Optimising the eating quality and shelf-life of retail pork cuts using muscle-specific three-gas MA-packaging

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Abstract – Fresh pork is packed in high oxygen modified atmosphere packaging (MAP) to preserve an attractive bloom colour on the surface of the meat and to extend the microbial shelf-life. Unfortunately, the gas composition consisting of 70-80% oxygen (O_2) and 20-30% carbon dioxide (CO_2) results in less tender and less juicy meat with a more rancid flavour compared with wrapped or vacuum-packed pork. To establish whether three-gas MAP (O_2, CO_2 and N_2), instead of two-gas MAP, would affect sensory attributes, shelf-life and colour stability, three different retail cuts were packed in MAP with 0%, 40%, 50% or 80% O_2 and 20% or 40% CO_2. Packing pork chops and schnitzels in 40% O_2 + 20% CO_2 + 40% N_2 maintained the shelf-life and resulted in more tender, more juicy and less rancid pork compared with traditional MAP, and packing sliced pork belly in 50% O_2, 40% CO_2 and 10% N_2 resulted in a more crispy texture and a less stale and bitter taste. Three-gas MAP could therefore be a suitable alternative to traditional MAP, maintaining shelf-life and enhancing eating quality.

Key Words – pork, gas composition, MAP

I. INTRODUCTION

Modified atmosphere packaging is widely used for packaging of fresh and processed foods. Traditionally red meat is packed in 70-80% oxygen (O_2) to obtain an attractive bloom colour and in 20-30% carbon dioxide (CO_2) to extend shelf-life (Singh et al. 2011). Unfortunately, high oxygen MAP results in less tender and less juicy meat with a more rancid flavour and premature browning (PMB) of pork (Lund el al., 2007) and beef (Tørngren, 2003, Lagerstedt, 2011, Kim et al. 2010). The reduction in eating quality is caused by oxidative changes of lipids and structural proteins (Lund el al., 2007, Jongberg 201, Estevez, 2011). MA-packing of minced beef in low O_2 and low CO_2 (50% O_2, 30% CO_2, 20% N_2) can maintain quality (colour, oxidative stability and microbial degradation) for 14 days at 4°C (Esmer, 2011). Different muscles vary in pigment content and microbial activity, influencing the oxygen consumption and therefore also the shelf-life and oxidative stability (Min et al., 2008).

The objective of this study was to investigate the effect of low oxygen three-gas MAP on shelf-life and eating quality.

II. MATERIALS AND METHODS

Three retail cuts (loin chops, longissimus dorsi (LD), schnitzels, semimembranosus (SM), and sliced pork belly) were packed in five different gas compositions, stored at 5°C and analysed during storage. For each cut, the experimental work was divided into two sub-trials – part 1: meat quality and part 2: shelf-life. For both sub-trials, all pigs were slaughtered on the same date, but for Part 1 pigs were selected according to gender (female) and weight (79-83 kg), whereas random pigs were used for Part 2. The same slaughter process was used for all three cuts: slaughtering on Monday, pH_{24}, cutting, deboning, shell freezing and slicing (Part 2) on Tuesday and slicing (Part 1) and MA-packing on Wednesday (day 0).

Table1. Design

3 x cut	Chops (LD)	Schnitzels (SM)		Pork belly	
5 x gas	0% O_2 20% CO_2	40% O_2 20% CO_2	50% O_2 20% CO_2	80% O_2 20% CO_2	50% O_2 40% CO_2
Storage	Quality: 0, 2, 6 and 9 days (5°C) Shelf-life: 0, 2, 5, 7, 9 and 13 days (5°C)				

Packing: 4 x chops (20 mm), 3 x schnitzels (10 mm) and 8 x sliced pork belly (9 mm) were MA-packed in five gas compositions: 1. 20% CO_2 + 80% N_2 (0/20); 2. 40% O_2 + 20% CO_2 + 40% N_2, (40/20); 3. 50% O_2 + 20% CO_2 + 30% N_2 (50/20); 4. 50% O_2 + 40% CO_2 + 10% N_2 (50/40); 5. 80% O_2 + 20% CO_2 (80/20) on a tray sealer (Multivac, T200, Denmark). Samples for Part 1 were stored for up to 9 days at 5°C and samples for Part 2 were stored for up to 13 days at 5°C.

Drip loss: was measured after storage as ((total package – (tray + meat)) *100/(total package). *Cooking loss*: was measured as: ((raw meat – (cooked meat)) *100/(raw meat).

Pigment: hemin (ppm) was measured spectrophotometrically at 640 nm.

Psychrotrophic count: samples (total surface) were diluted, surface-plated on PCA and incubated at 6.5°C for 10 days.

Shelf-life: was measured based on raw meat odour and colour and overall acceptance of bloomed and degassed meat 30 minutes after opening of the package using a 4-point scale, in which 1 = no off-odour; 2 = minor off-odour, acceptable; 3 = off-odour, unacceptable; 4 = intense off-odour, unacceptable.

Sensory analysis: the three meat cuts were tempered at room temperature to 10-12°C and cooked traditionally: chops (frying pan at 170°C, to 65-68°C), schnitzel (frying pan at 170°C, to 65-68°C) and pork belly (oven at 200°C, approx. 20 min until brown and crispy). Samples were evaluated by 8 trained assessors using a 15-point unstructured line scale anchored at the extremes (0 = low intensity and 15 = high intensity). The descriptive attributes were developed specifically for each meat cut during training, with focus on flavour, texture, juiciness and appearance.

Statistical analysis: data were analysed using mixed models (SAS, 9.2, 2002-2008). The model included gas mixture, storage time and interaction as fixed effects, and assessors and pig (storage time) as random effects. Non-significant interactions were deleted from the model. Least squares (LSmeans) were calculated and separated using probability of difference. Levels of significance: $p > 0.05$ = non-significant (ns), $0.05 > p > 0.01$ = *, $0.01 > p > 0.001$ = **, $p < 0.0001$ = ***.

RESULTS AND DISCUSSION

Metmyoglobin and microbial counts are responsible for oxygen consumption and could influence gas composition during storage. Hemin and CFU counts on the day of packaging are listed in Table 2.

Table 2.Raw material, pigment (ppm hemin) and psychrotrophic plate count (log/cm2)

	n	Chops	Schnitzels	Pork belly
Hemin, ppm	3	24	31	55
Counts, log/cm^2	5	1.8	1.7	2.5

Pork chops (LD). The shelf-life of the pork chops (longissimus dorsi) varied between gasses, and packaging in 50/40 clearly resulted in a longer shelf-life compared with the other gasses (Table 3). More than 50% of the samples would be acceptable for 10-12 days. In all cases, the shelf-life, based on colour stability, was longer than the shelf-life based on the odour of raw degassed chops.

Table 3. Shelf-life of sliced pork belly in MAP. Acceptable level (%) of odour of degassed meat.

	0/20	40/20	50/20	50/40	80/20
Day 2	100%	100%	100%	100%	100%
Day 5	100%	100%	100%	100%	100%
Day 7	100%	100%	100%	100%	100%
Day 9	70%	85%	100%	95%	100%
Day 13	36%	8%	24%	56%	36%

In Table 4, significance levels for sensory attributes are listed, and, as expected, appearance, structure and flavour of MA-packed pork chops were influenced by gas composition and storage time.

Table 4. Levels of significance. Effect of gas composition (Gas), storage time (days) and G*S interaction of pan-cooked pork chops (LD).

	Gas	Storage	G*S
Doneness	**< 0.0001**	0.9906	**0.0031**
Tenderness	0.0744	**0.0113**	**0.0048**
Hardness	**0.0219**	0.0619	**0.0063**
Juiciness	**0.0017**	**0.0465**	0.5042
WOF	**0.0080**	0.1285	0.1877
Fried flavour	0.2300	0.8980	0.0686

Nine days after packaging doneness and WOF of chops packed in 50/40 and 80/20, were more pronounced compared with all other gasses, and packing in 50/40 resulted in less juicy chops.

Unexpectedly, tenderness of 80/20 was equal to 0/20, 40/20 and 50/20 on day nine, which can be explained by the gas*storage interaction.

Table 5. Sensory attributes of pork chops (LD) in MAP with different gas mixtures (day 9, O_2/CO_2)

	0/20	40/20	50/20	50/40	80/20
Doneness	6.2^{c}	7.9^{b}	7.8^{b}	8.6^{a}	8.7^{a}
Tenderness	6.1^{a}	5.6^{ab}	5.3^{bc}	4.7^{c}	5.6^{ab}
Hardness	6.2^{a}	6.6^{ab}	6.8^{ab}	7.8^{a}	7.0^{b}
Juiciness	6.1^{a}	5.9^{a}	6.1^{a}	4.9^{b}	5.6^{a}
WOF	1.3^{c}	2.0^{bc}	1.4^{c}	2.4^{ab}	2.8^{a}
Pork flavour	5.4	5.4	5.3	4.9	4.8

On day six, as expected, MAP 0/20 and 40/20 were significantly more tender than 50/40 and 80/20, but on day nine, only packaging in 0/20 resulted in more tender chops than 50/20 and 50/40.

Pork schnitzels. Like pork chops, the shelf-life of the pork schnitzels (semimembranosus) also varied between gasses, and packaging in 0/20 or 50/40 resulted in a longer shelf-life than 40/20, 50/20 and 80/20 (Table 6).

Table 6. Shelf-life of pork schnitzels (SM) in MAP. Acceptable level (%) of odour of degassed meat.

	0/20	40/20	50/20	50/40	80/20
Day 2	100	100	100	100	100
Day 5	50	100	100	100	100
Day 7	80	100	100	100	100
Day 9	100	93	100	100	100
Day 13	56	36	8	76	40

Significance levels for sensory attributes for pork schnitzels are listed in Table 7, and, as expected, appearance, structure and flavour were influenced by the gas composition.

Table 7. Levels of significance. Effect of gas composition (Gas), storage time (days) and G*S interaction of pan-cooked pork schnitzels (SM).

	Gas	Storage	M*S
Doneness	**0.0012**	0.5099	0.1358
Small holes	**0.0007**	**0.0197**	**<0.0001**
Tenderness	0.2420	0.9493	**0.0482**
Hardness	0.2144	0.7064	**0.0252**
Juiciness	0.**0009**	0.4268	0.2655
Rancid	0.1143	**0.0701**	**0.0126**
Pork flavour	0.5045	0.6304	0.2186
Bitter taste	0.0243	0.7642	0.0635

On day nine, doneness, small holes in the meat and hardness were most pronounced in gas 50/40 and least pronounced in gas 0/20. Differences in tenderness were only significant on day two (not shown) with 0/20 being more tender than 50/40 and 80/20. Packaging in 0/20 or 40/20 prevented rancid taste from developing, whereas packaging in 80/20 resulted in the most rancid flavour among the five gasses.

Table 5. Sensory attributes of pork schnitzels (SM) in MAP with different gas mixtures (day 9).

	0/20	40/20	50/20	50/40	80/20
Doneness	7.7^{c}	8.1^{bc}	8.2^{bc}	9.5^{a}	8.7^{b}
Small holes	0.9^{b}	0.8^{b}	0.9^{b}	2.5^{a}	0.9^{b}
Tenderness	6.2^{a}	6.3^{a}	5.8^{a}	5.4^{a}	6.1^{a}
Hardness	7.0^{b}	7.1^{b}	7.2^{ab}	8.1^{a}	7.0^{b}
Juiciness	4.9^{b}	5.2^{b}	5.0^{b}	3.7^{a}	5.3^{b}
Rancid	0.7^{c}	0.8^{c}	1.2^{bc}	1.5^{ab}	2.0^{a}
Pork flavour	5.2^{a}	5.8^{a}	5.2^{a}	5.0^{a}	5.2^{a}
Bitter taste	5.3^{a}	4.3^{c}	5.0^{ab}	4.7^{bc}	4.8^{b}

Sliced pork belly. The shelf-life of sliced pork belly also varied between gasses, and packing in 0/20 or 50/40 resulted in a longer shelf-life than 40/20, 50/20 and 80/20 (Table 8). Pork belly had a much shorter shelf-life compared with chops and schnitzels.

Table 8. Shelf-life of sliced pork belly. Acceptable level (%) of odour of degassed meat.

	0/20	40/20	50/20	50/40	80/20
Day 2	100%	100%	100%	100%	100%
Day 5	100%	60%	80%	100%	80%
Day 7	70%	10%	10%	80%	40%
Day 9	20%	0%	0%	70%	0%

Pork belly was cooked hard to obtain a crispy bite, and, as shown in Table 9, other sensory attributes were significant for this retail cut compared with chops and schnitzels.

Only flavour and crispness varied when pork belly was packed in different gas compositions. As seen in Table 10, packaging in 50/40 resulted in a more crisp bite compared with the other gasses.

Table 9. Levels of significance. Effect of gas composition (Gas), storage time (days) and G*S interaction of oven-cooked pork belly.

	MAP	Storage	M*S
Crispness	< 0.0001	0.0253	**0.0004**
Hardness	0.1792	0.6629	0.1136
Rancid	0.2046	0.1537	0.9948
Stale flavour	0.0061	0.0002	**0.0062**
Pork flavour	0.1620	**0.0045**	0.2537
Piggy flavour	**0.0044**	0.9155	0.2410
Bitter taste	**0.0227**	0.0727	0.8050

Hardness, rancidity and pork flavour were not significantly affected by gas composition. Stale and piggy flavours were less intense when packed in 50/40 compared with 0/20 and 80/20 and less bitter than 0/20.

Table 10. Sensory attributes of sliced pork belly in MAP with different gas mixtures (day 6).

	0/20	40/20	50/20	50/40	80/20
Crispness	4.9 [b]	6.5[a]	6.4 [a]	7.1 [a]	3.2 [c]
Hardness	6.8	6.8	6.5	6.9	5.7
Rancid	1.0	1.3	0.9	1.2	1.6
Stale flavour	4.0 [a]	4.0 [a]	3.2 [b]	2.7 [b]	4.6 [a]
Pork flavour	5.2	4.5	4.5	4.3	4.4
Piggy flavour	2.5[ab]	2.3[bc]	1.8 [c]	1.6 [c]	3.0 [a]
Bitter taste	5.0[a]	4.8[ab]	4.4[b]	4.7[ab]	4.6[ab]

III. CONCLUSION

Gas compositions in modified atmosphere packaging of retail packed pork cuts must be muscle-specific in order to optimise shelf-life, colour stability and eating quality.

Packaging of pork chops and schnitzels in 40% O_2 + 20% CO_2 + 40% N_2 maintained the same shelf-life as traditional MAP and resulted in more tender and juicy meat with less PMB and rancid flavour. Packaging of sliced pork belly in 50% O_2 + 40% CO_2 + 10% N_2 resulted in a more crispy texture and less stale and bitter taste. Three-gas MAP could therefore be a suitable alternative to traditional MAP, maintaining shelf-life and enhancing eating quality.

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