Research Note

Microbial and Sensory Quality of Marinated and Irradiated Chicken

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ABSTRACT

Chicken legs were subjected to two pretreatments (packaged in air or marinated in natural plant extracts and then packaged in air) followed by irradiation (0, 3, or 5 kGy). The control and irradiated chicken legs were stored at 4°C and underwent microbial analysis (mesophilic aerobic plate counts and Salmonella detection) and sensory evaluation at predetermined intervals. Microbial analysis indicated that irradiation had a significant effect (P ≤ 0.05) on the mesophilic aerobic plate counts of the poultry. For each treatment, the bacterial growth decreased with an increase of irradiation dose. The marinade had an additive effect with irradiation in reducing bacterial growth and controlling proliferation during storage. No Salmonella was observed until day 12 in marinated chicken irradiated at 3 kGy and for all experiments with chicken legs stored under air or marinated at 5 kGy. However, Salmonella was found in chicken legs irradiated at 3 kGy in air and in nonirradiated samples. The sensory evaluation indicated a significant (P ≤ 0.05) difference in odor and flavor intensities between the irradiated chicken at 5 kGy and the control. No significant difference was found (P > 0.05) between the marinated chicken irradiated at 5 kGy and the control.

Irradiation of food up to an overall dose of 10 kGy is accepted in several countries for commercial food processing (23). However, this commercial application can be limited by oxidation of fatty acids and some amino acids, resulting in off-flavor formation in the foodstuff (15). For example, the threshold dose for chicken at which a slight “irradiation flavor” is detected is 2.5 kGy (22). On the other hand, it is known that irradiation with over 2.5 kGy is required for the elimination of pathogenic bacteria, e.g., Salmonella (20). Antioxidant and antimicrobial compounds are of interest to the food industry because they prevent food rancidity and prolong the shelf life of food (10, 16). Many spices, including rosemary, thyme, sage, and Provençal herbs, exhibit antioxidative activities in a variety of biological systems (5, 9, 13, 30). Extracts from plant spices rosemary, thyme, and sage are reported to possess antioxidant properties comparable to or greater than butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) (9, 30). The antioxidant properties of these spices have been attributed to their essential oil fraction and the presence of phenolic compounds (13). Spices also can exhibit antimicrobial activity (7, 12, 24). The most active constituents of spices with wide spectra of antimicrobial effects are thymol and carvacrol of thyme (1, 6). These compounds inhibit a range of food spoilage microbes at much lower concentrations than herb extracts (10). The lemon juice marinade also shows a bacteriostatic effect (27). The principal constituents in lemon juice that bring about the inhibition of microbial growth are organic acids. Among the organic acids, citric acid is inhibitory to Salmonella on poultry carcasses (11). The availability of effective natural antioxidants would ameliorate irradiation processing for the decontamination and elimination of pathogens in meat (29).

The objective of this study was to evaluate the effects of two treatments, marinating in natural plant extracts prior to irradiation and irradiation in air, on the microbiological profile and sensory quality of fresh chicken during storage at 4°C.

MATERIALS AND METHODS

Sample preparation. Fresh, boned chicken legs (432) weighting 150 ± 50 g were purchased at a local grocery store (JGA, Laval, QC, Canada) on the day of slaughter. On the day of arrival, samples were randomly distributed into two groups (216 samples/group) and assigned to one of the two following storage conditions: packed in air (A) or marinated and packed in air (M). Chicken samples were stored at −20°C until used.

Marinating. Lemon juice containing dry thyme (8% wt/vol) and rosemary (8% wt/vol) powders were purchased at a local grocery store (IGA) and used as marinade for group M samples. The chicken legs were brought to a temperature of 4°C, immersed in the marinade (pH 2.76) at a ratio of 12 legs/liter, stored at 4 ± 1°C for 24 h, then removed and dried under a biological hood under sterile conditions.

Packaging. Within each storage condition, chicken legs were placed individually into high-barrier Cryovac BBI bags (8 by 10 in., 50 μm thick; Duncan, S.C.). The O2 and CO2 permeability
values were 20 and 80 cm$^3$ m$^{-2}$ day$^{-1}$ atm$^{-1}$, respectively. Legs from groups A and M were sealed in air in a biological hood under aseptic conditions.

**Irradiation.** The samples were placed in iced Styrofoam boxes (17 by 11 by 6 in.) and loaded in the JS-8900 carrier-type irradiator (MDS Nordion Int., Kanata, ON, Canada) with a $^{60}$Co source. The samples were brought to a temperature of 4 ± 1°C before irradiation. In the first run, 72 packages of each group (A, M) were irradiated at a dose ranging from 2.9 to 3.4 kGy, for a mean dose of 3 kGy. In the second run, 72 packages of each group (A, M) were irradiated at a dose ranging from 4.8 to 5.3 kGy, for a mean dose of 5 kGy. Amber Perspet 3042D (Atomic Energy Research Establishment, Harwell, Oxfordshire, UK) were used to validate the dose distributions throughout the boxes. Immediately after irradiation, the samples were stored at 4 ± 1°C. The unirradiated poultry (72 packages of each group [A, M]) were handled in the same way as the irradiated samples.

**Microbial analysis.** Microbial analysis of aerobic mesophilic bacteria and *Salmonella* spp. was carried out on days 1, 3, 6, 9, 12, and 15 of storage for each sample using procedures described by the American Public Health Association (2). For each analysis, five sample units were randomly selected and evaluated for mesophilic aerobic plate count and presence of *Salmonella*. *Salmonella* Typhimurium ATCC 14028 no. 494L160 (American Type Culture Collection, Rockville, Md.) was used as a positive control.

**Mesophilic aerobic plate counts.** Five individual chicken legs were randomly sampled from each treatment for plate count determination. A 10-g sample from each fresh leg was cut out aseptically with a sterile pastry cutter and histiory, diluted 1:10, and blended for 2 min with 90 ml of sterile peptone water (0.1% wt/vol) with a Waring laboratory blender (model 31BL91; New Hartford, Conn.). Subsequent dilutions were prepared by mixing a 10-ml sample with 90 ml of sterile peptone water. The blender was cleaned with 80% ethanol (vol/vol) before each use to avoid cross-contamination (17). For bacterial counts, volumes of 1 ml of selected dilutions were spread, in duplicate, onto plates containing approximately 12 ml of melted plate count agar (Difco Laboratories, Detroit, Mich.) and incubated for 48 h at 37 ± 1°C. Microbial counts were expressed as the logarithm (base 10) of the number of viable bacterial colonies per gram (log CFU/g). The average CFU value was determined for each experiment.

**Salmonella detection.** *Salmonella* was detected by following the Canadian Government Official method for microbiological analysis of foods (4). Five individual chicken legs were randomly sampled from each treatment for *Salmonella* determination. A 25-g sample from each fresh leg was mixed with 225 ml of pre-enrichment broth (Lauryl tryptose broth; Difco) and incubated at 35 ± 1°C for 24 h. One milliliter of each preenrichment medium was transferred to 9-ml tubes of two different selective broths, selenite-cystine broth and tetrathionate broth (Difco), and incubated for 24 h at 37 ± 1°C and 43 ± 1°C, respectively, in a warm water bath. A loopful of each selective enrichment broth was streaked to bismuth sulfite and brilliant green sulpha agars (Difco) and incubated at 35 ± 1°C for 24 h to obtain isolated colonies. Presumptive colonies were purified on MacConkey agar and confirmed by biochemical tests (lactose, saccharose, and dextrose) with triple sugar iron agar and lysine iron agar (Difco).

**Sensory evaluation.** Thirty panelists from the INRS-Institut Armand Frappier (Laval, Québec, Canada) who evaluated the sensory attributes of the cooked chicken had previously participated in training sessions to become familiar with the sensory characteristics of cooked chicken. Panelists were trained for a period of 3 months in 1-h sessions three times a week (36 h total). Triangle tests were performed for each session (13 h total) in order to select 10 panelists who could detect off-flavors in chicken irradiated at 7, 5, or 3 kGy. Prior to sample evaluation, the 10 selected panelists participated in 23 h of orientation sessions to learn to select, recognize, and scale attributes of chicken using references and an intensity scale. The panel agreed on and defined all attributes considered necessary for evaluation of the irradiated chicken. Panelists were asked to evaluate color, flavor, and odor intensities and muscle fiber integrity (mushiness) of the samples by making a vertical line across the instruction scale to reflect their judgment. The instruction scale is composed of an 15-cm-long horizontal line anchored with a term at each end containing gradations every 1.5 cm (26). For each attribute, the distance from the left endpoint to the point marked by the panelist was measured in centimeters with a ruler, and the numerical score was recorded. The terms from the left end to the right end were, respectively, none to strong (odor intensity), pale yellow to dark yellow (color intensity), no off-flavors to intense off-flavors (flavor intensity), and tough to tender (muscle fiber integrity).

The day after irradiation at 5 kGy, 40 fresh, boned chicken legs (20 packed in air and 20 marinated and packed in air) were roasted in a conventional oven at 190°C until the internal temperature reached 82 to 85°C. After cooking, roasted chicken legs were covered with aluminum foil and held in an oven at 77°C until served to the panelists on white polyfoam plates. Each pair of chicken samples (control versus irradiated) was evaluated for samples packed in air and packed in air after marinating. Each sample pair was tested on different days. Samples were presented in a random sequence to panelists and were served with the skin. The serving size was a whole, boned chicken leg. Evaluations were conducted in an air-conditioned sensory evaluation laboratory in individual partitioned booths. The samples were prepared in the kitchen adjacent to the sensory laboratory and were identified by a three-digit code number. Panelists were instructed to evaluate color first and odor second before removing the skin from the leg. They then removed a strip of meat from a specific part of the leg and cut it into cubes; these cubes were used for flavor and muscle fiber integrity evaluation. Water and unsalted crackers were provided for cleaning the palate between samples.

**Statistical analysis.** Data from microbial analysis were subjected to an analysis of storage conditions (air or marinade), irradiation doses (0, 3, and 5 kGy), and storage times (1, 3, 6, 9, 12, and 15 days) by simple and interaction effects using a statistical package (Stat-Packets 1987, Walonik Associates, Minneapolis, Minn.). Comparison of means were based on Duncan’s multiple range test. Multiple regression tests were also performed for the prediction of aerobic plate counts on irradiated samples. Results from sensory evaluation were analyzed using the Student’s *t* test for paired samples between controls and treated samples. The overall experiment was replicated three times.

**RESULTS AND DISCUSSION**

**Total aerobic plate counts.** According to the analysis of variance, the marinating pretreatment significantly (*P* ≤ 0.05) affected bacterial growth on fresh chicken legs. The first day, treatment means of total counts were 6.36 log CFU/g in nonirradiated marinated samples compared to 7.86 log CFU/g in nonirradiated air-packed samples (Table 1). For each pretreatment (air and marinade), the number of aerobic plate counts decreased with increase of irradiation...
tion dose (Table 1). Moreover, the aerobic plate count in samples irradiated at 5 kGy increased with storage time, as shown by data presented in Table 2. In marinated chicken, the increase in microbial load was slowest during the first 6 days of storage. On the ninth day of storage, the microbial load on both treatments was high and comparable. The limit of microbiological acceptability was assumed to be 6 logCFU/g.

**TABLE 2. Treatment means showing the effects of storage time on total aerobic plate counts on irradiated poultry (5kGy)**

<table>
<thead>
<tr>
<th>Days of storage</th>
<th>Microbial count (log CFU/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Air</td>
</tr>
<tr>
<td>1</td>
<td>2.53 A</td>
</tr>
<tr>
<td>3</td>
<td>3.48 A</td>
</tr>
<tr>
<td>6</td>
<td>4.36 A</td>
</tr>
<tr>
<td>9</td>
<td>6.64 B</td>
</tr>
<tr>
<td>15</td>
<td>7.97 B</td>
</tr>
</tbody>
</table>

*Means in a column bearing the same letter are not significantly different (P > 0.05), n = 15.*

The authors are grateful to MDS Nordion International Inc. for the irradiation operations. This research was supported by INRS-Institut Ar-

**Sensory evaluation.** Panelist scores for odor, flavor, and color intensity and for muscle fiber integrity were neutral for both the control and irradiated samples (Table 3). For chicken legs irradiated in air, scores for odor intensity (7.8) and flavor intensity (8.7) were significantly (P ≤ 0.05) higher than for controls (6.1 for odor intensity and 6.9 for flavor intensity), but there was no significant difference (P > 0.05) between the scores for color intensity and muscle fiber integrity (Table 3). In the case of marinated chicken, no significant difference (P > 0.05) was found between the control and the irradiated samples for all characteristics evaluated. In general, at a dose of 5 kGy, the initial changes in the odor and taste observed in the product disappear during storage and roasting (19). In this study, these changes were perceived only in samples irradiated in air.

Irradiation of poultry at 5 kGy is highly effective in eliminating *Salmonella* and other spoilage microorganisms and in ensuring safety and quality. Moreover, the marinate treatment before irradiation is highly effective, has an additive effect with irradiation to reduce the microorganism load, and controls the proliferation of microorganisms during storage. The essential oils in rosemary and thyme and the organic acids in lemon juice are practical antimicrobial agents and prevent the deterioration of stored foods by bacteria.

**ACKNOWLEDGMENTS**

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TABLE 3. Sensory means for control and irradiated (5 kGy) chicken packaged in air and marinated

<table>
<thead>
<tr>
<th>Pretreatment</th>
<th>Color intensity</th>
<th>Odor intensity</th>
<th>Flavor intensity</th>
<th>Muscle fiber integrity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>6.1 ± 2.9 A</td>
<td>6.1 ± 2.3 A</td>
<td>6.9 ± 2.1 A</td>
<td>6.2 ± 2.9 A</td>
</tr>
<tr>
<td>Irradiated (5 kGy)</td>
<td>6.1 ± 2.8 A</td>
<td>7.8 ± 1.4 B</td>
<td>8.7 ± 1.8 B</td>
<td>7.7 ± 2.1 A</td>
</tr>
<tr>
<td>Marinade</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>7.8 ± 2.1 A</td>
<td>8.5 ± 2.7 A</td>
<td>8.9 ± 1.6 A</td>
<td>8.9 ± 1.4 A</td>
</tr>
<tr>
<td>Irradiated (5 kGy)</td>
<td>7.7 ± 2.3 A</td>
<td>8.1 ± 2.1 A</td>
<td>8.2 ± 2.1 A</td>
<td>8.1 ± 2.7 A</td>
</tr>
</tbody>
</table>

Means between two samples (control versus 5 kGy) in each group (air and marinated) bearing the same letter are not significantly different (P > 0.05). Panelists (n = 10) evaluated the samples using a 15-cm line scale.

Sensory means for control and irradiated (5 kGy) chicken packaged in air and marinated.

**REFERENCES**


