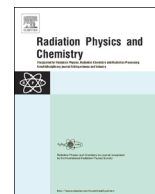




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Texture, color, lipid oxidation and sensory acceptability of gamma-irradiated marinated anchovy fillets

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HIGHLIGHTS

- Marinated anchovies were γ -irradiated at 2, 3 and 4 kGy and stored at 4 °C (10 months).
- Irradiation slightly hardened the texture and reduced its softening during storage.
- Irradiated marinades had good sensory acceptability without differences with controls.
- Irradiation improved the quality by reducing texture softening and color changes.

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ABSTRACT

The effect of gamma irradiation (0, 2, 3 and 4 kGy) on vacuum-packed marinated anchovy fillets was analyzed for their texture, color, lipid oxidation and sensory acceptability after 10 months under refrigeration. Marinated (3% acetic acid, 10% sodium chloride and 0.2% citric acid) *Engraulis anchoita* fillets were vacuum-packed and irradiated with a cobalt-60 source at a semi-industrial irradiation facility. The irradiation caused a slight increase in hardness values regardless of the applied dose but maintained a consistent texture over the 10 months, even though the control samples softened, most likely due to degradation. This hardness increase did not affect the textural sensory acceptability. Irradiation did not modify the color but still reduced color changes during storage, benefitting the product's quality. TBARS was increased in every sample throughout storage, but irradiation decreased these values. Sensory acceptability was not affected by gamma irradiation. Therefore, gamma irradiation could be successfully applied to this type of product for the purpose of shelf-life extension.

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1. Introduction

The anchovy *Engraulis anchoita* is the most abundant pelagic species in the Southwestern Atlantic Ocean. It is found South of Brazil (24°S) to the Argentine Patagonia (48°S) and, due to its current underexploitation, has an intriguing economic potential (Massa et al., 2007; Pastous-Madureira et al., 2009). Argentina, which is a pioneer in the exploitation and processing of *E. anchoita*, is the main manufacturer of several products from this species, including marinated anchovies (Pastous-Madureira et al., 2009). Marination is performed by immersing the whole fish or portions

of the fish in water solutions containing weak organic acids and sodium chloride as preservation agents in order to delay enzymatic and bacterial activities. The resulting product is a semipreserved, ready-to-eat fish with a characteristic flavor that is considered a high-value delicacy. This product has an extended but limited shelf-life (Capaccioni et al., 2011; Fuselli et al., 1994; Meyer, 1965), which is usually estimated at about six months based on food control regulatory organizations.

Fish and fish products are highly perishable foods because of their high protein and fat contents; much of the degradation is due to Gram negative bacteria (Huss, 1999). Gamma irradiation has been widely used to preserve a variety of foodstuffs, because it inactivates spoilage and pathogenic bacteria. After more than 60 years of intensive studies on its wholesomeness, gamma irradiation is considered a safe food preservation method by a number of global organizations, such as the WHO, FAO, FDA, USDA,

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among others (Josephson, 1983; Urbain, 1986; WHO, 1994, 1999). There have been many reports on the shelf-life extension of fish products by means of ionizing radiation (IAEA, 1969; ICGFI, 1991; Kilgen, 2001; Lescano et al., 1990; Narvaiz et al., 1989; Nickerson et al., 1983), including the inactivation of spoilage bacteria in anchovy (*Engraulis anchoita*) marinades (Tomac and Yeannes, in press). Despite its high potential efficacy as a preservation method, the effects of gamma irradiation on a product's sensory characteristics related to consumer acceptance should be assessed. Texture is one of the quality attributes that should be analyzed, as fish muscle can become softer due to autolytic activity (Huss, 1999). Regarding anchovy marinades, texture has been considered the main parameter determining the degree of marination for *Engraulis anchoita* (Yeannes and Casales, 1995; Cabrer et al., 2002). Firmness loss and color changes during storage are typical indicators of marinated fish spoilage (Günsen et al., 2011; Yeannes and Casales, 2008; Yeannes et al., 2007). Color is a very important qualitative characteristic of anchovy marinades due to the contributions of lipid oxidation to color changes. *Engraulis anchoita* is a fatty species with high amounts of unsaturated fatty acids, making it particularly sensitive to lipid oxidation (Massa et al., 2007; Yeannes and Casales, 1995).

Thus, the objective of this work was to analyze the effect of gamma irradiation on the texture, color, lipid oxidation and sensory acceptability of marinated anchovy fillets.

2. Materials and methods

2.1. Sample preparation

Whole specimens of *Engraulis anchoita* caught in May were frozen and stored at $-18\text{ }^{\circ}\text{C}$ for 7 months. The specimens were thawed, washed, beheaded, and gutted; their tails were cut off; and two fillets were obtained from each anchovy for marination in a water solution containing 3% acetic acid, 10% sodium chloride and 0.2% citric acid at a 1:1 w/w fish to solution ratio over two days at $16\text{ }^{\circ}\text{C}$ and then 3 days at $5\text{ }^{\circ}\text{C}$. The fillets were removed from the marinating solution and centrifuged for 1 minute at 2800 rpm. The proximate composition of the marinated fillets was as follows: 65.3% water (AOAC, 1990; Sec. 984.25); 13.3% fat (Bligh and Dyer, 1959); 17.2% proteins (AOAC, 1990; Sec. 920.152); 2.6% ashes (AOAC, 1990; Sec. 945.46) and 1.1% acetic acid (Kirk et al., 1996). Approximately 150 samples consisting of $130 \pm 5\text{ g}$ of fillets (approximately 26 fillets) were vacuum-packed using a Minimax 430 M machine (Servivac, Argentina) in heat-sealed bags of polyethylene/polyamide (Cryovac[®], 125 μm thickness). Samples were stored at $4 \pm 1\text{ }^{\circ}\text{C}$ for 48 hours until they were transported 400 km to the semi-industrial cobalt-60 irradiation facility of the Ezeiza Atomic Center (National Atomic Energy Commission, Argentina. Activity: $2.22 \times 10^{16}\text{ Bq}$). During transportation and irradiation, the samples were kept in polystyrene boxes with cooling gel ice packs. Samples were divided into four lots, each of which consisted of 37 bags. The lots were gamma-irradiated at 0, 2, 3 or 4 kGy at a dose rate of 10.91 kGy/h. The real minimum absorbed doses were 2.18; 3.12 and 3.85 kGy; the dose uniformity (maximum dose/minimum dose) was 1.13, 1.00 and 1.01, respectively. Doses were determined with silver dichromate dosimeters (ISO/ASTM 51401:2003(E), 2003).

Samples were kept at $4 \pm 1\text{ }^{\circ}\text{C}$ during irradiation, transportation and storage. Analyses were carried out in duplicate the day before irradiation and at 5, 125, 180, 243 and 330 days after irradiation.

2.2. Texture analysis

2.2.1. Sensory determination

The trained panel was composed of seven panelists between 30 and 55 years old with broad experience on the sensory evaluation

of fish products, including marinated anchovies. They evaluated the marinades' hardness based on the sensory texture parameter *shear force*, which was defined as the *force required to cross cut the middle part of the fillet using a metal fork* (Yeannes and Casales, 1995). A continuous scale of increasing hardness intensity, ranging from 0 to 10, was used. The panelists defined the scale extremes and anchoring. The highest intensity of shear strength (10) corresponded to the hardness of a raw, non-marinated anchovy fillet, whereas a score of 5 corresponded to the typical hardness of the marinated anchovy fillet. The optimum degree of marinating was defined as a firm texture that could easily be cut with a fork (Yeannes and Casales, 1995). Four fillets (20 g approximately) from each sample were served at room temperature ($20 \pm 3\text{ }^{\circ}\text{C}$) on white plastic plates that were codified with random three-digit numbers. The fillet size was similar to that used in the instrumental determination in order to allow more precise comparisons among results. Evaluations were carried out in individual sensory cabins.

2.2.2. Instrumental determination

Shear force assays were carried out after six months of refrigerated storage with a TX.T2i Texture Analyser (Stable Micro System, Godalming, Surrey, UK) controlled by the Texture Expert[®] software. The machine was equipped with a standard knife blade of 3 mm thickness and 70 mm length and a 25 kg load cell. Marinated anchovy samples ($n=60$) were $4.4 \pm 0.4\text{ mm}$ thick; $17 \pm 1\text{ mm}$ wide; and $80 \pm 2\text{ mm}$ long. Thirteen anchovy fillets per radiation dose were cross cut in the middle. The maximum shear force (N), defined as the maximum force necessary to cut the sample, and the shear work (Ns), defined as the work needed to move the blade through the sample, were derived from the curves' shear force (N) against the time (s) obtained for each sample.

2.3. Color

The L^* , a^* and b^* parameters of the CIELAB color space system were measured with a portable colorimeter (Lovibond, SP60) using a D65 standard illuminant and a 10° standard observer (L^* =lightness, a^* =positive values for red color intensity and negative values for green color intensity, and b^* =positive values for yellow color intensity and negative values for blue color intensity) (C.I.E., 1978). Five marinated fillets per radiation dose were analyzed in triplicate.

2.4. Lipid oxidation. TBARS assay

Extraction was performed in duplicate according to Tironi et al. (2007). Incubation was carried out according to Botsoglou et al. (1994). Absorbance was measured with a Shimadzu[®] UV-1601 PC spectrophotometer (Kyoto, Japan) at a wavelength of 532 nm. TBARS was expressed as mg of MDA per kg of fish. Determinations were performed in duplicate.

2.5. Sensory acceptability

Sensory acceptability was determined using a pilot scale panel of 12 consumers, according to Witting de Penna (2001). The panel was composed of 60% women and 40% men, all of whom were between 25 and 60 years old. Three marinated fillets (15 g approximately) per radiation dose were served to the panelists at room temperature ($20 \pm 3\text{ }^{\circ}\text{C}$) in closed polypropylene containers coded with random three-digit numbers. Panelists evaluated the appearance, color, odor, taste, texture, and overall acceptability by means of a free translation into Spanish of the nine-point hedonic scale originally developed by Peryam and Pilgrim (1957).

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