THREE-GAS MAP IS OPTIMIZING EATING QUALITY AND SHELF LIFE OF RETAIL PACKED BEEF STEAKS

Mari Ann Tørngren[1] and Mianne Darré[1]

[1]Meat Technology, Danish Meat Research Institute, 2630 Taastrup, Denmark

Abstract – To optimize eating quality of fresh meat in modified atmosphere packaging (MAP), oxygen exposure has to be minimized. Oxygen pressure in the headspace is highly responsible for the chemical state of the myoglobin, and through that the colour of the raw meat. Oxygen consumption is muscle specific and has to be balanced with the oxygen content in the gas mixture to achieve an attractive red surface throughout shelf life and to minimize oxidation of proteins and lipids. To establish whether low O_2 three-gas MAP (O_2, CO_2 and N_2) could increase sensory quality without compromising shelf life and colour stability, aged strip loin steaks were retail packed in MAP with 30%, 40%, 50% or 70% O_2 and 30% CO_2. Packing of beef steaks in 30% O_2 + 30% CO_2 + 40% N_2 resulted in more tender, more juicy and less rancid steaks compared with beef steaks packed in traditional MAP (70% O_2 + 30% CO_2). Three-gas MAP could therefore be a suitable alternative to traditional MAP, maintaining shelf life and colour stability and increasing eating quality.

Key Words – gas, oxygen, packaging, vacuum

I. INTRODUCTION

Modified atmosphere packaging is widely used for packing fresh and processed foods. Traditionally, red meat is packed in high oxygen MAP with 70-80% oxygen (O_2) to obtain an attractive bloomed colour and in 20-30% carbon dioxide (CO_2) to extend shelf life [1]. Unfortunately, high oxygen MAP results in less tender and less juicy meat with a more rancid flavour along with pronounced premature browning (PMB) of pork [2] and beef [3, 4, 5]. The decreased eating quality is caused by oxidative changes of lipids and structural proteins [2, 6, 7]. Different muscles vary in pigment content and microbial activity, influencing the oxygen consumption and therefore also the shelf life, the oxidative stability and the need for oxygen during storage [8]. [9] showed, that MA-packaging of minced beef in low oxygen MAP (50% O_2, 30% CO_2, 20% N_2) can maintain an acceptable colour of the surface and avoid microbial degradation for 14 days at 4°C, but the consequences on eating quality was not explored.

The objective of this study was to investigate the effect of low oxygen three-gas MAP on shelf life and eating quality of retail packed beef steaks from aged strip loins.

II. MATERIALS AND METHODS

Twelve dairy cows (Holstein Friesian, 46-81 months, 263-326 kg carcass weight) were selected at a Danish slaughterhouse on the day after slaughter (loin temperature < 5°C). *Longissimus dorsi* (LD) was excised from the carcasses, vacuum-packed and aged for 20 days at 3°C. Strip loins from the left side of the carcass were used for eating quality analysis, whereas the right side strip loins were used for shelf life analysis. After ageing, each strip loin was sliced into 20 mm thick steaks and packed in five different retail packaging methods – one vacuum skin packing (VSP) and four different types of MAP. All packs were stored at display conditions (5°C, 1200 lux). Samples for eating quality analysis were stored for up to 7 days at 5°C, and samples for shelf life analysis were stored for up to 19 days (Table 1).

Table1. Experimental design

1 x cut	Beef steaks (20 mm from aged strip loin)				
5 x packing	1	2	3	4	5
	VSP	30% O_2 30% CO_2 40% N_2	40% O_2 30% CO_2 30% N_2	50% O_2 30% CO_2 20% N_2	70% O_2 30% CO_2
Storage	Quality: 6/7 days at 5°C, 1200 lux Shelf life: up to 19 days at 5°C, 1200 lux				

Packing: Each loin was cut into 5 x 3 steaks and retail packed with three steaks per pack in five different types of retail packaging. 1. Vacuum skin packing (VSP); 2. MAP_{30} = 30% O_2 + 30% CO_2 + 40% N_2; 3. MAP_{40} = 40% O_2 + 30% CO_2 + 30% N_2; 4. MAP_{50} = 50% O_2 + 30% CO_2 + 20% N_2; 5.

MAP_{70} = 70% O_2 + 30% CO_2. VSP samples were packed on a Multivac R575 CD Thermoformer, and MAP samples were packed in PP trays on a NEMCO Sealpac 800 plus tray sealer connected to four different pre-mixed gases (YARApraxair, Denmark).

Cooking loss was measured as: (raw meat – cooked meat) *100/raw meat.

Pigment: Myoglobin was extracted from the meat with acetone and hydrochloric acid. Hemin (ppm) was measured spectrophotometrically at 640 nm. The method is based on [10].

Psychrotrophic count: The total surface of the samples was diluted, surface-plated on PCA and incubated at 6.5°C for 10 days.

Shelf life: Evaluation of the raw meat odour and colour, and overall acceptance of bloomed and degassed meat 30 minutes after opening of the package. Five samples per treatment were evaluated four times during storage. The evaluation was performed by an internal expert panel (three assessors) 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 beef steaks were tempered at room temperature to 10-15°C and cooked on a frying pan at 170-180°C until a core temperature of 62-63°C was reached. Cooked samples were evaluated by nine 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 during training with focus on appearance, texture and juiciness.

Statistical analysis: Sensory data were analysed using mixed models (SAS, 9.2, 2002-2008). The model included packing method as fixed effect and animal (replicates), assessor and assessor interactions as random effects. 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

As shown in Table 2, the odour was unacceptable before or at the same time as appearance, and odour is therefore a better shelf life indicator than appearance. For samples packed in three-gas MAP, odour and appearance were unacceptable at the same time, whereas the colour stability is slightly longer in MAP_{70}. The initial average counts on the steaks before retail packaging were 3.3 log cfu/cm^2 varying from 2.7-3.8 log cfu/cm^2.

Surprisingly, shelf life of steaks packed in the different packing methods did not differ much, as odour limits were reached after 6 to 7 days of storage for all treatments. Steaks packed in VSP deteriorated just as fast as steaks in MAP regarding odour, but showed, as expected, a much longer colour stability.

Table 2. Shelf life of retail packed beef steaks packed in VSP and MAP gas mixtures, shown as % acceptable samples (score 1 + 2) and storage time before acceptance limit (average 2.5) is reached (n=15).

	VSP	MAP_{30}	MAP_{40}	MAP_{50}	MAP_{70}
Day 2		100%	80%	93%	100
Day 5	80%	60%	67%	100%	73%
Day 7		27%	13%	7%	53%
Day 9	27%	0%	7%	13%	27%
Day 14	7%				
Day 16	0%				
Odour limit	7 d	6 d	6 d	6.5 d	7 d
Appearance limit	15-19d[1]	7 d	7 d	6.5 d	9 d

[1] Day 16 = score 2.6 and day 19 = score 2.5

The weight loss during cooking of the steaks (core temperature: 62-63°C) is shown in Table 3.

Table 3. Cooking loss (%) of retail packed beef steaks packed in VSP and MAP gas mixtures after 6 -7 days of storage (n=9).

	VSP	MAP_{30}	MAP_{40}	MAP_{50}	MAP_{70}
Cooking loss	15.3	14.5	16.6	16.8	15.5

Cooking losses were 14.5-16.8%, but the packing method had no impact on the variation of the cooking loss ($p = 0.1272$).

Significance levels for the sensory attributes of pan-fried beef steaks are listed in Table 4. In contrast to the shelf life measurements, the packing methods had a large impact on the eating quality of the meat (Table 4).

Table 4. Levels of significance of sensory attributes describing eating quality of retail packed beef steaks packed in VSP and MAP after 6/7 days of storage

	Attributes	Packaging	Level
Appearance	Small holes	0.9134	Ns
	Doneness	0.0476	*
Texture	Tenderness	0.0108	*
	Juiciness	<0.0001	***
	Chewing time	0.0090	**
	Hardness (first bite)	0.0046	**
Flavour	Beef flavour	0.0002	***
	Warmed over flavour	<0.0001	***
	Rancid flavour	0.0014	**
	Sour taste	0.0001	***
	Bitter taste	0.5680	Ns

As shown in Table 5, doneness (PMB) becomes more and more pronounced when the oxygen level increases in the gas mixture. For optimum appearance, the meat has to be packed in a non-oxygen environment, like VSP.

Texture of the steaks is also affected by the packing method, with decreasing intensity as the oxygen level increases. Highest scores for tenderness are reached when steaks are packed in VSP, but are not significantly different from the tenderness score of MAP_{30}. Hardness of first bite as well as juiciness is optimized too when oxygen is decreased to 30% or less.

Since cooking loss is unaffected by the packing method, the decrease in juiciness with increasing O_2 level might be due to a higher drip loss during display storage as seen by [2].

As expected, the flavour scores were influenced by the oxygen level. Beef flavour was less intensive in MAP than in VSP, regardless of the gas composition. This might be due to the advanced spoilage and lipid oxidation, as the sour taste, rancid flavour and warmed over flavour was increased in the MA-packed samples compared to VSP.

The extend of lipid oxidation seems to be dose dependent in regard to oxygen, as the intensity of warmed over flavour increases in following order: 50-70% > 30-40% > VSP, and rancid flavour exhibit the same tendency.

Table 5. Sensory attributes of retail packed beef steaks packed in VSP and MAP after 6/7 days of storage (n=81).

	VSP	MAP_{30}	MAP_{40}	MAP_{50}	MAP_{70}
Holes	0.8	0.8	0.8	0.8	0.8
Doneness	4.4^{a}	5.5^{b}	8.0^{c}	9.9^{d}	10.9^{e}
Tenderness	6.4^{b}	5.8^{ab}	5.1^{a}	5.3^{a}	5.5^{a}
Juiciness	9.0^{b}	8.8^{b}	7.4^{a}	6.7^{a}	7.4^{a}
Chew time	8.1^{a}	8.7^{ab}	9.5^{c}	9.6^{c}	9.2^{bc}
Hardness	6.4^{a}	6.6^{a}	7.6^{b}	7.4^{b}	7.4^{b}
Beef	6.7^{b}	5.2^{a}	4.9^{a}	4.4^{a}	4.5^{a}
WOF	2.7^{a}	4.7^{b}	4.6^{b}	6.3^{c}	5.9^{c}
Rancid	0.9^{a}	1.9^{bc}	1.4^{ab}	2.2^{c}	2.0^{bc}
Sour	1.5^{a}	3.2^{b}	2.1^{a}	3.5^{b}	3.1^{b}
Bitter	4.5	3.9	3.8	3.6	4.0

Letters that are different from each other within the same row are significantly different.

IV. CONCLUSION

Gas compositions in modified atmosphere packaging of retail packed beef steaks from aged strip loin can be adjusted in order to optimize the eating quality, while maintaining surface colour and without compromising shelf life.

- According to odour of the raw meat, this study shows that shelf life of retail packed beef steaks is approx. 6-7 days at 5°C regardless of the packing method.
- The colour stability is twice as long when steaks are packed in a non-oxygen VSP compared to MAP.
- The appearance of the meat is affected by the packing method. To optimize appearance, oxygen must be avoided or minimized.
- Eating quality is impaired by the oxygen levels in the traditional high oxygen MAP. To optimize tenderness and juiciness, the oxygen

level has to be reduced to 30% or less, and to minimize WOF, oxygen has to be 40% or less.

To *optimize* eating quality of MA packed beef steaks, these results suggest that low oxygen three-gas MAP (30% O_2 + 30% CO_2 + 40% N_2) is an useful alternative. To achieve *maximum* eating quality, a non-oxygen packing method must be considered.

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