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IMPACT OF TEMPERATURE DURING TRANSPORT ON MEAT QUALITY AND SHELF-LIFE IN CONVENTIONAL AND ORGANIC PIG FARMING

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I. INTRODUCTION

Animal welfare must be guaranteed throughout the animal's life, also during the slaughter. Loading, transporting, unloading and slaughtering are stressful events for animals, so it is essential to reduce the pain, stress, and suffering they may experience [1]. In addition to the impact on well-being, these stress responses can affect perimortem muscle metabolism and meat quality. Heat stress, especially during long journeys, can accelerate muscle glycogenolysis, increasing lactic acid and rapidly decreasing muscle pH post-mortem, resulting in PSE (pale, soft, exudative) meat with lower water holding capacity [2]. Conversely, chronic heat stress reduces muscle glycogen reserves, producing DFD (dark, firm, dry) meat with a high final pH. Thermal stress can also unbalance the redox potential in meat from stressed pigs, negatively affecting its shelf-life. This study aims to evaluate the impact of ambient temperature during transport on meat quality and shelf-life, comparing winter and summer transport conditions while considering the particularities of conventional and organic pigs.

II. MATERIALS AND METHODS

This study was conducted on two pig fattening farms, one organic (Duroc based; ORG_DU) and one conventional (Pietrain based; CONV_PI). The methodology was repeated in two seasons (winter and summer), considering the slaughter day. On the CONV_PI farm, animals were housed in pens of 10, separated by sex, while on the ORG_DU farm in groups of about 60, also by sex Pigs were transported to the slaughterhouse, all systems on the same day. A total of 280 animals were evaluated in this study, with 70 CONV_PI and 70 ORG_DU pigs in each batch, half of them entire males and half females. The recorded mean temperature during transport was 12.6 °C on winter and 22.7 °C on summer. The carcass weight and leanness percentage were provided by the abattoir, and at 18 h post-mortem the pH was measured in the carcass at *Longissimus thoracis* (LT). From each production system, 20 representative carcasses were selected and loin samples from the last rib level were obtained. At IRTA facilities, at 52 hours post-mortem, the pH and electrical conductivity, the instrumental colour (CIELab) and the drip loss percentage by the EZ-drip method were measured. For the shelf-life test, each loin was sliced into 4 sections and were placed in MAP trays with 70 % oxygen and 30 % carbon dioxide. A total of 160 trays were analysed (20 loins x 2 production systems x 4 evaluation times), kept at 4 °C in cycles of 12 h of LED light. They were evaluated by two IRTA panelists at 5, 7, 9 and 11 days after packaging, including their visual perception, considering a rating scale between 5 (maximum colour stability) and 1 (evident loss of colour stability) and the olfactory attributes, rating between 5 (no sensory defects) and 1 (evident rancidity and/or microbial attributes). For meat quality and shelf-life data an ANOVA was carried out (SAS v9.4) considering the production system, the season, sex and their possible interactions as fixed effects ($P<0.05$).

III. RESULTS AND DISCUSSION

The avarage carcass weight was slightly higher in the summer batch compared to the winter batch and heavier in CONV_PI than in ORG_DU, with no significant effect of sex (Table 1). The leanness was higher in winter carcasses and greater in the CONV_PI system compared to ORG_DU, with no differences according to sex. Summer-slaughtered animals had lower pH values at 18 h post-mortem, compared to winter animals, and males had lower values than females, with no differences according to the production system. Lower summer pH values may be related to greater ante-mortem heat stress. Regarding the loin pH at 52 h post-mortem, ORG_DU animals from winter had higher values than in summer, while CONV_PI animals showed no differences (Table 2). Thus, optimal pork pH (5.6-5.7) was more achievable in winter. Electrical conductivity was higher in summer, indicating less favourable conditions for water retention. No significant differences were found between ORG_DU and CONV_PI systems, though males had slightly higher values than females. Loin samples from summer animals had greater drip losses than those from winter, confirming an inversely proportional relationship between electrical conductivity and the water holding capacity. CONV_PI animals had more exudation than

ORG_DU ones, likely due to genetic traits favoring oxidative red fibers with higher water holding capacity, and no differences were observed between sexes. Instrumental color showed that ORG_DU pigs slaughtered in winter had the darkest meat (L*), while those slaughtered in summer had paler meat, similar to CONV_PI pigs. ORG_DU pigs had higher red intensity (a*) due to genetic predisposition for red fibers. In relation to the stability of loin samples along shelf-life, the sex effect was excluded for not being significant. Summer loin trays were rated worse than winter trays, reaching the estimated consumer acceptance threshold (value 3) by day 7, while winter samples reached it two days later. Olfactory attributes related to meat degradation (rancidity, microbial activity), appeared earlier in summer samples.

Table 1 - ANOVA LSmeans of the meat quality parameters, according to the studied effects.

	Season			Production system			Sex		
	Summer	Winter	P-value	CONV_PI	ORG_DU	P-value	Female	Male	P-value
Abattoir (n=280)									
Carcass weight (kg)	94.2	90.4	0.0003	95.4	89.2	<0.0001	91.6	92.9	0.2235
Lean (%)	59.1	60.3	0.0001	63.8	55.7	<0.0001	59.5	60.0	0.1404
pH 18 h LT	5.70	5.89	<0.0001	5.80	5.80	0.9930	5.77	5.82	0.0105
IRTA (n=80)									
EC LT (mS)	8.99	7.68	0.0013	8.31	8.36	0.9055	7.83	8.84	0.0132
Drip loss (%)	4.40	2.39	<0.0001	4.29	2.50	<0.0001	3.51	3.28	0.4003
a*	0.55	0.90	0.1172	-0.04	1.48	<0.0001	0.65	0.80	0.4822

LT: *Longissimus thoracis;* EC: electrical conductivity; a*: redness. Significance considered when P < 0.05.

Table 2 - ANOVA LSmeans of pH and L*, considering sex and the interaction between season and production system.

	Sex			Summer		Winter		
	Female	Male	P-value	CONV_PI	ORG_DU	CONV_PI	ORG_DU	P-value
IRTA (n=80)								
pH LT	5.49	5.51	0.2087	5.47_{bc}	5.50_{b}	5.44_{c}	5.59_{a}	<0.0001
L*	49.52	49.04	0.3164	49.01_{b}	50.00_{ab}	50.80_{a}	47.32_{c}	<0.0001

LT: *Longissimus thoracis*; L*: lightness. Significance considered when P < 0.05.

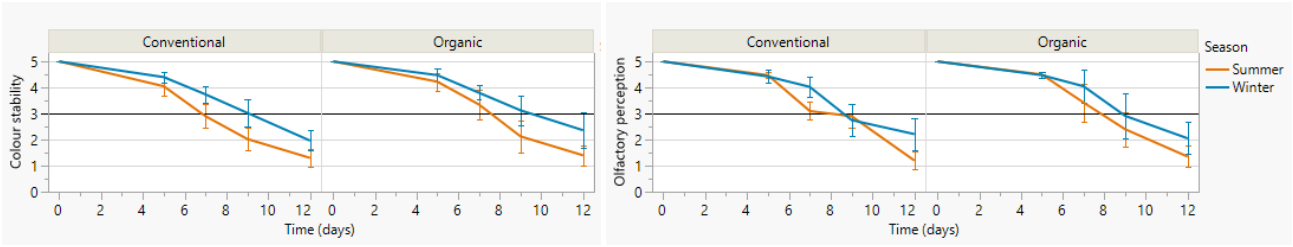


Figure 1. Evolution of colour stability and olfactory attributes in loin samples, according to season and production system.

IV. CONCLUSION

The 10ºC average temperature difference between summer and winter transports led to poorer meat quality and reduced shelf-life. Differences in product quality parameters were observed between production systems, likely due to genetic variations. Therefore, ambient temperature is a critical factor when slaughtering pigs in summer, both in CONV_PI and ORG_DU. In this ORG_DU system, where a higher meat quality is expected, thermal disconfort could be a limiting factor to achieve the standards. Implementing effective ante-mortem and post-mortem strategies is essential to mitigate the negative effects of temperature on animal welfare and meat quality.

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