Oscillatory High Pressure Processing Applied to Mechanically Recovered Poultry Meat for Bacterial Inactivation

J. YUSTE, R. PLA, M. CAPELLAS, E. SENDRA, E. BELTRAN, AND M. MOR-MUR

ABSTRACT: The effect of oscillatory high pressure processing on mesophile and psychrotroph populations of mechanically recovered poultry meat (MRPM) was evaluated. Vacuum-packaged samples were subjected to cycles by alternating moderate pressure (60 MPa) and high pressure (450 MPa) at 20 °C, once or several times so that the total time under high pressure was 15 min. A continuous treatment at 450 MPa for 15 min at 20 °C was also performed. Oscillatory treatments did not generate significantly higher decreases in counts of both populations than continuous pressurization. Reductions from 3.2 to 3.8 log CFU g⁻¹ were found for mesophiles. Psychrotrophs proved more sensitive: one of the cyclic treatments induced a lethality of 5.2 log CFU g⁻¹. Pressurization improves the microbiological quality of MRPM.

Key Words: high-pressure processing, oscillatory pressurization, mechanically recovered poultry meat, mesophiles, psychrotrophs

Introduction

MICROBIAL INACTIVATION IS AN IMPORTANT EFFECT OF HIGH pressure processing, with bacterial spores being the most pressure-resistant microorganisms. Vegetative bacterial cells are inactivated at 400 to 600 MPa, whereas spores of some species survive pressures above 1,000 MPa, at least at refrigeration or at room temperatures (Cheftel 1992; Sojka and Ludwig 1994; Gould 1995). Carlez and others (1994) and O’Brien and Marshall (1996) investigated the effect of pressure on indigenous mesophile microbiota of minced beef meat and chicken, respectively, and found considerable decrease in counts and extension of shelf-life. In a previous study (Yuste and others 2000b), the authors observed better microbiological quality in pressurized cooked sausages compared with heat-treated cooked sausages. Shige-hisa and others (1991) and Patterson and others (1995) reported the effectiveness of high pressure against many important foodborne pathogens.

Pressure treatment causes spore germination under relatively mild conditions (Hölters and others 1997). Thus, a mechanism to minimize spore survival is the application of oscillatory pressurization (i.e., various cycles of pressure) by alternating moderate pressure (50-250 MPa), to induce germination, and high pressure (from 400 MPa), to inactivate the germinated forms, once or several times (Sale and others 1970; Sojka and Ludwig 1994; Wuytack and others 1997). Another oscillatory pressurization mechanism is applying a series of high pressure cycles (with no previous moderate pressure cycles), which inactivates bacterial spores directly (Hayakawa and others 1994). Few studies dealing with cyclic treatment effect on vegetative bacterial cells have been done. Again, oscillatory pressurization (only involving high pressure) was found more effective than continuous pressurization (Yuste and others 1998; Ponce and others 1998, 1999; Capellas and others 2000).

Mechanically recovered poultry meat (MRPM) is very perishable because usually presents high microbial load. The main reasons for such contamination are poor hygienic measures (environment, handlers and equipment) and improper holding temperature during all phases of production, storage and subsequent use as an ingredient in food products. Several aspects of the mechanical recovery process (release of intracellular fluids that are very rich in nutrients, incorporation of air and rise in temperature), the small particle size (ca. 500 μm) and so the large surface, and the low acidity of MRPM favor microbial development (Froning 1981; Field 1988).

In this work, oscillatory pressurization (involving moderate and high pressures) at room temperature was applied to reduce the microbial load of MRPM. The objective was to evaluate the lethal effect of such treatment on mesophile and psychrotroph populations of MRPM.

Materials and Methods

Sample and physicochemical analyses

Mechanically recovered poultry meat, provided by an industrial company, was manufactured from meat remaining on carcasses and left-overs originated in poultry processing and kept frozen until use. The AOAC official methods of analysis (McNeal 1990) were applied to determine composition. Potentiometric measurements of pH were done with a penetration pH-meter combination electrode (CRISON, Alella, Spain). Samples of ca. 30 g were vacuum-packaged and kept under refrigeration for 24 h at 2 °C until use. Throughout the sample preparation, rigorous hygiene measures were applied to prevent any further microbial contamination.

High pressure treatment

The equipment used was a discontinuous isostatic press (ALSTOM, Nantes, France), schematically illustrated in Figure 1. The time needed to achieve the treatment pressure was 15 s for 60 MPa and 90 s for 450 MPa, and the decompression time was ca. 30 s. The pressure chamber and the
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Table 1—Continuous (CP) and oscillatory (OP) pressure treatments at 20 °C applied to mechanically recovered poultry meat

<table>
<thead>
<tr>
<th>CP</th>
<th>450 MPa/15 min</th>
</tr>
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<tbody>
<tr>
<td>OP1</td>
<td>60 MPa/30 min + 450 MPa/15 min</td>
</tr>
<tr>
<td>OP2</td>
<td>60 MPa/60 min + 450 MPa/15 min</td>
</tr>
<tr>
<td>OP3</td>
<td>60 MPa/30 min + 450 MPa/10 min + 60 MPa/30 min + 450 MPa/5 min</td>
</tr>
<tr>
<td>OP4</td>
<td>60 MPa/90 min + 450 MPa/15 min</td>
</tr>
<tr>
<td>OP5</td>
<td>(60 MPa/30 min + 450 MPa/5 min) × 3</td>
</tr>
<tr>
<td>OP6</td>
<td>60 MPa/120 min + 450 MPa/15 min</td>
</tr>
</tbody>
</table>

Table 2—Proximate composition and pH of mechanically recovered poultry meat

<table>
<thead>
<tr>
<th></th>
<th>Mean ± st. dev.</th>
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<tbody>
<tr>
<td>% Total solids</td>
<td>30.38 ± 0.332</td>
</tr>
<tr>
<td>% Fat</td>
<td>14.78 ± 0.247</td>
</tr>
<tr>
<td>% Total nitrogen</td>
<td>2.38 ± 0.020</td>
</tr>
<tr>
<td>% Ash</td>
<td>0.97 ± 0.028</td>
</tr>
<tr>
<td>pH</td>
<td>6.51 ± 0.007</td>
</tr>
</tbody>
</table>

Microbiological analysis

Microbiological analysis was done the day after pressurization. Twenty-five grams of nonpressurized and pressurized MRPM were homogenized in 225 mL of peptone water for 1.5 min in an electromechanical blender, and decimal dilutions were also prepared with peptone water. Plate count agar was used to enumerate aerobic mesophilic and psychrotrophic bacteria; plates were incubated at 30 °C for 72 h and at 7 °C for 10 days, respectively. Media were purchased from Oxoid (Basingstoke, U.K.).

Statistical analysis

Continuous and oscillatory treatments were performed twice. For each treatment, the sample was plated in duplicate both for mesophiles and for psychrotrophs. Counts were subjected to analysis of variance of the General Linear Models procedure of SAS software (the SAS System for Windows™, release 6.12, SAS Institute, Cary, N.C.) to determine if there were significant differences (p < 0.05) among pressure treatments.

Results and Discussion

Proximate composition and pH of MRPM are shown in Table 2. Initial mesophile and psychrotroph counts were almost 8 log CFU g⁻¹. All the pressure treatments assayed significantly decreased counts of both populations. Reductions from 3.2 to 3.8 log CFU g⁻¹ were found for mesophiles (Table 3). There was no significant difference in counts among treatments. Continuous pressurization induced a lethality of 3.7 log CFU g⁻¹. The maximum decrease in counts was obtained with OP3. O’Brien and others (1996) observed a similar lethality in ground chicken treated at 616 MPa for 10 min at room temperature. Carlez and others (1994) inactivated ca. 6 log CFU g⁻¹ by pressurizing minced beef meat at 450 MPa for 20 min at 20 °C.

Psychrotrophs proved more sensitive. Reductions between 3.6 and 5.2 log CFU g⁻¹ were achieved (Table 3). Continuous pressurization, OP3 and OP4 caused significantly higher lethalitys (4.7, 5.2 and 4.6 log CFU g⁻¹, respectively) than the rest of oscillatory treatments. Higher lethality of psychrotrophs and, as a result of this, greater variability were found in previous studies (Yuste and others 1998, 2000a,b). The same occurred in the current work. This is probably the reason why certain treatments were more effective, but with results not following a regular pattern.

In previous studies (Yuste and others 1998, 2000a), the authors treated MRPM at 450 MPa for 15 min (three 5-min cycle and continuous pressurizations). Lethalities of mesophiles and psychrotrophs were, respectively, 2.3 and 5 log CFU g⁻¹ for oscillatory pressurization at 2 °C, and ca. 4 CFU g⁻¹ for continuous pressurization at 20 °C. As spoilage microbiota of MRPM is partly composed of spore-forming bacteria, mostly Bacillus spp. (Yuste and Mor-Mur 1998), oscillatory pressurization by alternating moderate and high pressures was assayed in the current work to increase the lethality. The results were similar to or better than those obtained in the previous studies.

Nishi and others (1994), in inoculated whole milk, and Hölters and others (1997), in spore suspensions, caused germination of Bacillus spp. with high pressure processing, at pressures from 30 MPa and temperatures from 25 °C. They
Table 3—Aerobic mesophile and psychrotroph counts (log CFU g$^{-1}$) of mechanically recovered poultry meat pressurized at 20°C

<table>
<thead>
<tr>
<th>Mesophiles$^1$</th>
<th>Psychrotrophs$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonpressurized</td>
<td>7.93$^a$</td>
</tr>
<tr>
<td>CP$^3$</td>
<td>4.23$^b$</td>
</tr>
<tr>
<td>OP1$^4$</td>
<td>4.69$^a$</td>
</tr>
<tr>
<td>OP2</td>
<td>4.75$^a$</td>
</tr>
<tr>
<td>OP3</td>
<td>4.13$^a$</td>
</tr>
<tr>
<td>OP4</td>
<td>4.39$^a$</td>
</tr>
<tr>
<td>OP5</td>
<td>4.41$^a$</td>
</tr>
<tr>
<td>OP6</td>
<td>4.79$^a$</td>
</tr>
</tbody>
</table>

$n = 4$.

$^{a,b,c}$ Means within a column lacking a common superscript differ significantly ($p < 0.05$).

$^1$ Least significant difference (LSD) = 0.650.

$^2$ OP: oscillatory pressurization.

$^3$ CP: continuous pressurization.

$^4$ OP: oscillatory pressurization.

References


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stated that, at a given pressure and time of treatment, generally the higher the pressurization temperature the greater the germination rate. Sojka and Ludwig (1994) induced germination and inactivation of Bacillus subtilis by alternating moderate pressure (60 MPa) and high pressure (500 MPa). They reported a reduction of 6 log CFU g$^{-1}$ at 40°C and complete inactivation at 50°C.

In this work, in contrast to what literature states, oscillatory pressurization did not offer better results than continuous pressurization. This could be due to several correlated facts: (i) working with a food product (instead of a buffered suspension), which increases microbial resistance to pressure (Cheftel and Culioli 1997); (ii) the temperature of treatment (20°C); (iii) working with indigenous microbiota (instead of inoculated laboratory collection strains), which is said to grow more readily even after being severely stressed (Cheftel 1992).

To determine whether it is worth applying oscillatory pressurization in the food industry, the effect of such treatment on the pathogenic and spoilage bacterial populations of major concern together with the shelf-life of the treated products have to be evaluated and compared to those achieved with a continuous treatment.

Moreover, oscillatory pressurization at higher temperatures applied to MRPM has to be tested to further investigate the improvement in preservation induced with this process. However, high temperature modifies the sensory properties (appearance, flavor and texture) of MRPM (Yuste and others 1999) and so this meat cannot be used as raw material. Thus, oscillatory pressurization at high temperature should be applied to final products formulated with MRPM.

Conclusions

Oscillatory and continuous high pressure processing improve the microbiological quality of MRPM, which allows to extend the shelf-life and to enhance the safety of this meat. When MRPM is pressurized at room temperature, oscillatory treatments do not generate higher decreases in mesophile and psychrotroph counts than continuous treatment.

Oscillatory and Continuous High Pressure Processing improve the microbiological quality of MRPM, which allows to extend the shelf-life and to enhance the safety of this meat. When MRPM is pressurized at room temperature, oscillatory treatments do not generate higher decreases in mesophile and psychrotroph counts than continuous treatment.