Comparative effect of steaming and irradiation on the quality of dried red pepper

(Capsicum annuum L.)

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ABSTRACT

The comparative effects of steaming and gamma irradiation on the microbiological and physicochemical properties of dried red pepper were evaluated during post-treatment storage. The dried red peppers were steamed under the commercial conditions, hot air-dried, and processed into powder. The dried peppers were also powderized, packed in PE bottles, and subjected to irradiation at 0 and 10 kGy. All the packaged samples used were stored at refrigerated (4±2°C) and room (20±2°C) (RT) temperatures for 6 months. Irradiation resulted in a 5-log reduction from the initial microbial load with minimal effects on the physicochemical properties (moisture content, pH, extractable yield, reducing sugar, soluble pigment, DPPH radical-scavenging activity, capsanthin, capsaicin, Hunter’s color, and sensory attributes) of pepper, whereas steaming led to 1- to 2-log reduction only accompanied with the darkening of the spice as indicated by low Hunter’s color L-, a-, and b-values and a decrease in the capsaicin content in RT-stored samples. Irradiation is a better disinfection method than steam treatment as it eliminates microorganisms while maintaining the physicochemical quality of the dried red peppers.

Keywords: red pepper, steaming, irradiation, quality
1. Introduction

Known for its characteristic flavor and pungency, red pepper is cultivated worldwide and consumed fresh or in dried powdered form as a food ingredient. This pungent spice is primarily used to impart bright red color and enhance the flavor of many processed foods. Since red pepper powders are of agricultural origin, they are often contaminated with high levels of molds, yeasts, and bacteria (Banerjee and Sarkar, 2003; Buckenhuskes and Rendlen, 2004; Oularbi and Mansouri, 1996), which then results in a rapid spoilage of the foods they are supposed to enhance. Furthermore, presence of pathogenic bacteria like \textit{Clostridium perfringens}, \textit{Staphylococcus aureus}, and \textit{Bacillus cereus}, and high levels of aflatoxin B$_1$ were found in powdered red pepper (Aydin et al., 2007; Banerjee and Sarkar, 2003; Buckenhuskes and Rendlen, 2004). Contaminated spices can result in a serious foodborne illness when they are added to foods that do not undergo further cooking such as processed meat.

Superheated steam treatment was reported to reduce the number of microorganisms in paprika (Almela et al., 2002). While steam-treated pepper is readily accepted by consumers as it does not involve the use of chemicals, the application of high-temperature steam is associated with color degradation, a decrease in volatile oil content, and an increase in moisture content of the spices which leads to a decreased shelf-life (Almela et al., 2002; Lilie et al., 2007). Irradiation of dried spices is also widely recognized and is now legally accepted in at least 51 countries with a maximum overall average of 10 kGy (IAEA, 2007). In some countries, such as Australia and USA, up to 30-kGy dose is permitted. However, irradiation at 10 kGy was found to be effective in destroying bacteria and molds without affecting the quality attributes of different spices (Farag et al., 1995; Munasiri et al., 1987; Onyenekwe and Ogbadu,
1995; Sharma et al., 1989). Therefore, this study was conducted to compare and evaluate the effects of steam treatment and ionizing radiation on the physicochemical properties and microbiological quality of powdered red pepper. The effect of storage time and temperature on the quality of spice was also assessed.

2. Experimental

2.1. Sample preparation, treatment, and storage

Whole dried red peppers were divided into 3 lots (~1 kg each). One lot was steamed under the commercial conditions of a batch type at 1020 mbar and about 100°C for 16 min using a steam sterilizer (DEBAC, Bucher, France). The steamed peppers were processed into powder form using a sterile Waring blender (Dynamic Corp. of America, New Hartford, CT). The second lot was also powderized, packed in polyethylene bottles and irradiated at 10 kGy using a Co-60 gamma irradiator (KAERI, Cheongeup, Korea). The absorbed dose was verified with a ceric/cerous dosimeter (Bruker Instruments, Rheinstetten, Germany). The third lot, which served as control, was powderized and packed in polyethylene bottles. All samples were stored at 4°C and analyzed for physicochemical and microbiological qualities. Samples from each lot were subdivided into two. The first half was kept refrigerated at 4°C and the other half was kept at 20°C. All analyses were repeated after 6 months of storage.

2.2. Analysis of chemical properties

The moisture content of steamed or irradiated red pepper powder (1 g each) was determined using an Infrared Moisture Determination Balance (FD-240, Japan). Pepper extracts were prepared by mixing 2 g powder sample with 80 ml distilled water in a
shaker-incubator for 3 hr at 200 rpm. The mixture was centrifuged and the supernatant was filtered (Whatman No. 41). The pH of the extract was obtained using a pH meter (Thermo Scientific Orion Star Series, USA). The extractable yield content was determined by placing a 2-ml sample extract in an aluminum disk having a pre-determined constant weight and dried in an oven at 105°C until a constant weight was obtained. The total reducing sugar contents of the powder samples were determined using the modified Somogyi method (Kobayashi and Tabuchi, 1954). Analysis of the total soluble pigment was done by measuring the absorbance of the pepper extract at 420 nm using a UV-vis spectrophotometer (Optizen 2120UV, Korea).

2.3. Analysis of functional components

The 1,1-diphenyl-2-picrylhydrazyl (DPPH) scavenging activity of pepper was determined according to the method of Blois (1958). The capsanthin content was analyzed by measuring the absorbance of the acetone extract of the sample at 460 nm. The capsaicin content of red pepper powder was determined based from the AOAC method (2000).

2.4. Determination of Hunter’s color values

The Hunter’s color L- (lightness), a- (redness), and b- (yellowness) values were determined using a Colorimeter (Minolta CR-200, Japan). Powdered samples were spread in a piece of paper and measurements were taken at 3 random locations. A numerical total color difference (ΔE) was calculated from the Hunter values obtained.

2.5. Sensory evaluation

The peppers were evaluated for color, odor, pungent taste, and overall acceptability
by 15 sensory panels. The panelists were instructed to record their ratings using a 5-
point hedonic scale (5 = like extremely; 1 = dislike extremely for color, odor, and
overall acceptability, and 5 = extremely strong; 1 = extremely weak for pungent taste)
(Larmond, 1970).

2.6. Microbiological analysis

All samples were analyzed for the total aerobic bacteria, yeasts and molds, and
coliforms. Five grams of the pepper powder were mixed with 45 ml sterile peptone
water. Subsequent dilutions were prepared and plated on Plate Count Agar for the total
aerobic bacteria, Potato Dextrose Agar (acidified with 10% tartaric acid) for yeasts and
molds, and Desoxycholate Agar for coliforms. Microbial counting was performed 24-48
hr after incubation at 30°C and 37°C for total aerobic bacteria and coliforms,
respectively. Yeast and mold colonies were counted 3 days after incubation at 30°C.

2.7. Statistical analysis

Results from the measurements (n=3) were analyzed statistically using the
Statistical Analysis System for Windows V8. Analysis of Variance and Duncan’s
Multiple Range Test were employed.

3. Results and discussion

3.1. Chemical properties

Steam-treated pepper exhibited slightly higher moisture content than that of the
control and irradiated ones (Table 1). Application of high-temperature steam to whole
spices results in a condensation of moisture on the surface of the particles which if not
properly air-dried and rapidly cooled could lead in an increased moisture content of the spice powder (Schweiggert et al., 2007). After 6 months of storage, all moisture contents decreased in both control and treated peppers. Steam and irradiation treatments did not significantly affect the pH of the samples but the values slightly decreased after storage. The extractable yield, on the other hand, increased considerably in all samples after storage. This is probably due to the increase of dry matter content during storage of the spice. A slight, but significant decrease in the reducing sugar was observed in both steamed and irradiated pepper which further decreased after storage. Earlier studies conducted by Kwon et al. (1984) also revealed a decrease in the reducing sugar content of irradiated and non-irradiated red pepper during storage. Steam treatment resulted in an increased total soluble pigment content in the pepper. This increase in the absorbance of the pepper extract is may be due to the darkening of the spice as a result of the steaming process.

3.2. Functional components

Steamed red pepper exhibited high DPPH radical-scavenging activity even after 6 months of storage (Table 2). According to Suresh et al. (2007), chemical alteration could occur to the components in pepper during heat treatment which then results in an increased extractability of some compounds in the spice. The antioxidant activity increased in all samples after storage regardless of the storage temperature. Similarly, Suhaj et al. (2006) and Waje et al. (2008) observed an increase in the DPPH radical-scavenging activity of irradiated and non-irradiated black pepper after 5 and 6 months of storage which was attributed to the increased dry matter content of the spice. The capsanthin content was lowest in irradiated red pepper even after storage at refrigerated or room temperature. Kwon et al. (1984) also found that capsanthin content of red
pepper powder decreased with irradiation treatment. The capsaicin content, on the other
hand, was not affected by both steam and irradiation treatments but slightly decreased
after storage. The functional components analyzed in this study exhibited lower
amounts in samples stored at room temperature than those stored at refrigerated
conditions indicating the importance of keeping red pepper powder in low temperature.

3.3. Hunter’s color values

Color degradation was greater in steamed red pepper than in irradiated samples as
indicated by lower L-, a-, and b-values in steamed ones (Table 3). The steamed pepper
became darker and its degree of redness and yellowness was less intense. The color
values increased slightly after storage in refrigerated conditions, but further decreased
in samples stored at room temperature. The L- and b-values of irradiated pepper slightly
increased after storage but the a- and b-values were lower in samples stored at room
temperature compared to those at refrigerated conditions. Color of the untreated
samples did not significantly change during storage but the b-value was relatively lower
in samples under room temperature. These findings demonstrated that red pepper
powders must be stored under refrigerated conditions to minimize the color degradation
as a result of thermal and irradiation treatments. In studying the effect of thermal
treatment on the color properties of paprika, Almela et al. (2002) noted that high-
temperature promotes color degradation as the paprika became darker and the
intensities of reddish and yellowish hues became lesser. However, the degradation was
less pronounced in paprika stored under refrigerated conditions. Waje et al. (2008) also
reported that steam treatment of black pepper resulted in the darkening of the spice.
With regards to irradiated pepper, Kim et al. (2005) found that the Hunter’s lightness,
redness, and yellowness of dried pepper decreased after irradiation. They also observed
that the storage period was more influential than irradiation treatment in the color
changes of red pepper powder. In this study, the overall changes in color (ΔE, NBS) of
red pepper revealed that storage at room temperature had a greater effect than steam or
irradiation treatment on the color changes of the spice. Nevertheless, all samples
exhibited trace (0.03-0.33) to slight (0.84-1.05) color difference only.

3.4. Sensory attributes

Results of the sensory evaluation of red pepper powder showed a lower color score
for steamed red pepper than the control and irradiated ones (Table 4) indicating that the
panelists had a lower likeness for the darker pepper. The color score further decreased
when the steamed pepper was stored at room temperature. The odor was slightly
affected by irradiation but the difference in sensory scores among treatments
disappeared after storage. Such a difference in odor may be due to the disappearance of
some volatiles in the pepper after irradiation and prolonged storage (Lee et al., 2004).
The pungent taste was not affected by either steam or irradiation treatment. Higher
overall acceptability was observed for untreated samples compared to steamed or
irradiated ones. Storage time had no effect on the sensory properties of red pepper.

3.5. Microbiological quality

The untreated red pepper contained relatively high aerobic bacteria (10^6 CFU/g)
(Table 5) but treatment with irradiation reduced the population by 5 logs. Similarly, a
dose of 10 kGy reduced the total aerobic bacteria by 4-5 logs in powdered hot pepper
(Farag et al., 1995), red chili pepper (Munasiri et al., 1987), and ground black pepper
(Waje et al, 2008). Steam treatment slightly decreased (1 log) the total plate count in
peppers. These results illustrate that irradiation is a better disinfection method than
steam treatment in spice powders. A 2-log reduction in the yeasts and molds was observed in steamed and irradiated peppers while coliforms were not detected in both samples. No considerable changes on the population of aerobic bacteria were observed after storage at refrigerated temperature but the count slightly increased (1 log) in irradiated samples stored at room temperature. On the other hand, the yeast and mold counts decreased to non-detectable level in both treated peppers after storage. The coliform count slightly increased in steamed red pepper stored at room temperature. Storage under refrigerated conditions further enhanced the microbial quality of treated powdered pepper since the injured microbial cells, as a result of steaming and irradiation, were unable to repair and proliferate over time.

4. Conclusions

This study demonstrated that irradiation is a better decontamination method than steam treatment in disinfecting the powdered red peppers. Furthermore, application of high temperature during steaming could cause a significant loss of color in the spice. Gamma irradiation at 10 kGy is sufficient to eliminate microorganisms while preserving the physicochemical quality of spice. To improve the microbiological quality and minimize the color degradation and changes in the levels of functional components, powdered red peppers must be kept in refrigerated conditions.

References


Suresh, D., Manjunatha, H., Srinivasan, K., 2007. Effect of heat processing of spices on the concentrations of their bioactive principles: turmeric (Curcuma longa), red pepper (Capsicum annum) and black pepper (Piper nigrum). J. Food Compos. Anal. 20, 346-351.

Table 1

Chemical properties$^a$ of steamed and irradiated red pepper powder stored at 4° and 20°C for 6 months

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Month</th>
<th>Refrigerated temperature (4°C)</th>
<th>Room temperature (20°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>Steamed</td>
</tr>
<tr>
<td>Moisture content (%)</td>
<td>0</td>
<td>10.00 ± 0.13 bx</td>
<td>10.56 ± 0.05 ax</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>9.88 ± 0.34 ax</td>
<td>9.56 ± 0.24 ay</td>
</tr>
<tr>
<td>pH</td>
<td>0</td>
<td>5.22 ± 0.06 ax</td>
<td>5.18 ± 0.02 ax</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>5.05 ± 0.02 ay</td>
<td>4.98 ± 0.01 bcy</td>
</tr>
<tr>
<td>Yield (%)</td>
<td>0</td>
<td>0.62 ± 0.01 by</td>
<td>0.66 ± 0.01ay</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>0.92 ± 0.09 bx</td>
<td>0.97 ± 0.01 abx</td>
</tr>
<tr>
<td>Total reducing sugar (%) d.b.</td>
<td>0</td>
<td>13.76 ± 0.18 ax</td>
<td>13.17 ± 0.06 bx</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>11.69 ± 0.37 ay</td>
<td>11.29 ± 0.12 by</td>
</tr>
<tr>
<td>Total soluble pigment (O.D. 420 nm)</td>
<td>0</td>
<td>0.23 ± 0.00 by</td>
<td>0.32 ± 0.00 ay</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>0.56 ± 0.05 dx</td>
<td>0.80 ± 0.02 bx</td>
</tr>
</tbody>
</table>

$^a$ Mean of three replications ± standard deviation. Values followed by the same letters within the row (a-e) and within the column per parameter (x-y) are not significantly different ($p<0.05$).
Table 2

Functional components\(^a\) of steamed and irradiated red pepper powder stored at 4° and 20°C for 6 months

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Month</th>
<th>Refrigerated temperature (4°C)</th>
<th>Room temperature (20°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>Steamed</td>
</tr>
<tr>
<td>Electron-donating ability (% d.b.)</td>
<td>0</td>
<td>57.72 ± 0.83 by</td>
<td>73.63 ± 1.01 ay</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>76.92 ± 0.47 dx</td>
<td>90.42 ± 0.67 ax</td>
</tr>
<tr>
<td>Capsanthin (O.D. 460 nm)</td>
<td>0</td>
<td>0.47 ± 0.00 ax</td>
<td>0.46 ± 0.00 bx</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>0.41 ± 0.01 ay</td>
<td>0.38 ± 0.02 by</td>
</tr>
<tr>
<td>Capsaicin (mg/g d.b.)</td>
<td>0</td>
<td>0.56 ± 0.00 ax</td>
<td>0.56 ± 0.01 ax</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>0.52 ± 0.00 ay</td>
<td>0.52 ± 0.01 ay</td>
</tr>
</tbody>
</table>

\(^a\) Mean of three replications ± standard deviation. Values followed by the same letters within the row (a-e) and within the column per parameter (x-y) are not significantly different (\(p<0.05\)).
Table 3

Hunter’s color values\(^a\) of steamed and irradiated red pepper powder stored at 4\(^\circ\) and 20\(^\circ\)C for 6 months

<table>
<thead>
<tr>
<th>Hunter’s parameter(^b)</th>
<th>Month</th>
<th>Refrigerated temperature (4(^\circ)C)</th>
<th>Room temperature (20(^\circ)C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>Steamed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>0</td>
<td>50.85 ± 0.32 ax</td>
<td>48.17 ± 0.13 cy</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>50.91 ± 0.19 ax</td>
<td>49.25 ± 0.15 bx</td>
</tr>
<tr>
<td>a</td>
<td>0</td>
<td>21.53 ± 0.29 ax</td>
<td>19.54 ± 0.09 cy</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>21.88 ± 0.30 ax</td>
<td>19.93 ± 0.11 cx</td>
</tr>
<tr>
<td>b</td>
<td>0</td>
<td>25.03 ± 0.54 ax</td>
<td>21.50 ± 0.23 by</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>25.27 ± 0.39 bx</td>
<td>22.99 ± 0.40 cx</td>
</tr>
<tr>
<td>(\Delta E)</td>
<td>0</td>
<td>0.00</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>0.19</td>
<td>0.03</td>
</tr>
</tbody>
</table>

\(^a\) Mean of three replications ± standard deviation. Values followed by the same letters within the row (a-e) and within the column per parameter (x-y) are not significantly different (\(p<0.05\)).

\(^b\) Hunter’s parameters: L, degree of whiteness (white +100→0 black); a, degree of redness (red +100→-80 green); b, degree of yellowness (yellow +70→-80 blue); and \(\Delta E\): overall color difference \((\sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2})\)
Table 4

Sensory properties\(^a\) of steamed and irradiated red pepper powder stored at 4\(^\circ\) and 20\(^\circ\)C for 6 months

<table>
<thead>
<tr>
<th>Sensory parameter</th>
<th>Month</th>
<th>Refrigerated temperature (4(^\circ)C)</th>
<th>Room temperature (20(^\circ)C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>Steamed</td>
</tr>
<tr>
<td>Color</td>
<td>0</td>
<td>3.9 ay</td>
<td>3.2 bx</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>4.5 ax</td>
<td>3.2 cx</td>
</tr>
<tr>
<td>Odor</td>
<td>0</td>
<td>3.6 ax</td>
<td>3.7 ax</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>3.3 abx</td>
<td>3.3 abx</td>
</tr>
<tr>
<td>Pungent taste</td>
<td>0</td>
<td>3.2 ax</td>
<td>3.0 ax</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>3.4 ax</td>
<td>3.0 ax</td>
</tr>
<tr>
<td>Overall acceptability</td>
<td>0</td>
<td>3.8 ax</td>
<td>3.4 abx</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>4.2 ax</td>
<td>3.1 bcx</td>
</tr>
</tbody>
</table>

\(^a\)Sensory evaluation was conducted by 15 panelists using a 5-point hedonic scale (5 = like extremely; 1 = dislike extremely for color, odor and overall acceptability; and 5 = extremely strong; 1 = extremely weak for pungent taste). Means followed by the same letters within the row (a-c) and within the column per parameter (x-y) are not significantly different (\(p<0.05\)).
Microbial count (CFU/g)\(^a\) of steamed and irradiated red pepper powder stored at 4\(^{\circ}\) and 20\(^{\circ}\)C during 6 months

<table>
<thead>
<tr>
<th>Microorganism</th>
<th>Month</th>
<th>Refrigerated temperature (4(^{\circ})C)</th>
<th>Room temperature (20(^{\circ})C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>Steamed</td>
</tr>
<tr>
<td>Total plate</td>
<td>0</td>
<td>2.1 x 10(^6)</td>
<td>1.1 x 10(^3)</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>1.5 x 10(^6)</td>
<td>1.4 x 10(^3)</td>
</tr>
<tr>
<td>Yeasts and molds</td>
<td>0</td>
<td>4.6 x 10(^3)</td>
<td>1.0 x 10(^1)</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>1.2 x 10(^1)</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Coliforms</td>
<td>0</td>
<td>6.1 x 10(^1)</td>
<td>&lt;10</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>&lt;10</td>
<td>&lt;10</td>
</tr>
</tbody>
</table>

\(^a\)Mean of three replications.