OPTIMISING EATING QUALITY AND SHELF LIFE OF ENHANCED AND MARINATED PORK CHOPS USING THREE-GAS MAP

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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 (O₂) and 20-30% carbon dioxide (CO₂) 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 (O₂, CO₂ and N₂) with less oxygen, instead of two-gas MAP, would affect sensory attributes, shelf life and colour stability, enhanced and enhanced + marinated pork chops were packed in MAP with 0%, 40% or 80% O₂ and 20% or 40% CO₂ an N₂ as filler gas. However, it was not possible to optimise the eating quality and shelf life of enhanced pork chops without compromising the acceptance of the raw meat, as seen for fresh pork. By marinating enhanced pork chops, the acceptance limit was extended by two to seven days depending on the gas mixture, and differences in eating quality were equalised. It is recommended to pack enhanced pork chops and enhanced + marinated pork in an anoxic atmosphere (20% CO₂ + 80% N₂) to preserve the appearance, flavour and texture of the meat.

I. INTRODUCTION

Modified atmosphere packaging is widely used in the packaging of fresh and processed foods. Traditionally, red meat is packed in 70-80% oxygen (O₂) to obtain an attractive bloom colour and in 20-30% carbon dioxide (CO₂) 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), beef (Tørngren, 2003, Lagerstedt, 2011, Kim et al. 2010) and chicken (Jongberg 2013). The reduction in eating quality is caused by oxidative changes of lipids and structural proteins (Lund el al., 2007, Jongberg 2011, Estevez, 2011).

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

Two retail meat products (1. Enhanced (brine-injected) loin chops, longissimus dorsi (LD), and 2. Enhanced (brine-injected) + marinated loin chops (LD)) 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: eating quality, and part 2: shelf life. For both sub-trials, all pigs were slaughtered on the same date. However, for Part 1 pigs were selected according to gender (female) and weight (79-87 kg), whereas random pigs were used for Part 2. The same slaughter process was used for both cuts: slaughtering on Monday, pH₂₄, cutting, deboning and injection (10% weight gain) on Tuesday, and slicing and MA-packing on Wednesday (day 0).

Table 1. Experimental design

<table>
<thead>
<tr>
<th>2 x cut</th>
<th>Enhanced pork chops (LD)</th>
<th>Enhanced, marinated pork chops (LD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 x gas</td>
<td>-</td>
<td>40% O₂</td>
</tr>
</tbody>
</table>

Packing: 3 x chops (20 mm) were MA-packed in five different gas compositions (Table 1) with a tray sealer (Multivac, T200, Denmark). Samples for Part 1 were stored for up to nine days at 5°C, and samples for Part 2 were stored for up to 13 days at 5°C.

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 ten days.

Shelf life: 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

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<td>-</td>
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</tr>
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Shelf life: 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, where 1 = no off-
odour; 2 = slight off-offour, acceptable; 3 = off-
odour, unacceptable; 4 = intense off-offour, unacceptable.

Sensory analysis: the meat was tempered at room
temperature to 10-12°C and cooked on a frying pan
at 170°C to a core temperature of 65-68°C. Samples
were evaluated by eight 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 product 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 = ***.

III. RESULTS AND DISCUSSION

Enhanced pork chops

Odour is the limiting factor for acceptance of MA-
packed enhanced pork chops, regardless of the gas
mixture (Table 2), although the meat will
deteriorate at different times.

Table 2. Acceptance of enhanced pork (%
able acceptable samples/days for average score 2.5),
MA-packed in different atmospheres (O2/CO2/N2)
stored for 6-7 days at 5°C (n=25).

<table>
<thead>
<tr>
<th></th>
<th>0/20/80</th>
<th>40/20/40</th>
<th>40/30/30</th>
<th>40/40/20</th>
<th>80/20/0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 2</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Day 3</td>
<td>84%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Day 4</td>
<td>0%</td>
<td>32%</td>
<td>84%</td>
<td>68%</td>
<td>92%</td>
</tr>
<tr>
<td>Day 5</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>50%</td>
</tr>
<tr>
<td>Day 6</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>4%</td>
</tr>
</tbody>
</table>

Colour
 limit
Odour
 limit

Odour limits for traditional MAP in 80% O2 + 20%
CO2 and packing in 40% O2 + 30-40% CO2 are
comparable. Fewer than 50% of the evaluated
samples were unacceptable after approx. eight days
of storage.

The appearance, texture and flavour of enhanced
pork chops are affected by the gas mixture (Table
3). Packing of enhanced pork chops in 30-40% CO2
increases the number of small holes in the cutting
surface, although the level is generally very low.

Doneness is also affected by the gas mixture, and
oxygen seems to be responsible for the changes,
with doneness or PMB increasing in the following
order: 0% O2 < 40% O2 < 80% O2.

Texture is affected with respect to hardness of the
first bite, which increases when packing in high
oxygen MAP (80% O2 + 20% CO2) or in three-gas
MAP with 40% O2 + 30% CO2 + 30% N2 compared
with MAP in 0-20% O2 + 20% CO2.

Rancid flavour and sour taste are related to the
oxygen level in the pack and increase in the
following order: 0% O2 < 40% O2 < 80% O2. The
significance level between gas 0/20/80 and gas
40/40/40 is as low as p = 0.0619, and between gas
40/40/20 and gas 80/20 p = 0.0645. These samples
are therefore considered different.

Table 3. Sensory attributes (1-15) of enhanced
pork chops, MA-packed in different atmospheres
(O2/CO2/N2) and stored for 6-7 days at 5°C (n=48)

<table>
<thead>
<tr>
<th></th>
<th>0/20/8</th>
<th>40/20/20</th>
<th>40/30/30</th>
<th>40/40/20</th>
<th>80/20/0</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>0.5</td>
<td>0.6</td>
<td>1.1</td>
<td>0.9</td>
<td>0.6</td>
<td>0.0017</td>
</tr>
<tr>
<td>holes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doneness</td>
<td>7.0</td>
<td>8.5</td>
<td>8.7</td>
<td>8.8</td>
<td>9.4</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Tenderness</td>
<td>8.3</td>
<td>8.2</td>
<td>7.6</td>
<td>7.8</td>
<td>7.5</td>
<td>Ns</td>
</tr>
<tr>
<td>Hardness</td>
<td>5.0</td>
<td>5.0</td>
<td>6.1</td>
<td>5.3</td>
<td>5.8</td>
<td>0.0061</td>
</tr>
<tr>
<td>Juiciness</td>
<td>7.9</td>
<td>7.6</td>
<td>7.2</td>
<td>6.9</td>
<td>7.6</td>
<td>Ns</td>
</tr>
<tr>
<td>Stale</td>
<td>2.9</td>
<td>4.0</td>
<td>4.1</td>
<td>4.1</td>
<td>4.5</td>
<td>Ns</td>
</tr>
<tr>
<td>Rancid</td>
<td>1.0</td>
<td>1.9</td>
<td>1.7</td>
<td>1.8</td>
<td>2.6</td>
<td>0.0263</td>
</tr>
<tr>
<td>Pork</td>
<td>5.3</td>
<td>4.7</td>
<td>4.6</td>
<td>4.5</td>
<td>4.5</td>
<td>Ns</td>
</tr>
<tr>
<td>Sour</td>
<td>1.7</td>
<td>2.6</td>
<td>2.5</td>
<td>2.4</td>
<td>3.6</td>
<td>0.0042</td>
</tr>
</tbody>
</table>

In comparison with traditional MAP, two-gas MAP
with an anoxic atmosphere (20% CO2 + 80% N2)
optimises the appearance, texture and flavour of
MA-packed enhanced pork (Table 3). Packing in
three-gas MAP (40% O2 + 40% CO2 + 40% N2)
optimises appearance and flavour, but to a smaller
degree.
In an earlier study by Tørngren et al. (2013), packing in three-gas MAP with 40% O₂ + 20% CO₂ + 40% N₂ was recommended for fresh pork chops. For enhanced pork, 40% CO₂ is needed to achieve an acceptable shelf life.

**Enhanced + marinated pork chops**

Odour is the limiting factor for acceptance of MAP-packed enhanced + marinated pork chops (Table 4). In general, the marinade keeps the odour and the colour acceptable for longer compared with enhanced pork chops (Table 2), and the meat is perceived as acceptable for at least 13 days when packed in an anoxic atmosphere (20% CO₂ + 80% N₂).

Table 4. Acceptance of enhanced + marinated pork (% acceptable samples/days for average score 2.5), MAP-packed in different atmospheres (O₂/CO₂/N₂) and stored for 6-7 days at 5°C (n=25).

<table>
<thead>
<tr>
<th>Day</th>
<th>0/20/80</th>
<th>40/20/40</th>
<th>40/30/30</th>
<th>40/40/20</th>
<th>80/20/0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0/20/80</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>40/20/40</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>40/30/30</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>92%</td>
<td>100%</td>
</tr>
<tr>
<td>40/40/20</td>
<td>100%</td>
<td>64%</td>
<td>80%</td>
<td>48%</td>
<td>92%</td>
</tr>
<tr>
<td>80/20/0</td>
<td>28%</td>
<td>52%</td>
<td>32%</td>
<td>56%</td>
<td>100%</td>
</tr>
</tbody>
</table>

In contrast to enhanced pork (Table 3), only the appearance and flavour are affected by the MAP gas mixture, whereas texture remains unaffected when the marinade is added to the surface (Table 5).

With respect to appearance, the number of small holes increases when the gas mixture contains 40% CO₂ compared with 20% or 30% CO₂. Premature browning (PMB), measured by the attribute doneness, is reduced only when packing the meat in an anoxic atmosphere (20% CO₂ + 80% N₂). Furthermore, the anoxic atmosphere decreases the stale flavour and increases the pork flavour of the meat.

The high level of acceptance of the enhanced + marinated pork chops could partly be due to the masking of the off-flavour and discoloration by the red and flavourful marinade. Nevertheless, colourful marinades can be a way to enhance consumer acceptance of meat packed in an anoxic atmosphere, as the red surface might look more attractive than the purple deoxymyglobin.

Table 5. Sensory attributes (1-15) of enhanced + marinated pork chops, MAP-packed in different atmospheres (O₂/CO₂/N₂) and stored for 6-7 days at 5°C (n=48).

<table>
<thead>
<tr>
<th>Gas Mixture</th>
<th>0/20/80</th>
<th>40/20/40</th>
<th>40/30/30</th>
<th>40/40/20</th>
<th>80/20/0</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small holes</td>
<td>0.6</td>
<td>0.7</td>
<td>0.7</td>
<td>1.1</td>
<td>0.6</td>
<td><strong>0.0202</strong></td>
</tr>
<tr>
<td>Doneness</td>
<td>5.9</td>
<td>7.4</td>
<td>8.3</td>
<td>8.3</td>
<td>8.1</td>
<td><strong>0.0002</strong></td>
</tr>
<tr>
<td>Tenderness</td>
<td>9.0</td>
<td>8.3</td>
<td>8.3</td>
<td>8.1</td>
<td>8.7</td>
<td>Ns</td>
</tr>
<tr>
<td>Hardness</td>
<td>4.7</td>
<td>5.3</td>
<td>5.2</td>
<td>5.6</td>
<td>5.3</td>
<td>NS</td>
</tr>
<tr>
<td>Juiciness</td>
<td>7.7</td>
<td>7.7</td>
<td>7.6</td>
<td>8.1</td>
<td>8.2</td>
<td>Ns</td>
</tr>
<tr>
<td>Stale</td>
<td>1.8</td>
<td>3.6</td>
<td>3.6</td>
<td>2.8</td>
<td>3.0</td>
<td><strong>0.0136</strong></td>
</tr>
<tr>
<td>Rancid</td>
<td>0.4</td>
<td>1.1</td>
<td>1.2</td>
<td>0.7</td>
<td>0.9</td>
<td>Ns</td>
</tr>
<tr>
<td>Fried pork</td>
<td>3.0</td>
<td>2.5</td>
<td>2.5</td>
<td>2.8</td>
<td>2.6</td>
<td><strong>0.0357</strong></td>
</tr>
<tr>
<td>Sour</td>
<td>1.2</td>
<td>2.5</td>
<td>2.3</td>
<td>2.1</td>
<td>2.4</td>
<td>Ns</td>
</tr>
</tbody>
</table>

**IV. CONCLUSION**

Enhanced pork should be MAP-packed in a two-gas anoxic atmosphere (20% CO₂ + 80% N₂) to optimise the appearance, flavour and texture of the meat. Unfortunately, it will shorten the shelf life by approx. two days at 5°C.

To maintain a shelf life comparable to high-oxygen MAP, it is recommended to pack in a three-gas MAP (40% O₂ + 40% CO₂ + 20% N₂), although this gas mixture will optimise only appearance and flavour, and to a smaller degree.

It is recommended to MAP-pack enhanced + marinated pork chops in an anoxic atmosphere (20% CO₂ + 80% N₂), since shelf life remains uncompromised, and appearance and flavour are optimised.

**ACKNOWLEDGEMENTS**

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**REFERENCES**

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