Storage Life of Chilled Scallops Treated with Low Dose Irradiation

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ABSTRACT

The effect of low dose irradiation on the chilled storage life of saucer scallops (Amusium balloti) was investigated. Scallops were packed in polythene bags and treated with doses of 1, 0.5, 1.5, and 3 kGy, then stored at 0°C. Sensory assessment indicated that nonirradiated scallops had a storage life of 13 d and this was extended to 18, 23 and 42 d when scallops were treated with 0.5, 1.5, and 3 kGy, respectively. Irradiation resulted in a 2 to 4 log reduction in bacterial numbers from an initial total viable count of $2.5 \times 10^7/g$. No irradiation-induced off-odors or off-flavors were detected, but a naturally occurring garlic-like off-flavor was reduced in intensity by irradiation treatment.

The saucer scallop (Amusium balloti) fishery comprises a small but valuable part of a complex multi-species otter trawl fishery off the Queensland coast. The value of the scallop fishery in 1988 was $12-14 million from a volume of around 400 tonnes (flesh weight). Of this total, 80% was exported and 20% was consumed on the domestic market.

Exported scallops are currently processed as frozen product; however recently, industry has experimented with sending chilled product to the United States. Demand for chilled saucer scallops is strong in specialized markets, and such markets are willing to pay a premium price for the product.

Low dose irradiation is one method of preservation which avoids addition of chemicals to product. It has been used successfully to extend the storage life of many seafoods (9); however, there are few reports on the effect of irradiation on scallop meats. Schultz and Lee (13) stated that the process was feasible for Alaskan scallops (Pecten caurinus) and Power et al. (11) found that the chilled storage life of sea scallops (Placopesten magellanicus) was doubled after irradiation at 0.75 kGy. These reports pertain to colder water scallop species and it was considered that tropical species may react differently.

This investigation was carried out to determine the effect of irradiation on scallops (A. balloti) taken from subtropical waters.

MATERIALS AND METHODS

Scallops
Meats of saucer scallops (A. balloti) harvested from waters between 22°S and 25°S were obtained from a local seafood exporter within 24 h of being shucked. Scallops were obtained at four different times to complete replicate trials. The scallops were randomly divided and packed into sterile Whirlpak (Nasco) bags, 15-20 meats per bag. Each bag was randomly allocated to one of four treatments.

Irradiation treatment
Scallops were flown chilled to the Australian Nuclear Science and Technology Organization (Lucas Heights, Sydney) for irradiation within 24-28 h of purchase. Scallops were treated with gamma irradiation in a pond irradiator at a dose rate of 104.4 Gy/min, as measured by ceric-cerous sulphate dosimetry. Scallops received doses of 0, 0.5, 1.5, or 3 kGy (minimum:maximum dose ratio was 1:1.2). The temperature of the scallops was maintained between 1 and 2°C throughout treatment and transit. At the laboratory scallops were stored in melting ice.

Sampling
At regular intervals during storage, packs were taken from each treatment, and five scallops from each pack removed aseptically for microbiological and chemical analysis. The remaining scallops were vacuum-packed in oxygen permeable Cryvac E bags using a single chamber Webomatic machine (Werner Bank, West Germany) and immediately blast frozen (-40°C). Scallops were stored at -18°C for future organoleptic evaluation.

Microbiological analyses
Sections from five scallop meat were homogenized with diluent in a ratio of 1:10 for 60 sec at high speed in a Waring blender. The diluent was artificial seawater (ASW) consisting of; g/L: NaCl, 17.05; KCl, 0.75; MgSO₄·7H₂O, 12.35; CaCl₂·2H₂O, 1.45; distilled water to 1 L. Serial decimal dilutions of the homogenate were made and appropriate dilutions spread plated in duplicate onto nutrient agar containing ASW. Plates were incubated at 20°C/5 d or 4°C/10 d for enumeration of total viable count (TVC) and psychrotroph count (PC), respectively.

Chemical analyses
An extract of scallops was prepared by blending samples with 0.6N HClO₄, filtering the homogenate, and neutralizing...
with 2N KOH. Hypoxanthine (Hx) was determined from the extract by high performance liquid chromatography (Waters Assoc., Milford, MA), separated using a μ-Bondapak C_{18} column with 0.5N (NH_{4})_{2}PO_{4}/acetonitrile (95:5) as solvent, with a flow rate of 1 ml/min. Hx was monitored by a Waters Model 440 detector at 254 nm with the full scale deflection unit set at 0.2 absorbance units. Determination of thiobarbituric acid (TBA) number was carried out as per Quaranta et al.(12).

Sensory evaluation

The sensory panel consisted of 10 staff members selected from training sessions held prior to commencement of the trials. Scallops were baked at 180-190°C for 4 min in individual covered dishes and presented hot to the panelists. Panelists were asked to score the samples for odor, texture, flavor, and overall acceptability on a 9 point hedonic scale with 9 being the highest score for each attribute and 1 the lowest score. A score of 5 indicated the borderline of acceptability, implying no storage life remained. In addition to sensory assessment of cooked product, the odor and appearance of the raw scallops during storage were noted.

Texture analysis

Compression measurements were made using an Instron Universal Testing machine, Model 1122 (Instron Pty Ltd, Baywater, Victoria) and the procedure of Findlay and Stanley (4). Ten samples of each treatment were compressed between a 10 cm² flat disc and the platform of the load cell to 50% of their original height. Instrumental settings were 50 mm/min crosshead speed, 100 mm/min chart speed, and 20 N fullscale response. The maximum force was recorded and adjusted for sample weight to N/g.

RESULTS

Sensory evaluation of raw scallops

Odor was described as changing from “sea smell/sweet/fresh scallop” to “slightly mushroomy/strong scallops” to “off/old sandshoes/sweaty gym”. Odor changes were the same for all treatments but the onset of the different odors was delayed in irradiated samples. Drip loss from the raw scallops was greater from irradiated meats but was not quantified.

Sensory evaluation of cooked scallops

Overall acceptability. All irradiation treatments caused a delay in deterioration of acceptability of scallop meats as evidenced by the times taken for scallops from the different treatments to reach a score of 5 (Table 1). Despite nonirradiated scallops always scoring lower than irradiated scallops from 8 d storage onwards, significant differences between treatments were only established after 28 d iced storage (Fig. 1).

The trends shown for overall acceptability at each irradiation dose were the same for odor, texture, and flavor; hence, individual figures are not presented.

Odor. No odor differences were detected immediately postirradiation between nonirradiated and irradiated samples. All samples scored between 6.0 and 6.7 initially, and little change occurred for 8 d in any of the treatments. With subsequent storage, a steady decrease in acceptability was observed for scallops treated with 0, 0.5, and 1.5 kGy, and by day 15 there was a significant difference (P<0.05) between nonirradiated meats (4.8) and all treated scallops (5.7-6.1). For scallops treated with a 3 kGy dose, the odor remained highly acceptable during storage, only declining noticeably after 34 d to reach a score of 5.5 at the end of the trial (day 42). At this time the odor was described as “odorless/bland”.

For all treatments, the initial odor was “sea smell/slightly sweet/fresh scallops” which increased in intensity, then disappeared leaving scallops “odorless/bland”. Subsequently, off-odors such as “stale/cheesey/sour/off” were detected.

Texture. No texture differences were detected immediately postirradiation between irradiated and nonirradiated scallops. Initial texture scores of 6.5-6.9 were maintained for 8 d. After 15 d storage, sensory assessment indicated that irradiation at 0.5 and 1.5 kGy delayed toughening as treated scallops scored 6.3-6.4 compared to nonirradiated meats which scored 5.5. Scallops treated with a 3 kGy dose retained their initial texture for 26 d and only became undesirably tough after 38 d.

Instron results ranged from 6.7-9.8 N/g, with an average compression force of 8.2 N/g required. Statistical analysis showed that scallops treated with 0.5 and 1.5 kGy were significantly less tough (P<0.01) than nonirradiated scal-
lops, but no significant differences were found with the 3 kGy meats.

**Flavor.** The trends in flavor deterioration were practically identical to those of overall acceptability (Fig. 1). There were no flavor differences between irradiated and nonirradiated scallops detected immediately post irradiation, with treatment means of scallops scoring between 5.5 and 6.2. Loss of flavor and the development of off-flavors were retarded by irradiation as evidenced after 15 d storage by nonirradiated scallops scoring 4.8 compared to 5.5, 5.6, and 5.8 for scallops treated with 0.5, 1.5, and 3 kGy, respectively. Like the trend in Fig. 1, the nonirradiated scallops rated lower than all irradiated scallops by at least 0.5 score units at any time after 8 d storage. When spoilage flavors were detected, they were the same for all treatments and described as tangy/sour/vinegary/off-cheesey”.

**Chemical analyses**

Hx was not affected by any irradiation dose applied to scallops (Fig. 2). All treatments accumulated Hx slowly during storage, and although Hx appeared to peak in nonirradiated meats before it did in irradiated meats, no significant differences were found.

TBA was not enhanced immediately post-irradiation; however, after 8 d storage, scallops from all irradiated treatments had higher TBA levels than nonirradiated scallops (Fig. 3). No significant differences were established until 33 d storage.

**Microbiological analysis**

The initial TVC of raw scallops from all replicates ranged from $1.2 \times 10^5$ to $8.4 \times 10^7$ cfu/g. Irradiation treatment at 0.5, 1.5, and 3 kGy caused a 2-log, 3-log, and 4-log reduction in bacterial numbers, respectively (Fig. 4). These decreases were all significantly different ($p<0.05$) from TVC of nonirradiated scallops. The TVC of nonirradiated scallops was significantly higher ($P<0.05$) than irradiated scallops after 8 d storage and remained significantly higher than 1.5 and 3 kGy treated scallops after 22 d. Populations reached the level initially present ($10^7$/g) after 13, 20, and 27 d for 0.5, 1.5, and 3 kGy treatments, respectively.

Reductions in numbers of psychrotrophs present were less than those for TVC but were statistically significant ($P<0.05$). Irradiation at doses of 0.5, 1.5, and 3 kGy resulted in psychrotrophs being reduced from a mean initial count of $4.1 \times 10^6$ cfu/g by 1, 2, and 3 logs, respectively. The PC of scallops treated with a 3 kGy dose remained significantly lower ($P<0.01$) than nonirradiated scallops for 22 d chilled storage. With nonirradiated scallops the psychrotroph population reached $10^7$/g after only 7 d chilled storage, whereas for 0.5, 1.5, and 3 kGy treated scallops this level was not reached until 14, 20, and 28 d storage, respectively.

**DISCUSSION**

Immediately after irradiation, treated scallops were judged to be indistinguishable from nonirradiated scallops.
Power et al. (11) reported similar results for scallops irradiated up to a dose of 3 kGy. By contrast, 3 kGy had adverse effects on oysters (8) and crabmeat (10).

The storage lives of saucer scallops as shown in Table 1 contrast with those reported by Power et al. (11) for the scallop Placopesten magellanicus. They found that dose of 1.5 and 3 kGy resulted in no practical extension of storage life due to the rapid development of “burned” irradiation off-odors and flavors.

Other workers have reported a delay in the increase in bacterial counts after product has been irradiated (1,2). However, with irradiated sauer scallops the rate of increase of bacteria was similar for all treatments. Additionally, many people have observed that at the time of product spoilage, irradiated product has higher numbers of bacteria present than nonirradiated product (9). Our results showed that the bacterial count from all treatments was around 5.0-9.0 x 10^7/g when the quality of scallops was considered borderline.

TBA values obtained for irradiated scallops were very low but showed a similar pattern during storage to those reported for irradiated Indian mackerel, Rastrelliger kanagurta (18). With tuna meat, irradiation caused elevated TBA values immediately postirradiation compared to values obtained from nonirradiated tuna (12). However, with sauer scallops TBA values of irradiated meats increased over an 8 d period to a greater extent than nonirradiated meats, then gradually decreased. Venugopal et al. (18) suggested that such decrease could result from the highly reactive nature of TBA and also volatile TBA escaping through the polyethylene bags during storage.

Changes in Hx levels showed that accumulation of this compound was related to time, rather than being affected by irradiation dose. Thomson et al. (17) considered the limit of edibility corresponded to 3.5-4 mol Hx/g in prepackaged queen scallop meats (Chlamys opercularis) stored in ice. Such levels were not reached with irradiated sauer scallops until after 31 d and the nonirradiated scallops reached a maximum of only 2.6 mol Hx/g at 29 d. Scallops from all treatments, except those irradiated with 3 kGy, were well spoiled by this time as judged by sensory assessment.

An additional finding during this research was that bis-(methylthio)-methane, present in two batches of sauer scallops used and which imparts an “onions/garlic” off odor to seafoods (19,20), was reduced 66% by irradiation (5).