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Radiation Physics and Chemistry 63 (2002) 317–322

Radiation Physics and Chemistry

www.elsevier.com/locate/radphyschem

The effect of irradiation of fresh pork loins on the protein quality and microbiological changes in aerobically—or vacuum-packaged

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Abstract

The effect of γ-irradiation on the physico-chemical, organoleptic and microbiological properties of pork was studied, during 43 d of storage at 4°C. Irradiation treatments were carried out under air or vacuum packaging on fresh pork loins at a dose of 6 kGy, at two dose-rates: 2 and 20 kGy/h. Regardless of the type of packaging and dose-rate of irradiation, all irradiated pork samples were prevented from bacterial spoilage during 43 d. Meat redness and texture of irradiated loins were well preserved during storage especially when samples were stored under vacuum. The physico-chemical and organoleptic changes in pork loins appeared to be relatively little affected by the 6 kGy dose.

Keywords: γ-irradiation; Packaging; Bacterial spoilage; Physico-chemical properties

1. Introduction

Extended shelf-life of 4–8 weeks for fresh meat is possible under modified atmosphere packaging, involving both vacuum and gas packaging. However, food irradiation is limited due to fatty acid decomposition and subsequent off-flavor formation in the foodstuff (Lacroix et al., 1997). Mechanisms other than the bacterial meat spoilage involve the action of atmospheric oxygen, irradiation, high pressure and temperature.

Furthermore, the threshold dose for preserving the taste of pork was reported as low as 1.75 kGy (Sudarmadjii and Urbain, 1972). In this study, we examined the quality of irradiated pork loins using classical analyzes of volatile flavors and instrumental measurements of texture and redness. We also assessed the quality of irradiated pork proteins by analyzes of protein sulfydryl content. Our objective was to optimize the shelf-life prolonging benefit vs. the off-flavor formation. Combination of physical factors was taken into consideration, such as different dose-rate of irradiation, air and vacuum packaging.

2. Experimental

2.1. Sample packaging

Boneless pork loins (*longissimus dorsi*) samples weighing approximately 1 kg each were individually vacuum-packed in plastic bags (Cryovac, BB1 2 mil) or without vacuum in commercial polyethylene bags with a sealing clamp. The food-contact layer of medium-density polyethylene, designed for use in vacuum

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0969-806X/02/$ - see front matter
PII: S0969-806X(01)00519-9

packaging of cold meats, provided properties of low oxygen permeability (15.5 cc/m^2/24 h at 25°C). Samples were vacuum-sealed to a dial reading of 690 mm Hg. The samples were transported on ice to Canadian Irradiation Center (CIC), INRS-Institut Armand-Frappier (Laval, Québec, Canada).

2.2. Sample irradiation

Samples were irradiated under vacuum or air atmosphere by γ-rays in the ^{60}Co source irradiator (MDS Nordion Intl. Inc., Kanata, ON), as previously reported (Lacroix et al., 1997). Irradiation, at 6.0 kGy dose was applied using an underwater calibrator UC-15 at 20 kGy/h or a Gammacell 220 at 2 kGy/h, under controlled temperature 3°C ± 2°C. Optichromic and Gammachrome dosimeters were used to validate the dose distribution throughout the samples (Lacroix et al., 1992). Immediately after irradiation, the samples were stored at 4°C for 43 d. The unirradiated samples were handled in the same way as the irradiated samples.

2.3. Microbiological analysis

On each sampling day, bags were aseptically opened, samples were cut from the center of the loin with a sterile knife and blended under sterile conditions. All subsequent dilutions were made from the initial 10^{-1} dilution. Total aerobic counts were determined by plating appropriate dilutions on Plate Count Agar (Difco) using pour plate technique (Lambert et al., 1992). Mesophylic plates and Psychotropic plate counts were, respectively, determined from plates incubated at 37°C and 48 h at 5°C for 10 d. Lactic acid bacteria were enumerated on plates of *Lactobacillus* MRS agar (MRS broth, Difco, plus 1.5% agar) incubated at 35°C for 48 h. Total anaerobic counts were determined by plating appropriate dilutions on Trypticase Soy-Agar (TSA; BBL Inc.), and incubating plates in anaerobic jars at 35°C for 48 h.

2.4. Sensorial analysis

2.4.1. Off-odor of raw meat

Ten trained panelists from the INSR-Institut Armand-Frappier, were asked to evaluate the odor of irradiated and unirradiated pork during the 0–43 d of storage at 4°C (Lacroix et al., 1991). The hedonic test was done to evaluate the degree of acceptance of the odor on a nine-point hedonic scale (1 = dislike extremely, 9 = like extremely). The packages were opened and off-odor was evaluated under red fluorescent light, in order to prevent the off-odor evaluation from being influenced by the color of the sample.

2.4.2. Flavor of cooked pork

Twice a week, one loin from each treatment, assigned at random, was cooked in an oven at 163°C, at internal temperature 80°C ± 3°C. Pork loins were cut in cubes with a multiblade knife and were kept warm for the evaluation session. Each session started immediately after the cooking was completed. Samples were distributed to 10 panelists who were asked to assess the intensity of odor and flavor perceived. Two sets of stored samples and reference samples of fresh cooked pork loin were presented to each panelist. Scores were placed on a nine-point hedonic scale between dislike extremely:1 to like extremely:9, in order to characterize the intensity of flavor of cooked pork loins.

2.4.3. Texture of raw and cooked meat

Samples of 100 g pork were cooked in a conventional oven at 163°C to reach an internal temperature 80°C ± 3°C. Slices ($4 \times 4 \times 20$ mm^3) of raw and cooked pork were weighed and used for texture determinations in a texturometer Voland Stevens LFRA model 1000 equipped with two blades joined in a "V" shape at 50° angle. The perforation speed of the blade was fixed at 2.0 mm/s, and 12 mm distance. The maximal cutting force (g) was determined using Linseins recorder.

2.4.4. Color of red raw meat

Luminosity and intensity of red raw meat was determined for control and irradiated samples during storage of pork loins at 4°C. The color of the samples was determined with a standard Colormet colorimeter (Instrumar Ltd., St-John's, Newfounland). In order to interpret the color changes, calculation of the hue angle = ($\tan^{-1}\ b^*/a^*$) was carried out from the control and irradiated samples. All measurements were performed in triplicate.

2.4.5. Protein analysis

2.4.5.1. Determination of protein sulfydryls (-SH) and disulfides (S–S). Total concentration of disulfides (S–S) and concentration of free sulfydryl groups (-SH) in extracted pork proteins was determined with Ellmans's reagent (Li-Chan, 1983) as described previously (Dogbevi et al., 1999).

2.4.6. Statistical analysis

Data were statistically analyzed using analysis of variance and Duncan multiple-range tests with $p < 0.05$. The student t-test was utilized for paired comparisons (Snedecor and Cochran, 1978).

3. Results and discussion

3.1. Microbiological analysis

The bacterial counts, presented by plotting of $\log_{10}$ values of colony forming units (CFUs/sample vs. storage time), are shown in Fig 1. Bacterial count over 10^6 CFU/sample in control pork by psychotropes, mesophiles and *Lactobacillus* flora occurred after 20–30 d of storage at 4°C, regardless of the type of air or vaccum packaging. As expected, 6 kGy γ-irradiation prevented from both aerobic and anaerobic bacterial spoilage since the bacterial counts in irradiated pork never exceeded the acceptable 10^6 CFU/sample limit during the 43 d storage period (Fig. 1). Thus, commercial γ-irradiation of pork at 6 kGy, at different dose-rate of 2 or 20 kGy/h, substantially reduced bacterial loads. Data showed, however, that psychotropic microorganisms were more resistant when irradiation treatment was done under air and started to increase after 10 d to reach 10^3 and 10^1 for, respectively, 2 and 20 kGy/h treated samples, after 15 d of storage. Likewise, mesophilic and *Lactobacillus* microorganisms were more resistant when irradiation treatment was done under vacuum conditions. Mesophilic bacteria started to increase after 28 d of storage, to reach 10^4 and 10^1 for, respectively, 2 and 20 kGy/h treated samples, after 43 d of storage. *Lactobacillus* bacteria started to increase after 28 d of storage, only for 2 kGy/h treated samples to reach 10^4 after 43 d. In the case of 20 kGy/h, any bacteria was founded during all the experiment. In both cases, the level of microorganisms decreased as the irradiation dose-rate increased.

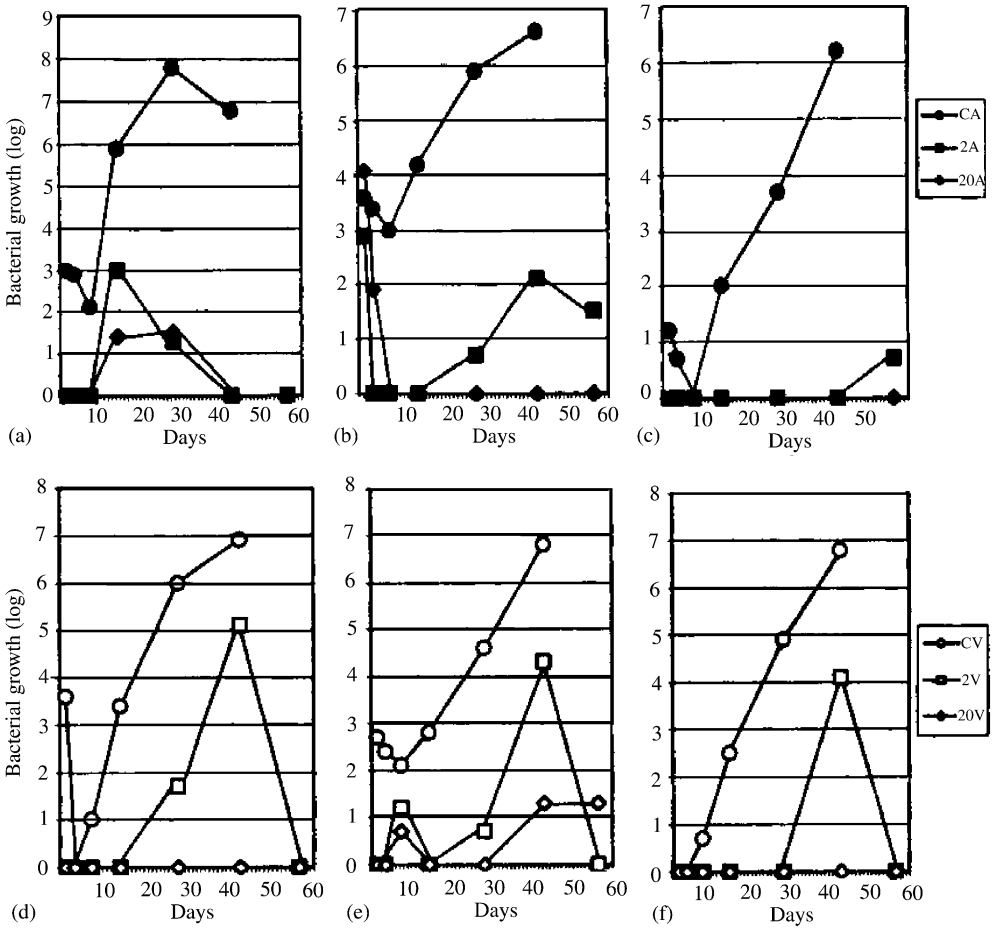

Fig. 1. Bacterial count ($\log_{10}$ CFU/sample) during storage of pork at 4°C of air-packaged (black) or vacuum-packaged (hollow unirradiated controls, CA-CV), 6 kGy-irradiated pork, at a dose-rate of 2 kGy/h (2A-2 V) and 6 kGy-irradiated pork, at a dose-rate of 20 kGy/h (20A-20 V): bacterial growth of psychotropes (A); mesophiles (B) and *Lactobacillus* (C) on air-packaged samples and bacterial growth of psychotrophes (D), mesophiles (E) and *Lactobacillus* (F) on vacuum-packaged samples.

3.2. Sensorial analysis

Extension of organoleptic shelf-life of irradiated pork was analyzed by sensory evaluation of flavor and odor. Scores were placed on a hedonic scale between extremely dislike to extremely like, and results were presented by plotting arbitrary units vs. storage time (Fig. 2). The flavor and the odor of control pork was relatively unchanged throughout the storage time, regardless of the type of air or vacuum packaging. The evaluation of control samples was stopped at 28 d of storage at 4°C due to the bacterial spoilage. As shown in Fig. 2, no marked changes in both flavor and odor of the 6 kGy-irradiated pork were noted, at the two different 2 and 20 kGy/h dose-rates of irradiation. The scores were from slightly superior to equal to the controls. Thus, no marked off-odor and no unfavorable flavor of cooked pork, related to the 6 kGy-irradiation, were detected during the 43 d storage period.

3.3. Color and texture of red raw meat

Quality of irradiated pork was further analyzed by determination of red meat color and meat texture during the 57 d storage period. No marked difference in the intensity or red color or in the meat texture was found in samples during the first 20 d of storage. However, beween 20–40 d of storage, the red color was more intense ($P<0.05$) in samples packed under air. A more intense red color was observed in samples treated at 20 kGy/h as compared to samples treated at 2 kGy/h at the end of the experiment (Fig. 3). A marked difference in the meat texture ($P<0.05$) was also found between the air- and vacuum-packed pork throughout the storage at 4°C. Irradiation under air and at a higher 20 kGy/h dose-rate weakened the texture of the meat (Fig. 3). Also, irradiation under air packaging had a better protection on red color of pork throughout the storage time. However, irradiation under vacuum had a better protection on the texture of the meat.

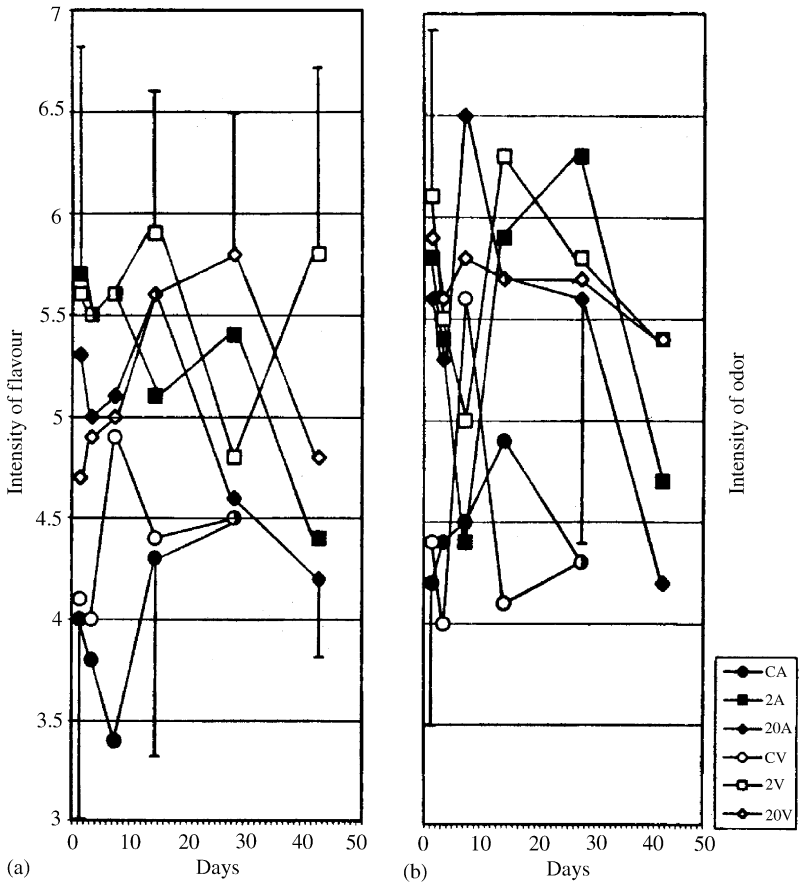

Fig. 2. Sensory evaluation of pork quality: intensity of flavor (A) and intensity of odor (B) during storage at 4°C of controls (CA-CV), pork irradated at 6 kGy, at a dose-rate of 2 kGy/h (2A-2 V) and pork irradiated with 6 kGy at a dose-rate of 20 kGy/h (20A-20 V): cooked air-packaged (black) and vacuum-packaged samples (hollow). Vertical lines represent standard deviation (SD).

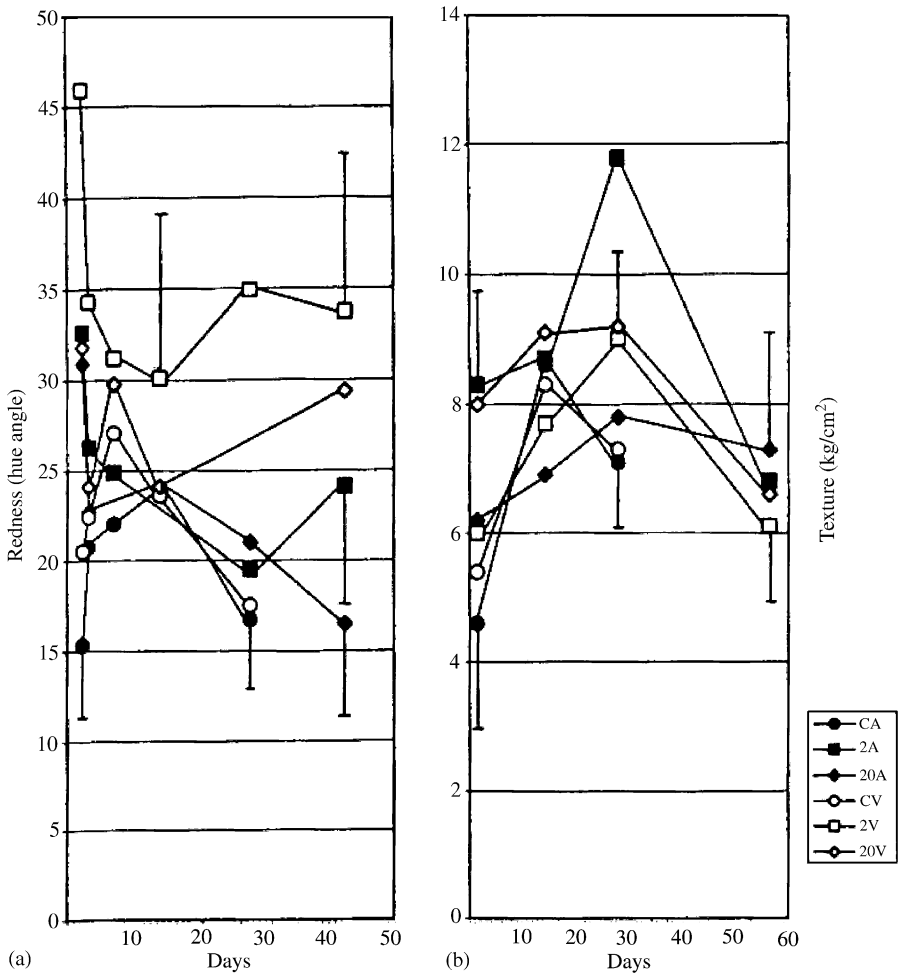

Fig. 3. Intensity of redness (A) and texture (B) of raw pork during storage at 4°C of controls (CA-CV), pork irradiated with 6 kGy at a dose-rate of 2 kGy/h (2A-2 V), and pork irradiated with 6 kGy at a dose-rate of 20 kGy/h (20A-20 V); air-packaged (black) and vacuum-packaged samples (hollow). Vertical lines represent standard deviation (SD).

3.4. Protein analysis

Sulfydryl content was evaluated throughout the storage period.

Total sulfydryls of control pork proteins varied from 108.9 to 122.9M SH/g (mean 121.4 ± 14M SH/g) in air-packaged samples and from 109.9 to 126.9M SH/g (mean 121.3 ± 15M SH/g) in vacuum-packaged samples, showing relative stability in the -SH content throughout the storage period. Thus, the type of packaging little influenced the protein sulfydryls during 43 d storage at 4°C. Total sulfydryls in the irradiated samples varied from 102.6 to 133.7M SH/g (mean 109. 0 ± 12 and 115.9 ± 13M SH/g for air and vacuum packaging, respectively), under the 2 kG/h dose-rate, and from 100.7 to 121.0M SH/g (mean 112.7 ± 16 and 109.4 ± 14M SH/g for air and vacuum packaging, respectively), under the 20 kGy/h dose-rate of irradiation. Thus, no significant changes ($P > 0.05$) were noted for sulfydryl content in all irradiated samples. Similarly, no major changes in total protein disulfides in control and irradiated samples were noted throughout the storage period (data not shown). Therefore, it could be concluded that no major fluctuations in -SH/S–S content occurred throughout the storage period. Overall, relatively little changes in the protein sulfydryls and disulfides were noted, regardless of the dose-rate (2 or 20 kGy/h) of the 6 kGy-irradiation.

4. Conclusion

γ-irradiation increased significantly ($P < 0.05$) the shelf-life of pork samples without affecting their physico-chemical and sensorial quality.

Acknowledgements

This work was supported by the Research Center in Microbiology and Biotechnology and the Canadian Irradiation Center, INRS-Institut Armand-Frappier, Université du Québec. The authors would also like to acknowledge the collaboration of MDS Nordion for irradiation operations.

References

Dogbevi, M.K., Vachon, C., Lacroix, M., 1999. Physico-chemical and microbiological changes in irradiated fresh pork loins. Meat Sci. 51, 349–354.

Lacroix, M.L., Jobin, M., Hamel, S., Stahl, V., Gagnon, M., Couvercelle, C., 1991. Effects of 3 and 7 kGy gamma irradiation doses on odor and flavor of fresh chicken breast. Microbiol. Aliments-Nutr. 9, 375–7379.

Lacroix, M., Gagnon, M., Latreille, B., Probst, C., Simard, C., Boileau, S., 1992. Effects of the dose of irradiation, vacuum packaging and cold storage on porcine proteins. Microbiol. Aliments-Nutr. 10, 253–260.

Lacroix, M.L., Smoragiewicz, W., Pazdernik, L., Kone, M.I., Krzystyniak, K., 1997. Prevention of lipid radiolysis by natural antioxidants from rosemary (*Rosmarinus officinalis* L.) and thyme (*Thymus vulgaris* L.). Food Res. Int. 30, 457–462.

Lambert, A.D., Smith, J.P., Dodds, K.L., Charbonneaux, R., 1992. Microbiological changes and shelf-life of map, irradiated fresh porc. Food Microbiol. 9, 231–244.

Li-Chan, E., 1983. Heat-induced changes in the proteins of whey protein concentrate. J. Food Sci. 48, 47–56.

Snedecor, G.W., Cochran, W.G., 1978. In: Statistical Methods. The Iova State University Press, Ames, IA.

Sudarmadjii, S., Urbain, W.M., 1972. Flavor sensitivity of selected animal protein foods to gamma radiation. J. Food Sci. 37, 671–672.