pH (measured from the *semimembranosus* muscle) at 45 minutes post mortem.

Variable	Carcass temperature	P value*	Initial pH	P value*
----------Distance (km)----------				
< 100	38.37+2.17b	< 0.0001	6.29+0.25a	0.005
100 to 200	38.39+2.24b		6.29+0.25a	
201 to 300	38.64+2.06a		6.26+0.24b	
> 300	37.38+2.76c		6.29+0.26a	
----------Transport duration (hours)----------				
< 3	39.21+1,13a	< 0.0001	6.26+0.26ab	0.022
3 to 6	38.16+2,22c		6.26+0.25b	
6.1 to 9	38.48+2.24ab		6.29+0.25a	
9.1 to 12	38.25+2.33bc		6.28+0.24ab	
> 12	38.45+1.91ab		6.28+0.22ab	
----------Loading density (kg/m^2) ----------				
< 0.35	38.60+2.09a	< 0.0001	6.30+0.24a	< 0.0001
0.35 to 0.40	38.45+2.31a		6.27+0.24b	
0.41 to 0.45	38.24+2.18b		6.28+0.25ab	
> 0.45	37.73+2.52c		6.25+0.26b	
----------Average weight (kg) ----------				
< 100	38.15+2.58a	0.059	6.26+0.26ab	0.003
100 to 110	38.35+2.22a		6.27+0.24b	
110.1 to 120	38.39+2.22a		6.30+0.24a	
> 120	38.75+1.91a		6.26+0.25b	
----------Fasting duration (hours) ----------				
< 24	38.50+2.10b	0.003	6.30+0.24a	< 0.0001
≥ 24	39.19+2.43a		6.26+0.25b	
----------Resting duration (hours) ----------				
< 3	38.68+1.64b	< 0.0001	6.25+0.25b	< 0.0001
3 to 6	38.39+2.25b		6.25+0.25b	
6.1 to 9	38.16+2.32b		6.31+0.23a	
9.1 to 12	38.27+2.32b		6.27+0.25b	
> 12	39.23+1.72a		6.31+0.24a	
----------Average temperature in the resting area (º C) ----------				
≤ 24	38.41+2.22a	< 0.0001	6.29+0.24a	0.012
> 24	37.80+2.58b		6.27+0.26b	
----------Maximum temperature in the resting area (º C) ----------				
< 24	39.30+1.40a	< 0.0001	6.24+0.22c	< 0.0001
24 to 28	38.97+1.85b		6.28+0.24b	
28.1 to 32	37.81+2.44c		6.27+0.26b	
> 32	37.98+2.44c		6.34+0.22a	

*Kruskal–Wallis Test (α = 0.05).

Conversely, the results showed that there was an influence of fasting duration and average temperature in the resting area on the incidence of carcasses with PSE (Table 2). The animals fasted for more than 24 hours had a higher risk (1.41 times higher) of PSE meat, as did those with average temperatures in the resting area above 24 °C (1.52 times higher). The other parameters evaluated did not influence the occurrence of PSE (Table 2).

DISCUSSION

pH_{45} and temperature

In the present study, several variables influenced the pH_{45} and temperature values. The pH verification is an important tool to predict the final quality of pork because pH directly or indirectly influences the properties and quality characteristics of the meat such as color, tenderness and flavor (BRIDI

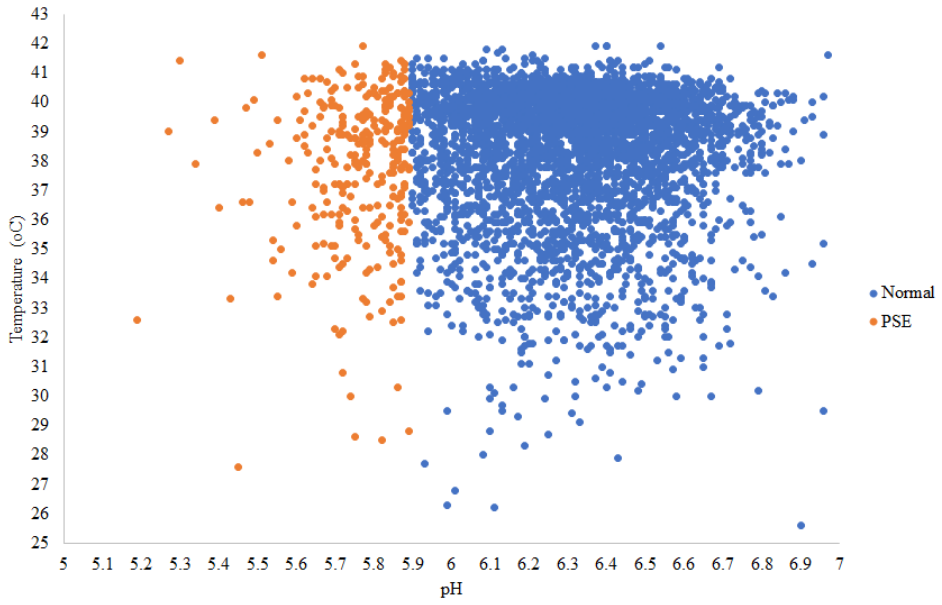

Figure 2 - Relationship between initial pH and initial temperature (measured from *semimembranosus* muscle at 45 minutes after slaughter) in pig carcasses.

& SILVA, 2006). Low pH associated with high carcass temperature leads to greater denaturation of myofibrillar proteins with a consequent reduction in the water retention capacity of the meat (CALDARA et al. 2012).

Regarding the distance of transport, the animals transported from 201 to 300 km presented muscles with higher temperature and lower initial pH than the other transport distances. MARZOQUE et al. (2020) reported pH values <5.8 in 11% of carcasses of animals transported over distances between 25 and 65 km and noted that animals transported over distances of 320 km did not present pH values lower than 5.8. In the evaluation of the impact of distances of 45, 430 and 700 km on the initial values of pH and temperature by OCHOVE et al. (2010), the distance of 700 km provided lower values of pH and higher temperatures of carcasses. The authors concluded that these results were possibly the consequence of the longer transport duration and thus greater exposure to stress due to poor road conditions, exposure to sunlight and high environmental temperatures (35 °C); these circumstances promote greater exhaustion of muscle glycogen, resulting in lower levels of pH and higher temperatures of pigs transported for longer periods. Under appropriate conditions, when pigs are transported over long distances, they are able to recover from the stress of loading and adapt to transport, in contrary to pigs transported over shorter distances (< 100 km), where there is not enough time for recovery from stress during pre-slaughter phases (RIOJA-LANG et al., 2019); this explanation could apply to the results found in this study and those of MARZOQUE et al. (2020).

The transport duration results consolidate these transport distance findings because shorter transport durations of up to 3 hours led to higher temperature and lower initial pH values of carcasses. In addition to transport distance and duration, another variable associated with transport is the loading density. Pigs transported over short distances and at high loading densities during hot weather conditions need more time in the resting area to recover from the stress associated with transport; when undergoing longer transport durations (>3 h) and provided with sufficient space, the animals can acclimate to the transport conditions and partially recover from the stress induced during loading (COBANÓVIC et al. 2021). The highest temperature values in the study were reported in the carcasses of animals transported at loading densities below 0.35 kg/m², lower initial pH values were observed from animals transported at densities greater than 0.45 kg/m². Transporting pigs at low density also increases injuries due to the excess space, as animals may collide with the sides and divisions of the truck, in addition to being at higher risk of slips and falls (DALLA COSTA et al., 2021).

The lowest pH_{45} values and highest temperatures occurred in animals with a live weight

Table 2 - Occurrence of PSE in pig carcasses as a function of the independent variables.

Variables	----------Classification----------				------Total-----		P value*	OR (95%)
	--------Normal---------		----PSE**----					
Distance (km)	n	%	n	%	N	%		
< 100	716	93.6	49	6.4	765	17.2		
100 to 200	1806	93.3	130	6.7	1936	43.5	0.910	-
201 to 300	1244	92.8	96	7.2	1340	30.1		
> 300	379	92.9	29	7.1	408	9.2		
Transport duration (hours)	n	%	n	%	N	%		
< 3	98	89.9	11	10.1	109	2.4		
3 to 6	748	92.6	60	7.4	808	18.2		
6.1 to 9	1983	93.5	137	6.5	2120	47.7	0.417	-
9 to 12	1277	93.1	95	6.9	1372	30.8		
> 12	39	97.5	1	2.5	40	0.9		
Loading density (kg/m^2)	n	%	n	%	N	%		
< 0.35	1310	94.2	81	5.8	1391	31.3		
0.36 to 0.40	1404	93.0	106	7.0	1510	33.9	0.072	-
0.41 to 0.45	993	93.2	72	6.8	1065	23.9		
> 0.45	438	90.7	45	9.3	483	10.9		
Average weight (kg)	n	%	n	%	N	%		
< 100	470	92.0	41	8.0	511	11.5		
100 to 110	1701	92.5	137	7.5	1838	41.3	0.069	-
110.1 to 120	1718	94.3	103	5.7	1821	40.9		
> 120	256	91.8	23	8.2	279	6.3		
Fasting duration(hours)	n	%	n	%	N	%		
< 24	2410	94.1	151	5.9	2561	57.6	0.002	1.41
≥ 24	1753	91.9	153	8.1	1888	42.4		
Resting duration (hours)	n	%	n	%	N	%		
< 3	155	92.3	13	7.7	168	3.8		
3 to 6	783	90.7	80	9.3	863	19.4		
6.1 to 9	1360	95.8	60	4.2	1420	31.9	0.441	-
9.1 to 12	1428	92.0	124	8.0	1552	34.9		
> 12	419	93.2	304	6.8	446	10.0		
Average temperature in the resting area (º C)	n	%	n	%	N	%		
≤ 24	2283	94.4	136	5.6	2419	54.4	0.001	1.52
> 24	1862	91.7	168	8.3	2030	45.6		
Maximum temperature in the resting area (º C)	n	%	n	%	N	%		
< 24	295	94.9	16	5.1	311	7.0	0.845	-
24 to 28	1552	93.9	101	6.1	1653	37.1		
28.1 to 32	1685	90.9	169	9.1	1854	41.7		
> 32	613	97.1	18	2.9	631	14.2		

*Chi-square test (α = 0.05). **considering pH_{45} values < 5.9. OR = odds ratio.

above 120 kg, the largest weight considered in this study. ELLIS & BERTOL (2001) studied the effects of slaughter weight on meat quality and inferred that heavier pigs have a greater risk of producing PSE meat. Similarly, BERTOL et al. (2015) reported lower initial pH values in heavier pigs. The explanation for this susceptibility lies in the fact that heavier carcasses take longer to cool due to the surface area × mass ratio. In addition, there is evidence that muscle glycogen content may be higher in heavier animals, increasing the risk of *post mortem* glycolysis and a faster pH drops.

Occurrence of PSE

The occurrence of PSE meat results from the elevation of the glycolysis rate immediately before and immediately after slaughter, which causes

a higher concentration of lactic acid and more rapid drop in muscle pH; this situation, related to stress during preslaughter handling, promotes the increased release of hormones that interfere with muscle glycogen reserves, leading to *post mortem* glycolysis (CALDARA et al. 2012; DALLA COSTA et al., 2021).

The incidence of PSE meat in carcasses from animals fasted for more than 24 hours increased by 37.29% ($P < 0.05$). These results showed that there is a positive correlation between the increase in fasting duration and loss of meat quality because (in addition to increasing the number of carcasses with pH_{45} values below 5.90) there was a decrease in pH values of the carcasses and an increase in temperature, which are the two factors that lead to the occurrence of PSE meat. Prolonged fasting duration can increase fights and damage meat quality, such as leading to PSE meat, since physiological stress can increase the release of hormones that exacerbate muscle activity, resulting in higher rates of glycolysis in the muscle (ABCS, 2014, ABCS, 2016).

Similar results were reported by ACEVEDO-GIRALDO et al. (2020), who evaluated total fasting durations from 3 to 34 hours, with 2 hours allotted for transport, and found that total fasting duration had significant effects on pH values, leading to a reduction in pH_{45} values and negative impacts on the color and water holding capacity of the meat ($P < 0.01$); they concluded that fasting durations should not exceed 12 hours for animal welfare and better meat quality. DRIESSEN et al. (2020) describe the preslaughter fasting duration as a tool to increase muscle pH and decrease the incidence of PSE pork, pointing out that fasting duration less than 18 hours can increase the incidence of PSE meat and duration above 22 hours induced muscle glycogen depletion, increasing the risk of DFD (Dark, Firm and Dry) meat; these findings differ from the present results. Similarly, PANELLA-RIERA et al. (2012) reported that fasting duration of 12 hours increased pH_{45} values. In addition, animals subjected to fasting duration of 24-26 hours had meats with a lower rate of exudation, evaluated from drip losses (DRIP). LUDTKE et al. (2010) noted that a fasting duration above 24 hours promoted excessive energy expenditure and loss in carcass yield and increased the final pH values (24 hours *post mortem*), interfering with meat quality.

An average temperature in the resting area above 24 °C before slaughter caused a reduction in the pH_{45} value and a consequent increase in the incidence of carcasses predisposed to PSE meat by 48.21%. This result indicated that on warmer days, the incidence of PSE meat has a tendency to increase. These results corroborated the findings of CULAU et al. (1993) and GAJANA et al. (2013), who stated that high ambient temperatures on the day of slaughter decreased the initial pH values and increased the frequency of PSE carcasses. Similarly, COBANÓVIC et al. (2021) reported that meat from pigs slaughtered in summer had lower initial pH values and water holding capacity, which are parameters associated with PSE meat. Pigs are sensitive to high ambient temperatures, as this condition stimulates heat stress due to an impaired thermoregulation mechanism resulting from keratinized sweat glands and a large amount of adipose tissue (LUDTKE et al., 2010; MUN et al., 2022). Heat stress immediately before slaughter accelerates muscle glycogenolysis, increasing lactic acid concentration and producing a rapid decrease in muscle pH while the carcass is still warm, resulting in PSE meat (GONZALES-RIVAS et al., 2020; MUN et al., 2022).

When acute stress occurs just before slaughter, the muscles use more energy reserves, metabolism becomes exothermic and, due to the difficulty of pigs in thermoregulating (i.e., dissipating the heat generated), muscle and body temperature increase. Lower muscle pH with high carcass temperature increases protein denaturation and may result in PSE meat. In addition, high muscle temperatures allow short-term accumulation of lactic acid, which alters protein functionality and increases the proportion of PSE meat (FLORES PEINADO et al., 2020; VERMEULEN et al., 2015).

Maintenance of body temperature in pigs, when exposed to higher temperatures during rest, is achieved by increasing heat loss to the environment and reducing metabolic heat production, a stressor to the animal (DRIESSEN et al., 2020; RENAUDEAU et al., 2011).

CONCLUSION

The initial temperature and pH_{45} values of the carcasses were affected by pre-slaughter factors. Furthermore, the fasting duration of the animals and the average temperature of the resting area increased the incidence of PSE meat.

ACKNOWLEDGEMENTS

The authors would like to thank the "Nutrili Indústria e Comércio de Carnes Ltda" for allowing data collection and was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Brasil – Finance code 001.

DECLARATION OF CONFLICT OF INTEREST

We have no conflict of interest to declare.

AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final version.

BIOETHICS AND BIOSSECURITY COMMITTEE APPROVAL

We authors of the article entitled "Influence of pre slaughter factors in pigs on initial pH and temperature: A case study" declared, for all due purposes, the project that gave rise to the present data of the same has not been submitted for evaluation to the Ethics Committee of the University of Lavras, but we are aware of the content of the Brazilian resolutions of the National Council for Control of Animal Experimentation – CONCEA "http://www.mct.gov.br/index.php/content/view/310553.html" if it involves animals.

Thus, the authors assume full responsibility for the presented data and are available for possible questions, should they be required by the competent authorities.

REFERENCES

ACEVEDO-GIRALDO, J. D. et al. Effects of feed withdrawal times prior to slaughter on some animal welfare indicators and meat quality traits in commercial pigs. **Meat Science**, v.167, 107993, 2020. Available from: <http://dx.doi.org/10.1016/j.meatsci.2019.107993>. Accessed: Jul. 16, 2022. doi: 10.1016/j.meatsci.2019.107993.

ASSOCIAÇÃO BRASILEIRA DOS CRIADORES DE SUÍNOS (ABCS). **Bem-estar animal na produção de suínos**: frigorífico. Brasília: ABCS, 2016, 38p.

ASSOCIAÇÃO BRASILEIRA DOS CRIADORES DE SUÍNOS (ABCS). **Produção de suínos: Teoria e prática**. Brasília: ABCS, 2014, 908p.

BARTON-GADE, P. A. Some experience on measuring the meat quality of pig carcasses. **Acta Agriculturae Scandinavica**, v.28, sup21, p.61-70, 1978. Available from: <http://dx.doi.org/10.1080/09064702.1978.11884470>. Accessed: Sep. 12, 2022. doi: 10.1080/09064702.1978.11884470.

BERTOL, T. M. et al. Meat quality and cut yield of pigs slaughtered over 100kg live weight. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v.67, p.1166-1174, 2015. Available from: <http://dx.doi.org/10.1590/1678-4162-8113>. Accessed: Sep. 24, 2022. doi: 10.1590/1678-4162-8113.

BRASIL. Portaria n° 365, de 16 de julho de 2021. Aprova o Regulamento Técnico de Manejo Pré-abate e Abate Humanitário e os métodos de insensibilização autorizados pelo Ministério da Agricultura, Pecuária e Abastecimento. **Diário Oficial da União**: seção 1- Extra A Página: 1 Brasília, DF.

BRASIL. Portaria n° 711, de 1° de novembro de 1995. Aprova as Normas Técnicas de Instalações e Equipamentos para Abate e Industrialização de Suínos. Ministério da Agricultura, Pecuária e Abastecimento. **Diário Oficial da União**. Brasília, DF.

BRIDI, A. M.; SILVA, C. A. **Métodos de Avaliação da Carcaça e da Carne Suína**. Londrina: MIDIOGRAF, v.1, 2006, 97p.

CALDARA, F. R. et al. Physical and sensory properties of PSE pork. **Revista Brasileira de Saúde e Produção Animal**, Salvador, v.13, n.3, p.815-824, jul./set., 2012. Available from: <https://www.scielo.br/j/rbspa/a/bHbXYwGp6f79NL6cvpBs8wL/abstract/?lang=pt>. Accessed: Oct. 18, 2022.

COBANÓVIC, N. et al. Combined effects of weather conditions, transportation time and loading density on carcass damages and meat quality of market-weight pigs. **Archives Animal Breeding**, v.64, n.2, p.425–435, 2021. Available from: <http://dx.doi.org/10.5194/aab-64-425-2021>. Accessed: Oct. 15, 2022. doi: 10.5194/aab-64-425-2021.

COBANOVIC, N. et al. The effects of season on health, welfare, and carcass and meat quality of slaughter pigs. **International Journal of Biometeorology**, v.64, n.11, p.1899-1909, 2020. Available from: <http://dx.doi.org/10.1007/s00484-020-01977-y>. Accessed: Aug. 27, 2022. doi: 10.1007/s00484-020-01977-y.

CULAU, P. O. V. et al. Effect of pre-slaughter management on the incidence of PSE and DFD in swine. **Archivos Latinoamericanos de Produção Animal**, v.1, n.2, p.139-146, 1993. Available from: <http://ojs.alpa.uy/index.php/ojs_files/article/view/2408>. Accessed: Sep. 18, 2022.

DALLA COSTA, O. A. et al. Effect of pre-slaughter conditions on meat quality of heavy-weight pigs. **Archivos de Zootecnia**, v.59, n.227, p.391-402, 2010. Available from: <https://scielo.isciii.es/scielo.php?script=sci_arttext&pid=S0004-05922010000300007>. Accessed: Sep. 05, 2022.

DALLA COSTA, O. A. et al. **Transporte Legal – Suínos**. Concórdia: Embrapa Suínos e Aves, 2021, 146p. Available from: <https://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/1137988>. Accessed: Jul. 22, 2022.

DOKMANOVIC, M. et al. The effects of lairage time and handling procedure prior to slaughter on stress and meat quality parameters in pigs. **Meat Science**, v.98, n.2, p.220–226, 2014. Available from: <http://dx.doi.org/10.1016/j.meatsci.2014.06.003>. Accessed: Sep. 24, 2022. doi: 10.1016/j.meatsci.2014.06.003.

DRISSEN, B.; et al. Fasting finisher pigs before Slaughter Influences Pork Safety, Pork Quality and Animal Welfare. **Animals**, v.10, n.12, 2206, 2020. Available from: <http://dx.doi.org/10.3390/ani10122206>. Accessed: Aug. 25, 2022. doi: 10.3390/ani10122206.

ELLIS, M.; BERTOL, T. M. Efeitos do peso de abate sobre a qualidade de carne suína e da gordura, Concórdia, SC, 2001. In: **2 CONFERÊNCIA INTERNACIONAL VIRTUAL SOBRE QUALIDADE DE CARNE SUÍNA**, 2001, Concórdia, SC, 2001. Anais... Concórdia, SC: Embrapa, 2011, p.227-239. Available from: <http://www.cnpsa.embrapa.br/sgc/sgc_publicacoes/anais01cv2_bertol_pt.pdf>. Accessed: Sep. 01, 2022.

EMBRAPA. **Qualidade da carne suína**, 2022. Online. Available from: <https://www.embrapa.br/qualidade-da-carne/carne-suina>. Accessed: Sep. 19, 2022.

FLORES-PEINADO, S. et al. Physiological responses of pigs to preslaughter handling: infrared and thermal imaging applications. **International Journal of Veterinary Science and Medicine**, v.8, n.1, p.71–84, 2020. Available from: <http://dx.doi.org/10.1080/23144599.2020.1821574>. Accessed: Sep. 03, 2022. doi: 10.1080/23144599.2020.1821574.

GAJANA, C. S. et al. Effects of transportation time, distance, stocking density, temperature and lairage time on incidences of pale

soft exudative (PSE) and the physico-chemical characteristics of pork. **Meat Science**, v.95, n.3, pág.520-525, 2013. Available from: <http://dx.doi.org/10.1016/j.meatsci.2013.05.028>. Accessed: Apr. 24, 2022. doi: 10.1016/j.meatsci.2013.05.028.

GARCÍA-CELDRÁN, M. et al. Reduction of transport-induced stress on finishing pigs by increasing lairage time at the slaughter house. **Journal of Swine Health and Production**, v.20, n.3, p.118-122, 2012. Available from: <https://www.aasv.org/shap/issues/v20n3/v20n3p118.html>. Accessed: Aug. 30, 2022.

GONZALES-RIVAS, P. A. G. et al. Effects of heat stress on animal physiology, metabolism, and meat quality: A review. **Meat Science**, v.162, 108025, 2020. Available from: <http://dx.doi.org/10.1016/j.meatsci.2019.108025>. Accessed: Apr. 24, 2022. doi: 10.1016/j.meatsci.2019.108025.

LAWRIE, R. A. **Ciência da carne**. Porto Alegre: Artmed, 2005, 384p.

LIMONI, B. H. S. et al. Influência do pH na qualidade da carne, Campo Grande, MS, 2017. In: **X MOSTRA CIENTÍFICA FAMEZ/UFMS**, 2017, Campo Grande, MS, 2017. Anais… Campo Grande: Faculdade de Medicina Veterinária e Zootecnia, 2017, p.236-239. Available from: <https://famez.ufms.br/files/2015/09/INFLU%C3%8ANCIA-DO-PH-NA-QUALIDADE-DA-CARNE.pdf>. Accessed: Oct. 10, 2022.

LUDTKE, C. B. et al. **Abate humanitário de suínos**. 132p. Rio de Janeiro - RJ: WSPA, 2010. Available from: <https://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/920389>. Accessed: Oct. 12, 2022.

MARZOQUE, H. J. et al. Evaluation of pH in swine carcasses regarding on the transport distance of the animals: a case study. **Research, Society and Development**, v.9, n.10, p.e6379108893, 2020. Available from: <http://dx.doi.org/10.33448/rsd-v9i10.8893>. Accessed: Oct. 25, 2021. doi: 10.33448/rsd-v9i10.8893.

MOURA, J. W. F. et al. Fatores Influenciadores na Qualidade da Carne Suína. **Revista Científica de Produção Animal**, v.17, n.1, p.18-29, 2015. Available from: <http://dx.doi.org/10.15528/2176-4158/rcpa.v17n1p18-29>. Accessed: Aug. 23, 2022. doi: 10.15528/2176-4158/rcpa.v17n1p18-29.

MUN, H. S. et al. Effect of ambient temperature on growth performances, carcass traits and meat quality of pigs. **Journal of Applied Animal Research,** v.50, n.1, p.103–108, 2022. Available from: <http://dx.doi.org/10.1080/09712119.2022.2032084>. Accessed: Sep. 15, 2022. doi: 10.1080/09712119.2022.2032084.

OCHOVE, V. C. C. et al. Influence of distance on the welfare and meat quality of pigs transported in Mato Grosso. **Revista Brasileira de Produção Animal**, v.11, n.4, p.1117–1126, out/dez, 2010. Available from: <http://hdl.handle.net/11449/140626>. Accessed: Aug. 30, 2022.

PANELLA-RIERA, N. P. et al. Effect of feed deprivation and lairage time on carcass and meat quality traits on pigs under minimal stressful conditions. **Livestock Science**, v.146, n.1, p.29-37, 2012. Available from: <http://dx.doi.org/10.1016/j.livsci.2012.02.017>. Accessed: Sep. 15,2022. doi: 10.1016/j.livsci.2012.02.017.

RAMOS, E. M.; GOMIDE, L. A. de M. **Avaliação da Qualidade de Carnes: Fundamentos e Metodologias**. Viçosa: Editora UFV, 2017, 473p.

RENAUDEAU, D; et al. A meta-analysis of the effects of high ambient temperature on growth performance of growing-finishing pigs. **Journal of Animal Science**, v.89, n.7, p.2220-2230, 2011. Available from: <http://dx.doi.org/10.2527/jas.2010-3329>. Accessed: Apr. 24, 2022. doi: 10.2527/jas.2010-3329.

RIOJA-LANG, F. C. et al. A Review of Swine Transportation Research on Priority Welfare Issues: A Canadian Perspective. **Frontiers in Veterinary Science**, v.6, 36, 2019. Available from: <http://dx.doi.org/10.3389/fvets.2019.00036>. Accessed: Apr. 24, 2022. doi: 10.3389/fvets.2019.00036.

ROSSI, G. A. M. **Qualidade, tecnologia e inspeção de carnes**. São Paulo: Medvet, 2022, 348p.

SALMI, B. et al. Bayesian meta-analysis of the effect of fasting, transport and lairage times on four attributes of pork meat quality. **Meat Science**, v.90, n.3 p.584–598, 2012. Available from: <http://dx.doi.org/10.1016/j.meatsci.2011.09.021>. Accessed: Apr. 24, 2022. doi: 10.1016/j.meatsci.2011.09.021.

SANTIAGO, J. C. et al. Resting time pre-slaughter and sex on the incidence of PSE (pale, soft, exsudative) meat in pigs. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v.64, n.6, p.1739-1746, 2012. Available from: <http://dx.doi.org/10.1590/S0102-09352012000600045>. Accessed: Sep. 24,2022. doi: 10.1590/S0102-09352012000600045.

SILVA, T. C. F. et al. Influence of siscal and conventional rearing systems on ph values of pork. **Enciclopédia Biosfera**, Goiânia, v.10, n.19; p.1216-1224, 2014. Available from: <http://www.conhecer.org.br/enciclop/2014b/AGRARIAS/influencia%20dos%20sistemas.pdf>. Accessed: Oct. 25, 2021.

TREVISAN, L.; BRUM, J. S. Incidence of pale, soft and exudative (PSE) pork meat in reason of extrinsic stress factors. **Anais da Academia Brasileira de Ciencias**, v.92, n.3, e20190086, 2020. Available from: <http://dx.doi.org/10.1590/0001-3765202020190086>. Accessed: Oct. 29, 2021. doi: 10.1590/0001-3765202020190086.

VERMEULEN, L. et al. Pre-slaughter rectal temperature as an indicator of pork meat quality. **Meat Science**, v.105, p.53–56, 2015. Available from: <http://dx.doi.org/10.1016/j.meatsci.2015.03.007>. Accessed: Apr. 24, 2022. doi: 10.1016/j.meatsci.2015.03.007.