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PHYSICAL CHANGES IN IRRADIATED TROUT (Salmo gairdneri)

INTRODUCTION

THE FEASIBILITY of radiation preservation of seafood (Kumta et al., 1973; Miyauchi et al., 1967; Ronsivalli et al., 1971) and of fresh water fish (Ehlermann and Münzner, 1970; Hansen and Joergensen, 1967) has been demonstrated by a number of authors.

There have been numerous investigations concerning effects of radiation on the chemical and organoleptic properties of irradiated fish but relatively few on the physical parameters (Dagbjartsson and Solberg, 1973; Gore and Kumta, 1970; Kumta and Gore, 1970; Spinelli et al., 1967).

Denaturation of fibrillar protein which governs the textural properties of flesh foods has been reported in irradiated fish by Kumta and Tappel (1961), Spinelli et al. (1969) and Urbain (1973). Radola (1970) found sarcoplasmic protein aggregation in meat irradiated with 1 and 5 Mrad.

Microorganisms can be effectively reduced or eliminated in food products by radiation treatment and microbiologically stable products can thus be obtained. On the other hand endogenous enzyme systems remain active in irradiated foodstuffs even at the highest doses foreseen for food preservation (Radola and Delincee, 1972; Rhodes, 1969; Vas, 1966). The high radiation resistance of enzymes in food frequently results in undesired and uncontrolled post-irradiation effects and may cause textural alterations during storage.

The purpose of the present investigation was to study the effect of different radiation doses (0.25 to 5.0 Mrad) on shear force (SF), water-holding capacity (WHC) and plasticity index (PI) of fresh water trout. The changes in these parameters during storage in ice were also determined.

MATERIALS & METHODS

Materials

Whole gutted fresh water trout (*Salmo gairdneri*) were obtained directly from a nearby fish farm and transported to the laboratory under melting ice. Upon arrival, fish samples were individually vacuum packed (95%) in plastic film (Hostaphan-PE) impermeable to oxygen and water vapor and were immediately irradiated using 10 MeV electrons from a linear accelerator at a dose rate of 10^{10} rad/sec. Time required for packaging and irradiation was about 5 min so that the fish could not warm up significantly. Radurization (0.25, 0.50 and 0.75 Mrad) and radappertization (1.5, 3.0 and 5.0 Mrad) dose levels were used. Deviation from the intended dose was ± 15%. Irradiated and nonirradiated samples were stored under melting crushed ice for a maximum duration of 14 wk, while control samples were frozen and stored at −30°C. Samples were taken at different storage periods for the physical determinations; zero storage time for irradiated samples being counted as immediately after irradiation, and for frozen control samples after approximately 20 hr of storage. Thawing was at room temperature.

Fish samples were skinned and filleted. Pieces of fish fillet from the dorsal body muscles close to the front dorsal fin were used for SF measurements; two pieces from each side of the fish were cut to a standard 25–30 mm length × 10–12 mm width × 8–10 mm thickness. The rest of the fillets were ground and used for WHC and PI determinations. The average of at least five determinations was reported for each parameter.

Shear force (SF)

A modification of the Wolodkewitsch machine (Grünewald, 1957) equipped with 6 kg force and a shear strength cell was used to determine the shear resistance of muscle samples. The shear strength cell was composed of five blades 2 mm thick and spaced 2 mm apart. These blades passed through a sample holding box having a corresponding number of slots. The sample was laid across the slots in the box and was sheared by raising the shear box upwards so that the shear blades passed through the sample. The sample was sheared perpendicular to the major surface of the sample and across the fibers at a rate of 1.6 mm/sec. All measurements were performed with both the shear cell and the muscle sample at room temperature.

Shear force was recorded by an electric recorder operating at a speed of 37 cm/sec and the maximum shear force values (kg) were reported.

Water–holding capacity (WHC)

The method used was a modification of one proposed by Grau and Hamm (1957). 300 mg ground fish muscle was weighed on a 7 cm Schleicher and Schüll No. 2040b filter paper which had been preconditioned by standing overnight in a desiccator over saturated KCl solution. The filter paper and muscle sample at room temperature were placed between two metal plates and immediately pressed under 60 kg pressure for 2 min using the Wolodkewitsch machine. The total wetted area and the meat film area were measured using a sliding bar pattern compensating planimeter (A.OTT-type 30113). All recorded areas were taken as the mean of two separate determinations.

To calculate the WHC, it was necessary to establish the relationship between free water area and weight of the free water (Roberts et al., 1972; Wierbicki and Deatherage, 1958). The regression coefficient was determined as 10.465 mg free H_2O/cm^2 and was used in calculating the WHC as follows:

$$\% \text{ free water} = \frac{(\text{Total wetted area} - \text{meat film area})\ 10.465}{\text{mg sample} \times \% \text{ moisture}} \times 100$$

WHC = 100-% free water.

Thus WHC in this experiment is defined as the % water retained in muscle (% of total moisture) after applying 60 kg pressure for two minutes.

Plasticity index (PI)

The method used was that of Roberts et al. (1972). Determination of PI was made using the meat film area from the WHC determination divided by the weight of the sample. Thus PI is expressed in cm^2/g.

RESULTS

NONIRRADIATED SAMPLES showed a slight decrease in SF values during the 4-wk storage period (Fig. 1). These alterations were significant ($P < 0.05$) at 2 wk storage and thereafter. WHC showed a sharp decrease after 2 wk storage (Fig. 2) and was significantly different from nonstored (i.e., fresh) samples at 2 ($P < 0.05$), 3 and 4 wk ($P < 0.01$) storage. These samples also showed a significant ($P < 0.01$) increase in PI values at 2 wk and thereafter (Fig. 3). In the frozen control samples the three parameters remained practically unchanged during the entire storage period.

Radurization dose levels had no significant effect on PI and SF values, while WHC values were slightly lower in samples irradiated at 0.50 Mrad (not significant) and 0.75 Mrad (significant, $P < 0.05$). During storage no significant changes in SF values were apparent; WHC values decreased slightly (less than in nonirradiated samples) and PI increased slightly (also less than in nonirradiated samples).

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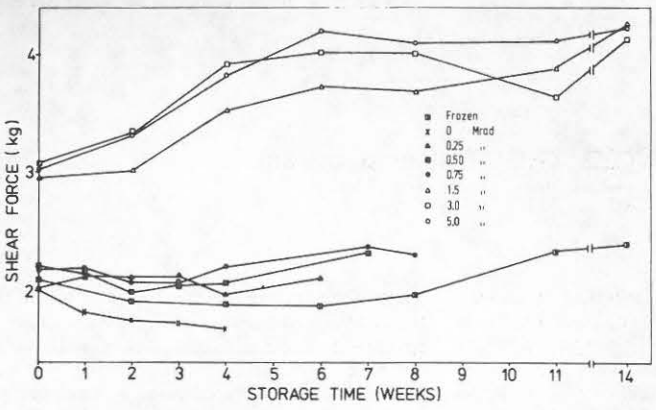

Fig. 1—Shear force changes in frozen, nonirradiated and irradiated (0.25—5.0 Mrad) stored trout.

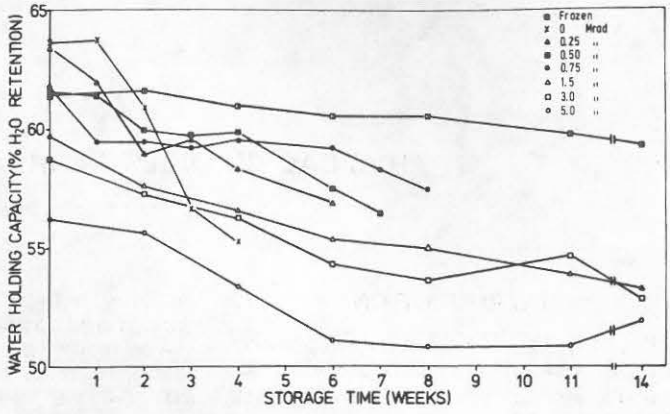

Fig. 2—Water-holding capacity changes in frozen, nonirradiated and irradiated (0.25—5.0 Mrad) stored trout.

In radappertized samples, SF values were significantly ($P < 0.01$) higher than in nonirradiated samples—an effect which became even more pronounced during storage. WHC values were significantly ($P < 0.01$) lower in radappertized samples; however, this difference disappeared during storage due to the decrease of WHC values in nonirradiated samples. Irradiation with doses of 3 and 5 Mrad caused a significant ($P < 0.01$) lowering of PI values. During storage this effect became even more apparent.

No drip loss was noticed in unirradiated and in radurized samples. Radappertized samples showed some drip loss; amounts were small and did not correlate with radiation dose or storage time. It should be noted that in this respect results obtained in this study on whole fish differ from results obtained on fish fillets.

DISCUSSION

Effect of radiation dose level on SF, WHC and PI

The physical parameters—SF, WHC and PI—were distinctly affected at radappertization dose levels. Presumably protein denaturation leading to protein-protein interaction or aggregation caused a loss of water-holding capacity (WHC decrease) and consequently increased muscle toughness (SF increase) and rigidity (PI decrease). These results are in agreement with findings of other workers.

Spinelli et al. (1969) showed a correlation between textural and myofibrillar protein changes in irradiated ocean perch and English sole. Other workers have reported increased drip loss in irradiated fish (Gore and Kumta, 1970) and meat (Cain et al., 1958; Urbain, 1973), and increased shear resistance of irradiated chicken muscle (Whiting and Richards, 1971) and irradiated meat (Stadelman and Wise, 1961). Soft, mushy texture of radappertized meat (Coleby et al., 1961; Pearson et al., 1960) may be attributed to enhancement of residual proteolytic activity by elevated storage temperature. Other workers found a decrease in WHC as measured by the solubility of myofibrillar proteins in irradiated fish (Jay, 1967; Kumta and Gore, 1970; Spinelli et al., 1969). Jay (1967) also reported an increase in meat shrinkage (decreased PI) when the radiation dose level was increased.

Effect of storage on SF, WHC and PI

During storage nonirradiated samples showed a softening effect as evidenced by SF decrease and PI increase, which was probably due to enzymatic spoilage at ice temperature. It is believed that deterioration of fish muscle is caused mainly by proteolytic exogenous bacterial enzymes rather than endogenous tissue enzymes (Liston, 1965; Love, 1968). Rhodes (1969) and Kumta and Gore (1970) also reported the denaturation of sarcoplasmic proteins and at the same time decrease in the solubility of myofibrillar proteins during ice storage. Both factors decrease the total binding capacity of muscle.

In radurized samples significant changes were apparent at extended storage periods (depending on radiation dose level and physical parameter measured). In general a slight insignificant SF increase, significant WHC decrease and PI increase was found. These changes could be due to chemical reactions, i.e., protein-protein interaction during storage in ice. Kumta and Gore (1970) and Spinelli et al. (1969) reported decrease in the extractability of myofibrillar proteins and increase in the drip loss during storage of irradiated fish. Another factor involved in the changes during storage is the microbial growth. Although the bacteria responsible for spoilage are rather susceptible to radiation and may be largely eliminated by radurization (Miyauchi et al., 1967), microbial growth does take place during ice storage (Ehlermann and Münzner, 1970; Kumta et al., 1973; Spinelli et al.,

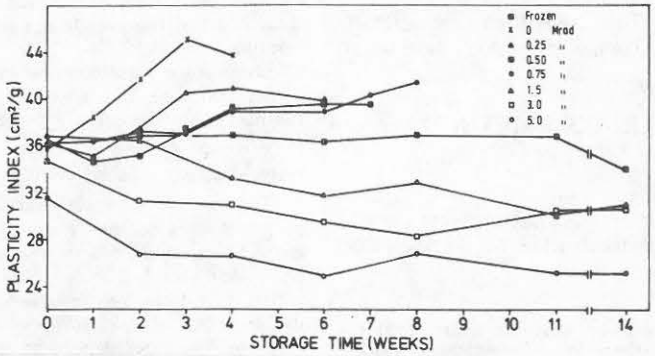

Fig. 3—Plasticity index changes in frozen, nonirradiated and irradiated (0.25—5.0 Mrad) stored trout.

1965), and after reaching a certain level triggers changes in muscle tissue that affect indirectly the physical properties of irradiated stored fish.

Radappertized samples showed significant SF increase and WHC and PI decrease during the early storage period. These changes are consistent with the supposition that irradiation causes crosslinking between protein molecules, resulting in some contraction of the fibrils and a more rigid structure. Lawrie et al. (1961) indicated, from the persistence of the cross striation on the fibrils, that the structural proteins are denatured but not proteolyzed during irradiation and storage of meat.

With regard to the practical application of radiation processing to fish, it is of interest to note that low dose treatment as foreseen for the proposed onboard irradiation of iced ocean fish (Diehl, 1973) had very little effect on physical properties. This is in agreement with the high organoleptic ratings given to radurized fish in numerous studies. During storage physical parameters, particularly WHC and PI, changed less in radurized samples than in nonirradiated, unfrozen samples, i.e., the low dose radiation treatment preserved the condition of the fresh fish. Differences observed between nonirradiated and radurized samples during storage appear to be due to the retardation of microbial spoilage caused by radiation, rather than being due to an effect of radiation on the fish tissue itself. Only at doses of 1.5 Mrad and above did the radiation treatment result in immediate and pronounced effects on the physical properties of the tissue. This is in agreement with the observation that protein aggregation can be demonstrated in foodstuffs irradiated at radappertization doses but not, or only in traces, at dose levels below 1 Mrad (Radola, 1973).

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