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Consumer and sensory investigations in relation to physical/chemical aspects of cooked pork in Scandinavia

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Abstract

The present study addresses sensory quality and liking for pork (eight samples) varying in quality due to adrenaline injection resulting in elevated ultimate pH post-slaughter $_{24h}$, meat ageing, cooking temperature and warmed-over flavour (WOF) among consumers ($n=288$) in Scandinavia. The consumers preferred meat with higher pH ($pH_{24h}=6.0$), cooked to the lowest temperature (65 °C versus 80 °C). Consumers least preferred samples with WOF described as metallic, acidic and off-flavour by a trained panel. "Elevated pH_{24h} meat" cooked to 65 °C resulted in a more sweet and tender meat. Juiciness, tenderness and the absence of off-flavour were the most important characteristics for consumers' liking of pork. Consumption frequency and liking of pork were positively related. The consumers that were most satisfied with pork quality reported highest consumption frequency. Elderly people and males expressed the highest liking score and consumption frequency, respectively.

Keywords: Pork flavour; pH; WOF; Ageing; Sensory; Consumer testing; Liking

1. Introduction

Knowledge of consumer preference for pork is of great importance to the meat industry in order to produce pork products that satisfy consumers' demand. To consumers, the sensory experience imparted during consumption is a very important aspect of food quality (Agerhem & Tornberg, 1993). Meat quality of pork is a complex term consisting of attributes such as colour, flavour and texture (Bredahl, Grunert, & Fertin, 1998). Consumers consider flavour to be one of the most important sensory traits of pork (Bryhni, Byrne et al., 2002; O'Mahony, 1991), and the absence of off-flavours is expected to be critical for acceptance (Risvik, 1994).

Meat quality of pork is dependent on pre- and post-mortem treatment. Ultimate pH of the meat is largely affected by ante mortem treatment like stress, and this may influence water-holding capacity, tenderness and juiciness (Brewer & McKeith, 1999; Byrne et al., 2001). Adrenaline, by its direct action on glycogenolysis constitutes a very potent tool to manipulate ultimate pH (Henckel, Karlsson, Oksbjerg, & Petersen, 2000). Sellier (1994), Flores, Armero, Aristoy, and Toldrá (1999) and Miller, Moeller, Goodwin, Lorenzen, and Savell (2000) found dark, firm and dry (DFD) meat to be more tender than normal. Others demonstrated negative effects on colour and water holding capacity of pale, soft and exudative pork (PSE) (Jeramiah, Murray, & Gibson, 1990; Brewer & McKeith, 1999). Variation within normal ultimate pH meat and effect on meat quality characteristics are less well documented. Fernandez, Monin, Talmant, Mourot, and Lebret (1999) found curvilinear relationships between ultimate pH and tenderness, with

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meat being tougher at intermediate pH values (around 6). Moreover, Byrne et al. (2001) found increasing pre-slaughter stress, resulting in elevated ultimate pH, reduced the development of WOF in cooked pork. The authors indicated that this was related to the higher pH reducing the activities of pro-oxidants. Kauffman (1993) stressed the importance in taking greater advantage of high pH meat to gain profit for the processor and greater satisfaction for the consumer.

Meat ageing of pork has a positive effect on meat quality (Agerhem & Tornberg, 1993), and Jonsäll (2000) showed higher meat taste intensity and tenderness as ageing time increased while acidulous taste decreased. The glutamic acid was affected by ageing of the meat, and a higher glutamic acid will contribute to the meat taste. According to Agerhem and Tornberg (1993) ageing influences both sensory quality (tenderness and juiciness) and consumer acceptance. Consumers contribute negatively or positively to meat quality by their methods of cooking. A number of studies have investigated how cooking can influence meat quality (Agerhem and Tornberg, 1993), and how it influences the development of warmed-over flavour (WOF) (Spanier, Vincent Edwards, & Dupuy, 1988; Byrne, Bredie, Mottram, & Martens, 2002).

According to Richardson (1994) consumer perceptions of meat are changing. Increased consumer demand for pre-cooked and "ready to eat" products has raised the issue of WOF which results in loss of meatiness and development of rancid off-flavours with cooked meat chill-storage (Byrne et al., 2001). Only two studies have come to our attention of consumer awareness of WOF. Cross, Leu, and Miller (1987), indicating that consumers in USA believe WOF as a major problem, and Bryhni, Byrne et al. (2002) showed in a questionnaire that consumers in Scandinavia were concerned about WOF in pork, but how well consumers detected WOF was unclear.

Various pre- and post-mortem treatments have been found to influence sensory quality of pork detected by trained panel, but how this influences consumers preference is still a question of debate (Miller et al., 2000). A number of studies have been published relating eating quality of pork and consumers preference such as PSE/DFD and physiological properties (Wachholz, Kauffman, Henderson, & Lochner, 1978; Bredahl et al., 1998), RN^{-} (Jonsäll, 2000) and rancidity (Bryhni, Ofstad, & Hunt, in press) demonstrating consumers' awareness of quality characteristics of meat. No studies that we are aware of have been performed to understand how consumer liking is related to sensory characteristics of samples varying in pH, ageing, cooking temperature and WOF. For consumers it is the combination of various pre- and post-mortem treatments that make up the final eating quality experience of pork. Combining results from trained panels with consumer liking for different treatments is less well documented. Various treatments tested together in consumer tasting can give valuable information if and to what extent, consumers can taste differences, and which treatments are the most important for consumer liking.

It has recently been shown that Swedish consumers seem to be more satisfied with pork products, and have a higher frequency of eating pork than Norwegian and Danish consumers (Bryhni, Byrne et al., 2002), possibly due to differences in meat quality between the three countries (Bryhni, Byrne et al., 2002; Bryhni, Kjos, Ofstad, & Hunt, 2002), or that consumer liking for pork in general varies. A consumer tasting of the same samples in all three countries would disclose if such differences in consumer liking of pork in these countries existed.

The purpose of the present study was to investigate consumer and profiling data using multivariate data techniques to gain insight into the sensory reasons for consumer liking and consumption of pork in the three Scandinavian countries Denmark, Norway and Sweden in relation to;

1. Consumer liking of pork samples varying in sensory properties due to
   (a) adrenaline injection resulting in elevated ultimate pH post-slaughter 24h,
   (b) meat ageing,
   (c) cooking temperature and
   (d) warmed-over flavour.
2. Consumer frequency of eating pork meat in relation to country, gender and age of consumers.

2. Materials and methods

2.1. Treatment

A total of eight different treatments each derived from the loin sample (*M. longissimus dorsi* = LD) of 12 animals were utilised in the consumer and sensory profiling investigations. The 8 different sample treatments, shown in Table 1, involved variation that included; adrenaline injection, meat ageing, core cooking temperature and WOF. The pork samples for sensory and consumer tasting were a subset of an original set that included 12 different sample treatments. It was deemed that 12 samples were excessive for consumer testing, thus, so as not to fatigue participants, eight samples were selected for presentation, through principal component analysis (PCA) of results from the trained sensory panel. This reduced sample set was determined to equally span the sensory dimensionality of the full sample set.

2.2. Production, treatment and slaughter

A total of 96 female slaughter pigs from 48 litters of a cross between purebred Danish Duroc boars mated with

Table 1
Description of the eight treatment groups

Treatment	B1	B2	B3	B4	B5	B6	B7	B8
pH[a]	Normal	Normal	Normal	Normal	Normal	Normal	Elevated pH	Elevated pH
Ageing time (days)	0	0	6	6	6	6	0	0
Core cooking temperature (°C)	65	80	65	65	80	80	65	80
Warmed-over[b]	No	No	No	WOF	No	WOF	No	No

[a] Pigs in group B7 and B8 were given adrenaline (0.3 mg/kg body weight) 15 h prior to stunning.
[b] The warmed-over flavour (WOF) samples (B4 and B6) were roasted to either 65 or 80 °C, then chill-stored at 4 °C for 2 days and reheated before being served for sensory analyses.

Danish Large White–Danish Landrace sows were used in this experiment. As the halothane gene is known to influence meat quality, all parents were halothane tested to exclude this gene from the population. All animals were produced and reared at the Danish Institute of Agricultural Sciences (DIAS), Research Centre Foulum, in the same stable. The pigs were given a standard growing/finishing diet consisting mainly of barley, soya and wheat ad libitum in-groups from automatic feeders. Water was given by free access from bite nipples. The pigs entered the experiment at a live weight of approximately 23 kg.

From each litter, two sisters were given one of two treatments with the purpose to produce pork with variation in *ultimate* $pH = pH_{24h}$. One of two littermates was given an adrenaline injection (0.3 mg/kg body weight) 15 h prior to stunning (elevated pH meat). The other littermate served as a control (normal pH meat) and was given a saline injection at the same time as a placebo treatment (Henckel et al., 2000). The transport distance from stable to slaughterhouse was 200 m, and the holding time at the abattoir was a minimum of 1 h. The animals were slaughtered at an average live weight of 101 kg in the experimental abattoir at DIAS, Foulum. The animals were stunned using 80% CO_2 for 3 min, exsanguinated, scalded at 62 °C for 3 min, cleaned and eviscerated within 30 min. At 45 min post mortem carcasses were transferred to a room at 12 °C, and at 60 min post mortem carcasses were stored at 4 °C. The average hot carcass weight was 82 kg, and the average estimated carcass meat percentage, using a Fat-O-Meter (SFK Technology, Denmark) 24 h post mortem, was 61%.

2.3. Sample preparation

The LD muscles from each animal were deboned, and the subcutaneous fat layer was adjusted to a thickness of 5–10 mm. The LD muscles were cut in 20 mm slices, vacuum packed, and were not aged or *aged* for 6 days at 2 °C before freeze storage at −21 °C.

After freezing (max 3 months), the pork samples were thawed at 4 °C overnight, before tempering at room temperature to 15 °C (for approximately 2 h). The *WOF-samples* were prepared 2 days before the sensory analysis and consumer test. They were first cooked to either 65 or 80 °C, and then chill-stored at 4 °C for 2 days. Before serving, the samples were put in aluminium foil and kept in the oven at 80 °C until the samples had a core temperature of 65 °C.

For heating of all samples a frying pan with vegetable margarine at 155±5 °C was utilised. The temperature of the frying pan was monitored. The serving plates were heated in a heating cabinet to better keep the temperature of the meat. A thermometer was used to measure the temperature during roasting to ensure the correct core temperature was attained. Two end-temperatures were selected in this study: 65 or 80 °C. The samples were cooked on both sides until the temperature reached 65 or 80 °C, depending on treatment (Table 1). A half or one chop, 1 cm thick, was then served, hot. The samples for the sensory and consumer study were treated identically.

2.4. Sensory profiling

Sensory profiling was carried out in the sensory laboratory by Swedish Meat R&D, which fulfils requirements according to the international standards (ISO, 1985a, 1988, 1993). A list of 17 descriptive terms was developed according to the methodology described by Byrne, Bak, Bredie, Bertelsen, and Martens (1999) and these terms were subsequently used in sensory profiling (ISO, 1985b) to describe the sample variation (Table 2). In sensory profiling eight assessors used these 17 terms to describe the eight different sample treatments. The samples were evaluated in duplicates in a randomised order in sessions of six samples. The experimental design balanced out the effect of order of presentation and the first-order carry-over effect (MacFie, Bratchell, Greenhoff, & Vallis, 1989). The attributes were assessed as in a normal, conventional profiling exercise. The attributes were rated on an unstructured line-scale (0–100). The scale was anchored at the extremes with the labels ‘‘none’’ and ‘‘very strong’’. Each assessor evaluated the samples at individual speed using a continuous scale and a computerized system for data recording (PSA System-OPP).

Table 2
Final list of 17 sensory descriptive terms[a] with definitions developed for the evaluation of pork samples in sensory profiling

Term[a]	Definition
Colour	*Visual stimulus associated with:*
Brownness-C	The intensity of brown colour
Odour	*Odour associated with:*
Meat-O	Meat complex/lean/brothy
Pig-O	Piggy/animal
Metallic-O	Bloody/iron/metallic
Sweet-O	Brothy/sweet,
Off-O	Cheesy/liver/old
Acidic/sour-O	Sour/soured/acidic
Warmed over-O	Oxidised/butter/cod liver fat/wet cardboard
Flavour	*Aromatic taste sensation associated with:*
Meat-F	Meat complex/lean/brothy/organy/umami
Pig-F	Piggy/animal
Metallic-F	Bloody/iron
Warmed over-F	Oxidised/butter/cod liver fat/wet cardboard
Taste	*Taste associated with:*
Sweet-T	Sweet taste (sucrose solution like)
Bitter-T	Bitter taste (quinine chloride solution like)/bile
Acidic/sour-T	Sour taste (citric acid solution like)
Texture	*Texture associated with:*
Juiciness-Tx	Mouth feel/juiciness perceived during chewing
Tenderness-Tx	Oral texture/perception of sample disintegration during chewing

[a] Suffix to sensory terms indicates method of assessment by panelists;-C = Colour,-O = Odour,-F = Flavour,-T = Taste,-Tx = Texture.

2.5. Chemical analyses

M. longissimus dorsi pH was measured at 1 min, 45 min and 24 h (ultimate pH) post mortem using a pH meter (Radiometer PHM201, Denmark) equipped with a probe type glass electrode (Methrom LL Glas Electrode WOC, Switzerland) calibrated in pH 4.01 and 7.00 IUPAC buffers (Radiometer, Denmark) at 35 °C (carcass temperature) for the measurements at 1 min and 45 min post mortem, and at 4 °C (carcass temperature) at 24 h post mortem.

Colour was measured on cut LD samples using a Minolta Chroma Meter CR-300 (Osaka, Japan). Samples were allowed to bloom for 1 h at 4 °C prior to the measuring procedure. Five replicate measures were performed on each chop. A white tile ($L^* = 92.30$, $a^* = 0.32$ and $b^* = 0.33$) was used as standard.

Water-holding capacity was measured in LD 5 cm from the last rib in the cranial direction, expressed as drip loss, in approx. 100 g samples, using the plastic bag method described by Honikel (1998).

2.6. Consumer studies

The questionnaire design for the present study was based on the findings from a study of consumer perception of pork in Denmark, Norway and Sweden (Bryhni, Byrne et al., 2002). Each consumer completed a questionnaire consisting of two parts. In the first part respondents were asked to indicate their liking after tasting each of the eight pork samples, using one sheet for each sample. The questionnaire included the following text: "Q1. Taste the sample and answer the following questions: How do you like the sample?". The respondents received one sample at a time, and were to mark a cross in one of nine boxes graduated from "like very little" to "like very much". Additionally, respondents were asked to give the main reason for their evaluation of each sample in a comment section: "Q2. What was the main reason for you to give the mark on the box specifically?".

The second part of the questionnaire included questions about consumption frequency of pork, age and gender of the respondents. The questionnaire was identically formulated in all three countries (apart from nuance differences due to language translations).

The consumer panel consisted of 96 persons in each country, equal distribution of males and females, aged between 16 and 75 years old, who ate pork meat. In this study the participants were selected either randomly from a local telephone book, among people visiting selected food stores, or by contacting various organisations which helped in recruiting consumers for the target group that were willing to participate.

Each consumer received one half chop of pork, *M. longissimus dorsi* (LD) from the eight different treatments. The samples were presented in random order to each consumer identified with a three-digit code direct from a heated plate, one sample at a time. The back fat was removed from the loin before serving. Consumers had neutral mineral water and biscuits for pallet cleansing available between each sample tasting. The evaluations were performed in a laboratory facility as described in ISO (1988). Consumers received a reward/payment for their participation.

2.7. Data analysis

2.7.1. Mean consumer question responses

An ANOVA Partial Least Squares Regression (APLSR) analysis was carried out with the X-matrix set as 0/1 design main effect variables for country (Denmark, Sweden, Norway), adrenaline injection (normal/elevated pH), meat ageing (aged/not aged), warmed-over flavour (no WOF/WOF), cooking temperature (65/80 °C) and the *Y*-matrix as consumer question response for consumption frequency and liking data averaged over individual consumers from each country.

2.7.2. Mean sensory profiling data

Further APLSR analysis was performed with the *X*-matrix set as 0/1 design main effect variables for country (Denmark, Sweden, Norway), adrenaline injection (normal/elevated pH), meat ageing (aged/not aged), warmed-over flavour (no WOF/WOF), cooking temperature (65/80 °C) and the *Y*-matrix as sensory profiling data averaged over consumers from each country.

2.7.3. Mean consumer question responses and sensory profiling data

Partial Least Squares Regression (PLSR) was carried out with the sensory profiling data set as the *X*-matrix averaged over individual consumers from each country and *Y*-matrix as the consumer question response for liking averaged over individual consumers from each country.

The APLSR and PLSR correlation loading plots show relationships between *X* and *Y*, while the regression coefficient plots summarise the main contribution to variation after optimal numbers of components. In addition, jack-knife analysis of regression coefficient uncertainty estimates was performed to determine the significance of effects at the 5% level (Martens & Martens, 2001). Original data set had 96 responses for each of eight samples for each country (96 × 8 × 3 = 2302 'objects').

Unscrambler (CAMO ASA, version 7.6) was used for multivariate analysis. The chemical data were analysed by the univariate least-squares method using Proc. GLM for each of the chemical analysis alone (SAS, Version 8.02). The effect of treatment was considered as fixed.

3. Results

3.1. Consumer studies

The overall liking score for the eight sample treatments (Table 1) are shown in Fig. 1. Pork with elevated pH_{24h}, cooked to 65 °C without ageing and reheating (no WOF) (B7) obtained the highest consumer liking score, followed by normal pH meat cooked to 65 °C (B3) and aged for 6 days. The other elevated pH_{24h} meat (B8) had the third highest liking in spite of no ageing and cooked to 80 °C. The two WOF samples obtained the lowest liking score. APLSR analysis (Figs. 2 a) was determined to have three significant PCs explaining 49, 38 and 9% variance in PC 1, 2 and 3, respectively. PC1 in Fig. 2a describes the liking for WOF. The highest liking was found for no WOF samples and lowest liking for WOF. Meat with elevated pH got higher liking than the normal pH meat ($P < 0.05$). There was also a significant ($P < 0.05$) difference in liking between core cooking temperature to 65 and 80 °C, with highest liking for 65 °C. The difference between aged and not aged pork is not significant ($P > 0.05$), but the results in Fig. 1 indicates the higher liking for aged meat.

PC2 in Figs. 2a revealed differences between the countries with the highest sample liking by Swedish consumers and lowest by Norwegian consumers. No significant interaction between countries and sample treatments was determined, which contributes to the

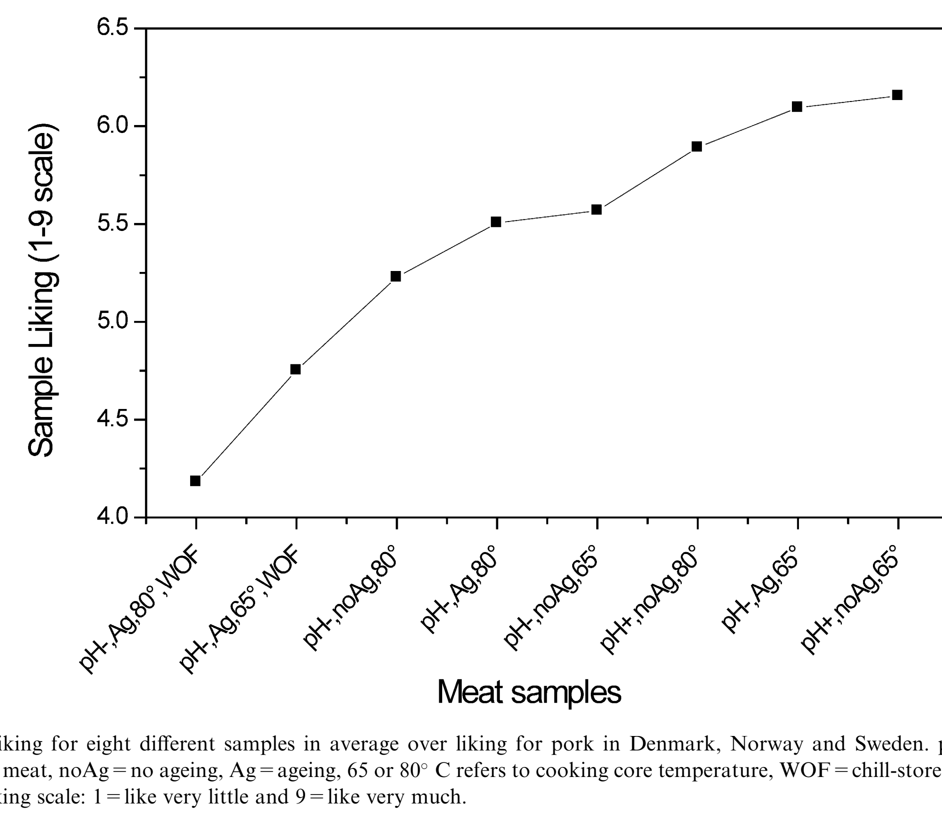

Fig. 1. Consumer liking for eight different samples in average over liking for pork in Denmark, Norway and Sweden. pH- = normal pH meat, pH + = elevated pH meat, noAg = no ageing, Ag = ageing, 65 or 80° C refers to cooking core temperature, WOF = chill-stored at 4 °C for 2 days and reheated. Sample liking scale: 1 = like very little and 9 = like very much.

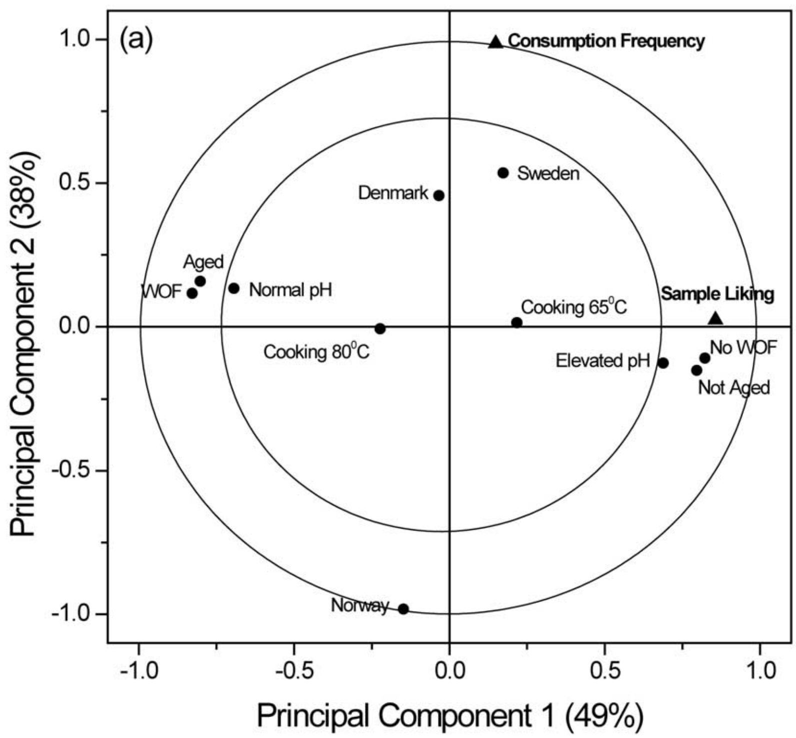

Fig. 2. ANOVA partial least squares regression (APLSR) model showing two significant Principal Components (PCs) explaining 49 and 38% variance in PC 1 and 2, respectively, including average over liking and consumption frequency (π) for pork in Denmark, Norway and Sweden versus main design variables (•): pH related to adrenaline injection (Normal/Elevated pH_{24h}), meat ageing (Aged/Not Aged), warmed-over flavour (No WOF/WOF), and cooking temperature (65/80 °C).

understanding that the consumers in all three countries agree about the sample liking. The disliking for WOF and liking for elevated pH meat cooked to 65 °C, are the major results from the consumer's judgement of these samples, which is shown in the regression coefficients in Fig. 3 ($P<0.05$). No WOF was the single most important contributing factor to consumer liking.

The comments related to liking in question 2 (Q2) were summarised to reveal possible systematic pattern. The comments were split into four categories; flavour, consistency, appearance and odour (results not shown). The major difference when summarising the flavour comments was found between the WOF and the no WOF samples. More negative comments such as "bad off-flavour" and "missing taste", and fewer comment indicating good flavour were given for WOF samples. The two elevated pH_{24h} samples received most positive comments and more than 90 consumers (31%) had answered "pleasant flavour". Comments like "juicy" and "tender" were mainly given for samples with elevated pH_{24h}, but in addition samples cooked to 65 °C with no WOF had many of these comments. Fewer comments and no major pattern were shown for appearance and odour.

3.2. Sensory profiling

APLSR analysis of the sensory profiling data in relation to the main design variables was determined to have three significant PCs explaining 55, 25 and 11% variance in PC 1, 2 and 3, respectively (Fig. 4a and b). PC1 showed that WOF samples had more off-flavours and off-odour, among them pig flavour, metallic taste and warmed over flavour, and less meat flavour, than the no WOF samples ($P<0.05$). Meat with elevated pH_{24h} was judged to contain more sweet, less acidic and less meat flavour (PC2, Fig. 4a) in addition to be more juicy and tender than normal pH meat. The trained panel in accordance with the consumers clearly differentiated the two cooking temperatures, with higher sweetness, juiciness and tenderness associated with 65 °C than for 80 °C ($P<0.05$). In addition, the samples cooked to 80 °C scored higher for brown colour intensity (Fig. 4a, PC 2). The aged meat samples scored higher for meat flavour and acidic/sour than not aged ($P<0.05$).

3.3. Chemical analysis

The adrenaline injection of pigs resulted in elevated ultimate pH_{24h}. Table 3 shows the temperature, pH, colour and drip loss for the eight treatments. Differences in pH_{24h} show that normal pH meat (treatment B1-6, Table 1) and elevated pH meat (treatment B7-8 with stressed animals) were produced ($P<0.05$). In addition to higher pH_{24h} and pH_{45min}, B7-8 scored lower for colour values (L^*a^*b) and lower for drip loss than B1-6 ($P<0.05$).

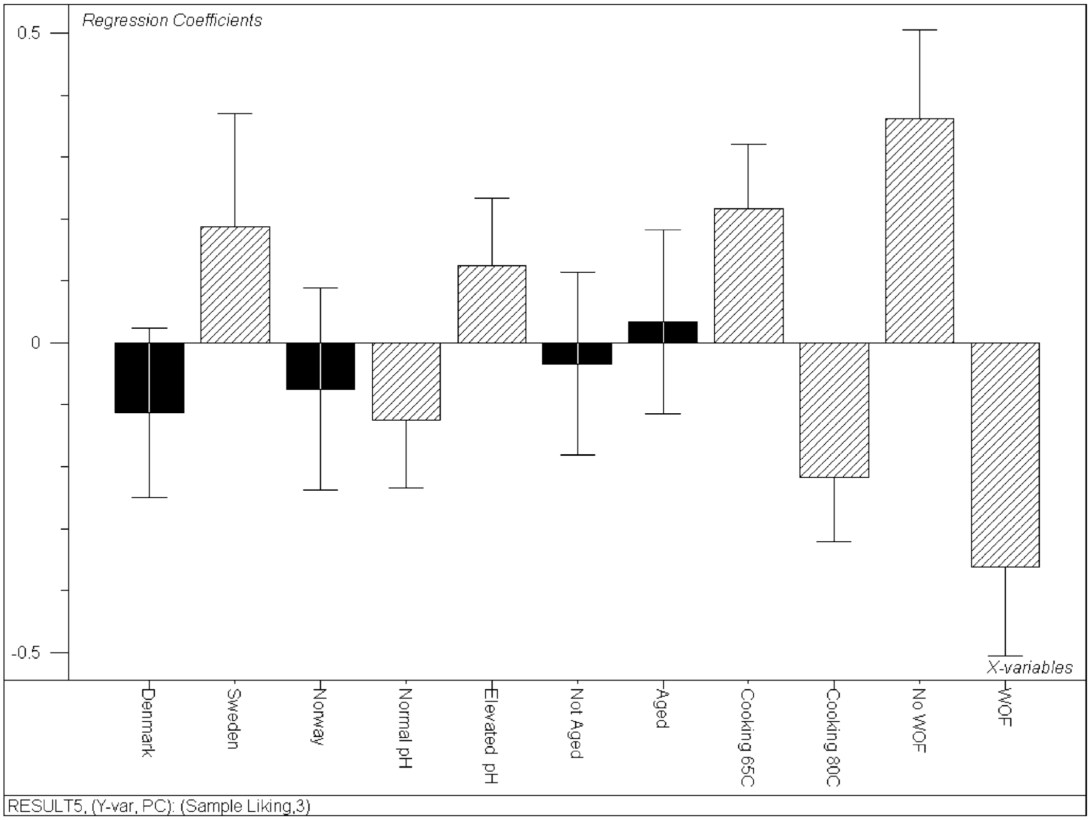

Fig. 3. Regression coefficients after three significant principal components ±2 standard uncertainties from a ANOVA Partial Least Squares Regression (APLSR) model, including average over liking for pork in Denmark, Norway and Sweden versus main design variables country, adrenaline injection, ageing, cooking and warmed-over flavour (WOF). Significant coefficients are shown as striped column.

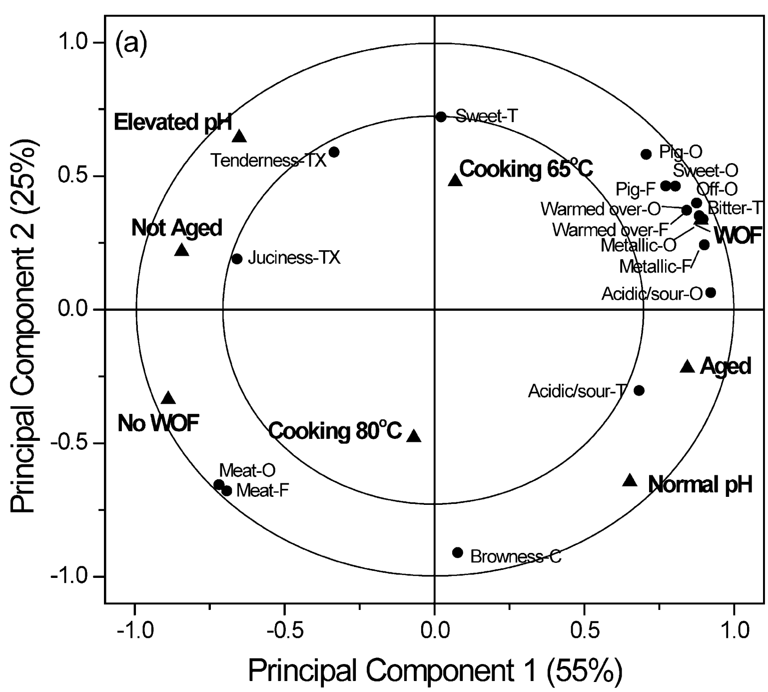

Fig. 4. ANOVA partial least squares regression (APLSR), showing two significant principal components (PCs) explaining 55 and 25% variance in PC 1 and 2, respectively, of the 17 sensory profiling terms (●) in relation to the eight different sample treatments (π): ▲ pH related to adrenaline injection (Normal/Elevated pH_{24h}), meat ageing (Aged/Not Aged), warmed-over flavour (No WOF/WOF), and cooking temperature (65/80 °C). Suffix to sensory terms indicates method of assessment by panelists; -C = Colour,-O = Odour,-F = Flavour,-T = Taste,-Tx = Texture.

Table 3
Quality characteristics for the sample in the eight treatment groups[a]

Treatment[b]	B1	B2	B3	B4	B5	B6	B7	B8	P value
pH_{1min}	6.8	6.7	6.8	6.7	6.7	6.8	6.8	6.8	0.268
pH_{45min}	6.6a	6.5a	6.6a	6.6a	6.6a	6.6a	6.7b	6.8b	0.002
pH_{24h}	5.5a	5.6a	5.5a	5.5a	5.5a	5.6a	5.9b	6.0b	0.001
$Temp_{1min}$	39.7	39.6	39.5	39.5	39.4	39.4	39.6	39.6	0.486
$Temp_{45min}$	38.2	38.7	38.6	38.3	38.6	38.7	38.1	38.0	0.888
$Temp_{24h}$	4.0	4.3	4.5	4.4	4.3	4.7	4.0	3.9	0.111
L Lightness	56.0c	53.2b	55.3c	53.6b	54.6b	53.5b	48.2a	47.5a	0.001
a red/green	7.6c	7.6c	7.9c	7.6c	7.7c	7.3c	6.5b	6.1a	0.001
b yellow/blue	6.8c	6.2c	6.8c	6.2b	6.4b	6.1b	4.0a	4.1a	0.001
Drip loss%	6.7c	6.6c	6.5c	6.0b	6.5c	6.6c	2.5a	1.9a	0.001

[a] Twelve animals in each treatment. Means in a row with a different letter differ ($P<0.05$).
[b] Pigs in B7 and B8 were given adrenaline (0.3 mg/kg body weight) 15 h prior to stunning (elevated pH meat).

3.4. Relationships between sensory and consumer studies

The relationships between sensory and consumer data are illustrated in Fig. 5, the regression coefficients relate the sensory terms to sample liking directly. Samples characterised by the trained panel as juicy, tender and without off-flavour also received higher consumer liking ($P<0.05$). Metallic flavour, warmed over flavour, bitter taste, off-odour, sweet odour and acidic/sour odour all had negative influences on consumer liking ($P<0.05$). Meat flavour, pig flavour and sweet taste had a less evident influence on liking ($P>0.05$). Consumer liking was lower for the brown colour characteristics by trained panel, which is probably due to the higher brown colour for pork cooked at 80 °C ($P<0.05$), which is associated with less tender and juicy meat. Adrenaline injection resulting in elevated pH, cooking temperature and WOF influenced both trained panel profiling and consumer liking ($P<0.05$). Significant effects of ageing (6 days) were found by the trained panel (results not shown), but these differences were not detected ($P>0.05$) by consumers (Fig. 3). When looking at all single sensory attributes separately, WOF is the single treatment showing most significant differences detected by both trained panel and consumer.

3.5. Frequency of eating pork

Eating frequency of pork between consumers in Denmark, Sweden and Norway varied. Highest consumption

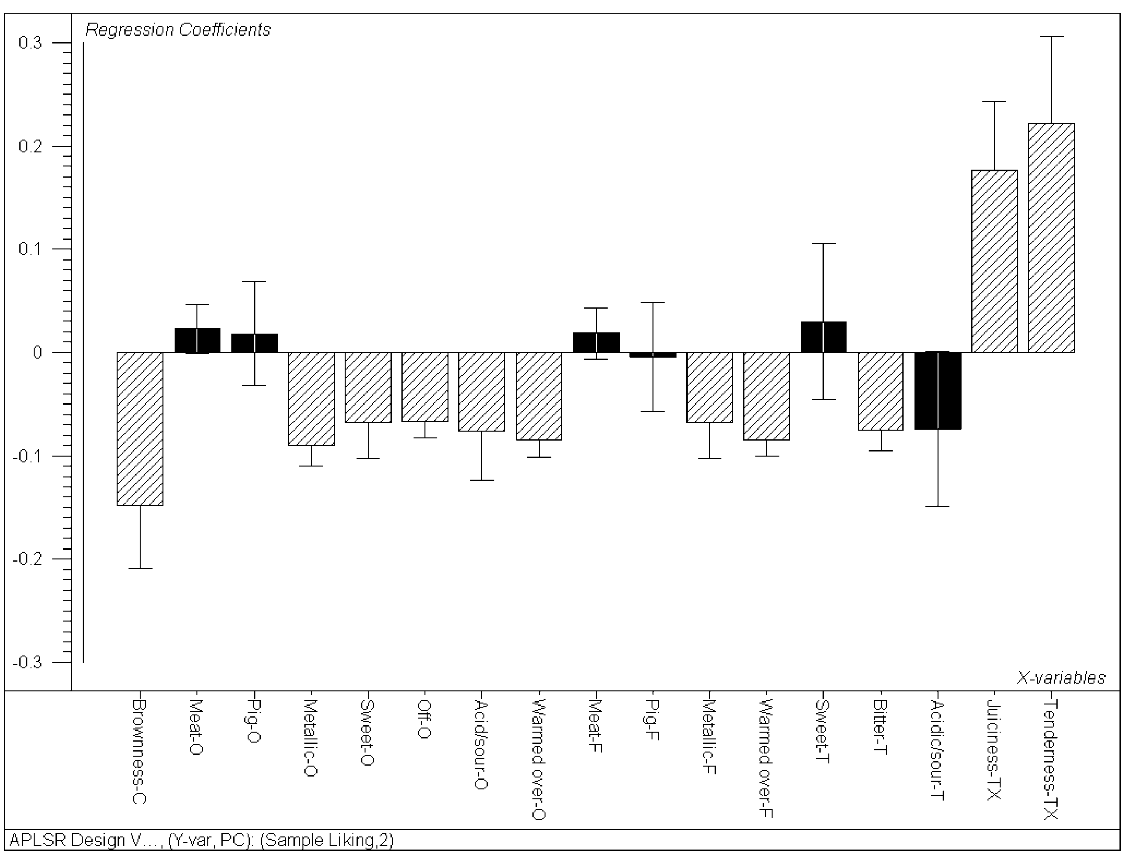

Fig. 5. Regression coefficients after two significant principal components ±2 standard uncertainties from a partial least squares regression (PLSR1) model, relationship between sensory profiling and consumer sample liking for the different treatments; pH related to adrenaline injection (Normal/Elevated pH_{24h}), meat ageing (Aged/Not Aged), warmed-over flavour (No WOF/WOF), and cooking temperature (65/80 °C). Significant coefficients are shown as striped column. Suffix to sensory terms indicates method of assessment by panelists; -C = Colour,-O = Odour,-F = Flavour,-T = Taste,-Tx = Texture.

frequency was found in Sweden and Denmark and lowest consumption frequency in Norway (Fig. 6). This is in accordance with an earlier study by Bryhni, Byrne et al. (2002), but in that study the Swedish consumer showed distinct higher consumption frequency than the Danish consumers. The present study shows that 9% of Danish consumers eat pork more than 3 times a week, which is more than in the other countries. Most Danish and Swedish (59 and 72%, respectively) consumers reported to eat pork 1–3 times a week, while most Norwegian (73%) reported to eat pork 1–3 times a month. None of the Swedish consumers ate pork less than once a month, and none of the Norwegian consumers ate pork more than 3 times a week. As illustrated in Fig. 7, consumer liking of the tested samples is related to consumption frequency. Consumers with the higher score for liking reported to eat pork more often (3 times a week or more), while those who had lower liking score seldom eat pork.

3.6. Difference between age groups and gender

The age and gender distribution was fairly equal between countries (Table 4), with a higher proportion from the age group 16–25 in the Danish sample and more consumers from the age group 56–65 from Norway. The

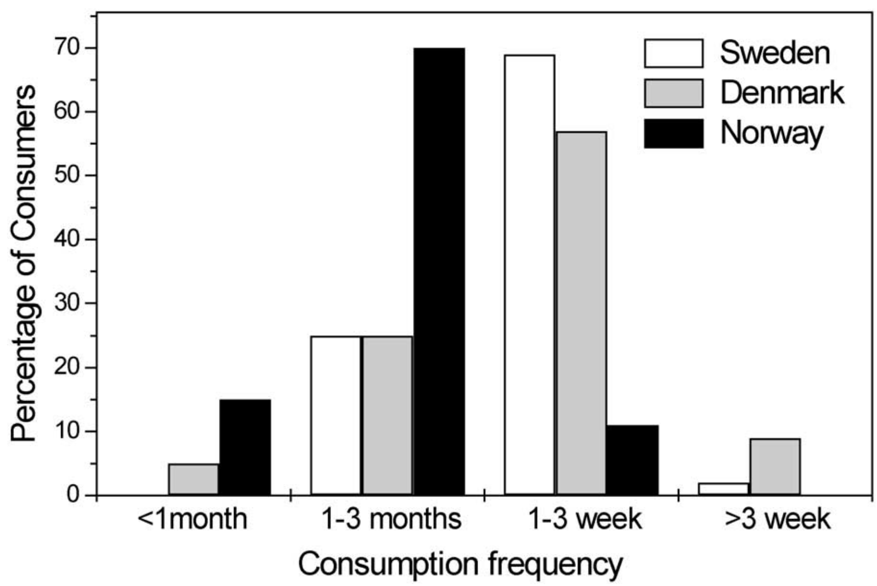

Fig. 6. Consumption frequency of pork in Sweden, Denmark and Norway.

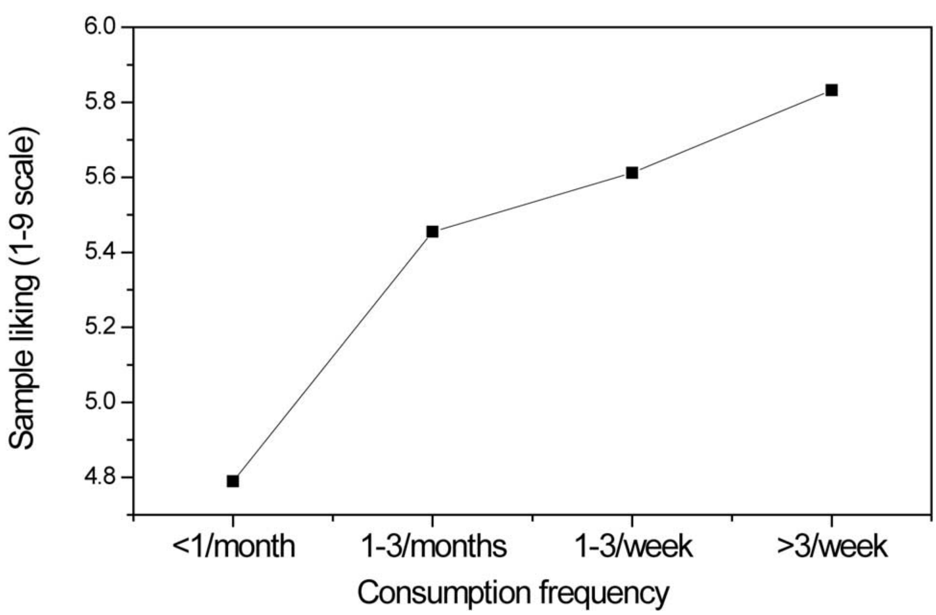

Fig. 7. Frequency and liking for pork in average between countries and treatments.

Table 4
Number of consumers that responded segmented into age and gender for each country, including 288 consumers in total and 96 consumers from each country

Country	Age					Gender	
	16–25 mean ($n=52$)	26–35 mean ($n=53$)	36–45 mean ($n=54$)	46–55 mean ($n=59$)	56–65 mean ($n=70$)	Female mean ($n=150$)	Male mean ($n=138$)
Denmark	23	17	16	20	20	50	46
Sweden	18	20	18	18	22	49	47
Norway	11	16	20	21	28	51	45

Norwegian sample also had a higher percentage of women (53%) than the other countries, but none of these small differences are believed to influence the results.

Overall, older people liked pork more than younger people did. Consumers aged 55–65 liked pork most followed by the age groups 46–55 and 36–45. In contrast the consumers in the age groups 16–25 and 26–35 years disliked pork the most. The difference between consumers aged 26–35 and 46–55 was significant ($P<0.05$). The same pattern was shown for pork eating frequency. In all three countries, older people (age 56–65) appeared to eat pork more frequently ($P<0.05$) than younger people (26–35).

There was a significant ($P>0.05$) gender difference showing that men ate pork more often than the women, but a significant age-gender interaction was also evident, where in contradiction women between 46 and 55 ate pork more often than men ate in the same age group. The higher general eating frequency of pork for men is in accordance with studies by Bjørkum and Lien (2001). No major difference in liking of pork was found between men and women ($P>0.05$), which is in accordance with Bryhni, Byrne et al. (2002), but a significant interaction between age and gender shows the lower liking by female between 16–25 and 36–45 compared to men in the same age group.

4. Discussion

Finding the optimal combination of sample treatments is important to fulfil consumer satisfaction. According to the present study non-reheated samples (no WOF), heated to a core temperature of 65 °C and with elevated pH are preferred. The sensory panel characterised these samples with low off-flavour and high scores for tenderness and juiciness. The difference between WOF samples and non-reheated samples was the major source of variation in this study. This is in accordance with Cross et al. (1987) showing the consumer awareness of warmed over flavour. Ahead of these experiments we did a focus group. This showed consumers' awareness of WOF, where the consumers pointed out that "The taste is not as good when preheated" and "The flavour becomes different" (Bryhni, Byrne, et al., 2002). The present study strengthens the conclusion that the meat industry has to be aware of WOF and off-flavour related to WOF, especially when making ready to heat and eat products. Otherwise the liking and probably also the frequency of pork purchase will decrease, because the consumer can detect off-flavour and WOF, which they dislike. In addition to WOF, texture attributes must also be considered when dealing with reheated pork, since lower juiciness and tenderness were shown in these samples.

The higher consumer liking for pork cooked to 65 °C compared to 80 °C was related to the sensory description of a more sweet taste, and a more tender and juicy meat, which is in accordance with Agerhem and Tornberg (1993). Consumers' liking for meat cooked at a lower temperature shows the potential for improving the eating quality through teaching consumers and food preparation establishments about the importance of lower cooking temperature of pork. In the focus group described by Bryhni, Byrne et al. (2002), consumers were worried about "red" or undercooked pork, and one explanation was the possibility for presence of trichinosis even the existence of Trichinella spiralis is very seldom found in Norwegian slaughter pigs (approx. 1/10,000,000) (Ostroff et al., 1994). The presence of Yersinia enterocolitica and other zoonotic bacteria also have to be considered when discussing cooking temperature of pork (Ostroff et al., 1994), but to obtain the best eating quality alone, a lower temperature is preferable. A more optimal cooking may contribute to pork being served more often as a party dish. Today most consumers consider pork as an everyday food (Bryhni, Byrne et al., 2002).

The relationship between pre-slaughter stress and the general quality of meat has been studied by a number of authors (Byrne et al. 2001; Fernandez & Tornberg, 1991; Lewis, Rakes, Brown, & Noland, 1989; Miller et al., 2000; Warris, Brown, Adams, & Corlett, 1994). It has been shown that the amount of pre-slaughter stress imposed on animals leads to variation in pH decline post-mortem (Henckel et al., 2000). Brewer and McKeith (1999) showed that consumers could discriminate among pork of varying colours and appearance (wet/dry). Pork with a dry appearance is perceived negatively by consumers. The present study shows that consumers can detect differences in pH related to stress, and prefer the elevated pH_{24h} meat even within the "normal" pH area. Miller et al. (2000) showed higher preference for high pH meat (>5.9 classified as DFD meat), while Fernandez et al. (1999) found meat being tougher at intermediate pH values (around 6). In the present study the elevated pH (pH above normal 24 h slaughter pH) meat was described to have a sweet taste and to be more tender, which is in accordance with a recent study by (Byrne, O'Sullivan, Bredie, & Martens, 2003) who found similar elevation in sweetness and a reduction in sourness in high pH RN^- gene pork. To find optimum normal pH is an everlasting question. To meet consumers' demand for pork quality it is important to avoid pre-slaughter stress, but ultimate pH can also be influenced genetically or by feeding (Rosenvold et al., 2001). To produce pork with higher pH_{24h} (6.0 versus 5.5) will according to the present study increase consumer liking, but this may have negative consequences for its utilisation for other purposes, e.g. hygienic aspect and lower storage time.

There was a tendency that consumers liked aged more than not aged meat, but the difference was not significant. The sensory analyses describes more tender meat when aged, which is preferable for consumers, still it seems that ageing was the least important treatment in the present study. The most probable reason for this is, ageing resulted in relatively smaller difference between samples when compared to the other factors, such as WOF.

The fact that Swedish consumers expressed higher liking score for the same pork samples than Norwegian consumers, is probably due to a more general positive attitude towards pork. Glitsch (2000) also found variation in attitude and behaviour towards meat between countries. Still consumers in all three countries agreed about the major differences between samples, and fortify the importance of treatment independent of the country.

By studying many treatments together, it is possible to find the most optimal combination. It is the result from different treatment combinations that gives the possibilities to present pork with a more optimal eating quality. More research is needed to find the optimal treatment combination, which results in higher consumer liking of pork. Probably the optimal for one consumer will be different from others, which makes it even more complex. The present study shows that younger people liked pork less than older people. This is in accordance with a previous study by (Bryhni, Byrne et al., 2002), where younger consumers (16–35 years) were found to be more aware of off-flavour such as rancid flavour. In addition, do younger people think pork is fatty meat. Therefore, minimisation of problems connected to off-flavour is critical for the meat industry in the future (Bryhni, Byrne et al., 2002).

5. Conclusions

The present study contributes to a better understanding of the relationship between consumer liking and the sensory characteristics of pork. For pork quality special attention should be put on the optimal treatment combination to ensure tender and the juicy meat, and absence of off-flavour, such as WOF, metallic and pig flavour.

Consumer liking of pork was influenced by quality characteristics such as WOF development, cooking temperature and pH. Despite differences in perception of pork in the three Scandinavian countries, the overall results show that pork samples with no WOF were liked more than samples with WOF. Meat with a core temperature of 65 °C was preferred compared to 80 °C, and "elevated pH_{24h} meat" preferred compared to meat with normal pH. Swedish consumers showed higher liking for pork in general and consumed pork more often. In addition, older people and males ate pork more often than younger people and females.

The present study shows the importance of pre- and post-mortem factors in relation to the fulfilment of consumers' demands for pork quality. The meat industry can benefit substantially by taking into account the importance of sensory characteristics and this is particularly important in pre-cooked ready to heat products. Consumers do detect quality differences, and it does influence their liking and consumption of pork.

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