REVIEW

HIGH-OXYGEN MODIFIED ATMOSPHERE PACKAGING OF ORGANIC MEATS?

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Abstract

In the last few years, it became widespread to package fresh meat for retail under modified atmosphere containing 70–80% oxygen ("high O_2-MAP"). Oxygen preserves the bright-red colour of oxymyoglobin while CO_2 (20–30%) inhibits obligatory aerobic bacteria such as psychrotrophic *Pseudomonas* spp., the common spoilage agents for unpackaged fresh meat. On the other hand, high oxygen partial pressure has been shown to cause some oxidative changes in the meat, resulting in sensory deviations.

Use of high O_2-MAP is also legally permitted for the packaging of organic meats. This may be regarded as being in conflict with the principle of "processing food with care" as stipulated by Article 6 of the Regulation (EU) 834/2007 on organic production and labelling of organic products. Therefore, the aim of our research was to provide information to decision-makers in the organic food chain on the necessity of high O_2-MAP for organic meats. Literature data from market research show that even consumers of organic food seek "convenience" in purchasing and preparing it. Hence, of the major associations of organic agriculture in Germany, only Demeter e. V. prohibits the use of high O_2-MAP. Literature data also indicate that undesirable changes of the meat could be delayed by reducing the oxygen content in the packages to about 40–50%, with only a slight reduction of shelf life. In our view, this would be a good compromise between "convenience" and eating quality.

Keywords: meat, packaging, modified atmosphere, organic.

Introduction

In various countries, there is a major trend that consumers tend to reduce the time spend for shopping and for preparing food in their households. The socio-economic reasons for it have been summarized by Schulze and Spiller (2008a) for Germany. As a consequence, an increasing percentage of food is sold in retail packages rather than "over the counter". This also applies for fresh meat. From 2000 to 2005, the market share of pre-packaged red meat increased from 23 to 42% (Schulze, Spiller, 2008b). In Europe, the percentage is similar (Belcher, 2006). The Fraunhofer-IVV Institute (Anonymous, 2013a) mentioned a market share for pre-packaged fresh meat (chilled or frozen) of 53% in 2010. Recent data are available for processed meats (hams, sausages) in Germany: From 2005 to 2012, the market share of pre-packaged products (excluding canned meats) increased from 62.3 to 65.3% (Anonymous, 2013b).

Appearance is a critical factor affecting buying decisions at the point of sale. The chemistry of meat colour has been reviewed by Manchini and Hunt (2005). A bright-red colour of oxymyoglobin is regarded as an indicator of freshness of meat, in particular, beef and pork (Carpenter et al., 2001; Becker et al., 2000; Robbins et al., 2003). At sufficient levels of oxygen, myoglobin is kept in this form whereas low oxygen partial pressure accelerates the formation of brownish metmyoglobin. Total exclusion of oxygen is difficult to achieve, and the resulting dark-red colour of myoglobin is less attractive, especially for pork. Hence, most pre-packaged fresh meat is displayed under oxygen-enriched atmospheres ("high O_2-MAP"). To avoid growth of aerobic spoilage bacteria such as *Pseudomonas spp*., carbon dioxide is included in the package at levels of 20–30%. As a "rule of thumb", high-O_2-MAP of fresh meat may double the time until spoilage by micro-organisms (see Sun, Holley, 2012).

It is common practice to package fresh meat under 70–80% oxygen ("high O_2-MAP") plus 20–30% CO_2. Such high oxygen levels, however, have been shown to cause some oxidative changes in the meat, resulting in sensory deviations.

Such changes occur in lipids and proteins. Thus, it may be argued that the consumer is misled because the meat looks fresher than it actually is. Accordingly, packaging meat in high O_2-MAP has been criticised by consumer organisations (Anonymous, 2013c).

According to Article 6 c and d of the Regulation (EC) 834/2007 on organic production and labelling of organic products (Anonymous, 2007), substances and processing methods should be excluded "that might be misleading regarding the true nature of the product", and the processing of food should be done "with care", preferably with the use of biological, mechanical and physical methods. Nevertheless, high O_2-MAP is also used for the packaging of organic meats.

Therefore, the aim of our research was to provide information to decision-makers in the organic food chain on the necessity of high O_2-MAP for organic meats, with focus on red meats (beef, pork).

Approach

We searched the literature on data about effects of high-O_2 MAP on meat quality, analysed the legal situation in the European Union, and interviewed representatives of the German "organic food sector" on the compatibility of high-O_2 MAP with the requirements of organic food processing.

Results and Discussion

1. Effect of oxygen levels in MAP on meat quality parameters

Colour

Table 1 summarizes data on atmospheres in MAP giving colour stability equal to high-O_2 MAP (70–80% O_2). It may be seen that the oxygen content in the package may be reduced to about 40–50% without major effects on colour and shelf life.

Table 1

Gas atmospheres giving a meat colour similar to high-O_2 MAP (70–80% O_2)

Product	Gas composition[1]		Storage		Ref.[3]
	O_2	CO_2	°C	days	
Beef steak	55	45	2	10	(1)
Beef steak	40	20	4	12	(2, 3)
Beef steak[2]	60	40	4	8	(4)
Ground beef	50	30	4	14	(5)
Pork chop	35	20	4	8	(6)
Pork retail cuts	20	20	2	10	(7)

[1] balance: nitrogen.
[2] aged 7 days, frozen and thawed before storage
[3] (1) Jakobsen, Bertelsen, 2000; (2) Zakrys et al., 2009; (3) Zakrys-Waliwander et al., 2011; (4) Resconi et al. 2012; (5) Esmer et al., 2011; (6) Zhang, Sundar, 2005; (7) Nitsch, 2012

Sensory deviations due to oxidative changes

Sensory deviations of meat packaged under high O_2 levels were frequently reported. Deficiencies include lack of meat aroma, rancidity, excess warmed-over flavour, as well as toughness and lack of juiciness (Lautenschläger, Müller, 2006; Dederer et al., 2014). In high-O_2 MAP, the rate of lipid oxidation is higher, as indicated by the concentrations of thiobarbituric acid-reactive substances (Jakobsen, Bertelsen 2000; John et al., 2004; Seyfert et al., 2004; Clausen et al., 2009; Kim et al., 2010). However, at least for beef steaks and ground beef, considerable less oxidative changes could be achieved by reducing the oxygen level in MAP to about 50% (Table 2).

A lack of tenderness of high-O_2 MAP meat is mainly due to cross-linking of myosin molecules (Lund et al., 2011; Kim et al., 2010). However, this effect could be minimized by reducing the oxygen level in MAP to 40% (Zakrys et al., 2009).

Table 2

Gas atmospheres in MAP minimizing oxidative changes in lipids

Product	Gas composition[1]		Storage		Ref.[3]
	O_2	CO_2	°C	days	
Beef steak	50	30	4	14	(1)
Ground beef	50	30	4	14	(2)
Pork chop	25	20	4	8	(3)

[1] balance: nitrogen.
[2] aged 7 days, frozen and thawed before storage
[3](1) Zakrys-Waliwander et al., 2011; (2) Esmer et al., 2011; (3) Zhang, Sundar, 2005.

Cholesterol oxidation

During storage of meat in high-O_2 MAP, cholesterol oxidation products (COP) are formed, in particular, 7β-hydroxy- 7α-hydroxy-, 7-keto- and β-epoxycholesterol (Ferioli et al., 2008; Boselli et al., 2009). In beef slices packaged in MAP containing 32% O_2 and exposed to light, levels were about twice as high as in meat packed in air (Boselli et al., 2009). There is some evidence from in-vitro experiments and from animal studies that uptake of these COP increases the risk of atherosclerosis (Anonymous, 2010a). On the other hand, the type of meat, the length of storage and the cooking process also affect the levels of COP, and it was concluded that meat stored in high-O_2 MAP contributes only little to the overall uptake of COP (Anonymous, 2010a). However, in view of the scarcity of data, it is advisable to minimize the formation of COP during meat storage and processing.

Premature browning

Consumers normally use greyish-brownish discoloration of meat as an indicator for doneness during cooking. Indeed, times and temperatures to achieve this are similar to those required for inactivation of pathogens such as salmonellae, shigatoxin-forming *Escherichia coli* (STEC) and *Campylobacter*. Various authors (Hunt et al., 1999; Seyfert et al., 2004; Clausen et al., 2009; Røsvoll et al., 2014) observed that meat packaged under high-O_2 atmospheres turn grey/brownish at lower cooking temperatures. This is due to the fact that oxymyoglobin is less stable to heat than myoglobin. "Premature browning" may result in a health hazard, especially to the consumer of hamburgers and similar cooked minced meats. For example, hamburgers looked "done" at internal temperature of about 60 °C. Stopping the cooking process at this stage will not inactivate STEC to a sufficient degree. In a survey, most consumers judge doneness by colour and preferred the batch with premature browning (Røsvoll et al., 2014). Reduction of oxygen levels in MAP to

50% did not completely eliminate this problem (Clausen et al., 2009).

2. Consumer attitudes and expectations

In response to open questions, German consumers (n=991) mention "freshness" as the main quality criterion for meat, followed by price and origin (Branscheid, 2008). "Colour" was mentioned by only 18% of all respondents, and by 23% of respondents stating that they eat meats daily. These results are in contrast to data clearly showing the major role of meat colour in buying decision (Becker et al., 2000; Robbins et al., 2003; Carpenter et al., 2001). Moreover, in open questions, only few consumers mentioned "best-before date" as a quality criterion. Therefore, it is plausible to assume that consumers trust their senses when buying meat and appearance (of the meat and the point of sale) is the main criterion.

In contrast, the best-before date was mentioned as an important criterion for their buying decisions by 87% of consumers participating in the German National Nutrition Survey II (Anonymous, 2008a). The results are based on questionnaires that eliminate most of the bias introduced by face-to-face or even telephone interviews and may reflect the reality more closely.

In May 2013, 1 002 German consumers were asked (by telephone interviews) about their attitude towards organic food (Anonymous, 2013d). Consumers regularly buying organic food mentioned regional origin (87%), animal welfare (85%), and absence of residues (83%) as the most important reasons. This confirms the importance of altruistic motivations, as also stressed by Padilla Bravo et al. (2013) on the basis of data from German National Nutrition Survey II. Of various parameters affecting buying decisions, "optimal freshness and quality" ranked first. 32% of the interviewees stated that they frequently (or even exclusively) buy organic meats. Consumers have more trust in the original producers of organic food, and in specialized shops but in contrast, they buy most organic food from supermarkets, and even from discounters, which are perceived as even less trustful. This indicates that, along with price, "convenience" in shopping is a major criterion even for the consumer of organic food (Padilla Bravo et al., 2013). However, many consumers may not always be ready to admit this.

3. Legal situation for conventional and organic meat

It is generally prohibited to mislead the consumer by insufficient or misleading information (see Article 7 of Regulation (EU) no. 1169/2011; Anonymous, 2011). Hence, the key question is whether or not the consumer mistakes "old" meat for fresh. To date, it is compulsory to label the use of "protective atmospheres" but not to indicate the composition of gas. In a document published by a working group of experts from the German official food control, it was stated that offering unpackaged meat treated with hyperbaric oxygen in order to restore its bright-red colour is only permitted if the consumer is appropriately informed about this treatment (Möllers et al., 2007).

Oxygen is a permitted food additive in the European Union. It is also listed in Annex VIII Section A of Regulation (EC) No. 889/2008 (Anonymous, 2008b) as a permitted additive for organic foods. German non-governmental associations for organic food generally prohibit the use of high-pressure oxygen treatment to restore the bright-red meat colour. Of the German associations, Bioland e.V. (Anonymous, 2010b) and Naturland e.V. (Anonymous, 2013e) permit high-O_2 MAP packaging of meat, arguing that O_2 only affects the colour of the surface. In contrast, Demeter e.V. approves only nitrogen and CO_2 as packaging gases (Anonymous, 2013f).

4. Alternatives to high-O_2 MAP

The available data indicate that reducing the oxygen level in MAP to about 40–50% still sufficiently stabilizes meat colour while reducing sensory deficiencies caused by oxidative processes. Other packaging methods for fresh meat have been reviewed by McMillin (2008) and O'Sullivan and Kerry (2010). Packaging in vacuum-skin packages may reduce oxygen levels so much that metmyoglobin formation is inhibited, and had a favourable effect on beef colour (Li et al., 2012). However, with many meat cuts (especially from pork), the dark-red colour of myoglobin is less attractive to the customer, and acid formation by lactic acid bacteria on the meat surface during storage may affect the globin moiety and lead to discolouration. The inclusion of carbon monoxide stabilizes the meat colour in the absence of oxygen but spoilage may be masked, and CO is unlikely to ever be approved for organic meat. Fat oxidation in meat packaged in high-O_2 MAP may be retarded in avoiding exposure to UV light (Anonymous, 2013a). Last but not least, it makes no sense to package "white meat" (e. g. many cuts from poultry) under oxygen. This also applies to poultry meat covered with skin.

Conclusions

In summary, using high-O_2 MAP with 70-80% oxygen appears in contradiction to the principle of "careful" processing of organic meat. On the other hand, there is clearly a market demand for fresh organic meats in convenient retail packages. A sound compromise could be to reduce oxygen levels in MAP to about 40-50% or even less.

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