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The effects of blast chilling on pork quality

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ABSTRACT

The aim of this study was to determine the effects of blast chilling of pig carcasses on the physiochemical and sensory properties of the *longissimus lumborum* muscle. To this end, right half-carcasses were blast-chilled for 70 min at −24 °C and then for 22 h and 50 min at 1 °C, while left half-carcasses were chilled conventionally at 1 °C for 24 h. At 2 h and 6 h *post mortem*, blast chilling had significantly reduced the temperature of the carcasses, as well as the rate of pH decrease and the rate of increase in EC. It had no significant effect on the ultimate pH or its range, or on EC at 24 h *post mortem*, but it significantly lowered L*, b*, C* and drip loss compared to the conventionally chilled carcasses. Blast chilling adversely affected sensory characteristics such as tenderness and flavor. There were no significant differences between the effects of blast and conventional chilling systems on meat quality between conformation classes.

1. Introduction

In recent years, research on pork carcass chilling has been focused on accelerated cooling to minimize evaporation-induced loss in carcass weight (Huff-Lonergan & Page, 2003) and the incidence of microbiological contamination (Lenahan et al., 2009). Further, accelerated chilling may also improve the physiochemical properties of meat due to the decreased rate of *post mortem* metabolism; a reduced rate of glycolysis results in lower drip loss in muscles and lower incidence of PSE meat (Bertram, Dønstrup, Karlsson, Andersen, & Støkilde-Jørgensen, 2001; Kondjoyan & Daudin, 1997).

The rapid reduction in muscle temperature before it reaches the appropriate level of acidification may result in carcass shrinkage (loss of weight) (Honikel, Kim, Hamm, & Roncales, 1986; Huff-Lonergan & Page, 2003). Shrinkage during blast chilling may especially affect high yielding carcasses, due to their lower external fat content and faster heat release. Blast chilling also pre-disposes to crust freezing of the skin and muscles located directly beneath the skin. During thawing, this results in leaching of the underlying tissue and an undesirable meat color (Wal van der, Engel, van Beek, & Veerkamp, 1995).

In the only study mentioning a relation between chilling treatment and conformation, by Jones, Tong, and Murray (1987), boneless pork loins and whole hams were subjectively assessed for muscle color and structure; the effects of chilling were found to be similar for carcasses of different weight and depth of subcutaneous fat. In order to verify those findings, the aim of this study was to determine the effects of blast chilling on the physiochemical and sensory properties of pork, and also differences between the carcass conformation classes as classified in the EUROP system.

2. Material and methods

2.1. Animal management

An examination was carried out on 60 hybrid pigs (similar share of gilts and barrows), in winter season, from a pig production farm in the Western Pomeranian Voivodeship (Poland). The study involved the offspring of Hypor and PIC337 boars and Danbred sows (Landrace–Yorkshire) which were housed under the same environmental conditions and fed using a balanced feed mixture *ad libitum*. All the examined pigs (180 individuals) were transported on a truck from the farm located 171 km from the abattoir. The animals were grouped in the truck on three levels, in four pens on each level (12 pens × 15 pigs). In the area of the meat plant, the pigs were kept in one lairage pen, in accordance with density standards, with constant access to water, and were not mixed with pigs from other transports. Until the moment of slaughter, the pigs were subjected to 24 h fasting, including 12–13 h lairage.

2.2. Slaughter processing and pork quality

At the slaughter line we selected the same numbers of carcasses from three classes of conformation in the EUROP system (S, E, U; 20 carcasses each) with a similar warm weight (90 ± 5 kg). The EUROP system classifies carcasses according to their lean meat content: S > 60%, E in the range of 55–60%, and U ranging from 50 to 54.9%.

At the slaughter line, 35 min after stunning the pigs (Butina CO_2 gas stunning system, type Combi 34, Denmark), temperature and pH were

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measured using a portable CP-411 pH-meter (Elmetron, Zabrze, Poland) between the 4th and 5th lumbar vertebrae of the right half-carcass. Carcass lean content, the thickness of the *longissimus dorsi* muscle and backfat between the 3rd and 4th ribs, 7 cm from the line of carcass partition on the left half-carcass, were measured by means of CGM optic-needle apparatus (Sydel, France). Hot carcass weight was also determined. Next, 60 right half-carcasses were chilled using a two-tier system; first they were placed in a cooling tunnel for 70 min (−24 °C, 270 carcasses per hour) and then in a cold store where they remained for 22 h and 50 min at 1 °C. The left half-carcass was cooled using a conventional one-tier system for 24 h at 1 °C. During carcass chilling and 2, 6 and 24 h *post mortem* (p.m.), temperature and pH were measured using the aforementioned apparatus. At 2 and 24 h p.m., electrical conductivity (EC_2 and EC_{24}) was measured using an LF-Star (Ingenieurbüro Matthäus, Nobitz, Germany). At those times, pH, temperature and EC were measured between the 4th and 5th lumbar vertebrae of each half-carcass. After 24 h of carcass chilling, *longissimus lumborum* (LL) muscle samples were collected from the 1st–4th lumbar vertebral regions of each half-carcass. The samples were wrapped in foil, transported to the laboratory in a vacuum flask and stored at 4 °C. On the same day, the meat was separated from the bone, and the external fat and perimysium were removed. In thus prepared LL muscle samples, we cut (starting from the cranial end) a 3 cm slice to determine the drip loss and pH; an about 1 cm slice to perform color measurement and a 2.5 cm slice for the sensory evaluation of heat-treated meat.

At 24 h p.m., 50 g muscle samples were collected (3 cm thick and 4.1 cm in diameter) and placed in polyethylene bags. Drip loss was determined as percentage of weight loss after 1 day (48 h p.m.) and 2 days (72 h p.m.) of storage at 4 °C according to Prange, Jugert, and Schamer (1977). In thus prepared samples, pH was measured directly in the muscle tissue at 48 and 72 h p.m. (CP-411 pH-meter).

About 48 h p.m., meat color traits, *i.e.* lightness (L*), redness (a*), yellowness (b*), chroma (C*) and hue angle (h°), were measured on a freshly cut surface muscle after a 20 min blooming period at 4 °C, by means of a HunterLab Mini Scan XE Plus 45/0 (HunterLab Inc., Virginia, U.S.) with the standard illuminant D65 and 10° Standard Observer (CIE, 1976). The remaining part of the left loin was vacuum-packed in polyethylene bags, and frozen at −20 °C until proximate analyses.

2.3. Sensory analysis of pork quality

At 48 h p.m., raw meat samples from the LL muscle, cut into 2.5 cm thick slices and placed in an oven bag (a plastic bag used for cooking meat), were heated in water at 80–81 °C until the internal temperature of the meat samples reached 72 °C, and were then subjected to sensory evaluation after cooling to 20 °C. Samples had approximately equal sizes (about 25 g) and were placed in lidded one ounce glass jars labeled with three digit random codes and held in a water bath (54 °C) until presented to the panelists. The analysis was conducted in rooms at daily light and at room temperature (20 °C). To neutralize the taste, each person received hot tea without sugar between the assessments of samples. Sensory evaluation of the LL samples was performed to determine their color, aroma, tenderness, juiciness and flavor. This evaluation was performed in 12 sessions by a team of 4 to 5 trained individuals using a 5-point scale (1 = unacceptable and 5 = very acceptable) according to PN-ISO 4121:1998. At each session, the panelists evaluated 10 randomly presented samples which were served at the same time to each of the panelists. Two sessions were held each day.

2.4. Proximate analysis

The following chemical constituents were measured in the ground and thawed samples of meat according to official methods of analysis of the AOAC (2003): moisture content by the oven-drying of 2 g samples at 102 °C to a constant weight (950.46B, see p.39.1.02); crude protein content by the classical macro-Kjeldahl method (981.10 see p. 39.1.19); and intramuscular fat content by petroleum ether extraction using a Soxhlet apparatus (960.39 (a), see 39.1.05).

2.5. Statistical analysis

The obtained data was analyzed statistically by means of Statistica 9.1 PL software using the least squares method of the GLM procedure according to the following linear model:

$$Y_{ijk} = \mu + a_i + b_j + ab_{ij} + e_{ijk}.$$

For the sensory attribute data, the following model was used:

$$Y_{ijkl} = \mu + a_i + b_j + c_k + ab_{ij} + e_{ijkl}$$

where: Y_{ijk} — measured trait; μ — overall mean; a_i — effect of the chilling method ($i = 1, 2$); b_j — effect of the carcass conformation ($j = S, E, U$); c_k — effect of the panelist ($k = 1, 2, 3, 4, 5$); ab_{ij} — interaction (chilling system × carcass conformation); and e_{ijk} — random error. Detailed comparison of mean least squares (LSQ) for the analyzed chilling systems and carcass conformation levels was performed using the Tukey's test at $p \leq 0.01$ and $p \leq 0.05$.

3. Results

3.1. Carcass characteristics and chemical composition of meat

According to the research criteria, carcasses in the three analyzed conformation classes (S, E, U) differed significantly ($p \leq 0.01$) in conformation, backfat thickness and LL thickness at a similar warm weight (Table 1). Analysis of chemical composition of the LL muscle in the carcasses from the various conformation classes showed a similar content of protein, and a similar ash and dry matter. A significantly ($p \leq 0.05$) higher intramuscular fat was found in U carcasses compared to S and E carcasses.

3.2. Temperature decline

The examined carcass chilling methods differed significantly in the LL muscle temperature 2 and 6 h p.m., but not 24 h p.m. (Table 2). Half-carcasses subject to the two-stage blast chilling had a significantly ($p \leq 0.01$) lower temperature ($temp_{2h}$, $temp_{6h}$) of the LL muscle compared to conventionally chilled carcasses. On the basis of mean values, one can see a tendency that the higher the conformation, the lower

Table 1
Quality of carcass and basic chemical composition of the *longissimus lumborum* muscle, by conformation class.

Traits	Total n = 60	EUROP carcass class		
		S n = 20	E n = 20	U n = 20
Hot carcass weight (kg)	91.04 ± 2.71	91.00 ± 3.21	91.05 ± 1.99	91.08 ± 2.82
Meatiness (%)	57.33 ± 3.34	61.24^{A} ± 1.32	57.11^{B} ± 1.27	53.64^{C} ± 0.84
Backfat thickness (mm)	14.33 ± 3.41	10.80^{C} ± 1.96	14.40^{B} ± 1.74	17.80^{A} ± 1.80
Muscle thickness (mm)	59.88 ± 6.50	66.20^{A} ± 4.68	59.25^{B} ± 3.12	54.20^{C} ± 4.65
Total protein (%)	22.20 ± 0.44	22.36 ± 0.41	22.11 ± 0.39	22.13 ± 0.49
Fat (%)	1.45 ± 0.48	1.33^{b} ± 0.53	1.27^{b} ± 0.49	1.75^{a} ± 0.60
Ash (%)	1.00 ± 0.18	1.00 ± 0.17	1.00 ± 0.16	1.00 ± 0.20
Dry matter (%)	25.39 ± 0.55	25.34 ± 0.50	25.29 ± 0.64	25.55 ± 0.49

Results in the table are given as Least Squares Quadratic mean ± standard deviation.
^{A,B}Mean values signed by different capital letters differ significantly at $p \leq 0.01$ ($p \leq 0.01$).
^{a,b}Mean values signed by different small letters differ significantly at $p \leq 0.01$ ($p \leq 0.05$).