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Effects of binders combined with glucono-δ-lactone on the quality characteristics of pressure-induced cold-set restructured pork

Ji-Yeon Chun [a], Mi-Jung Choi [b], Sang-Gi Min [a], Geun-Pyo Hong [c,*]

[a] Department of Bioindustrial Technologies, Konkuk University, Seoul 143-701, Republic of Korea
[b] Department of Bioresources and Food Science, Konkuk University, Seoul 143-701, Republic of Korea
[c] Department of Food Bioengineering, Jeju National University, Jeju 690-756, Republic of Korea

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ABSTRACT

This study investigated the effects of binders and glucono-δ-lactone (GdL) on characteristics of pressure-induced (450 MPA for 3 min) cold-set restructured pork. Isolated soy protein (SP), wheat flour (WF), and κ-carrageenan (CG) were adopted as binders. The addition of binders improved water-binding properties of restructured pork, and the binders diminished the decrease in water binding properties caused by GdL-induced acidification. Pressure-induced restructured pork prepared with binders showed less harder and more cohesive texture than those of the thermal-treated control (TC). The results indicate that pressure-induced cold-set meat restructuring could be achieved when binders and GdL were used in the formulation.

1. Introduction

Restructured meat has been recognized as an intermediate value product between burgers and intact muscle steak based on the definition of restructured meat, which is made by comminution and reassembly or binding of constituent meat pieces (Sheard, 2002). Value-added products at a reduced cost can be obtained from valueless meat pieces or trims using meat restructuring processes (Tsai, Unklesbay, Unklesbay, & Clarke, 1998). Conventional meat restructuring depends not only on extracting myofibrillar proteins by adding salts but also forming a protein gel network through thermal processing (thermal-set meat restructuring). Cold-set meat restructuring techniques with reduced salt have been introduced using enzymes, cold-set binding agents, and physical processes (Farouk, 2010; Hong, Min, Ko, & Choi, 2008; Kuraishi et al., 1997).

Enzymatic protein cross-linking by microbial transglutaminase has the potential to restructure meat pieces without thermal processing (Kuraishi et al., 1997), however, the high cost of the enzyme limits production of restructured meat on a large industrial scale. The use of binding agents such as carrageenan (CG) and alginate is an alternative technique for cold-set meat restructuring (Farouk, 2010).

Protein undergoes a reversible unfolding or irreversible denaturation during pressurization depending on the applied pressure levels, suggesting that meat pieces can be restructured by high pressure processing. However, based on a study by Hong et al. (2008), pressurization alone (at 200 MPa for 30 min) has no effect on cold-set meat restructuring, and an additional binding agent was required to achieve acceptable meat-to-meat binding. Gums, alginate, and various non-meat proteins have no effect on meat restructuring under high pressure, whereas CG (κ-form) exhibits acceptable meat restructuring ability. Although CG shows good meat binding ability under high pressure, the toxicological effects of CG discourage its use as a binding agent in restructured meat products (Cohen & Ito, 2002).

Glucono-δ-lactone (GdL) can form an acid-induced myofibrillar protein gel (Ngapo, Wilkinson, & Chong, 1996). Hong, Park, Kim, Ko, and Min (2006) indicated that pressure-induced meat restructuring (200 MPa for 30 min) was possible by adding GdL, however, large amounts of moisture are lost by GdL-induced low pH. Consequently, non-meat proteins can be applied to a meat restructuring formulation as a meat binder concomitantly with the addition of GdL.

It is hypothesized that the GdL-induced pH decrease affects binding ability of a protein-based binder more than a carbohydrate-based binder, particularly CG. Therefore, we explored the effect of three different binders with and without GdL on meat binding ability of the pressure-induced restructured pork.

* Corresponding author. Tel.: +82 64 754 3615; fax: +82 64 755 3601.
E-mail address: gphong@jejunu.ac.kr (G.-P. Hong).

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2. Materials and methods

2.1. Materials

Porcine *M. longissimus dorsi* (crossbreed of Landrace × Yorkshire × Duroc, 6 month old hogs) was purchased randomly from both sides of six carcasses 24 h post-mortem, and all visible fat and connective tissue were completely trimmed off. The meat was ground once through an 8-mm plate and used for sample preparation without further storage. Isolated soy protein (SP, >93% protein based on the manufacturer) was kindly donated by Sias Corp. (Seoul, Korea), and CG (>95% purity) was purchased from Sigma-Aldrich Co. (St. Louis, MO, USA). Commercial wheat flour (WF, 12% protein and 72% carbohydrate based on the manufacturer) was purchased from a market. Additional ingredients, including NaCl, sodium tripolyphosphate (STPP) and GdL were food grade, and all chemicals for analyses were of analytical grade.

2.2. Sample preparation and treatment

The restructured pork (2 kg batch per treatment) was prepared by the method of Hong et al. (2008). Briefly, ground pork (96.7%, w/w) was hand-mixed with 0.5% (w/w) NaCl and 0.3% (w/w) STPP for 3 min. Then, 0.5% (w/w) of the binder (2% in the case of SP, w/w) with and without 0.5% (w/w) GdL was added (Table 1). Different binder contents were based on previous studies (Hong, Park, Kim, Ko, & Min, 2006; Hong, Park, Kim, & Min, 2006). The binder was replaced with water for the control. Each treatment was further mixed for 3 min, and approximately 300 g of mixture (six chubs per treatment) was filled into fibrous casings (65 mm in diameter). The samples were vacuum-packed individually using polynylon pouches and kept at 4 °C for 24 h for acidification. The samples were pressurized using a commercial high pressure device (SQF-215L, AVURE-Technologies, Franklin, TN, USA). Water was used as the pressure-transmitting medium. Pressurization was conducted at 450 MPa for 3 min under ambient temperature (~18 °C). After pressurization, the samples were maintained at 4 °C for 5 h. The thermal-treated control (TC) samples were immersed in a 75 °C water bath for 30 min, cooled in ice/water for 30 min, and then kept under the same conditions as those of the pressure treatments.

2.3. Yield

All sample mixtures were weighed prior to thermal and pressure treatments. The casings were removed carefully after the treatment. The surface exudate of the sample chubs was softly wiped off using tissue, and the chubs were weighed again. Yield was determined by percentage weight of the chubs over initial weight.

2.4. pH

Five grams of sample (three chubs) was taken and homogenized at 10,000 rpm for 2 min with 20 mL distilled water using a homogenizer (SMT Co., Ltd., Tokyo, Japan). The pH of the samples was determined using a pH-meter (pH900, Precisa Co., Dietikon, Switzerland).

Table 1
Formulations of the restructured pork containing binders.

	Treatments (g/2 kg batch)			
Additives[a]	Control	CG	WF	SP
Pork loin	1934	1934	1934	1934
Sodium chloride	10	10	10	10
Sodium tripolyphosphate	6	6	6	6
κ-Carrageenan (CG)	–	10	–	–
Wheat flour (WF)	–	–	10	–
Isolated soy protein (SP)	–	–	–	40
Water	50	40	40	10

[a] The 10 mg of water was replaced with GdL for the glucono-δ-lactone (GdL) treatments.

2.5. Water holding capacity (WHC)

Approximately 1 g of sample (W_S) was taken from three chubs and placed in a centrifuge tube with gauze as an adsorbent. The samples were centrifuged at 1500 ×*g* for 10 min (RC-3, Sorvall Co., Asheville, NC, USA) at 4 °C. After centrifugation, the meat pellet was carefully removed, and the weight of the centrifuge tube before (W_I) and after drying at 102 °C for 24 h (W_F) was measured. WHC was expressed as the percentage of moisture remaining in the sample using the following equation:

$$\text{WHC}\ (\%) = \left(1 - \frac{W_I - W_F}{W_S}\right) \times 100.$$

2.6. Texture profile analysis

Three slices (20 mm in height) were cut from three chubs and placed into a plastic bag to prevent surface drying. The samples were tempered at an ambient temperature (~18 °C) for 1 h and compressed to 50% of initial height for two cycles using a texture analyzer (CT3, Brookfield Engineering Labs Inc., Stoughton, MA, USA) equipped with TA43 sphere D probe (Brookfield Engineering Labs) under the conditions of 0.05 mm/s test speed and a trigger load of 5 g. Hardness, cohesiveness, and springiness were calculated from the double cycled load-distance curve as described by Peleg (1976).

2.7. Scanning electron microscopy

The microstructure of the restructured pork was determined by the method of Haga and Ohashi (1984). A sample piece ($2 \times 2 \times 2$ mm^3) was fixed with 0.1 M sodium phosphate buffer containing 2.5% glutaraldehyde (pH 7.0) at 4 °C for 24 h and washed with 0.1 M sodium phosphate buffer (PBS, pH 7.0). The sample was post-fixed using 0.1 M PBS containing 1% osmium tetraoxide (pH 7.0) at an ambient temperature for 5 h, and washed three times with 0.1 M PBS (pH 7.0) for 10 min. The samples were dehydrated by immersing them in varying concentrations of ethanol (in order of 50, 60, 70, 80, and 90 and three times in 100%) for 10 min per solution, and then they were dipped into acetone for 10 min. The dehydrated samples were gold-coated (~15 nm layer) using an ion sputter (E-1010. Hitachi Science System Ltd., Hitachinaka, Japan). The microstructure of the sample was observed using a scanning electron microscope (S-2400, Hitachi Science System) at an accelerating voltage of 18 kV.

2.8. Instrumental color

Two sliced samples (1 cm thickness) from three chubs were oxygenated at an ambient temperature for 10 min, and surface color was measured using a color reader (CR-10, Konica Minolta Sensing Inc., Tokyo, Japan) calibrated with a white standard plate ($L^* = 97.83$, $a^* = -0.43$ and $b^* = +1.98$). The CIE L^*, a^*, and b^* values were determined as indicators of lightness, redness, and yellowness, respectively. Instrumental color was taken randomly from the surface of the sample slices. The total color difference (ΔE) between fresh pork loin ($L^* = 40.3$, $a^* = 10.7$ and $b^* = 12.4$) and the treatments was numerically calculated with the following equation.

$$\Delta E = \sqrt{\Delta L*^2 + \Delta a*^2 + \Delta b*^2}.$$

2.9. Statistical analysis

A randomized complete block design was adopted to evaluate the effect of the binder treatments and acidification. The entire experiment was repeated three times on three different days (n = 3), and the data