EFFECTS OF DRY-AGEING ON PORK QUALITY

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Abstract—**Dry-ageing has been reported to enhance flavour attributes of beef by surface desiccation, increasing the concentration of flavour-related compounds. However, the effects of dry-ageing on fresh pork have not been evaluated. Large White (LW, n=24) and Large White x Duroc (Duroc, n=24) barrows were slaughtered and three *longissimus thoracis et lumborum* sections from each side of the carcass were wet or dry-aged for 2, 7 or 14 days. Meat from Duroc barrows had lower (P<0.001) moisture and protein content, and higher (P<0.01) fat content, L^* and hue values. Instrumental and sensory tenderness, juiciness and flavour were higher (P<0.01) in meat from Duroc than LW barrows. The increase (P<0.01) in flavour intensity and the decrease in off-flavour of meat from LW barrows were greater (P<0.05) in day 7 than in day 14. The increase in duration of ageing decreased moisture content and drip loss and increased (P<0.001) protein content, purge loss and L^*, chroma and hue values. These changes were more accentuated in dry-aged meat (P<0.01). Moreover days of ageing dependent increases (P<0.001) were observed for instrumental and sensory tenderness and juiciness. The increase in purge losses (P<0.001) in dry-aged meat resulted in lower (P<0.001) moisture and higher (P<0.001) protein content compared with wet aged meat. Nevertheless, when standard sensory methodologies were applied (sampling the centre of the chop), no dry-ageing effect (P>0.05) was observed on sensory characteristics. These data suggest that if any change in pork flavour happens during dry-ageing, it is limited to the meat surface. Therefore duration of ageing affected most quality and sensory characteristics, there were only variable changes to quality attributes of dry versus wet-aged pork, but shrink losses associated with dry-ageing were higher.**

Index Terms— **ageing, flavour, genotype, purge loss, tenderness.**

I. INTRODUCTION

Dry-ageing is a traditional method of ageing beef, that involves direct exposure to air-flow and humidity in a cooler for a variable number of days followed by trimming of spoiled or oxidized meat prior to cooking. Based on the perception of improved flavour and tenderness (Campbell, Hunt, Levis & Chambers IV, 2001; Warren & Kastner, 1992) many upscale restaurants will dry-age beef before serving customers. However the effects of dry-ageing on flavour attributes is not clear (Parrish, Boles, Rust & Olson, 1991).

In general, increasing wet-ageing time has been reported to improve instrumental and sensory tenderness (Ellis, Brewer, Sutton, Lan, Johnson & McKeith, 1998; Juárez, Caine, Larsen, Robertson, Dugan & Aalhus, 2009; Rees, Trout & Warner, 2002), juiciness, flavour (Channon, Kerr & Walker, 2004) and colour (Lindahl, Karlsson, Lundström & Andersen, 2006) in pork. However, with the exception of cured ham, bacon or sausage aged by smoking or treating with salt or nitrites (Ai-Nong & Bao-Guo, 2005; Flores, 1997; Misharina, Andreenkov & Vashchuk, 2001; Narváez-Rivas, Vicario, Constante & León-Camacho, 2008) information regarding dry-ageing of fresh pork is limited. Pork can suffer from excessive moisture losses and higher oxidative rancidity than beef, due to its higher levels of poly-unsaturated fatty acids. Furthermore, positive effects of ageing on quality characteristics in pork could be influenced by the level of fatness of the carcasses and the intramuscular fat content of the muscle, which is affected by pig genotypes.

The focus of this study was to evaluate the effect of dry-ageing compared to conventional wet-ageing on objective and subjective measures of pork loin quality from two genotypes differing in carcass and muscle fat composition.

II. MATERIALS AND METHODS

A. Animal management and slaughter processing

Forty-eight barrows from two genotypes, Large White × Large White (LW, n = 24) and Duroc × Large White

(Duroc, n = 24), were assigned on the basis of live-weight into pens of three animals at the Lacombe Research Centre Swine Unit. All pigs in the study were managed, handled and slaughtered in accordance with the principles and guidelines established by the Canadian Council of Animal Care (CCAC, 1993). Six weeks prior to slaughter the pigs received a finishing diet (*ad libitum*) consisting of ground corn (35.0%), ground peas (25.1%), ground barley (19.5%), canola meal (16.8%), finisher pre-mix† (2.6%), canola oil (1.0%) and selenium (0.01%). At 165 d of age, pigs were transported to the Lacombe Research Centre abattoir (0.5 km) for slaughter. The LTL was dissected from both sides of each carcass and the covering fat was trimmed to < 12 mm in depth at any point on the surface of the loin. Each loin was cut into thirds. Sections were weighed and vacuum packaged into polyethylene (left loin sections) (Winpak, Winnipeg, MB) or moisture permeable thermoplastic elastomer (right loin sections) (Unipac, Edmonton, AB), polyamide bags for ageing. The packaged loin sections were stored on wire racks in a 1 °C cooler. Controlling for loin location at 2, 7 or 14 d *post-mortem*, a loin section from each animal and ageing treatment was removed from the cooler and weighed to determine purge losses. pH was then recorded at the anterior end of each section using an Accumet AP72 pH meter (Fisher Scientific, Mississauga, ON, Canada) equipped with an Orion Ingold spear-type electrode (Ingold Messtechnik, AG, Urdorf, Switzerland). Four 2.5 cm chops were cut from each loin section and the remainder of the muscle was ground three times through a 3.2 mm grind plate. Moisture content was determined as the weight lost during heating 60-100 g of ground tissue at 102 °C for 24 h. After drying, samples were analyzed for crude protein (AOAC, 1995); Official Method; 981.10) and crude intramuscular fat extracted with petroleum ether (AOAC, 1995) Official Method; 991.36).

B. Meat quality

The first chop was pre-weighed into a polystyrene tray with a dri-loc pad, over-wrapped with oxygen permeable film and stored at 1 °C for 48 h to determine gravimetric drip loss. The second chop was exposed to atmospheric oxygen for 20 min and instrumental colour measurements of L^*, a^*, b^* (CIE, 1978) were determined in duplicate using a Minolta CR-300 with Spectra QC-300 Software (Folio Instruments, Kitchener, ON, Canada). The spectral values were used to calculate hue and chroma. The second chop was then weighed and grilled (Garland Grill ED30B; Condon Barr Food Equipment Ltd., Edmonton, AB, Canada) to an internal temperature of 34 °C, turned and cooked to a final internal temperature of 68 °C. Total cooking time and final weight were recorded to determine cooking loss. After chilling, chops were re-weighed, two cores were removed from each chop and peak shear force was determined on each core perpendicular to the muscle fibre using an Instron 4301 testing system with a Warner-Bratzler attachment (cross-head speed of 200 mm/min).

C. Sensory analysis of pork quality

The third and fourth chops were cooked on a grill as previously described, prior to taste-panel sensory analysis. Chops were sub-sampled by cutting 1.3 × 1.3 × 1.3 cm cubes from the centre of the chops taking care to avoid having an excess content of fat or connective tissue (AMSA, 1995). Panellist training and serving was based on published standards and guidelines (AMSA, 1995; ASTM International, 2009) with panellists previously extensively trained for evaluation of meat. Chops were evaluated for initial and overall tenderness, amount of perceptible connective tissue, juiciness and flavour intensity using a nine-point descriptive scale, as follows: 9 = extremely tender, no perceptible connective tissue, extremely juicy and intense pork flavour; 1 = extremely tough, abundant connective tissue, extremely dry and bland pork flavour.

D. Statistical Analysis

Data were analyzed by Mixed Models procedures (SAS, 2003). The statistical model included genotype, ageing method and days of ageing as main effects, with slaughter group as random variable. Linear contrasts with one degree of freedom were used for separation ($P < 0.05$) of least square means using the PDIFF and STDERR options in SAS (SAS, 2003). Since most interaction effects were not significant ($P > 0.05$), only main effect means were shown in tables. Two-way interactions, when significant, were included in the tables (P value only) and discussed in the text. No three or four-way interactions were observed ($P > 0.05$).

III. RESULTS AND DISCUSSION

Crossbreeding with Duroc increased ($P < 0.001$) LTL intramuscular fat content by 48.9% (Table 4) and decreased shear force values ($P < 0.001$), as reported previously by several authors (Channon et al., 2004; Edwards, Bates & Osburn, 2003; Ellis et al., 1998). Drip and purge losses were not affected by the genotype ($P > 0.05$). L^* and hue values were higher ($P < 0.001$) in meat from Duroc, partly explained by their intramuscular fat content (Juárez et al. 2009). Furthermore crossbreed has been reported to affect both blooming and colour stability (Lindahl et al., 2006).

Dry-ageing, as expected, decreased moisture content and drip loss and increased protein content and purge loss ($P < 0.001$) as reported by several authors in dry-aged beef (Ahnström, Seyfert, Hunt & Johnson, 2006; Campbell et al., 2001; Laster et al., 2008; Warren et al., 1992) and dry-aged cured pork products (Carrapiso & García, 2008; Ramírez & Cava, 2007).

As ageing progressed, decreased moisture content and drip loss, and increased pH, protein content and purge loss ($P < 0.001$) were observed. Increasing ageing time also decreased shear force values ($P < 0.001$). According to (Xiong, Gower, Li, Elmore, Cromwell & Lindemann, 2006), as ageing proceeds, shear force values gradually decrease($P < 0.05$), but beyond day 10, there is no further change in instrumental texture ($P > 0.05$). L^* and hue values increased from day 2 to 14 ($P < 0.001$), while chroma increased from day 2 to 7 ($P < 0.001$). Similar results were found by (Tikk, Lindahl, Karlsson & Andersen, 2008) related to increases in oxymyoglobin and decreases in myoglobin content. The changes in moisture, protein content and drip and purge losses were more accentuated in dry-aged meat ($P < 0.01$), due to its higher evaporative loss.

Table 1. Pork quality characteristics from barrows differing in genotype, ageing type and days of ageing

	Genotype		Aged		Day			SEM	Sig.				
	Duroc	**LW**	**Dry**	**Wet**	**2**	**7**	**14**		**Genotype**	**Aged**	**Day**	**G*D**	**A*D**
pH	5.61	5.61	5.62	5.60	5.57^{b}	5.63^{a}	5.62^{a}	0.02	ns	ns	***	ns	ns
Moisture, mg g^{-1}	725	731	722	734	736^{a}	729^{b}	719^{c}	1.10	***	***	***	ns	***
Protein, mg g^{-1}	244	247	251	240	239^{c}	243^{b}	255^{a}	0.56	***	***	***	ns	***
Fat, mg g^{-1}	28.6	19.2	24.6	23.3	23.0	24.4	24.5	1.56	***	ns	ns	ns	ns
Drip loss, mg g^{-1}	31.2	31.6	23.4	39.5	43.7^{a}	31.1^{b}	19.4^{c}	2.97	ns	***	***	ns	**
Purge Loss, mg g^{-1}	60.7	60.1	96.1	24.7	22.4^{c}	60.8^{b}	98.0^{a}	1.29	ns	***	***	ns	***
Shear, kg	5.27	5.79	5.54	5.52	6.13^{a}	5.40^{b}	5.07^{c}	0.10	***	ns	***	ns	ns
L^*	55.5	54.1	54.7	54.9	53.6^{c}	54.9^{b}	56.0^{a}	0.28	***	ns	***	*	ns
Chroma	11.3	10.9	11.2	11.0	10.3^{b}	11.3^{a}	11.7^{a}	0.15	ns	ns	***	ns	ns
Hue	35.4	33.3	34.7	34.0	30.7^{c}	34.5^{b}	37.9^{a}	0.48	***	ns	***	ns	ns

LW = Large White; SEM = Standard error of least square means; Interactions: G*D = genotype and days; A*D = ageing and days; Sig.: Significant differences. ns = $P>0.05$; *= $P<0.05$; **= $P<0.01$; *** = $P<0.001$

Most sensory characteristics (Table 2) were affected by genotype ($P < 0.05$) due to the differences in intramuscular fat content. Pork from Duroc barrows had lower cooking losses and obtained higher scores for initial and overall tenderness, juiciness and flavour intensity, while off-flavour intensity decreased.

Dry-ageing increased cook time and decreased cook loss ($P < 0.001$), similar to the results of Laster et al. (2008) in dry-aged beef. Higher moisture content may lead to a faster rate of heat transfer. However no difference in sensory characteristics was detected between wet and dry-aged pork ($P > 0.05$). Some authors have reported improvements in tenderness (Richardson, Nute & Wood, 2008) and flavour (Campbell et al., 2001) in dry-aged beef. The lack of effect on palatability in the present study may be partly explained by the use of official methodologies for sensory analysis. According to AMSA (1995), after cooking, samples for the sensory analysis were collected from the centre of the chop to avoid heterogeneous results from outside areas which may have been cooked to different endpoints. In future studies, alternative sampling methodologies could be used to try to evaluate the sensory effects of dry-ageing on the surface or conversely objective flavour chemistry methods could be employed.

Increasing the days of ageing increased cooking time and decreased cook loss ($P < 0.001$), especially in dry-aged meat ($P < 0.001$) due to purge losses during ageing. Initial and overall tenderness and juiciness increased from day 2 to 14 ($P < 0.001$), flavour intensity increased ($P < 0.01$) and the amount of connective tissue perception decreased ($P < 0.001$) from day 2 to 7, and off-flavour intensity increased from day 7 to 14 ($P < 0.05$). According to Meinert, Andersen, Bredie, Bjergegaard & Aaslyng (2007), ageing increases the concentration of flavour precursors responsible for forming the characteristic meat flavour during cooking. Moreover Ellis et al. (1998) observed that tenderness increased from 2 to 16 days ($P < 0.05$), but not from day 2 to 9 ($P > 0.05$). The effects on flavour intensity ($P < 0.05$) and connective tissue ($P < 0.05$) were more accentuated in meat from LW barrows, as indicated by the interactive effect between genotype and days of ageing.

Table 2. Pork sensory characteristics from barrows differing in genotype, ageing type and days of ageing

	Genotype		Aged		Day			SEM	Sig.				
	Duroc	**LW**	**Dry**	**Wet**	**2**	**7**	**14**		**Genotype**	**Aged**	**Day**	**G*D**	**A*D**
Cook time, sec g^{-1}	7.63	7.92	8.11	7.44	7.31^{b}	7.69^{b}	8.33^{a}	0.22	ns	***	***	ns	**
Cook loss, %	22.8	23.7	22.0	24.5	25.0^{a}	23.3^{b}	21.4^{c}	0.41	**	***	***	ns	***
Initial Tenderness	6.14	5.86	6.03	5.97	5.50^{c}	6.10^{b}	6.40^{a}	0.18	***	ns	***	ns	ns
Juiciness	4.70	4.48	4.63	4.56	4.39^{c}	4.58^{b}	4.81^{a}	0.09	**	ns	***	ns	ns
Pork Flavour Intensity	4.77	4.63	4.66	4.74	4.62^{b}	4.79^{a}	4.69^{ab}	0.03	**	ns	**	*	ns
Off Flavour Intensity	7.39	7.28	7.33	7.34	7.30^{ab}	7.43^{a}	7.27^{b}	0.11	*	ns	*	ns	ns
Connective Tissue	8.07	8.09	8.07	8.09	7.98^{b}	8.10^{a}	8.16^{a}	0.05	ns	ns	***	*	ns
Overall Tenderness	6.57	6.28	6.44	6.40	6.09^{c}	6.50^{b}	6.68^{a}	0.17	***	ns	***	ns	ns

LW = Large White; SEM = Standard error of least square means; Interactions: G*D = genotype and days, A*D = ageing and days; Sig.: Significant differences. ns = $P>0.05$; *= $P<0.05$; **= $P<0.01$; *** = $P<0.001$

Sensory characteristics were rated using a nine point descriptive scale, as follows: initial and overall tenderness (9 = extremely tender; 1 = extremely tough), juiciness (9 = extremely juicy; 1 = extremely dry), flavour intensity (9 = intense pork flavour; 1 = bland pork flavour), off-flavour intensity (9 = no off-flavour; 1 = extremely intense off-flavour), connective tissue (9 = no perceptible connective tissue; 1 = abundant connective tissue).

IV. CONCLUSIONS

As expected, ageing improved pork tenderness and palatability, and differences in intramuscular fat content among breeds affected sensory characteristics. However, according to the results obtained in this study, the increased purge loss in dry-aged loin was not compensated by significant improvements in pork flavour or tenderness attributes assessed by trained panellists using standard guidelines. Nevertheless, further investigation of the effects of dry ageing pork on sensory characteristics is warranted, either with a consumer panel that would base their evaluation on the consumption of a full chop or through the use of objective flavour chemistry methods.

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