29 Storage and processing characteristics of low-dose irradiated or frozen bovine muscles intended for cooked sausage production

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Introduction

The previous report from this laboratory (Grozdanov et al., 1982) indicated that a 20-day cooler storage of beef following low-dose irradiation treatment resulted in minor but significant reductions in water-holding capacity as compared to nonirradiated controls. Emulsifying capacity and gel stability were only slightly affected by irradiation plus storage. It was suggested that, although inferior to the chilled beef raw materials, irradiation-treated and then cooler stored meats might prove superior to the respective frozen controls.

This experiment was designed to compare the functional properties of low-cose irradiated and then cooler stored beef raw materials with those of frozen and freezer stored meat, as well as to evaluate the quality of cooked sausages made from irradiated beef raw materials.

Materials and Methods

Meat sources. Sixty kg of beef raw materials were obtained from the cooled hindquarters of four cow carcasses of the same breeding and management system. After transportation to the Meat Research Institute, all meat pieces, 400 to 700 g each, were randomized by hand and distributed into 24 vacuum-packages (2,5 kg each). The packages were randomly assigned to one of two treatments: (i) Freezing and storage at -18°C, and (ii) Low-dose irradiation followed by storage at 0° ± 0.5°C.

Upon the completion of each storage period (7, 30 or 60 days), three packages of each treatment group were sampled for pH and microbial determinations. The remaining beef raw materials were then used for sausage production. Prior to sampling, frozen samples were partially thawed at 5°C for 24 hr. Fresh postrigor pork and cooled pork backfat were obtained from the local slaughterhouse at the expiry of each storage period.

Microbiological assays. Upon opening in a sterile room, each meat piece in the bag was sampled by excising a disc-shaped sample from its surface (area, ca. 5 cm²; thickness, ca. 5 mm). Samples from the same bag were pooled together, weighed, and then homogenized in an appropriate quantity of sterile saline containing 0,1% peptone. The resulting homogenate was serially diluted and used for microbiological tests.

pH determinations. At the end of each storage period, pH of the beef raw materials was determined by inserting a combined electrode (GK 2321 C, Radiometer) into the tissue. At least one reading was taken on each single piece of meat; then each package mean value was calculated by averaging all the readings taken.

Water-holding capacity determination. A centrifuge technique was used in evaluating bound juice of cooked meat. Ten-gramme portions of ground beef raw materials were placed in glass tubes, capped with a stopper, and the tubes were heated at a 72°C water bath for 10 min. After heating, the solid meat was carefully taken out from the tube, placed onto a perforated plastic disc which fits a regular stainless steel centrifuge tube holder, and then centrifuged for 30 min at 1200 rpm (K-60, Janetzki, DDR). The water-holding capacity value was calculated as per cent water retained after heating and centrifugation.

Cooked sausage products. Sausage batters were prepared using the following formula: beef raw materials, 2,5 kg; postrigor pork, 1,5 kg; fresh cooled porcine backfat, 1 kg; ice/water slurry, 1 kg. The meat juice accumulated in the packages, either during storage from the irradiated beef or on thawing from the frozen beef, was added to the respective batter during chopping.

Each treatment x storage sample of beef raw materials was placed in a 3-blade nonvacuum bowl cutter and chopped for 15 sec. After sampling for water-holding capacity determination, the respective amounts of salt, nitrite, and sodium tripolyphosphate were added. Chopping was resumed for further 5 min with two additions of ice/water slurry. During the last few revolutions, pork, pork backfat and spices were added.

Resulting batters were stuffed into 55 mm diameter casings and linked in 40 cm lengths. Linked and marked sausages were weighed and then randomly placed in a smokehouse for cooking. The following schedule was used: 80 min at 85-90°C (dry bulb), and 30 min at 78°C. The products were cooked to an internal temperature of 72°C. After cooking, the sausages were showered for 5 min with tap water, and then stored at 4°C for 16 hr prior to weighing and sampling for chemical determinations.

Batter stability test. Approximately 80 g of each sausage batter were obtained prior to adding pork and backfat into the bowl cutter. Stability determinations were made by placing 10 g of the raw sausage batter into a 30 mm diameter glass tube, capping the tube and then cooking in a 72°C water bath for 60 min. After cooking, the juice that accumulated during the cooking process was recorded. Each batter was tested for stability in triplicate.

Chemical analyses. Moisture and fat determinations were performed according to the standardized methods (BDS 5712-74 and 8549-74, respectively). Residual nitrite content was determined by the ISO method 2918. A slightly modified version of Hornsey's method was used to estimate the relative content of nitrosomyochromogen (% of total pigment).

Sensory evaluation. A sensory panel composed of 9 trained panelists from the Meat Research Institute was asked to evaluate sausage samples representative for each treatment x storage group. Panel members rated colour and flavour using a 9-point hedonic scale with 1 being "dislike extremely", 5 being "neither like nor dislike", and 9 being "like extremely".

Statistical analyses. The experiment was carried out using a completely randomized design with a factorial arrangement of treatments. The sources of variation consisted of: (i) Treatment (irradiation followed by storage at 0°C, or freezing followed by storage at -18°C); and (ii) length of storage (7, 30, or 60 days).

Data were analysed by analyses of variance. Significance was determined by the F-test and significant differences were accepted at 5% level of probability. Duncan's multiple range test was used to indicate significant differences between particular variables.

Irradiation treatment. Vacuum-packaged beef raw materials were irradiated with a mean maximum dose of 2,5 kGy. The minimum and maximum absorbed dose rate were 1,96 kGy/hr and 2,30 kGy/h, respectively. Two packages were treated at a time and their positions were reversed at half irradiation time. Temperature was maintained at 0-4°C during the irradiation.

Results

Storage properties. As could be expected, the microbial status of beef raw materials was strongly dependent on the treatment applied. As estimated after a 7-day storage at 0°C, mesophilic counts in the irradiated beef were reduced by at least 2 log cycles as compared with the initial values, while no changes in mesophilic counts were found in frozen meat. The same was true for psychrophilic bacteria and lactobacilli. In the irradiated beef raw materials, increase in storage time produced a gradual increase in the levels of psychrophiles, while mesophilic organisms and lactobacilli reached their maximum counts after 30 days in storage at 0°C. Even after a 60-day storage, however, higher levels of these microorganisms were not accompanied by a persistent off-flavour which was specific for vacuum-packaged meat that had undergone anaerobic spoilage.

In the packages with irradiated beef raw materials, microbial growth was accompanied by a decrease in both pH and water-holding capacity (Fig. 1). Changes in pH were still not apparent after 30 days of cooler storage but pH value became significantly lower in the irradiated beef held for 60 days at 0°C. The water-holding capacity changes in the irradiated beef raw materials followed the same pattern as those of pH throughout the 60-day storage period. Even though being very variable among samples, the quantities of drip accumulated in the packages appeared to reflect the changes in water-holding capacity (data not shown).

Processing characteristics. Mean values for physical, chemical and sensory properties of sausages stratified by main effects (treatment, storage time) are presented in Table 1.

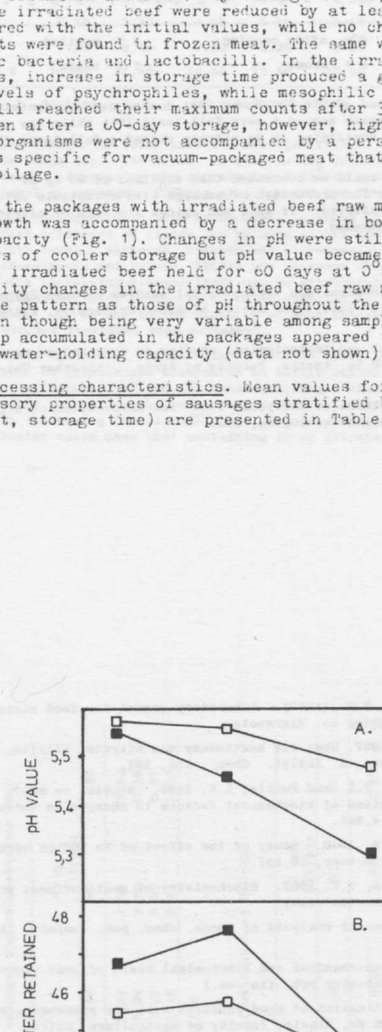

Figure 1. Effects of low-dose irradiation (2,5 kGy) and storage at 0°C on pH and the water-holding capacity of beef raw materials

■ nonirradiated
□ irradiated

Treatment (irradiation + cooler storage or freezing + freezer storage) did not significantly (P> 0.05) affect batter stability and processing shrinkage. These functional quality indicators, however, were influenced by the length of raw materials storage (7, 30 or 60 days). Millilitres batter cookout and percentage shrinkage were significantly higher (P< 0.05) for the 60-day storage group but not for the 30-day storage group.

Percentage moisture and fat content were not affected (P> 0.05) by either treatment or length of storage. These findings seemed to reflect the greater residual variance for these traits (greater variability being presumably introduced by the non-beef components in the formula).

Residual nitrite content was not influenced by treatment but decreased significantly (P< 0.05) with storage time. Once again, 60-day storage values, but not those for a 30-day storage, were responsible for the effect of storage time. Percentage nitrosyl hemochrome was higher (P< 0.05) in sausages produced with irradiated beef raw materials as compared with frozen meat. Higher values were also found in the 60-day storage group in comparison with other storage intervals. Residual nitrite content and percentage nitrosyl hemochrome seemed to reflect changes in the pH values of irradiated beef raw materials during their storage at 0°C.

The type of treatment influenced significantly (P< 0.05) the colour and flavour ratings of sausages. Products prepared from frozen beef were rated higher in colour and flavour than sausages prepared from the irradiated beef raw materials (8,0 vs. 6,7, and 7,3 vs 6,3, respectively). Sensory traits were also affected by the length of storage. Colour and flavour ratings did not change ($P > 0.05$) after the completion of the 30-day storage period; however, after 60 days in storage, the ratings for both colour and flavour decreased significantly ($P < 0.05$).

Table 1. Mean physical, chemical and sensory values of sausages stratified by main effects

Trait	Treatment			Storage (days)			
	Irradiation + cooler storage (A)	Freezing + frozen storage (B)	Order of means*	7 (C)	30 (D)	60 (F)	Order of means*
Batter cook-out (ml)	1,1	1,1	AB	0,8	1,0	1,4	CDF
Processing shrinkage (%)	7,4	7,3	AB	7,9	7,0	7,2	CDF
Moisture (%)	62,6	62,5	AB	61,8	63,5	62,2	CDF
Fat (%)	19,2	19,3	AB	19,2	18,3	20,2	CDF
Residual nitrite (ppm)	40,9	39,8	AB	41,9	40,2	38,8	CDF
Nitrosyl hemochrome (%)	73,8	70,1	AB	71,6	70,5	74,1	CDF
Colour**	6,7	8,0	AB	7,7	7,6	6,8	CDF
Flavour**	6,3	7,3	AB	6,8	7,2	6,3	CDF

* Means underlined by a common line are not different ($P > 0,05$);
** A 9-point hedonic scale (See 'Materials & Methods' Section).

Discussion

A well-known advantage of vacuum packaging is that it provides for a considarable extension of the storage life of meat. It was also suggested that a further extension might be achieved by the treatment of vacuum-packaged meat with low doses of ionizing radiation (IFT's Expert Panel, 1983).

The data of this study are in agreement with the previous findings that a combination of vacuum-packaging and low-dose irradiation does not only reduce the initial microbial population but also dramatically changes the ratio between various groups of microorganisms naturally present in meat. As evidenced in this study, lactobacilli became a predominant group thus determining the type of spoilage that occurred. Irradiated and subsequently cooler stored beef raw materials gradually developed a slightly sour off-odour which dissipated rapidly after opening the bags. The characteristic flavour of irradiated meat was detectable after 7 or 30 days in storage but was not easily discernible, at least in the uncooked state, after 60 days of storage at 0°C.

Before initiating the experiment, it was expected that the length of storage, batter chopping and cooking, and the addition of spices would all contribute to the disappearance of irradiation flavour in the finished product. However, it was not a problem for the expert panelists to pick out the sausage samples containing irradiated beef raw materials at all storage periods. Those samples were unanimously assigned lower scores as compared to the controls from frozen beef. It is worth noting, however, that when a consumer panel was asked to evaluate sausages made from irradiated beef raw materials without comparing them to the nonirradiated samples, most of the panelists found those sausage samples fully acceptable and only a few detected, as they described, an unknown but not repulsive off-flavour.

Furthermore, the 60-day storage of irradiated beef raw materials affected the flavour scores of sausage products significantly ($P < 0,05$). Apparently, it was not only the increased bacterial counts but also the off-flavour development that limited the storage life of low-dose irradiated beef raw materials at 0°C. Recent experiments (Egan and Shay, 1982) showed that vacuum-packaged fresh beef spoiled at 5°C in the absence of a significant population of contaminating microorganisms. The off-flavour which developed in the cooked mince prepared from beef which was stored 'sterile' under conditions of very low oxygen pressure was described by taste-testers as 'liver-like'. Therefore, it seems that no considerable further extension of storage life at about 0-3°C could be expected as a result of the irradiation treatment of vacuum-packaged beef raw materials mainly owing to flavour deterioration.

Drip accumulation is also of importance with regard to the maximum storage life of vacuum-packaged meat since it provides excellent conditions for bacterial growth and autolytic processes. In this study, the quantities of drip varied greatly among samples, being larger with longer storage time. Decreases in pH and water-holding capacity after a 60-day storage of irradiated beef raw materials at 0°C were undoubtedly responsible for the large quantities of drip accumulated in the packages.

Irradiation alone is also responsible for further loss of water-holding capacity. In a separate study, significantly ($P < 0.01$) greater quantities of drip were found in low-dose irradiated packages than in nonirradiated controls (3,64 vs 1,69 ml per 100 g of beef, respectively), after 30 days of storage.

Although being objectionable to the purchaser when vacuum-packaged meat is displayed at retail, drip would not be of primary importance if meat is intended for processing into comminuted meat products. In this experiment, any quantity of drip accumulated in the package was added back to the respective batch of beef raw materials while chopping in the cutter. Along with the added water, the drip fluid was re-bound to the meat proteins matrix. Therefore, the only limitation remaining is not the quantity but the quality of drip. Since bacterial growth, pH drop and off-flavour development are all favoured by drip accumulated in vacuum packages, it was the drip actually that rendered the irradiated beef raw materials unfit for further storage and processing.

After 30- and 60-day storage, although being superior in percentage nitrosyl hemochrome, sausages manufactured from irradiated beef raw materials were rated lower for colour. Panelists consistently described these products as lighter in colour than the products produced from frozen beef raw materials. Lycometros and Brown (1973) found that irradiated myoglobin exhibited less steric hinčrance to alkyl isocyanides binding at the sixth position. They also observed that nonliganded myoglobin was more vulnerable to radiation-induced structural changes than the respective liganded ferrous derivatives and concluded that the haem moiety did not suffer major changes. Our results seem to support those findings, as far as a significant increase in percentage nitrosyl hemochrome and no haem loss in irradiated beef were observed. However, it is likewise probable that the higher percentage nitrosyl hemochrome was only due to the pH-changes noted over the refrigeration storage of irradiated beef. Meanwhile, we could only speculate about the reason(s) for the lighter colour of sausages made from the irradiated beef raw materials. One possible explanation is to assume an irradiation-dependent transformation of myoglobin into oxymyoglobin-like red pigment, as suggested by Satterlee et al. (1971), this pigment having slightly modified spectral and binding characteristics.

Since one possible approach to eliminate drip accumulation during storage is comminuting and salting prerigor beef, we initiated a series of experiments to investigate if such a treatment combined with low-dose irradiation could provide for an extended storage life of beef raw materials at refrigeration temperatures. Prerigor beef was coarsely ground and mixed with either 3% salt or 3% salt plus 70 ppm sodium nitrite. Ground meat was distributed into polyethylene bags removing as much air as possible and stored in a 2-4°C cooler for 23 days. At 24 h post mortem, half the bags were irradiated with approximately 2,5 kGy. After 2, 9, 16, or 23 days, two bags of each treatment were withdrawn from storage and sampled for microbiological analyses and functional properties testing.

As could be expected, sensory observations reflected the differences in microbial status between the irradiated and nonirradiated beef preblends. In the nonirradiated samples, a strong off-flavour, mainly sour and stale, was noticed on opening the bags after 16 days in storage, while no signs of spoilage were present in irradiated meat after 23 days of cooler storage. Little or no changes were observed in both pH and water-holding capacity of the irradiated preblends over the 23-day storage. Nonirradiated presalted beef raw materials, however, suffered a decrease in pH and, concurrently, a drop in water-holding capacity as early as at 16 days of storage. Presalting with nitrite improved cured colour formation rates which had been lowered as a result of higher pH of presalted prerigor beef. Further experiments in this promising direction are under way in this laboratory.

Conclusions

Attempts to substitute low-dose irradiated and subsequently cooler stored beef raw materials for frozen stored raw materials suffered some drawbacks. One major disadvantage appeared to be the accumulation of drip in the vacuum packages as a result of reduced water-holding capacity. Failure to extend storage life beyond that of nonirradiated vacuum-packaged beef and, as we suppose, some flavour defects were mainly due to the drip accumulated. The preliminary results from the cooler storage of prerigor beef preblends following low-dose irradiation showed promising prospects.

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