Effects of low-dose irradiation and subsequent storage on the technological properties of beef

A. GROZDANOV, N. DIMITROVA, N.NESTOROV, N. DILOVA and G. DIKOVA

Meat Technology Research Institute, Sofia, Bulgaria

General practice at present is to store chilled meat at 0°-4°C until needed for processing. Under these conditions, the limit of acceptability for carcass meat, sides and quarters, is approximately 14 days; for boneless meat, 3-4 days. Vacuum-packed cuts can be stored for up to approximately 20 days under refrigeration. Freezing is the only way to store meat if a longer storage period is required, but frozen meat is inferior to the nonfrozen one when designated for processing(Miller et al,1980). Low-dose irradiation and subsequent storage at above-freezing temperatures could be the alternative when storage for up to 6-8 weeks is required. Considerable advantages with respect to energy saving and reduced weight loss might be expected.
Recently, hot-boning is also under consideration since after the meat is removed from the carcasses, the amount of chiller space used could be substantially reduced. However, handling of the hot-boned meat presents some bacteriological problems not entcountered to the same extent in conventional meat processing : the exposure of large areas of meat surface while still warm and moist is ideal for bacterial growth (Williams,1978). Low-dose irradiation could be useful to inhibit the growth of these microorganisms.
This set of experiments were designed as a first step of the project, aimed at giving an important information regarding : (i) the best time postmortem for a low-dose irradiation treatment of vacuum-packed meat, and (ii) the functional properties of low-dose irradiated meat as compared to the ones of chilled or frozen meat.

EXPERIMENTAL

Treatments and storage

Experiments were carried out with both hot-boned and chille bovine semimembranosus muscles. The former were excised from the left hind-quarters within 45 min after slaughter, then transported to the Meat Technology Research Institute within the following 30 min. After sampling for the surface microbial contamination, the muscles were divided into two equal parts, which were packaged individually under vacuum.
The first halves were carried to the gamma-irradiation facility within 30 min and subjected to an irradiation dose of 3 kGy. After the irradiation treatment, the meat samples were transported back to the Institute where they were stored and tested. For the same period of time, the control halves were kept without further treatment in a refrigerator, and then transfered to the cold store.
The corresponding pair muscles were excised from the right hind-quarters after a 24-hr conventional chilling and then handeled as described above for the hot-boned muscles. The ambient temperature for both hot-boned and chilled muscles was maintained within the range of 0-5°C throughout the whole period from the excision of the muscle to the end of the irradiation, and then at 2 ± 1°C during storage.

R-value and pH determinations

The R-values, which represent the degree of transformation of ATP to IMP, were determined as described by Honikel et al.(1981). The increase of R-value reflects the decrease of ATP level postmortem.
The pH-values of meat samples were determined in duplicate on a Radiometer model 25 pH-meter, with the combined electrode inserted into the tissue.

Functional property tests

The water-binding capacity of meat samples ground after the respective treatment and storage was determined in triplicate by the centrifuge technique as modified by Tsai and Ockerman (1981). Ten milliliters of a solution containing sodium chloride (1.2 g), sodium pyrophosphate (150 mg), and sodium nitrite(4 mg), were added to a mixture of a ground meat (40 g) and ground subcutaneus pork fat(10 g). An emulsion was formed by blending for 1 min ; then 10-g portions were placed in glass tubes capped with a stopper, and the tubes were heated at 90°C for 10 min in a water bath. After heating, the solid meat was carefully removed from the glass tube, placed onto a perforated plastic disc ,which fits a regular stainless steel centrifuge tube, and centrifugated for 20 min at 4000 x G. After centrifugation, the weight of the solid sample on the plastic disc was obtained. The water binding capacity was calculated as a percent of water retained after heating and centrifugation.
For measuring protein solubility, the muscles were blended in a modified Hasselbach-Schneider solution (0.6M NaCl, 1 mM $MgCl_2$, 10 mM $Na_4P_2O_7$, 0.1 M phosphate buffer, pH 6.5). After the samples were blended, they were allowed to stay for 30 min at 4°C, and then centrifuged at 3000 x G for 30 min. Total extractable protein was measured by a dye-binding method with Amido Black 10B (Dilova et al.,1981).
The emulsifying capacity of the total extractable protein was determined in triplicate by the method of Galluzzo and Regenstein(1978), adapted to the conditions of our laboratory. Ten milliliters of the Oil-red O-coloured sunflower oil were added to 10 ml of the diluted, 0.75 mg of protein per ml, protein extract. An emulsion was prepared by blending at medium speed for 10 sec ; then oil was continously added while the mixing continued until an abrupt colour change was observed, indicating that the emulsion was broken. The total volume of oil emulsified by the 7.5 mg of protein was recorded.

The least concentration gel test performed was similar to Trautman's one (Trautman, 1966). The total protein extracts were diluted to protein concentrations ranging from 5-10 mg of protein per ml with the Hasselbach-Schneider solution. These protein solutions were pipetted into 10x 100 mm tubes and placed in a water-bath set at 25°C and the thermostate changed to 70°C. Solutions were heated for 40 min and it took 10 min for the water to reach the 70°C temperature. Then the tubes were cooled at +4°C for 1 hr and a small spatula was used to loosen the the surface interface. A positive score was given if the gel remained in the tube, and a negative score if the gel ran out of the tube upon inversion.

RESULTS AND DISCUSSION

Immediately after the irradiation, a 2 to 3 log-cycles reduction of the microbial flora was established. Throughout the storage period, the difference between the irradiated and non-irradiated samples was reduced down to 1 log-cycle for total aerobic plate count, while the coli-titre remained 10^{-1}. Enterococci were also reduced significantly.
The reduction of microbial flora as a result of low-dose irradiation demonstrated once again the possibility to store meat under refrigeration (2-4°C.) rather than in the frozen state. As far as the further processing of meat into meat products is concerned, one is tempted to believe that the irradiated and chilled meat is superior to the frozen one. However, data on technological properties of irradiated and stored meat are limited.
In order to choose the most appropriate time postmortem for irradiation, a knowledge is required on the effect of low doses of ionizing radiation on the rate and extent of postmortem glycolysis. Relevant data with respect to beef or pork are not available. The changes in two most informative indices were used to follow the processes postmortem : (i) pH- value, and (ii) R-value (the higher values show advanced ATP-hydrolysis).
It was observed that both irradiated and nonirradiated hot-boned muscles followed the same pattern of postmortem glycolysis: pH-values decreased from 6.8-6.9 (on the 2nd hr) to 6.2-6.3 (on the 5th hr), then to 5.3-5.4 (on the 24th hr.). The R-values remained unchanged at a comparatively low level (0.8-0.9) during the first five hours postmortem, but increased up to 1.2- 1.4 on the 24th hr. These results of ours did not show any evidence of an accelerated glycolysis as a result of the irradiation treatment.
The effects of irradiation treatment and subsequent storage on some functional properties of beef are shown in Table 1. Little or no differences between the irradiated and control samples were established when the meat samples were tested immediately (24 hr) after the treatment. A slight trend towards a reduced water binding capacity, as well as a lower gelling ability was observed for irradiated hot-boned beef when compared to nonirradiated controls. After a 20-day storage period, slightly larger differences were established between the irradiated and nonirradiated meat samples. The water-binding capacity was the most affected : 13% and 8% less water was retained by hot-boned and chilled meat, respectively, following irradiation and storage. Both other indeces , which chracterize the properties of salt-soluble meat proteins, suffered less damage. It appears that even though irradiation does not affect postmortem glycolysis rate, it gives rise to some changes in the functional properties of meat.

Table 1. Functional properties of low-dose irradiated hot-boned beef as compared to those of chilled beef

Type of treatment	pH-value	Total extractable protein (mg/ml)	Least cocentration for gel stability (mg/ml)	Emulsifying capacity (ml oil/ mg protein)	Water binding capacity (% of water retained)
Hot-boned, stored for 24 hr					
-irradiated	5.40	30.5	9.0	1.80	56.5
-nonirradiated	5.35	31.0	8.0	1.85	61.0
Hot-boned, stored for 20 days					
-irradiated	5.45	32.8	7.0	1.70	46.5
-nonirradiated	5.35	32.2	6.0	1.85	59.6
Chilled, stored for 24 hr					
-irradiated	5.40	23.5	7.5	1.85	57.0
-nonirradiated	5.45	24.5	8.5	1.85	59.5
Chilled, stored for 20 days					
-irradiated	5.35	21.5	8.0	1.70	49.0
-nonirradiated	5.40	23.5	7.0	1.80	57.0

Although neither a difference in the quantities of total salt-soluble proteins, nor changes in the meat proteins ratio (results not reported) were observed, one could conclude that minor changes in the native state of proteins are responsible. Some evidences that this is the case with pork have been reported earlier (Grozdanov, 1979). Further detailed studies on the functionality of both beef and pork as influenced by low dose irradiation and subsequent storage are underway.

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