An Acad Bras Cienc (2020) 92(3): e20190086 DOI 10.1590/0001-3765202020190086
Anais da Academia Brasileira de Ciências | *Annals of the Brazilian Academy of Sciences*
Printed ISSN 0001-3765 I Online ISSN 1678-2690
www.scielo.br/aabc | www.fb.com/aabcjournal

AGRARIAN SCIENCES

Incidence of pale, soft and exudative (PSE) pork meat in reason of extrinsic stress factors

LAURA TREVISAN & JULIANA S. BRUM

Abstract: The incidence of PSE (pale, soft and exudative) pork meat is directly influenced by pre-slaughter handling of animals, compromising meat quality and resulting in economic losses for industry. Considering management, the main extrinsic stress factors are: the pre-slaughter rest time in lairage, the total fasting time and at farm and the transport time. To evaluate the effects of these factors on PSE meat incidence, pH of 1038 carcasses was measured at 45 minutes post mortem (pH_{45}) in a pig slaughterhouse in Paraná, Brazil. Carcasses with $pH_{45} \leq 5.8$ were classified as PSE, and those with $pH_{45} > 5.8$ as normal. In order to verify if the factors influence PSE meat appearance, it was divided into categories according to it duration, and according to the number of animals evaluated in each category, the PSE meat frequency was estimated, and which time intervals obtained the lower incidence of the change. The total incidence of PSE carcasses was 19.17%. The periods of rest in lairage, total fasting, fasting at farm and transport that minimized the occurrence of PSE meat were from 04h01 to seven hours, from 14h01 to 17h00, from 03h01 to five hours, and from 02h01 to three hours, respectively.

Key words: fasting time, lairage time, pH_{45}, pre-slaughter handling, transport time, swine.

INTRODUCTION

Brazilian pig farming, in order to comply with the new consumer market requirements, started to produce swine with high production of lean muscle thought the interaction of genetic enhancement, health improvements, nutrition and production systems. Thus, in addition to the desirable increase in lean meat production, there were changes in biochemistry and substantial composition of muscles. These changes responsible for formation of pale, soft and exudative (PSE) meat, were caused by appearance of the Pork Stress Syndrome (PSS). This syndrome is a consequence of a genetic mutation in the calcium-regulating protein, ryanodine, better known as halothane gene (Maganhini et al. 2007).

Until 24 hours after bleeding, changes occur in muscle causing a degradative and normal pH reduction. However, because of the high sensitivity of animals to stress, there is an excessive glycogen burning in musculature shortly before or shortly after slaughter. This causes higher concentration of lactic acid and rapid reduction of muscle pH, while carcass temperature is still high. Thus, there are actions of proteases that denature muscle proteins, resulting in PSE meat (Barbut et al. 2008).

At low pH, the myofibrilar proteins get near to the isoelectric point, presenting maximum approximation between thick and thin filaments and reducing the space between it. This makes impossible linking water molecules and filaments, reducing the water retention capability. Once water is out of muscle cells and filaments are more attenuated, there is

reflection of incident light, so the flesh become pale. As a consequence, the PSE meat texture is characterized by flaccidity, exudation and pale color (Rosenvold & Andersen 2001).

This type of meat is undesirable for consumers and cannot be marketed in its natural state. Due to low quality, it is intended for manufacture of processed products, which also present problems owing to increased cooking losses, decreased fat emulsification capacity and altered texture of products, resulting in considerable economic losses for industry (O'neill et al. 2003).

There are some factors that can influence the incidence of PSE meat. Besides genetics, among the main causes that may affect meat quality are the extrinsic factors, which involves pre-slaughter handling, since ante-mortem stress by management contribute to the appearance of PSE meat. This extrinsic factors are: long period of fasting, transport from farm to slaughterhouse and rest in lairage, loading and unloading animals and social regrouping, all this are moments when animals are exposed to stressors (Gispert et al. 2000, Maganhini et al. 2007, Barbut et al. 2008, Ludtke et al. 2010).

Based on the importance of this alteration in meat quality, the present study aimed to verify the incidence of PSE carcasses in a pig slaughterhouse in Paraná, Brazil. In addition, it was analyzed if there is influence of the extrinsic factors rest time, total fasting time and at farm, and transport time, on the presence of the alteration and which time intervals of these factors result in a lower occurrence of PSE carcasses.

MATERIALS AND METHODS

A total of 1038 carcasses from 35 randomly selected lots were evaluated during September of 2017 in a pig slaughterhouse located in the region of Campos Gerais, state of Paraná, Brazil, with a slaughtering capacity of 3000 heads per day. Ramps were used to board the animals at farm and disembark at slaughterhouse, and handling boards and rattles were used for leading. Animal density was respected according to the type of truck used for transport. There was a mixing of unfamiliar lots during the board at farm and in the lairages. The animals had free access to water and, on hotter days, were given a sprinkler to reduce thermal stress. Desensitization was made using a carbon dioxide chamber, followed by bleeding.

The pH of 1038 carcasses was verified at the cooling chamber entrance, approximately 45 minutes (pH_{45}) after beginning slaughter, and *Longissimus dorsi* was the muscle used for insertion of the Testo 206-pH 2® pH meter. Carcasses with $pH_{45} \leq 5.8$ were classified as PSE, and those with $pH_{45} > 5.8$ as normal (Velazco 2001, Santiago et al. 2012).

In order to evaluate the effects of extrinsic factors, the parameters were divided into classes according to their duration in hours: rest time in pre-slaughter pens (04h01 to 07h; 07h01 to 10h; 10h01 to 13h; 13h01 to 16h; and 16h01 to 19h); total fasting time (11h01 to 14h; 14h01 to 17h; 17h01 to 20h; 20h01 to 23h; 23h01 to 26h; and 26h01 to 29h); fasting time at farm until loading (03h01 to 05h; 05h01 to 07h; 07h01 to 09h; and 09h01 to 11h); and time of transport from farm to the slaughterhouse (01h01 to 02h; 02h01 to 03h; 03h01 to 04h; and 04h01 to 05h).

The total PSE incidence was obtained using the number of PSE positive animals ($pH_{45} \leq 5.8$) in relation to the total number of animals evaluated, expressed as a percentage. The influence of each extrinsic factor on the incidence of PSE was measured by the number of animals diagnosed as PSE in relation to the number of heads slaughtered in each time division evaluated, and

the chi-square test ($\chi 2$) was performed using the RStudio software (version 1.1.463) to verify if there is an association between each factor and the PSE frequency, using a significance of 5%.

RESULTS

All animals came from cooperated farms of the slaughterhouse, with an average live weight of 116 kg, non-free genetics of halothane gene, of both sexes, and the males were surgically castrated. Of the lots analyzed, only one had a dead pig during transportation.

Of the 1038 carcasses analyzed, 199 were positive for presence of PSE, representing 19.17%. There was a wide pH variation at 45 minutes after the beginning of slaughter, with a higher frequency in range of 6.0 to 6.3. The frequencies of pH_{45} are shown in Figure 1.

Resting time, total fasting time, fasting time at farm and transport time had a significant influence ($p < 0.05$) on pH of the carcasses at 45 minutes after slaughter, as well as the incidence of PSE meat.

There was an increase in pH_{45}, with a concomitant reduction in PSE carcass incidence, when rest time was between 04h01 and seven hours (7.07%). Periods higher than seven hours increased PSE incidence, with the highest incidence observed for animals whose rest period ranged from 10h01 to 13 hours (40.00%) (Table I).

For the fasting time from farm to slaughter, there was a lower incidence of PSE carcasses when time was between 14h01 to 17 hours, since only 4.21% carcasses presented PSE meat (Table II).

For the fasting time at farm to the moment of loading, there was a lower incidence of PSE carcasses when time was between 03h01 to five hours, since 5.83% carcasses presented PSE meat (Table III).

And for transport time from farm to slaughterhouse, there was a lower incidence of PSE carcasses when time was between 02h01 to three hours, since 15.71% presented PSE meat. Despite this, there was no significant statistical difference between the transports below four hours, showing that all these periods are feasible. Periods above 04h01 raised the PSE incidence to 31.67% (Table IV).

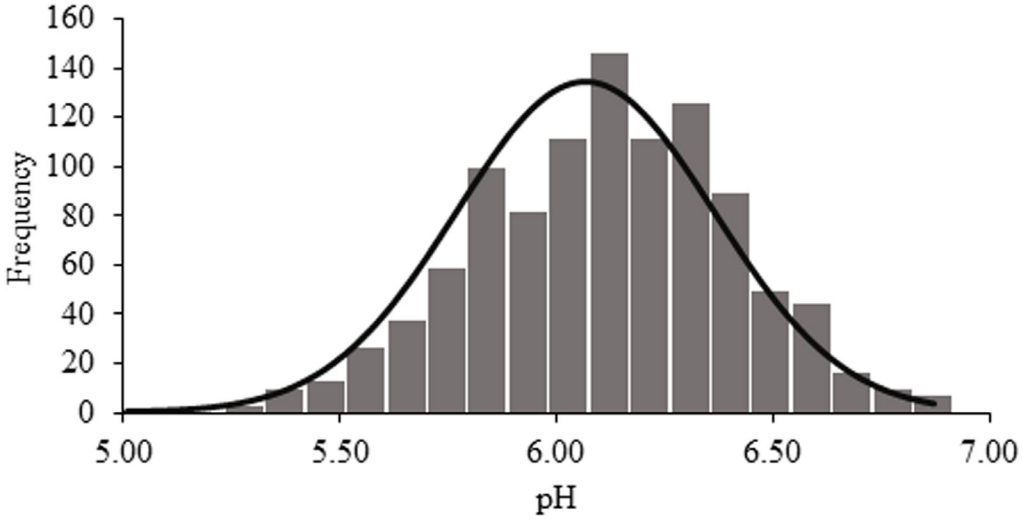

Figure 1. Histogram of pH frequency at 45 minutes post mortem of 1038 carcasses analyzed in a slaughterhouse in Paraná.

Table I. Incidence of PSE carcasses as a function of rest time.

Rest time	Nº of heads slaughtered	Nº of PSE carcasses	% PSE
04h01 to 07h	311	22[a]	7.07
07h01 to 10h	210	68[b]	32.38
10h01 to 13h	30	12[c]	40.00
13h01 to 16h	308	55[d]	17.86
16h01 to 19h	179	42[d]	23.46

Values followed by distinct letters in the 3rd column differ significantly by $\chi 2$ test ($p < 0.05$).

Table II. Incidence of PSE carcasses as a function of total fasting time.

Total fasting time	Nº of heads slaughtered	Nº of PSE carcasses	% PSE
11h01 to 14h	150	16[a]	10.67
14h01 to 17h	190	8[b]	4.21
17h01 to 20h	150	50[c]	33.33
20h01 to 23h	145	19[d]	13.10
23h01 to 26h	170	40[e]	23.53
26h01 to 29h	233	66[f]	28.33

Values followed by distinct letters in the 3rd column differ significantly by $\chi 2$ test ($p < 0.05$).

Table III. Incidence of PSE carcasses as a function of fasting time at farm.

Fasting time at farm	Nº of heads slaughtered	Nº of PSE carcasses	% PSE
03h01 to 05h	120	7[a]	5.83
05h01 to 07h	515	91[b]	17.67
07h01 to 09h	290	68[c]	23.45
09h01 to 11h	113	33[d]	29.20

Values followed by distinct letters in the 3rd column differ significantly by $\chi 2$ test ($p < 0.05$).

Table IV. Incidence of PSE carcasses as a function of transport time.

Transport time	N° of heads slaughtered	Nº of PSE carcasses	% PSE
01h01 to 02h	258	43[a]	16.67
02h01 to 03h	350	51[a]	15.71
03h01 to 04h	250	48[a]	17.60
04h01 to 05h	180	57[b]	31.67

Values followed by distinct letters in the 3rd column differ significantly by $\chi 2$ test ($p < 0.05$).

DISCUSSION

The results obtained in this work are similar to literature. In the southern region of Brazil, Maganhini et al. (2007) observed a prevalence of 22.83% and Andrade et al. (1993) found 17.2% of PSE carcasses in Paraná. Faucitano et al. (2010) obtained a result of 21% of PSE meat in Canada. In Mato Grosso do Sul, Brazil, Santiago et al. (2012) found a prevalence of 10.1% and Caldara et al. (2012) obtained 10.06% of PSE pork meat. Culau et al. (1994) identified, in Rio Grande do Sul, Brazil, 30.69% of PSE carcasses. These divergent results can be explained by a large number of factors, but mainly by genetic and pre-slaughter management, since it has a great influence on appearance of this alteration.

The *Longissimus dorsi* muscle used to evaluate the initial pH (45 minutes post-slaughter) was used by several authors, among them Caldara et al. (2012), Santiago et al. (2012), Ludtke et al. (2010), Faucitano et al. (2010), Maganhini et al. (2007) and Culau et al. (2002). This muscle is one of those with highest glycolytic potential due to transformation of an amount of carbohydrate into lactic acid, therefore is one of the most chosen for pH evaluation owing to greater probability of developing PSE condition (Murray 1995).

The halothane gene is one of the factors that contribute most to more severe PSE, however, PSE carcass frequency is not only due to the halothane genotype (Culau et al. 2002). Pre-slaughter management is one of the most important stages of production, because animals are exposed to several stressors, resulting in carcasses with quality problems (Ludtke et al. 2010). About management, the time of transportation to slaughterhouse, the ambient temperature during transport, the handling for loading and unloading animals, the incline of the ramp, the pre-slaughtering fasting time and lairage time are very important (Oda et al. 2004).

Adoption of a suitable pre-slaughter rest period is necessary for animals to eliminate excess lactic acid accumulated in muscles due to stress, and to restore their homeostatic balance (Dalla Costa et al. 2006). Higher blood lactate concentration is associated with lower initial pH value, higher meat temperatures and more skin excoriations, denoting pre-slaughter stress (Dokmanovic et al. 2015). Usually, two to three hours of rest are enough to recover from stress of transport without increasing problems of prolonged fasting and skin abrasions (Warriss et al. 1998). For Santiago et al. (2012), the most adequate time for recovering and reduction incidence of PSE meat was between six and eight hours and for Van Der Wal et al. (1997), two to four hours.

However, lairage period depends on the logistics of establishment, and in this study, the shortest rest period began at 04h01 to seven hours, which was the time when there was a lower incidence of PSE meat. Since Brazil has a tropical climate, the stress of animal handling and transportation is much more severe when compared to regions with milder climates (Santiago et al. 2012). Moreover, the hierarchy is established only about two hours and after this the animals start the lairage period (Grandin 1994). The animals in this study were submitted to mixing of unfamiliar batches during transport and resting period, therefore, the increase in PSE carcass incidence after seven hours rest may be related to the increase of aggression between animals submitted to very prolonged waiting periods. Depending on duration of resting time, it may lead to increased skin lesions and appearance of hard, dry and dark (DFD) meat (Gispert et al. 2000).

Swine kept fasted before slaughter contribute to feed economy at farm, and

in addition to reducing mortality rate, prevents vomiting during transport, reduces contamination of carcasses in production line by preventing spread of bacteria through feces, and improves meat quality by not negatively affecting glycogen stores, muscle water loss and color (Dalla Costa 2006). Food restriction, even if it leads to feed economy, also results in increased aggressiveness, especially after mixing animals from different batches (Turgeon & Bergeron 2000). Chevillon (1994) considers a total fasting not more than 24 hours in order to reduce losses of carcass yield. Magras et al. (2000) recommends a total period of 22 to 28 hours to reduce stomach weight. Warriss (1994) suggests a total fasting time of 8 to 18 hours. Periods over 24 hours cause excessive energy expenditure, leading up to 1% of carcass weight loss (Murray 2000), as well as compromising well-being, and reducing meat quality by raising pH at beginning of period post-mortem, as demonstrated by the results of this study. In Brazil, according to Ordinance Nº62, dated May 10, 2018, total fasting, including transportation and rest time, should be at least eight hours (Brasil 2018). According to the present study, from 14h01 to 17 hours of total fasting resulted in lower frequency of PSE carcasses.

There are divergences in relation to recommendations of fasting time at farm. Chevillon (1994) in France and Gispert et al. (2000) in Spain consider a farm fasting from 12 to 18 hours ideal, however Murray (2000) recommend 10 to 24 hours and Eikelenboom et al. (1991) recommends 16 to 24 hours of fasting. Dalla Costa et al. (2010) recommends the adoption of 15 hours of fasting at farm to reduce effects on meat quality. In Canada, at least five hours of fasting are recommended (NFAAC 2014). There is a great influence of logistic between farms and abattoirs in the recommendation of fasting time. In Brazil, at discretion of the Federal Inspection Service, animals that have begun fasting at farm may be slaughtered, provided that they have rested for at least two hours at abattoir (Brasil 2018). The fasting time at farm from 03h01 to five hours resulted in a lower frequency of PSE carcasses, and all the animals remained at rest in the establishment for at least 04h01. Fasting times at farm from 05h01 have considerably increased the incidence of PSE carcasses, diverging from literature.

Although a 12 to 18 hour fasting at farm decreased mortality rate in Spanish slaughterhouses (Guàrdia et al. 1996), there were no significant deaths at any time intervals in this study. The only batch with a dead pig was in the recommendations found for total and farm fasting time and rest time, but it was outside the recommended transport time (04h01 to five hours).

The transport is influenced mainly by animal density, time of transport and distance traveled (Pérez et al. 2002). Time is more important than distance, since factors that affect time like gathering animals at farms and characteristics of roads, can represent more pronounced effects in animal stress. In addition, when very long, it contributes to raise pH meat and cause fatigue to animal (Silveira 2006). The number of animals in each truck partition used to transport to the slaughterhouse of this study was calculated according to each type of truck and the average live weight of the pigs so that density was adequate. The recommendation is that transport time should be minimum and at most three hours (Warriss 1996). However, journeys of less than one hour may be more harmful than longer ones, because pigs should have time to recover from stress of loading (Bradshaw et al. 1996). The results found are similar to literature, since transport time between one and four hours did not present statistical difference, and more than

04h01 significantly increased the incidence of PSE.

The economic losses of PSE meat to industry are related to its use in preparation of meat products. Due to impairment of meat proteins functional properties, it can be used up to a certain limit for production of some fermented products and certain types of emulsions and is unsuitable for production of cooked ham and other cooked cured products (Wirth 1986). Caldara et al. (2012) calculated an annual loss of approximately R$340.800,00 in an industry in Mato Grosso do Sul with 10.06% of pig meat affected by PSE condition. Owen et al. (2000) showed that some researchers estimated economic losses from PSE meat, estimating that the United States loses US$ 32 million annually and Australia and the United Kingdom lose about US$20 million, due to appearance of this type of meat.

CONCLUSION

The incidence of pork PSE meat was 19.17%, and this was influenced by rest time of the animals in pre-slaughter pens, total fasting time, fasting time at farm until slaughter and time of transport of the animals from farm to abattoir. The hours that presented lower frequency of this problem were from 04h01 to seven hours, from 14h01 to 17h00, from 03h01 to five hours and from 02h01 to three hours, respectively.

REFERENCES

ANDRADE J, REMY C, NICOLAIEWSKY S, OURIQUE JMR, CULAU POV & BRESSAN MC. 1993. Levantamento e análise de alguns fatores pré e pós abate determinantes de anomalias na qualidade da carne suína. I Efeito da distância granja-frigorífico, tempo de descanso, sexo e peso vivo. In: VI Congresso Brasileiro de Veterinários Especialistas em Suínos. Goiânia, p. 132.

BARBUT S, SOSNICKI AA, LONERGAN SM, KNAPP T, CIOBANU DC, GATCLIFFE LJ, HUFF-LONERGAN E & WILSON EW. 2008. Progress in reducing the pale, soft and exudative (PSE) problem in pork and poultry meat. Meat Sci 79: 46-63.

BRADSHAW RH, PARROTT RF, GOODE JA, LLOYD DM, RODWAY RG & BROOM DM. 1996. Behavioural and hormonal responses of pigs during transport: effect of mixing and duration of journey. Animal Sci 62: 547.

BRASIL. 2018. Ministério da Agricultura Pecuária e Abastecimento/Secretaria de Defesa Agropecuaria. Portaria nº 62, de 10/05/18 do Regulamento Técnico de Manejo Pré-Abate e Abate Humanitário. Brasília, 3 p.

CALDARA FR, SANTOS VMO, SANTIAGO JC, ALMEIDA PAZ ICL, GARCIA RG, VARGAS JUNIOR FM, SANTOS LS & NÄÄS IA. 2012. Physical and sensory properties of PSE pork. Rev Bras Saúde Prod Anim 13(3): 815-824.

CHEVILLON P. 1994. Le contrôle des estomacs de porcs à l'abattoir: miroir de la mise à jeun en élevage. Techini-Porc 17: 23-30.

CULAU POV, LÓPEZ J, RUBENSAM JM, LOPES RFF & NICOLAIEWSKY S. 2002. A contribuição do gene halotano sobre as características de qualidade da carne suína. Cienc Rural 32(1): 115-119.

CULAU POV, OURIQUE JMR, NICOLAIEWSKY S & BRESSAN MC. 1994. Incidence of PSE in commercial pig carcasses in Rio Grande do Sul state, Brazil. Associação Sul Brasileira das Indústrias de Produtores Suínos. Boletim Técnico.

DALLA COSTA AO, COLDEBELLA A, PARANHOS DA COSTA MJR, FAUCITANO L, PELOSO JV, LUDKE JV & SCHEUERMANN GN. 2006. Período de descanso dos suínos no frigorífico e seu impacto na perda de peso corporal e em características do estômago. Cienc Rural 36(5): 1582-1888.

DALLA COSTA AO, LUDKE JV, COSTA MJRP, FAUCITANO L, PELOSO JV & DALLA ROZA D. 2010. Efeito das condições pré-abate sobre a qualidade da carne de suínos pesados. Arch Zootec 59(227): 391-402.

DOKMANOVIC M, BALTIC MZ, DURIC J, IVANOVIC J, POPOVIC L, TODOROVIC M, MARKOVIC R & PANTIC S. 2015. Correlations among stress parameters, meat and carcass quality parameters in pigs. Asian Australas J Anim Sci 28: 435-441.

EIKELENBOOM G & BOLINK AH. 1991. Effects of feed withdrawal before delivery on pork quality and carcass yield. Meat Sci 29: 25-30.

FAUCITANO L, IELO MC, LO FIEGO DP, METHOT S & SAUCIER L. 2010. Shelf of pork from five different quality classes. Meat Sci 84: 466-469.

GISPERT M, FAUCITANO L, OLIVER MA, GUAÁRDIA MD, COLL C, SIGGENS K, HARVEY K & DIESTRE A. 2000. A survey of pre-slaughter conditions, halothane gene frequency, and carcass and meat quality in Five Spanish pig commercial abattoirs. Meat Sci 55: 97-106.

GRANDIN TA. 1994. Methods to reduce PSE and bloodsplash. In: Allen D. Leman Swine Conf. 21. University of Minnesota: USA, p. 206-209.

GUÀRDIA MD, GISPERT M & DIESTRE A. 1996. Mortality rates during transport and lairage in pigs for slaughter. Meat Focus Int 10: 362-366.

LUDTKE CB, SILVEIRA ETF, BERTOLONI W, DE ANDRADE JC, BUZELLI ML, BESSA LR & SOARES GJD. 2010. Bem-estar e qualidade de carne de suínos submetidos a diferentes técnicas de manejo pré-abate. Rev Bras Saúde Prod Anim 11(1): 231-241.

MAGANHINI MB, MARIANO B, SOARES AL, GUARNIERI PD, SHIMOKOMAKI M & IDA EI. 2007. Carnes PSE (Pale, Soft, Exudative) e DFD (Dark, Firm, Dry) em lombo suíno numa linha de abate industrial. Ciênc Tecnol Aliment 27: 69-72.

MAGRAS C, DELAUNAY I & BÉNÉTEAU E. 2000. Quelles durées de mise à jeun des porcs charcutiers pour um optimun de qualité dês carcasses? Détermination à partir dún étude terrain. Journées Recherche Porcine en France 32: 351-356.

MURRAY AC. 1995. The evaluation of muscle quality. In: Jones SDM (Ed), Quality and grading of carcasses of meat animals, New York: CRC Press, New York, USA, p. 83-107.

MURRAY AC. 2000. Reducing losses from farm gate to packer. Advances in Pork Production 11: 175-180.

NFAAC. 2014. Code of practice for the care and handling of pigs. Agriculture and Agri-Food Canada. Ottawa, Canada, 78 p.

ODA SHI, BRIDI AM, SOARES AL, GUARNIERI PD, IDA EI & SHIMOKOMAKI M. 2004. Carnes PSE (Pale, Soft, Exudative) e DFD (Dark, Firm, Dry) em aves e suínos – diferenças e semelhanças. Rev Nac Carne 28(325): 108-113.

O'NEILL DJ, LYNCH PB, TROY DJ, BUCKLEY DJ & KERRY JP. 2003. Influence of the time of year on the incidence of PSE and DFD in Irish pig meat. Meat Sci 64: 105-111.

OWEN LB, MONTGOMERY LJ, RAMSEY BC & MILLER MF. 2000. Preslaughter resting and hot-fat trimming effects on the incidence of pale, soft and exudative (PSE) pork and ham processing characteristics. Meat Sci 54: 221-229.

PÉREZ MP, PALACIO J, SANTOLARIA MP, ACENA MC, CHACÓNG, VERDE MT, CALVO JH, ZARAGOZA MP, GASCÓN M & GARCÍA-BELENGUER S. 2002. Influence of lairage time on some welfare and meat quality parameters in pigs. Vet Rec 33: 239-250.

ROSENVOLD K & ANDERSEN HJ. 2001. Factors of significance for pork quality: a review. Meat Sci 59: 397-406.

SANTIAGO JC, CALDARA FR, SANTOS VMO, SENO LO, GARCIA RG & ALMEIDA PAZ ICL. 2012. Incidência da carne PSE (pale, soft, exudative) em suínos em razão do tempo de descanso pré-abate e sexo. Arq Bras Med Vet Zootec 64: 1739-1746.

SILVEIRA ETF. 2006. Manejo pré-abate de suínos. In: Castillo CJC (Ed), Qualidade da carne. São Paulo: Varella, São Paulo, Brasil, p. 75-87.

TURGEON MJ & BERGERON R. 2000. Effects of pre-slaughter practice on performance and behaviour of commercial pigs. In: North American ISAE Regional Meet. University of Guelph, Canada, p. 21.

VAN DER WAL PG, ENGEL B & HULSEGGE B. 1997. Causes for variation in pork quality. Meat Sci 46: 319-327.

VELAZCO J. 2001. Prevención de PSE en carne de cerdo. Carne Tec 8: 28-34.

WARRISS PD. 1994. Antemortem handling of pigs. In: Cole DJA et al. (Eds), Principles of Pig Science, Nottingham: Nottingham University Press, Nottingham, UK, p. 425-432.

WARRISS PD. 1996. Guidelines for the handling of pigs antemortem. In: EU-seminar "New Information on Welfare and Meat Quality of Pigs as Related to Handling, Transport and Lairage Conditions", Landbauforschung Volkenrode. 166. Mariensee, Germany, p. 217-224.

WARRISS PD. 1998. The welfare of slaughter pigs during transport. Animal Welfare 7: 365-381.

WIRTH F. 1986. Technologie der Verabeitung von flaisc mit abweichender Beschaffenhert. Fleischwirtschaft 65: 998-1001.

How to cite

TREVISAN L & BRUM JS. 2020. Incidence of pale, soft and exudative (PSE) pork meat in reason of extrinsic stress factors. An Acad Bras Cienc 92: e20190086. DOI 10.1590/0001-3765202020190086.

Manuscript received on January 25, 2019;
accepted for publication on April 2, 2019

LAURA TREVISAN
https://orcid.org/0000-0003-2763-2190

JULIANA S. BRUM
https://orcid.org/0000-0003-2147-9439

Universidade Federal do Paraná, Setor de Ciências Agrárias, Departamento de Medicina Veterinaria, Laboratorio de Diagnostico das Doencas dos Suinos, Rua dos Funcionarios, 1357, Cabral, 80035-050 Curitiba, PR, Brazil

Correspondence to: **Laura Trevisan**
E-mail: laurattrevisan@gmail.com

Author contribuitions

LT and JSB conceived the ideas and experimental design of the study. LT performed data collection, analysis, interpretation and wrote most of the paper. JSB provided revisions to scientific content of the manuscript.