High Pressure-Cooking of Chicken Meat Batters with Starch, Egg White, and Iota Carrageenan

P. FERNANDEZ, S. COFRADES, M.T. SOLAS, J. CARBALLO and F. JIMÉNEZ COLMENERO

ABSTRACT

High pressure/cooking combinations (200 MPa and 400 MPa, 70°C) of chicken gels caused the formation of less compact and aggregated microstructures, which had better binding properties and were less hard. Pressurizing caused a general decrease in color parameters. The addition of starch, egg white or iota carrageenan increased water binding of meat batters. The effect of adding starch and iota carrageenan on textural properties was similar, both causing an increase in hardness and chewiness. High pressure influenced the action of the ingredients and the extent of the effect was related to the type of ingredient and the pressure level but pressure clearly predominated over ingredient effects.

Key words: high pressure, chicken batter, starch, egg white, iota carrageenan

INTRODUCTION

HIGH PRESSURE CAUSES CONFORMATIONAL CHANGES IN FOOD PROTEINS, producing denaturation, aggregation or gelation depending on the protein system (type of protein, pH, ionic strength and conditions (pressure level, time, temperature) under which pressure is applied (Messens et al., 1997). Fundamental studies have been carried out on the pressure-induced denaturation and aggregation of meat protein model systems (Suzuki and Macfarlane, 1984; Ikeuchi et al., 1992; Yamamoto et al., 1993) and on the effects of high pressure on properties of meat and meat batters (Macfarlane et al., 1984; Mandava et al., 1994; Carballo et al., 1996c; Cheftel and Culioli, 1997). Pressure treatment prior to heating considerably enhanced thermal gelation ability of meat protein causing an increase in binding strength of meat patties (Macfarlane et al., 1984), and in Kramer shear force of low- and high-fat burgers (Carballo et al., 1997). However, no such behavior has been reported in studies on the effect of pressurization on meat emulsions (cooked product) with various fat contents (Mandava et al., 1994; Carballo et al., 1996c). In combined high-pressure/heat treatments applied to pork meat batters, the pressurization process preserved the protein from thermal denaturation during gelation (Fernández-Martín et al., 1997).

Many ingredients have been used in the formulation of meat products to endow desired textures and water binding properties. Different types and concentrations of starch have been used in the formulation of low-fat meat products (Shand et al., 1990; Claus and Hunt, 1991; Dexter et al., 1993; Carballo et al., 1995). Egg white is a functional ingredient for some products (Goute iosan and Dumont, 1990; Keeton, 1992), but studies on the way it influences the properties of myo-systems under thermal gelation have been contradictory (Chung and Lee, 1991; Hammer, 1992; Niwa, 1992; Carballo et al., 1995). Ingredients such as carrageenans have been used in meat products for their ability to form gels and retain water and to provide a desirable texture. Iota-carrageenan, alone or combined with other ingredients, has been used in a variety of low-fat meat products (Foegeding and Ramsey, 1986, 1987; Barbut and Mittal, 1989; Dexter et al., 1993; Bloukas et al., 1997).

The influence exerted by ingredients on the characteristics of meat products is affected by several factors, important among them being the processing conditions (Shand et al., 1990; Dexter et al., 1993; Bloukas et al., 1997). Very few results have been reported on the effects of such ingredients on properties of meat products and how they are influenced by the application of high pressure to the meat batters (Cheftel and Culioli, 1997).

The objectives of this research were (1) to assess the effects of applying high pressure (200 and 400 MPa) simultaneously with cooking at 70°C on the properties of chicken gels and (2) to determine how this effect was influenced by the addition of corn starch (CS), egg white (EW) and iota carrageenan (IC).

MATERIALS & METHODS

FRESH CHICKEN BREAST (PECTORALIS MAJOR and pectoralis minor muscles) was obtained from a local meat market. Sufficient amounts of meat and water and 1.5% NaCl were combined to formulate 4 meat batters. Three contained 5% waxy corn starch (CS) (Clearam CH 20, Roquettes Frères, Lestrem, France), 2% atomized-dried egg white (EW) (Sanofi, S.A., Barcelona, Spain) and 1% iota carrageenan (IC) (Satiagel® RPT 25, SBI, Cedex, France); a fourth with no ingredient, the control (N1) was prepared. Meat protein content was adjusted to 16% in all formulations. The batters were prepared as follows: raw meat material was homogenized and ground for 60s in a chilled cutter (2°C) (Stephan Universal Machine UM5, Stephan u. Söhne GmbH & Co., Hameln, Germany). Water, NaCl and the appropriate ingredients were then added and the mixture homogenized again under chilled vacuum (2°C, 610 mm Hg) for a variable length of time until the final chopping temperature of the batters reached 10°C. The time required to reach this point, which varied according to treatment, was from 4 to 6 min.

The batters were placed in flexible plastic jars (dia=3.3 cm, ht=6.7 cm) containing 60±1g sample. Each jar was hermetically sealed and placed in a 8 cm x 30 cm Ultra-Cover™ latex bag (Amevisa S.A., Madrid, Spain). Pressure of 200 and 400 MPa was applied using water at 70°C as the pressurizing medium. Pressurizing took place in a high pressure pilot unit ACB model AGIP No. 665 (GEC, Alsthom, Nantes, France) as described by Carballo et al. (1996c). For each formulation a nonpressurized control sample was made by heating the plastic jars under the same conditions as the pressurized samples. The heating conditions required to attain a temperature of 70°C were determined beforehand by inserting thermocouples connected to a temperature recorder (Yokogawa Hokushin Electric YEW, Mod. 3087, Tokyo, Japan) in the thermal center of the samples. After pressurizing, the jars were taken from the vessel and removed from the latex bags and then stored for 18 h, at 0–4°C for analysis. Before analyses, the samples were tempered at 20–22°C and removed from the jars, and weight loss (WL) was determined (in quintuplicate) as % fluid released. Under our conditions, there was no possibility of additional weight loss due to evaporation.

Moisture, protein and ash of raw materials and uncooked meat batters were evaluated (AOAC, 1984), in triplicate. Fat content was evaluated by difference. The pH was assessed using a pH meter (Radiometer PHM 93, Copenhagen, Denmark) on a homogenate of 5 g cooked sample in 50 mL distilled water. Surface color (lightness, L; redness, a and yellowness, b) of the various treatments was measured (8 determinations per formulation) on a Hunter Lab model D25-9 (Hunter Asso-
Pressurization of Chicken Meat Batters . . .

PRELIMINARY RESULTS (Table 1), showed moisture content was lowest in samples with starch, and protein was higher in samples with EW. The moisture and protein contents were generally influenced by the type and amount of ingredient added. There were no significant differences in pH between the control and samples with ingredients; however, samples containing CS varied according to the presence of EW and IC. Pressurization caused no significant changes in pH.

RESULTS & DISCUSSION

PROXIMATE ANALYSIS OF THE VARIOUS BATTERS (Table 1), showed moisture content was lowest in samples with starch, and protein was higher in samples with EW. The moisture and protein contents were generally influenced by the type and amount of ingredient added. There were no significant differences in pH between the control and samples with ingredients; however, samples containing CS varied according to the presence of EW and IC. Pressurization caused no significant changes in pH.

Weight loss

In the nonpressurized samples WL decreased (P<0.05) with the incorporation of any of the ingredients (Fig. 1). Starch produced the lowest WL values. Both starch (Dexter et al., 1993; Carballo et al., 1995) and IC (Foegeding and Ramsey, 1986, 1987; Barbut and Mittal, 1989; Defreitas et al., 1995) have been described as ingredients which improve the water binding properties of meat batters. Carballo et al. (1995) found that EW had no influence on water and fat binding properties of pork meat batters but that the effect of EW on the myosystem appeared to be related to the functional quality of myofibrillar protein.

In the control sample (NI), pressurization caused a reduction (P<0.05) of WL, which fell to around 44% at 200 MPa and almost 78% at 400 MPa (Fig. 1). A similar pattern has been described by Fernández-Martín et al. (1997). These results were attributed to the fact that pressurization (applied simultaneously with cooking treatment) to some extent preserved the meat protein from heat denaturation. A lower incidence of protein denaturation at 70°C would explain why the WL was less at 200 and 400 MPa.

Pressurizing of meat batters containing starch resulted in a significant increase in water binding properties only at 400 MPa (Fig. 1). Both pressurization and the addition of starch brought WL down to similar levels (<1%) and increased water-binding properties in much the same way. Use of starch for water binding would not be warranted when a meat batter is pressurized at 400 MPa.

In batters containing EW, pressurization caused a decrease (P<0.05) in WL (Fig. 1) which was independent of pressure. When compared with the NI samples, the results of applying 200 MPa indicated that the presence of egg white had no effect (P>0.05) on WL. At 400 MPa, however addition of EW limited the pressure-induced WL, which was clearly detected in the controls (Fig. 1). The presence of egg white did not enhance the effect of pressurization. At 200 MPa no effect was observed, but at 400 MPa EW appeared to interfere with the mechanism which enhanced water binding properties. We, therefore, concluded that under these conditions, addition of EW to pressurized meat batters was not warranted.

In chicken meat batters with IC, pressurization reduced (P<0.05) WL alike at 200 and 400 MPa (Fig. 1). At 200 MPa, addition of IC produced similar WL values to controls (NI) and the sample with EW, and higher values than for samples with starch. At 400 MPa the water binding properties of the samples with IC were similar to those exhibited by samples with EW and less than those in samples with starch or NI (Fig. 1). Addition of IC to meat batters pressurized at 400 MPa limited the effect of pressure on water binding properties. This behavior, which was similar to that found in EW, indicated that from the standpoint of water binding properties, addition of IC was not warranted.

Texture profile analysis

Analysis of nonpressurized samples showed a similarity in behavior of added CS and IC. The presence of these ingredients produced an increase (P<0.05) in Hd and Cw (Fig. 2 and 3) and no changes (P>0.05) in Sp and Ch (Fig. 2 and 3). Addition of EW caused no changes (P>0.05) in Hd and a decrease (P<0.05) of Sp, Ch and Cw (Fig. 2 and 3).

The effect of starch on textural parameters was consistent with other published results (Shand et al., 1990; Chen et al., 1993; Carballo et al., 1995), although others have found that starch had no influence on such parameters (Claus and Hunt, 1991; Dexter et al., 1993). As the microstructural analysis indicated the explanation of the effect of starch in our results appeared to be that its presence caused a decrease in the moisture/protein ratio (Table 1), rather than a contribution to stronger heat-induced structures through swelling of starch granules in the protein gel matrix (Chen et al., 1993; Carballo et al., 1996b). In either case the resulting structures were firmer with better water binding properties (Fig. 1, 2 and 3). There have been contradictory reports on the effect of EW on the properties of meat batters. The explanation in each case depends on the effects hypothesized for the EW in formation of the protein network (Carballo et al., 1996b), which may be influenced by the same factors as were cited for water...
binding. It has been reported that addition of IC increased hardness of salt-soluble meat protein gels in model systems (Defreitas et al., 1995) and hardness of meat products (Trius et al., 1994). Foegeding and Ramsey (1986, 1987) reported that addition of 1% IC increased force to fracture meat batters but did not affect hardness or springiness. Barbut and Mittal (1989) found variations in hardness in the presence of 0.4% IC. Addition of IC at > 0.25% increased firmness of low-fat frankfurters (Bloukas et al., 1997).

In the control samples (NI) pressurization at 200 MPa caused the formation of structures which were harder and chewier than nonpressurized samples, with similar (P>0.05) values of Sp and Ch (Fig. 2 and 3). Pressurization at 400 MPa caused a decrease (P<0.05) in all textural parameters (Fig. 2 and 3). The texture of batters with IC was not affected by pressurization at 200 MPa. At 400 MPa, however, the resulting products were less (P<0.05) hard and chewy (Fig. 2 and 3). The samples with IC were the least affected by pressurization and exhibited the highest hardness and chewiness values of all pressurized samples.

Comparison, at a given pressure level, of texture parameters of the control (NI) with parameters of samples containing ingredients showed that the effect of pressurizing was influenced by the addition of CS, EW or IC. This was clearly evidenced by the difference in behavior of Hd and Cw at 200 and 400 MPa, which were dependent on the ingredient added (Fig. 2 and 3).

Color measurements
Addition of ingredients caused alterations in color (Table 2). In nonpressurized samples, L value increased in the presence of CS and decreased in the presence of EW or IC. Pressurizing at 200 MPa caused a decrease in lightness, lower at 200 than at 400 MPa. Redness of nonpressurized chicken samples decreased (P<0.05) when CS or IC was added (Table 2) and EW had no effect on redness. Pressurizing caused a decrease (P<0.05) in all samples except those containing IC. It also caused a general decrease (P<0.05) in b value (Table 2). Meat decoloration has been associated with pressure-induced modifications in hemoprotein and sarcoplasmic and myofibrillar proteins (Cheftel and Culioli, 1997).

Microstructure
In the control samples (NI), the effect of pressure was reflected in the formation of different structures. The microstructure of nonpressurized gels was more fibrous and intermeshed and exhibited an apparently higher degree of denaturation in the protein matrix. Samples pressurized at 400 MPa, had structures which were coarser, more irregular and less compact and aggregated (Fig. 4a and 4b). The microstructure of samples pressurized at 200 MPa was intermediate between the two (micrographs not shown). This behavior has been associated with a lower level of heat denaturation (Carballo et al., 1996a), which would account for lesser hardness and greater water binding properties occurring under pressure treatment (Fig. 1 and 2).

In nonpressurized samples, the presence

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### Table 1—Proximate analysis (%) of the uncooked meat batters and pH of cooked samples

<table>
<thead>
<tr>
<th>Moisture</th>
<th>Protein</th>
<th>Fat</th>
<th>Ash</th>
<th>pH</th>
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<tbody>
<tr>
<td>NI</td>
<td>79.8</td>
<td>16.2</td>
<td>1.9</td>
<td>6.11</td>
</tr>
<tr>
<td>CS</td>
<td>75.9</td>
<td>15.9</td>
<td>1.7</td>
<td>6.07</td>
</tr>
<tr>
<td>EW</td>
<td>78.1</td>
<td>17.1</td>
<td>2.1</td>
<td>6.14</td>
</tr>
<tr>
<td>IC</td>
<td>79.3</td>
<td>16.4</td>
<td>2.2</td>
<td>6.16</td>
</tr>
<tr>
<td>SEM</td>
<td>0.0</td>
<td>0.1</td>
<td>0.2</td>
<td>0.08</td>
</tr>
</tbody>
</table>

*a,b* Values with different letters in the same column are significantly different (P<0.05). SEM = Standard error of the mean. NI control, no ingredient; CS containing 5% of starch; EW, 2% egg white; IC, 1% iota-carrageenan.
of starch resulted in microstructures closely resembling those of the controls but more compact (Fig. 5a). This change may be related to the fact that the starch granules expanded during heating, thus exerting pressure on the protein matrix (Lee et al., 1992). The starch was swollen and in the form of almost spherical, and crystalline granules, which remained separate from and hence not integrated in the matrix, in many cases located in partially empty cavities. Pressurization induced the same kind of change in the matrix as has been described for the controls. The most obvious change was the degree of deformation in the starch granule (Fig. 5b). The effect of the starch on batter properties appeared to result not from their direct action on the batter, because it seems to act as a filler, but rather from the lower moisture/protein ratio (Table 1) produced by its addition. The end result of this was the formation of stronger, more compact structures with better water binding (Fig. 1–3). Some published reports have indicated that during heating, starch exhibits little affinity for myofibrillar proteins, so that instead of interacting with the protein matrix, it acts as a passive filler (Ziegler and Foegeding, 1990; Lee et al., 1992). The crystalline morphology of the starch we examined may be attributed to the convergence of several factors. Firstly, the cooking process took place at ≤ 70°C, at which temperature starch undergoes moderate swelling and slight solubilization of its components, which is insufficient to result in gelatinization (Goméz-Guillén et al., 1996). The other factor to take into account is that not enough water was available for the starch to gelatinize, despite a moisture content of 75.9% (Table 1). Such condition has been described by Couso et al. (1997), who found that in gels with high moisture (83%) the characteristics of the matrix may be such as to render the water unavailable for hydration and gelatinization of the starch. The excellent water binding properties of chicken meat batters (Fig. 1) may also help to limit the availability of water.

Addition of EW contributed to the formation of filamentous structures within the protein network (Fig. 6a). Part of the EW, however, was not integrated in the matrix but formed a granular appearance which covered the matrix. The result was the formation of structures with better water binding, similar Hd and lower Sp, Ch and Cw (Fig. 1–3). Published results have reported that EW contributes to the protein network structure (Niwa, 1992; Carballo et al., 1996b), but others have concluded that the presence of EW had no technological effect because it does not form part of the protein structure (Hammer, 1992) or that it had a diluting effect and interfered with gelation (Chung and Lee, 1991). The most apparent effect of pressurization of samples containing EW was that although filamentous structures were present, they were less apparent (Fig. 6b). The matrix of the pressurized meat batters with EW exhibited similar characteristics to the control samples (NI) (Fig. 4a and 4b). This suggested that EW continued to participate in the formation of the protein network in the pressurized samples, if to a lesser extent. Nevertheless there was a decrease in Hd and Cw (Fig. 2 and 3) of samples containing EW pressurized at 400 MPa. This behavior would appear to be due in large part to the lesser degree of chicken protein denaturation occurring in the matrix.

The microstructure of samples with IC differed from the control (NI) more than did samples with any of the other ingredients (Fig. 7a). In pressurized samples, the added IC appeared integrated in the protein matrix, exhibiting a kind of filamentous mesh with connections between structural elements (Fig. 7b), so that the pressure-induced changes in texture were less pronounced than with the other ingredients. Formation of fine mesh structures by IC has been reported by Gómez-Guillén et al. (1996) in muscle protein.

We concluded that the gelation process was different in the pressurized and nonpressurized batters. The pressurized batters formed a less compact and rigid gel matrix with better water binding properties than nonpressurized samples. This may be related to a lesser degree of protein denaturation and aggregation, and hence less conformational change, so that the matrix was softer and shrank less. This behavior confirmed that high pressure to some extent protected meat protein from heat denaturation (Fernández-Martín et al., 1997). Also,

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**Table 2—Hunter color values of the meat batters as influenced by ingredients and pressure**

<table>
<thead>
<tr>
<th></th>
<th>L</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NP</td>
<td>200 MPa</td>
<td>400 MPa</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ni</td>
<td>69.80</td>
<td>64.60</td>
<td>68.07</td>
</tr>
<tr>
<td>CS</td>
<td>71.02</td>
<td>68.20</td>
<td>68.24</td>
</tr>
<tr>
<td>EW</td>
<td>67.97</td>
<td>65.09</td>
<td>69.04</td>
</tr>
<tr>
<td>IC</td>
<td>68.89</td>
<td>66.67</td>
<td>68.26</td>
</tr>
<tr>
<td>SEM</td>
<td>0.21</td>
<td>0.05</td>
<td>0.08</td>
</tr>
</tbody>
</table>

*SEM = Standard error of the mean. Lightness, L; redness, a; yellowness, b. NI-control, no ingredients; CS-starch (5%); EW-egg white (2%); IC-iota carrageenan (1%); NP-non pressurized.*

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Fig. 6—Scanning electron micrographs of chicken meat batters containing egg white (2%): (a) nonpressurized; (b) pressurized at 400 MPa. FS = egg white forming filamentous structures, GS = egg white forming granulous structures.

Fig. 7—Scanning electron micrographs of chicken meat batters containing iota carrageenan (1%): (a) nonpressurized; (b) pressurized at 400 MPa. FM = filamentous mesh.
although the effect of pressurization on the action of ingredients was dependent on the type of ingredient and pressure level, pressure effect clearly predominated over the ingredient effect. Our findings suggest that, with regard to water binding properties the addition of ingredients is not warranted in the case of batters which are to be pressurized.

REFERENCES


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Ms received 8/6/97; revised 10/27/97; accepted 11/4/ 97.

This research was supported by the Comision Interministerial de Ciencia y Tecnologia (CICYT) under the projects ALI94-0742 and ALI94-0786-C02-01 and by Comunidad de Madrid 066G/05396.