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Effect of CO_2 dissolution on the shelf life of ready-to-eat *Octopus vulgaris*

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ABSTRACT

Due to the increasing commercial importance of octopus (*Octopus vulgaris*) and the growing demand for convenient and ready-to-eat products, soluble gas solubilisation (SGS), a relatively recent methodology of active packaging proposed to extend the shelf life of packaged fish, was tested. The effect on cooked octopus of CO_2 dissolution applied in a 2 bar saturated atmosphere for 30 min was followed by sensory, microbiological and physical/chemical quality parameters of vacuum packed products during chilled (3 °C ± 0.5 °C) and abuse temperature (24 °C ± 0.5 °C) storage for 28 days and 48 h, respectively. The SGS pre-treatment of cooked octopus with CO_2 had a positive effect on the delay of the microbial growth during chilled storage. On the other hand, during the acceptability period TMA-N and TVB-N showed similar changes during storage period and were not affected by the CO_2 treatment. Oxidation of cooked octopus did not appear to be a significant problem during chilled storage. Sensory shelf life was estimated as 10 days and 12 h in chilled and abuse temperature storage, respectively and no significant extension was visible as a function of SGS treatment. Though not enough per se to increase the shelf life of cooked octopus, the use of SGS by the food industry as a hurdle technology component with bacteriostatic effect is a valuable tool to allow an effective extension of the period of use-by date.

Industrial relevance: Common octopus (*Octopus vulgaris*) is a highly appreciated marine species which requires at home a cooking step that entails some expertise, in order to attain the correct sensory quality, namely suitable tenderness. Supply of ready-to-eat products that offer healthy, tasty and fast meal solutions and that solves the problem of home preparation of octopus is of particular industrial relevance and stresses the need for new ways of marketing this species, other than in the fresh state. The current study aimed to develop a new seafood product that can be introduced in the market as fresh cooked octopus in a convenient package under vacuum, either as a ready-made meal or as a ready-to-be used product, to be further processed in more elaborated food preparations. To our knowledge no such product exists in the market and this is the first study dedicated to the evaluation of the shelf life of such a product and to a new active packaging technology that can extend the use-by date. Though not enough per se to increase the shelf life of cooked octopus, it is demonstrated that utilisation of CO_2 by the food industry, as a hurdle technology component with bacteriostatic effect under the conditions proposed, is a valuable tool to allow an effective extension of the period of use-by date.

1. Introduction

Common octopus (*Octopus vulgaris*) is a cephalopod typically marketed fresh, frozen and dried salted and eaten mainly in Mediterranean, South American and Oriental countries (Barbosa & Vaz-Pires, 2004). This species is highly appreciated and product demand commands high prices throughout all distribution chain thus, sustaining artisanal as well as industrial fisheries. Its type of consumption is usually affected by geographical and cultural traditions, but most of the processing at home requires a time consuming cooking step that entails some expertise, in order to attain products with the correct sensory quality, namely suitable tenderness. Increasing consumer demand for convenience products is one of the major contemporary trends in food consumption, particularly in what concerns seafood products. Therefore supply of ready-to-eat products that offer healthy, tasty and fast meal solutions and that solves the problem of home preparation of octopus stresses the need for alternative new ways of marketing this species. A good alternative could be the introduction in the market of a fresh cooked product in a convenient package as a readymade meal or as a ready-to-be-used product, to be further processed in more elaborated food preparations.

Among the technologies that ensure quality maintenance with minimum losses, modified atmosphere packaging (MAP) including vacuum-packaging, along with refrigeration, have become increasingly popular preservation techniques, which have brought major changes in storage, distribution, and marketing of raw and cooked products to meet consumer demands (Ashie, Smith, & Simpson, 1996). MAP solutions are

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however hampered by the necessary high gas volume to product volume ratio (g/p), in order to obtain the appropriate dissolution of CO_2 and to ensure CO_2 availability and thereby inhibition of bacterial growth. The g/p ratio is often as high as 2 or 3, implicating a package size 3–4 times the size of the product (Sivertsvik, Jeksrud, Vagane, & Rosnes, 2004). The consequence is increased distribution costs, necessary space in retail display cabinets, and amount of plastic packaging materials and waste. Too low g/p could induce package collapse by the inevitable volume contraction/pressure decrease caused by the diffusion CO_2 from the gas phase into the water and fat phase of the product (Sivertsvik, Rosnes, & Jeksrud, 2004). The effect of MAP on the shelf-life of foods is primarily conditioned by the amount of CO_2 dissolved into the product and storage temperature. More recently active packaging has emerged within MAP as a new technological development in the field of food packaging and is used whenever the package requires a function other than providing an inert barrier to external conditions. Generally, this technique consists of the inclusion in the package of components that delay product deterioration, such as gas scavengers or emitters. Soluble gas stabilisation (SGS) is a relatively recent methodology of active packaging that has been proposed by Sivertsvik (2000) to extend the shelf life of packaged fish.

In SGS the CO_2 is dissolved in the product (Eq. (1)) at low temperature (~0 °C) and high pressures (≥2 atm) prior to packaging, instead of as in MAP where CO_2 is introduced to the package atmosphere at the time of packaging.

$$CO_2(g) + H_2O(l) \leftrightarrow HCO_{3^-} + H^+ \leftrightarrow CO_3^{2-} + 2H^+ \tag{1}$$

Sivertsvik and Jensen (2005) showed that the rate of CO_2 absorption is not affected by total pressure but mainly dependent on the percentage level of CO_2. Recalling Henry's law and the fact that the amount of gas that dissolves in a liquid is proportional to the partial pressure of the gas over the liquid (Eq. (2)), it was shown that a period of ca. 5 h at 100% CO_2 would lead to the same amount of dissolved CO_2 into a cooked product as a product stored at 50% CO_2 for 72 h.

$$P_{CO_2}^{t=\infty} = H_{CO_2}, \text{prod X } C_{CO_2}^{t=\infty} \tag{2}$$

where H_{CO_2}, prod is Henry's constant for CO_2 in the product, $P_{CO_2}^{t=\infty}$ is the partial pressure of CO_2 (Pa) and $C_{CO_2}^{t=\infty}$ is the concentration (ppm, mg of CO_2 per kg of product).

The use of this technique would favour a CO_2 supersaturated product that could then be packaged with a smaller g/p ratio or even vacuum packaged. The same effect as normal MAP would therefore be obtained but with reduced packaging volume. Furthermore, using vacuum packaging, the deleterious effects that occur sometimes after a prolonged exposure of products to CO_2 (Goulas & Kontominas, 2007) could be avoided. In addition, packaging conditions that reduce the amount of oxygen present in the package (e.g. vacuum packaging) are known to extend the shelf life of product by inhibiting the growth of aerobic spoilage bacteria (FDA, 2001).

Targeting the introduction in the market of a new ready-to-eat seafood product, the objective of this work was to evaluate the effect of soluble CO_2 stabilisation (SGS) on the quality and shelf life of cooked octopus (*O. vulgaris*) by monitoring microbiological, sensorial and biochemical changes throughout refrigerated storage of vacuum packed products at 3 °C and under abuse temperature conditions at 24 °C.

2. Material and methods

2.1. Raw material, processing and sampling

Fresh octopus (*O. vulgaris*) was purchased frozen in a local supermarket in 1 kg packages, with a remaining best-before-date of 12 months. Octopus were thawed overnight in a refrigerated chamber and steamed cooked for 20 min at 100 °C in a model Combi-Master CM6 oven (Rational Cross Kuchen Technik CmbH, Landsberg am Lech, Germany). After cooking the octopus was put to drain during 5 min, cut in halves and each half placed in 1L polystyrene trays LINfresh Plus (22 cm × 17 cm × 2.5 cm) with a moisture absorbent (20 cm × 15 cm × 0.2 cm) in the bottom. To suppress individual variability one half of each cooked octopus was used as control sample (Control sample) and the other half for the SGS pre-treatment (SGS sample).

For the SGS treatment, the trays were placed inside a constant volume and gas impermeable steel chamber (Ø 50 cm; length 74 cm) at a temperature of 1.0 ± 0.5 °C. The cylindrical chamber was flushed with 100% CO_2 for removal of air and after closure of purging valve was kept filled with CO_2 by allowing a continuous supply of CO_2 at 2 bar for 30 min according to recommendations of Sivertsvik (2000, 2003). The ratio of gas volume to product volume in the SGS chamber was around 4.

Immediately after SGS treatment, trays were packaged in a polyamide/polyethylene gas barrier bag (Vaessen-Schoemaker, Portugal) with the following characteristics: 140 µm thickness (polyamide and polyethylene), transmission rates (cm^3/m^2/24 h at 75% RH and 23 °C): 25.0 — O_2, 61.0 — CO_2 and 8.8 — N_2.

Packages were immediately submitted to partial vacuum (40 mbar) and sealed on a Multivac A 300/52 machine (Multivac, Germany). Packages were further chilled stored at 3 ± 0.5 °C and in abuse temperature conditions (24 ± 0.5 °C), together with the control lot, composed by cooked octopus without the SGS treatment and therefore vacuum packaged directly. Samples were taken on the day of arrival in order to characterise raw material and during chilled storage, after 3, 6, 10, 13, 17, 23 and 28 days for sensory evaluation, physical/chemical and microbiological analysis. At abuse temperature conditions samples were taken after 12, 24, 36 and 48 h. Two packages from each batch (Control and SGS) were analysed at each sampling day.

2.2. Chemicals and reagents

All the chemicals and reagents used were analytical grade of the highest purity and supplied by Merck (Darmstadt, Germany). Aqueous solutions were prepared with Milli-Q purified water.

2.3. Sensory analysis

Sensory analysis was performed in a dedicated tasting room by a sensory panel composed of four experienced evaluators on fish quality control. The colour, odour and flavour of cooked products were assessed with an affective method (Meilgaard, Civille, & Carr, 1999) that involved a hedonic scale of 7 points (0 — dislike strongly; 6 — like very much). The average of parameter quotation was used as the sensory score and an average score of 2 (dislike slightly) considered the limit of acceptability. Instrumental smell intensity (number of molecules) was determined with a Portable Odour Level Indicator XP-329 (New Cosmos Electric Corporation, Osaka, Japan) that uses as a sensor a platinum heat coil covered with a high-sensitivity metal oxide (SnO_2/ZnO) semiconductor kept at high temperature during use. Measurements in chilled vacuum packages were made 10 min after being taken out of refrigeration. Gas barrier bags were carefully perforated in one end by insertion of a pointed Teflon tube and a second hole made in the opposite side of the bag in order to allow a stream of air through the product and into the Cosmos unit. Results are expressed as Cosmos units of odour intensity.

2.4. Microbiological analysis

For microbiological analysis a total amount of 25 g of muscle from octopus individual legs were cut into 225 ml Maximum Recovery