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Effect of vacuum or modified atmosphere packaging (MAP) in combination with a CO_2 emitter on quality parameters of cod loins (*Gadus morhua*)

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ABSTRACT

Bacterial growth, microbiota and sensory quality of cod loins (farmed Atlantic cod, *Gadus morhua*) was studied during 15 days of storage (2 °C), packaged in vacuum or in modified atmosphere package (MAP, 60% CO_2/40% N_2, g/p ratio 1.6/1), with a CO_2 emitter pad or a liquid absorbent pad. The objective was to investigate how packaging with CO_2 emitter can prolong shelf life in vacuum, and in low headspace MAP. Sensory analysis showed that the initial freshness was better preserved by adding a CO_2 emitter in both vacuum and MAP. The MAP had equal antibacterial effect compared to vacuum added CO_2 emitter. 16S rDNA sequencing showed that CO_2 emitter did not alter the dominant bacterial composition and that *Photobacterium* sp. dominated all packaging methods. Vacuum packaged samples past shelf life after 7 days of storage, vacuum added a CO_2 emitter and MAP after 9 days, and MAP added a CO_2 emitter after 13 days.

1. Introduction

Raw fish and especially fresh fillet products, are perishable, and initial bacterial load, packaging method and temperature prior to packaging, during transport and storage, affect bacterial growth, sensory quality and shelf life. Odor of raw fish products, which can be characterized by use of different attributes related to fresh fish odor, microbial spoilage odor and oxidized odor, is one of the most important quality parameter used to determine whether fish is acceptable for consumption or not (Ólafsdóttir, 2005). CO_2 is reported to preserve initial freshness and inhibit the formation of odor associated spoilage, evaluated by different odor attributes that correspond well to bacterial counts (Hansen, Mørkøre, Rudi, Rødbotten et al., 2009; Hansen, Rødbotten, Eie, Lea, Rudi & Mørkøre, 2012). Prediction of sensory quality of cooked fish by measuring odor of raw fillets is also reported (Rødbotten, Lea & Ueland, 2009).

It is well known that modified atmosphere packaging (MAP) by use of CO_2 inhibits bacterial growth of fresh fish products (Ashie, Smith & Simpson, 1996; Farber, 1991; Dalgaard, Gram & Huss, 1993; Dixon & Kell, 1989; Sivertsvik, Jeksrud & Rosnes, 2002). However, the inhibitory effect of bacterial growth is proportional to the amount of dissolved CO_2 in the product. CO_2 is highly soluble in both water and fat, which makes it possible to dissolve into the fish meat. An elevated concentration of CO_2 in the headspace and high gas volume to product volume ratio (g/p ratio) increases dissolution of CO_2 in the flesh, which is due to a higher partial pressure of CO_2. At low g/p ratios the importance of CO_2 concentration is more pronounced (Dalgaard, 1995; Zhao & Wells, 1995; Devlieghere, Debevere & Van Impe, 1998; Gill & Penney, 1988; Löwenadler & Rönner, 1994). Devlieghere and Debevere (2000) showed increased concentration of dissolved CO_2 by increasing g/p ratio from 1/1 to 2/1. However, others have reported low g/p ratios of 1/1 or 0.4/1 resulted in similar bacterial inhibition as vacuum packaging of the fish (Randell, Ahvenainen & Hattula, 1995). Furthermore, the initial bacterial load of the fillet product at time of packaging in addition to the level of CO_2 (gas mixture in headspace of the package) and storage temperature, are also crucial for the effect on quality preservation of MAP (Farber, 1991). Devlieghere et al. (1998) report that increasing levels of CO_2 in headspace can compensate for decreasing g/p ratios showed by different combinations of CO_2 concentrations (60.0%, 40.2%, and 31.4%) and g/p ratios (0.97, 1.74, 4.00, respectively). On the other

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hand, an increased g/p ratio in a package of modified atmosphere can be compensated by use of a CO_2 emitter, which develops CO_2 gas after sealing the package. Studies performed on fillets from farmed Atlantic cod and Atlantic salmon have shown that a CO_2 emitter can compensate for a g/p ratio of 4/1 and 3/1, respectively (Hansen, Mørkøre, Rudi, Olsen & Eie, 2007; Hansen, Mørkøre, Rudi, Rødbotten et al., 2009). The CO_2 emitter additionally functions as a liquid absorbent pad, and it enables low g/p ratios without packaging collapse.

There is an increasing interest of packaging raw, ready-to-prepare fish products in vacuum packages and MAP with low headspace volume, which are more transport efficient. However, simultaneously it is a demand for prolonged shelf life. The aim of this study was to verify how CO_2 emitter can compensate for reduced availability of CO_2, either in a vacuum package or in a MAP with low headspace. To our knowledge, vacuum packaging added a CO_2 emitter has not been published previously. This study was performed as the first stage in order to launch a pre-packaged cod product into the Norwegian retail market.

2. Materials and methods

2.1. Packaging methods, materials and storage

Loins of farmed Atlantic cod (*Gadus morhua*), processed pre-rigor one day before packaging, were transported by airplane from processing plant in northern Norway to the packaging site at the test centre of CFS in Biedenkopf Wallau, Germany (arrival the day after). The loins (mean weight of 289 ± 55 g) were packaged for transport in expanded polystyrene (EPS) boxes without drainage, added 4 kg ice in each box with 10 kg fish. At the arrival, ice was still present in the packages, which means good chilling conditions during transport. At the packaging site four different packaging methods were used:

1. Vacuum packaging (termed “Vacuum”, n = 25).
2. Vacuum and a CO_2 emitter (termed “Vacuum + CO_2 emitter”, n = 25).
3. Modified atmosphere packaging (termed “MAP”, n = 25).
4. MAP and a CO_2 emitter (termed “MAP + CO_2 emitter”, n = 25).

The packaging gas was 60% CO_2 and 40% N_2, with g/p ratio of 1.6/1. A thermoforming machine, CFS Powerpack 430, was used (CFS; today a part of GEA Food Solutions GmbH, Düsseldorf, Germany), with the internal and external measurement of 83×283 mm and 100×300 mm, respectively, of each forming unit (Fig. 1). The volume of the vacuum packages and the modified atmosphere packages (MAP) were 211 ml and 490 ml, respectively (different drawing depths). The top web used for both methods were polyamide (PA)/ethylene-vinyl alcohol (EVOH)/polyethylene (PE) (90 μm, Wipak Oy, Valkeakoski, Finland). The bottom web was 600 μm thick for the MAP samples and 150 μm thick for the vacuum packages (both made of PE/PA/EVOH/PA/PE, Wipak Oy).

The oxygen transmission rate (OTR) of the vacuum packages and the modified atmosphere packages were measured to be 0.014 and 0.103 cm^3/(package·d), respectively, at 2 °C and 100% humidity using the AOIR-method (Larsen, Kohler & Magnus, 2000). A liquid absorbent pad (SuperCore mP-2500, McAirlaid’s, Steinfurt, Germany) was placed in the bottom of half of the packages while a CO_2 emitting pad was placed in the rest. The CO_2 emitters were prepared (at Nofima, Ås, Norway) by adding 0.304 g $NaHCO_3$ and 0.237 g citric acid to a liquid absorber pad (Absorbent Pad Dri-Loc, Friedrichsdorf, Germany) based on prior experiment (Hansen et al., 2007). Similar CO_2 emitter was used for both vacuum packages and MAP. The ingredients and the liquid absorber pad were all approved for food contact. The samples were packaged in EPS boxes added ice and sent by airplane back to Norway (Oslo), and further by truck to the lab at Ås, for storage in up to 15 days. The temperature was 1.9 ± 0.3 °C during transport and storage, measured by use of the logger Elpro-Buchs AG (Buchs, Switzerland). Five replicates per packaging method at each sampling time were used for the different analyses, analyzed after 1, 7, 9, 13 and 15 days of storage (sensory analysis only after 1, 7 and 13 days).

Fig. 1. Packaging of cod loins in a thermoforming machine for modified atmosphere packaging (MAP) and vacuum packaging, using either liquid absorbing pad (picture) or a CO_2 emitter pad.

2.2. Analyses

2.2.1. Headspace gas analysis

The CO_2 and O_2 were analyzed at each sampling time by use of a CheckMate 9900 O_2/CO_2 analyzer (PBI Dansensor, Ringsted, Denmark).

2.2.2. Appearance of the packages

The appearance of the top web of the packages (“MAP” and “MAP + CO_2 emitter”) was evaluated by using a scale from 0 to 6, where 0 = extremely under-pressure (concave), 3 = neutral/optimal, and 6 = extremely overpressure (convex), in accordance to Hansen, Høy and Pettersen (2009).

2.2.3. Analyses of bacteria (plate count)

Sampling was done by a 3×3 cm cut (1 cm depth), and a 1/10 dilution was attained by use of approximately 90 ml peptone water, and run in Stomacher for 60 s. Appropriate 10-fold dilutions were made and spread on Iron agar (Oxoid, Basingstoke, Hampshire, U.K.) plates, for total bacterial count and sulfide producing bacteria (SPB, black forming colonies), and on MRS (Man