Does modified atmosphere packaging affect particle sizes and hardness of pork?

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Abstract

The effect of modified atmosphere packaging on particle size distribution and hardness of pork *longissimus dorsi* was investigated after storage for 2 and 13 days, respectively. The composition of the five atmospheres investigated was 70% O_2/30% CO_2 (Gas 1) 70% N_2/30% CO_2 (Gas 3) 50% O_2/50% CO_2 (Gas 4) 50% N_2/50% CO_2 (Gas 6) and 40% O_2/30% CO_2/30% N_2 (Gas 8). The present study is a part of a larger project, hence the name of the different gas mixtures. The particle size distribution was measured after homogenization of uncooked meat and calculated from data obtained using multi angle light scattering. Hardness of cooked meat was evaluated by a trained sensory panel. Atmospheres containing high levels of oxygen (balanced with carbon dioxide) resulted in harder meat and increased particle sizes, which may indicate cross-linking of proteins and/or reduced proteolysis.

Introduction

For retail display, pork is often packed in modified atmosphere with a high level of oxygen (70-80 %), which has a positive effect on the colour of the meat. However, these elevated oxygen levels have also been related to increased protein oxidation. Oxidation has been shown to lead to altered physical and chemical properties of the proteins such as reduced enzyme activity (Oliver, 1987; Rowe *et al*., 2004), susceptibility to proteolysis (Davies, 1987) and formation of protein cross-links (Lund *et al*., 2007). High-oxygen packaging atmospheres have negative effects on beef (Tørngren, 2003; Rowe *et al*., 2004) and pork (Lund *et al*., 2007) tenderness.

Traditionally, post-mortem proteolysis of meat has often been estimated as myofibrillar fragmentation using various complex and time-consuming methods. However, Lametsch *et al.* (2007) presented a novel method for determination of myofibrillar fragmentation in which multi angle light scattering is used to obtain information about the size distribution and mean diameter of the myofibrillar fragments. Multi angle light scattering was proved useful in determining differences in myofibrillar fragmentation as a function of storage period.

In the present study we have used this method to investigate how different packaging atmospheres affect myofibrillar fragmentation and sensory hardness of the pork chops.

Materials and methods

Female pigs were selected from a commercial abattoir production line (Danish Crown, Herning, Denmark). All pigs weighed between 82 and 86 kg at slaughter (warm carcass weight), contained between 59 and 61 percent lean meat, and had an ultimate pH in the range 5.6 to 5.7.

From the left side of the carcasses, *longissimus dorsi* (LD) was excised and sliced into 2 cm thick chops from the caudal end. The chops were then placed in polypropylene (PP) trays type 71-51A (Færch Plast, Denmark), packed in one of the five different modified atmospheres and sealed using a TOPSEAL™ PP MAP AF 57 film (Færch Plast, Denmark). The gas mixtures were pre-mixed and delivered by Yara Industrial A/S, Denmark, see Table 1.

The particle size distribution was determined using a novel method for determination of myofibrillar fragmentation as described by Lametsch *et al*. (2007). Particle sizes were measured and the calculated distribution was expressed in the three parameters of D(v, 0.1), D(v, 0.5) and D(v, 0.9), which represents the 10, 50 and 90 percentile values of the mean particle size distribution. All samples were homogenised and analysed in duplicate.

Hardness was evaluated by a trained sensory panel consisting of 6 assessors recruited from the professional sensory panel at the Danish Meat Research Institute. The panel was trained in accordance with ISO 4121, ASTM-MNL 13 and DIN 10964.

Multivariate statistical analysis was performed using the Unscrambler® 9.7 (CAMO ASA, Trondheim, Norway). The data was analysed using APLSR (*Analysis of variance* like use of *Partial Least Squares Regression*) which allows for significance testing. In all regression analyses, the data were centred

and full cross validated. The *X* variables (design variables) and the *Y* variables (response variables) were all standardized.

Table 1. Gas composition of the five different modified atmospheres investigated

	Aim			Actual		
	O_2 (%)	**CO_2 (%)**	**N_2 (%)**	**O_2 (%)**	**CO_2 (%)**	**N_2 (%)**
Gas 1	70	30	0	71	25	4
Gas 3	0	30	70	0.02	26	74
Gas 4	50	50	0	51	44	5
Gas 6	0	50	50	0.02	39	61
Gas 8	40	30	30	39	29	32

Results

From the APLSR model based on samples stored for two days in modified atmosphere (not shown), it became evident that only D(*v*, 0.5) of the mean particle size variables was valid. No significant differences could be ascribed this variable regarding the gas compositions investigated.

Table 2 shows the mean particle sizes and corresponding standard deviations based on samples stored in the five different gas mixtures for either 2 or 13 days. Pork chops stored two days in high levels of oxygen (70 and 50%) represents intermediate particle sizes (Gas 1 and Gas 4, respectively) whereas, samples stored in oxygen-free atmospheres represent the largest (Gas 3) and smallest (Gas 6) mean particle sizes, respectively. Gas 6 did not only result in the biggest fragmentation but also in significantly (P<0.05) harder meat samples after two days of storage. Table 3 shows the significance values obtained from the APLSR models based on samples stored in the five different gas mixtures for either 2 or 13 days.

Table 2. Mean particle size ± SDev (μm) of samples stored in modified atmosphere for 2 and 13 days

	Gas 1	Gas 3	Gas 4	Gas 6	Gas 8
			2 days		
D(*v*, 0.1)	25.0 ± 7.4	24.9 ± 6.4	21.9 ± 9.2	20.8 ± 4.0	21.0 ± 3.8
D(*v*, 0.5)	161.6 ± 41.2	175.9 ± 36.9	160.3 ± 50.9	137.1 ± 23.0	150.5 ± 26.0
D(*v*, 0.9)	341.3 ± 47.8	358.0 ± 36.7	342.0 ± 50.2	328.2 ± 23.7	336.0 ± 36.7
			13 days		
D(*v*, 0.1)	16.9 ± 4.4	16.1 ± 3.8	17.6 ± 4.3	14.6 ± 4.0	15.2 ± 2.9
D(*v*, 0.5)	144.3 ± 28.7	126.6 ± 25.9	137.6 ± 27.1	113.2 ± 25.1	121.6 ± 20.9
D(*v*, 0.9)	305.3 ± 37.4	286.3 ± 25.7	299.8 ± 23.3	274.4 ± 27.2	270.1 ± 17.9

From the correlation loading plot of the APLSR model based on samples stored for 13 days (Figure 1) it can be seen that hardness and the three mean particle size variables was positively correlated.

After storage for 13 days, it was found that pork samples stored in high levels of oxygen had significantly larger (Gas 4; P<0.05) or tended to have larger (Gas 1; P=0.07) particle sizes (Table 3). In addition, these samples were also harder (Gas 4; P<0.05 and Gas 1; P=0.07) than samples stored in lower levels of oxygen (Gas 8; 40% O_2) or in oxygen-free atmospheres (Gas 3 and Gas 6). Storage in Gas 6 resulted in significantly smaller particle sizes (P<0.001) and the least hard pork samples (P<0.01).

The myofibrillar fragmentation increased when the storage period was prolonged from 2 to 13 days, regardless of packaging atmosphere (Table 2). However, the increase in myofibrillar fragmentation was markedly smaller for samples stored in high-oxygen atmospheres (Gas 1 and Gas 4) as compared to samples stored in an oxygen-free atmospheres (Gas 3 and Gas 6) or in an atmosphere with an intermediate level of oxygen (Gas 8).

The decreased myofibrillar fragmentation obtained from the high-oxygen atmospheres investigated may be caused by protein cross-linking in that formation of cross-linked myosin heavy chain has been shown to occur in pork samples after storage in 70% oxygen and 30% carbon dioxide (Lund *et al*., 2007), which correspond to Gas 1 in the present study. Another possible explanation may be that the degree of proteolysis has been decreased due to inactivation of μ-calpain, which has been shown to take place in beef (Rowe *et al*., 2004)

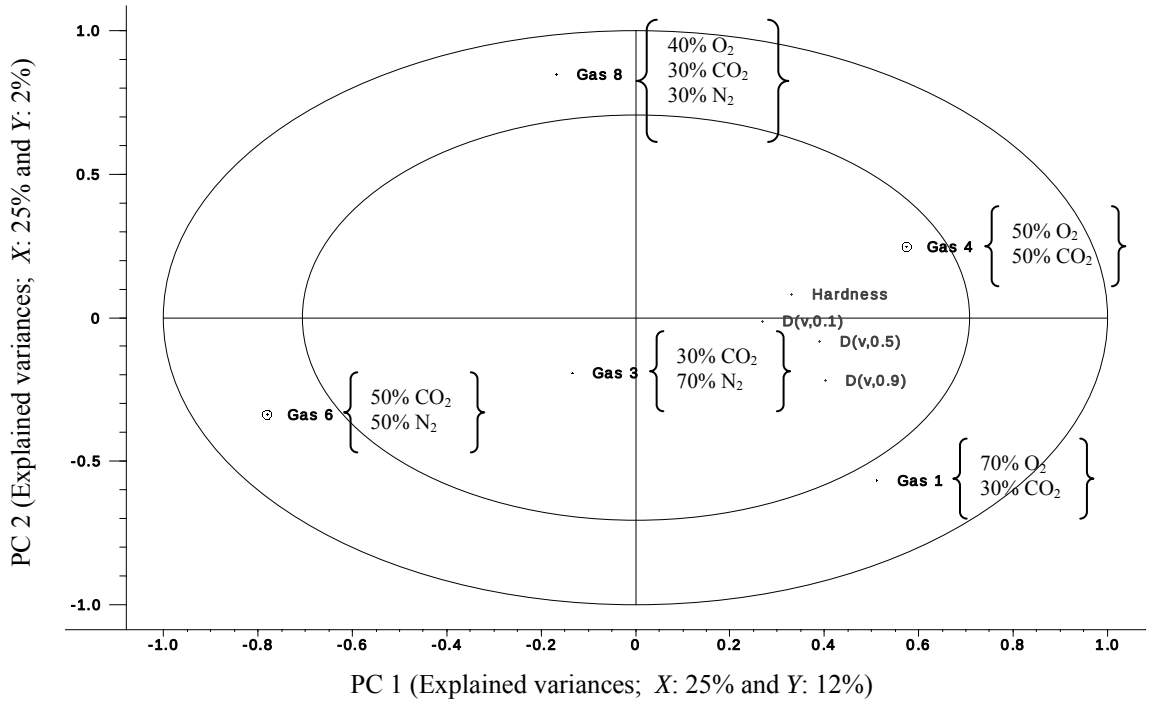

Figure 1. APLSR correlation loading plot of the first two principal components (PC 1 versus PC 2). ***X***: design variables (gas mixtures) versus ***Y***: response variables (particle size distribution and sensory hardness). Ellipses represent r^2 = 50 and 100%. Circles indicate significant differences. The model is based on samples which have been stored *13 days* in modified atmosphere.

Table 3. Significance values extracted from the APLSR models

	2 days					13 days				
	Gas 1	Gas 3	Gas 4	Gas 6	Gas 8	Gas 1	Gas 3	Gas 4	Gas 6	Gas 8
D(*v*, 0.1)	m	m	m	m	m	+ 0.06	– 0.5	+ 0.1	– 0.02	– 0.4
D(*v*, 0.5)	+ 0.1	+ 0.3	+ 0.3	– 0.1	– 0.1	+ 0.06	– 0.5	+ 0.01	– 0.001	– 0.3
D(*v*, 0.9)	m	m	m	m	m	+ 0.07	– 0.5	+ 0.02	– 0.0003	– 0.4
Hardness	– 0.3	– 0.2	– 0.3	+0.04	+0.3	+ 0.07	– 0.5	+ 0.01	– 0.004	– 0.3

The plus (+) and minus (-) sign indicate positive and negative correlations, respectively. Missing values are marked with the letter m.

Conclusions

Based on the results from this study, we can conclude that modified atmosphere packaging affects both hardness and particle sizes of pork. We found that high-oxygen atmospheres result in harder meat and increased particle sizes as compared to storage in oxygen-free atmospheres. This may indicate cross-linking of proteins and/or reduced proteolysis.

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