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Low temperature cooking of pork meat — Physicochemical and sensory aspects

André Becker, Annika Boulaaba, Sylvia Pingen, Carsten Krischek, Günter Klein *

Institute of Food Quality and Food Safety, University of Veterinary Medicine Hannover, Foundation, Bischofsholer Damm 15, D-30173 Hannover, Germany

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ABSTRACT

Low-temperature cooking is increasingly used in the food sector. This study compared three different low temperature heating methods and one conventional cooking procedure of pork meat in a combi steamer with special emphasis on sensory parameters. Low temperature, long time (LTLT) treatments over 20 h at 53 °C or 58 °C (LTLT 53 °C or 58 °C) showed considerable effects on meat tenderization. Heating to a core temperature of 60 °C (low temperature method = LT) at 60 °C oven temperature resulted in less tender but clearly juicier meat. LTLT 53 °C and LT were evaluated as being equally acceptable by the panelists. The tenderest meat (LTLT 58 °C) was mainly rejected because of a crumbly and dry mouth feeling. Conventional heating to a core temperature of 80 °C at 180 °C oven temperature resulted in low eating quality due to high toughness and low juiciness.
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1. Introduction

Low-temperature heating methods have increasingly become part of modern cooking techniques. They provide juicy meat by improving the water holding capacity of the muscle tissue during heating. Below 60 °C mainly transverse muscle fiber shrinkage occurs while at higher temperatures a severe longitudinal shrinkage takes place which significantly reduces cooking yield (Offer, Restall, & Trinick, 1984; Palka & Daun, 1999). Furthermore, higher cooking temperatures lead to myofibrillar protein alterations with a toughening effect (Bejerholm, Tørngren, & Aaslyng, 2014; Christensen, Purslowa, & Larsen, 2000; Palka & Daun, 1999), which can be avoided under low temperature conditions. Maintaining these low core temperatures for a prolonged time has a tenderizing effect which is mainly caused by a weakening in connective tissue strength (Becker, Boulaaba, Pingen, Röhner, & Klein, 2015; Beilken, Bouton, & Harris, 1986; Bouton & Harris, 1981; Bouton, Harris, & Ratcliff, 1981; Christensen, Bertram, Aaslyng, & Christensen, 2011a; Christensen, Ertbjerg, Aaslyng, & Christensen, 2011b; Christensen et al., 2013; Laakonen, Wellington, & Sherbon, 1970a; Roldan, Antequera, Martin, Mayoral, & Ruiz, 2013). These facts explain the comparatively low weight losses, improved juiciness and tenderness of LTLT (low temperature long time) cooked meat. Recent studies showed that it is possible to tenderize pork meat by means of water bath (sous-vide) (Christensen et al., 2011b) and combi steamer cooking (Becker et al., 2015) at temperatures below 60 °C for prolonged times up to 30 h. Unfortunately, these particularly prolonged times also led to higher cooking losses and less juicy products. Additionally, negative effects on meat texture like increasing crumbliness were reported and meat did not develop a well done appearance during low temperature heat treatment (Christensen, Torngren, & Gunvig, 2010; Christensen et al., 2012). This might lead to rejection by potential consumers because of an undesirable raw appearance or microbiological safety concerns. Furthermore, flavor development was limited at temperatures below 60 °C and consequently LTLT meat was described as neutral in taste (Christensen et al., 2012). Although some sensory studies describe the textural effects of low temperature cooked pork meat, the question of consumer acceptance remains unclear. The prolonged time necessary for LTLT cooking methods can only be justified by a clear improvement in palatability for consumers. For that reason we compared two LTLT heat treatments (53 and 58 °C for 20 h) with a conventional heating method (80 °C core temperature) and a low temperature alternative (60 °C core temperature). In contrast to many studies of sous-vide treated meat, we heated pork *Musculus longissimus thoracis et lumborum* in a conventional combi steamer as this is an increasingly used technology in kitchens and restaurants (Becker et al., 2015).

The primary aim of the present study was to investigate the influences of the different heating methods on physicochemical, textural, sensory and microbiological properties of pork meat. Secondly, we tried to clarify consumer attitude towards low temperature heating methods of pork meat.

* Corresponding author.
E-mail address: Guenter.Klein@tiho-hannover.de (G. Klein).

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2. Material and methods

2.1. Raw material and sample preparation

For each of 12 independent trials (n = 8 physicochemical and microbiological trials, n = 4 sensory trials), both pork loins of one commercial crossbreed pig were obtained 24 h post mortem (p.m.) from a local slaughterhouse. The pH (pH_{24}) and the electrical conductivity (EC_{24}) values were determined 24 h p.m. in the *M. longissimus thoracis et lumborum* (LTL) between the 13th and 14th thoracic vertebrae (Table 1). LTL was released from both sides, surface fat trimmed off and the cranial and caudal endings were removed. The remaining part (between 8th thoracic and 5th lumbal vertebrae) of each muscle was cut into 2 pieces of approximately 15 cm length and stored vacuum-sealed at 4 °C for 5 days. The four samples of one pig were used for four different heat treatments (Section 2.2). The studies on physicochemical and microbiological parameters were performed eight times with a total number of eight pigs (n = 8). Sensory evaluation was performed 4 times with a total number of 4 pigs (n = 4). A Latin square design was randomly assigned to the different treatments to minimize the effect of different muscle locations or the side of the loin.

2.2. Cooking procedure

Meat samples were heated on grates in aluminium shells in a combi steamer (Joker T, Eloma GmbH, Maisach, Germany) at 20% humidity. LTLT samples were heated at 53 °C (LTLT 53 °C) or 58 °C (LTLT 58 °C) ± 0.5 °C for 20 h after reaching core temperature (approximately 2 h). The conventional heating method (conventional samples) was performed at 180 °C oven temperature until the samples reached 80 °C core temperature (approximately 50 min). The low temperature cooking method (LT samples) was conducted at 60 °C oven temperature until the samples reached 60 °C core temperature (approximately 2 h).

2.3. Physical measurements

CIELab color space (Lightness (L*), redness (a*) and yellowness (b*)) was measured with a colorimeter (Minolta CR 400®, Konica-Minolta GmbH, Langenhagen, Germany) before and after heat treatment on a fresh cut (2° standard observer, D65 illuminant, 8 mm measuring field). The colorimeter was calibrated before each trial with a standard white reflectance calibration plate. Prior to measurement, the cut surface was dried with filter paper. The device was adjusted to perform 5 internal measurements, automatically calculating the average value. Each measurement was repeated three times, resulting in a total number of 15 measuring points per sample.

The pH_{24} value was measured with a portable pH meter (Portamess®, Knick GmbH, Berlin, Germany) combined with a glass electrode (InLab 427®, Mettler-Toledo, Urdorf, Switzerland) and a temperature sensor, between the 13th and 14th thoracic vertebrae. Additionally, the pH was measured after heat treatment in the center of the muscle. Prior to measurement, the pH meter was calibrated with pH 4 and pH 7 standard solutions. Mean values of 3 measuring points were calculated.

The EC_{24} (mS/cm) of the raw material was measured between the 13th and 14th thoracic vertebrae with an EC meter, equipped with two parallel stainless steel electrodes (LF-Star®, Matthäus GmbH, Poettmes, Germany).

Longitudinal shrinkage of the whole muscle was defined as the difference of the samples' length before (L1) and after (L2) heat treatment: (L1 − L2) / L1 * 100. Transversal shrinkage of the whole muscle was defined as the difference of the samples' circumference before (C1) and after (C2) heat treatment: (C1 − C2) / C1 * 100.

The cooking loss was defined as weight difference of the samples before (W1) and after (W2) heat treatment: (W1 − W2) / W1 * 100.

Slice Shear Force (SSF) was measured after heat treatment (Becker et al., 2015; Shackelford, Wheeler, & Koohmaraie, 2004). Each roast was cut into 4 slices of 2.5 cm thickness and each of these slices yielded one SSF sample (1 cm thick and 5 cm long), parallel to the muscle fibers. After reaching room temperature (22 °C), the samples were placed in a texture testing machine (Texture Analyzer TA.XT.plus, Stable Micro Systems, Surrey, England) and a rectangular blade sheared the samples perpendicular to the muscle fibers with a crosshead speed of 500 mm/min, recording the maximum force.

2.4. Chemical measurements

Chemical measurements were carried out in accordance with ISO guidelines. As examination material, raw meat was removed from the cranial and caudal endings of LTL (8th thoracic or 5th lumbal vertebrae), comminuted and stored frozen at −20 °C. Sample material was comminuted after heat treatment and also stored frozen until examination. All chemical analyses were performed with three technical replicates. The protein concentration was calculated by analysis of the nitrogen concentration, using the Kjeldahl method (Vapodest 50s®, Gerhardt Laboratory Systems GmbH, Koenigswinter, Germany) with the factor 6.25 (ISO 937:1978). Fat was determined after acid hydrolysis and extraction in Soxhlet equipment (LAT GmbH, Garbsen, Germany) (ISO 1443:1973). The ash concentration was analyzed from the weight difference before and after combustion (600 °C, 6 h) in a muffle furnace (Carbolite®, LAT GmbH, Garbsen, Germany) (ISO 936:1998). The moisture content was calculated as the weight difference before and after drying in a drying oven (Binder GmbH, Tuttlingen, Germany) at 105 °C for 4 h (ISO 1442:1997). The hydroxyproline content was measured photometrically (Evolution™ 201 UV-Visible Spectrophotometer, Thermo Fisher Scientific Inc., USA) after acid hydrolysis (ISO 3496:1994). Values were multiplied by the factor 8 to obtain the collagen content of the samples. The chemical parameters of the raw meat were analyzed for all eight repetitions. The chemical parameters of the cooked meat were analyzed for four repetitions (protein, fat, ash, hydroxyproline) or all eight repetitions in the case of the moisture content.

2.5. Microbiology

The TPC (total plate count) of aerobic, mesophilic organisms before and after each heat treatment was determined according to ISO 4833-1:2013. Samples were analyzed for the concentration of *Enterobacteriaceae* according to ISO 13720:2010 and *Pseudomonas* spp. according to ISO 4832:2006 (n = 8).

Additionally, an inoculation experiment was performed three times (n = 3) to ensure the safety of LT and conventional treated samples as previously described for LTLT samples by Becker et al. (2015). In brief, approximately 5 $\log_{10}$ cfu/g of three indicator microorganisms (*Listeria* (*L.*) *monocytogenes*, *Salmonella* (*S.*) Enteritidis and *Escherichia* (*E.*) *coli*) were injected into the meat samples which were analyzed qualitatively

Table 1
Classification of the raw pork meat (*M. longissimus thoracis et lumborum*) 24 h post mortem regarding means and standard errors of slaughter weight, pH_{24}, EC_{24} (electrical conductivity), color (CIELab), microbiological state (total plate count (TPC), content of *Enterobacteriaceae* and *Pseudomonas* spp.). Detection limits for quantification were 2 $\log_{10}$ cfu/g (*Pseudomonas* spp.) or 1 $\log_{10}$ cfu/g (TPC and *Enterobacteriaceae*) (n = 8).

Parameter	Results
Slaughter weight	92.79 ± 2.64 kg
pH_{24}	5.43 ± 0.01
EC_{24}	3.86 ± 0.12 mS/cm
L* (CIELab)	54.50 ± 0.27
a* (CIELab)	5.71 ± 0.17
b* (CIELab)	3.85 ± 0.11
TPC ($\log_{10}$)	2.90 ± 0.12 cfu/g
Enterobacteriaceae ($\log_{10}$)	0.77 ± 0.05 cfu/g
Pseudomonas spp.($\log_{10}$)	2.45 ± 0.10 cfu/g

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