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Effect of a finishing period in sea on the shelf life of Pacific oysters (*C. gigas*) farmed in lagoon

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ABSTRACT

The aim of this paper was to compare the influence of a five-month finishing period in a sea or in the lagoon site on quality changes during chilled storage of Pacific cupped oysters (*C. gigas*), farmed in the lagoon. The oysters were analysed for morphological and chemical characteristics, and for parameters useful to monitor changes during shelf life (intervalvar liquid content, colour, volatile organic compound profile, pH and microbiological load) on 1st, 3rd, 7th and 10th days of refrigerated storage at 4 °C. Oysters finished in the lagoon showed a higher incidence of soft part and higher condition indexes, even though oysters finished in the sea had larger biometric dimensions. Lagoon-finished oysters had edible part richer in total lipids (11.82 *vs* 9.34%) with lower percentages of PUFAn-6 and C20:5n-3, whereas C22:6n-3 percentages were similar. From sensory analysis, sea-finished oysters were judged saltier and more bitter, whereas lagoon-finished oysters kept better during refrigerated storage, presenting more stable pH values, higher retention of intervalvar liquor and a moderate capacity to control bacterial proliferation during 10 days of refrigerated storage. The profile of volatiles was the same in both groups of oysters, but the amounts of each volatile tended to be significantly higher in lagoon-finished oysters. The finishing period in the sea induced a decrease in quality of all market and sensory characteristics and poorer storage performance. The better nutritional status of lagoon-finished oysters at harvest, the better trophic conditions of lagoon finishing and the better adaptation of the molluscs to a wide range of fluctuations in environmental parameters were presumably linked to their greater ability to withstand hypoxia during out-of-water refrigerated storage.

1. Introduction

The monitoring of growth performance and quality evaluation of products from different sites is a prerequisite for developing mollusc farming. The quality requisites of bivalves are known to depend closely on water characteristics, which should ensure a safe and healthy product (Lees, 2000). A broad spectrum of factors largely affecting the quality of mollusc edible parts have been investigated; they include feed availability (Astorga-España, Rodríguez-Rodríguez, & Díaz-Romero, 2007; Khan, Parrish, & Shahidi, 2006; Orban, Di Lena, Nevigato, Casini, Marzetti, & Caproni, 2002; Regoli & Orlando, 1994; Szefer, Kim, Kim, Kim, & Lee, 2004), gametogenic cycle, seasonal variations (Orban, Di Lena, Masci, Nevigato, Casini, Caproni, Gambelli, & Pellizzato, 2004), water temperature and salinity. High safety and quality requisites are essential for marketing and consumer appreciation, especially for raw foods such as oysters.

Proteins, lipids, minerals and glycogen, together with minor components of hydrophilic and lipophilic nature, contribute to the nutritional value and sensory characteristics of oysters. Significant differences in sensory attributes have been described among oysters from different origins. This is why moving oysters from one site to another is suggested to improve survival, safety or quality of marketed molluscs (Powell, Klinck, Hofmann, & Ford, 1997; Wu & Shin, 1998). European Community Reg. 853/2004 (European Commission, 2004) considers the practice of translocation of bivalves from Class B to Class A water to obtain natural depuration, as an alternative to artificial depuration in dedicated plants. Existing literature on fish and shellfish farming has always emphasized the effects of different farming conditions (Dridi, Salah, & Elcafsi, 2007; Orban et al., 2004; Pennarun, Prost, & Demaimay, 2002), as well as different storage conditions (Aaraas et al., 2004) and post-harvest processing (Cruz-Romero, Smiddy, Hill, Kerry, & Kelly, 2004; Rong, Xue, Liu, & Xue, 2009) on biochemical, microbiological and sensory characteristics of the final product. These facts are much more evident in bivalve molluscs because the filter feeding habits make their characteristics dependent heavily on the environment in which they live.

As oysters are usually consumed raw, they are expected to be fresh and additive free, as well as competitive in price. Chilled storage is the most widely used technique for shelf life extension. However in

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the same way to other seafoods, their perishability exposes oysters to major changes during shelf life, mainly due to endogenous enzyme activities and bacterial growth. These factors are largely affected by the initial intrinsic characteristics of the bivalve and by storage conditions after harvesting (Songsaeng, Sophanodora, Kaewsrithong, & Ohshima, 2010).

Colour, texture, microbial growth and sensory characteristics have been proposed to monitor the freshness of seafood during shelf life (Huss, 1995). Although some are also useful to evaluate post-harvest changes in oysters, little information is available on quality changes occurring during post-harvest handling and treatment (Aaraas et al., 2004; Cruz-Romero, Kerry, & Kelly, 2008; Buzin, Baudon, Cardinal, Barillé, & Haure, 2011).

This study compared the influence of a five-month finishing period in the sea or in a lagoon on quality and quality changes during chilled storage of Pacific cupped oysters (*C. gigas*), previously farmed in the lagoon. In particular, the aim of the research was to assess the impact on oyster quality of translocation from a site with worse microbiological characteristics to another with better characteristics to enable natural depuration and to simplify the production chain.

2. Material and methods

2.1. Farming and finishing sites

Oyster spat 24.76 ± 4.79 mm in length was purchased from Seasalter Shellfish (Whitstable) Ltd. hatchery (Herne Bay, Kent, UK) and farmed in the Lagoon of Orbetello (42°26′10″ N–11°11′03″ E; Grosseto, Tuscany, Italy) in PVC "*poches*" (size: 60 × 40 × 5 cm), floating at a depth of about 5 cm. After 14 months of rearing the oysters reached a length of 88.70 ± 11.30 mm and a weight of 59.60 ± 17.33 g. About 2500 specimens were translocated from the lagoon (where a similar number of oysters was left) to a site in the open sea, 2000 m from the harbour of Porto Ercole (42°23′176″ N, 11°14′393′ E; Grosseto, Tuscany, Italy), where they were reared in a long line system.

The two sites differed in microbiological water quality, the lagoon being in Class B and the sea site in Class A, according to EC Reg. 853/2004 (European Commission, 2004). They also differed in trophic characteristics, being eutrophic (Lenzi, Palmieri, & Porrello, 2003) and lower trophic, respectively. Annual temperatures ranged 13 to 26 °C in the sea site and 6 to 37 °C in the lagoon site (24–13.5 and 23.7–9 °C in the finishing period, respectively). Salinity was approximately 37‰ in the sea and 30–40‰ in the lagoon site, which was also subject to wide seasonal fluctuations in the oxygen levels (8.5 ppm in winter, 3 ppm in summer). The finishing period lasted 151 days.

2.2. Oyster sampling

The oysters from both sites were collected at the same time. The samples were kept below 4 ± 2 °C and transported to the laboratories of the Department of Agricultural Biotechnology – Animal Science Section, Florence University. Until the beginning of the analyses, the oysters were maintained in a cold room at 4 °C, out of water, simulating normal storage conditions in the marketing phase. Sampling was carried out on the 1st, 3rd, 7th and 10th days of storage.

On each day of analysis, oysters from the two groups (lagoon- and sea-finished) were removed from the cold room and analysed for morphological and chemical characteristics, and for parameters indicative of changes during shelf life. Sensory analysis was also performed on the 2nd day of storage.

2.3. Morphological characteristics

On the 1st, 3rd, 7th, and 10th day of refrigerated storage, 15 oysters from each group underwent biometric measurements of length, width and thickness with a digital caliper (CEDWP15, Borletti, Italy) and total weight with a precision balance (Mettler-Toledo S.p.A., Novate Milanese, Milano, Italy). Then they were opened, and the edible part and shell of each individual were accurately separated and weighed. The economic Condition Index (eCI) according to the Imai and Sakai (1961) formula, and the Condition Index I according to the Booth (1983) formula were also computed as follows: eCI = shell thickness/0.5*(shell length + width), and Condition Index I = wet edible part weight/total weight. The following indexes, useful for characterizing oyster shape, were also calculated: total weight to length ratio, and depth to length ratio (Brake, Evans, & Langdon, 2003).

2.4. Chemical characteristics

The edible parts of oysters previously analysed for morphological characteristics, were pooled (3 to 7 specimens per pool, in relation to individual weight) after washing with distilled water and draining in a sieve for 10 minutes. The use of pooled tissues to analyse invertebrate edible part composition is recommended by Giese (1966) and Giese, Hart, Smith, and Cheung (1967). The single pools (2 to 4, for each site and day of storage, according to the weight of the edible parts) were analyzed for: moisture (method 950.46; AOAC, 2000), crude protein (method 976.05; AOAC, 2000), ash (method 920.153; AOAC, 2000), crude fat (method 991.36; AOAC, 2000) and total lipids (Folch, Lee, & Sloane Stanley, 1957).

The mean moisture content of the edible part was used to calculate the dry weight of the edible part. Then the Condition Index II, according to the Walne (1976) modified formula, was computed as follows: Condition Index II = edible part dry weight/shell weight.

Fatty acids were determined by gas chromatography on the total lipids extracted and methylated by the procedure described in Morrison and Smith (1964). C23:0 Methyl ester was used as internal standard. Fatty acid methyl esters (FAME) were analyzed using a flame ionization gas chromatograph (Varian 430-GC, Varian, Inc., CA, USA) equipped with a Stabilwax capillary column (Restek) (length 30 m, internal diameter 0.32 mm, bonded phase thickness 0.25 mm). The chromatograph operating conditions were: temperature programme: 160 °C for 1 min, increase to 220 °C at 2 °C/min, isotherm at 220 °C for 9 min, total time 40 min; total injection (1 mL sample) with an opening split after 40 s; helium carrier (1.1 bar). Chromatograms were recorded with integrator software (Galaxie Chromatography Data System 1.9.302.952). The gas chromatograph system was calibrated with standard FAME mixtures (reference standard Supelco 37 Comp. FAME Mix, Supelco, Bellefonte, PA, USA). Identification of sample fatty acids was made by comparing the relative retention times of FAME peaks from samples with those of the standards.

The following ratios were computed for fatty acids, where PUFA are polyunsaturated fatty acids and SFA saturated fatty acids:

- PUFAn-6/PUFAn-3
- PUFA/SFA
- hypocholesterolemic fatty acids/hypercholesterolemic fatty acids (h/H) ratio which considers the effect of fatty acid profile on cholesterol metabolism according to Santos-Silva, Bessa, and Santos-Silva (2002):

$$h/H = [(\Sigma C18:1c{-}9 + C18:1c{-}11 + C18:2n{-}6 + C18:3n{-}6 + C18:3n{-}3 + C20:3n{-}6 + C20:4n{-}6 + C20:5n{-}3 + C22:4n{-}6 + C22:5n{-}3 + C22:6n{-}3)/(\Sigma C14:0 + C16:0)].$$

The Atherogenic (AI) and Thrombogenic (TI) indexes were calculated according to Ulbricht and Southgate (1991) as follows:

$$AI = [C12:0 + (4 \times C14:0) + C16:0/(\Sigma PUFA) + (\Sigma MUFA)]$$