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TEXTURAL AND HYDRATION PROPERTIES OF PORK MEAT GELS PROCESSED WITH NON-MUSCLE PROTEINS AND CARRAGEENAN

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The combined influence of varying levels of carrageenan, CGN (0, 0.4, 0.8%) and three non-muscle proteins, NMP (blood plasma, BP, sodium caseinate, SC, soy isolate, SI) at two levels (1 and 2%) on binding, textural, and color characteristics of meat gels was investigated. Carrageenan favorably affected hydration properties and thermal stability, yielding lower cooking loss and higher water holding capacity for meat gels, but the effects were attenuated by increased NMP addition. CGN also increased hardness of gels containing sodium caseinate and blood plasma but not soy protein. The combination of carrageenan with NMP was unable to improve springiness or cohesiveness and led to the formation of harder but more brittle gels. The soy protein either alone or in combination with carrageenan generally was found to be inferior to sodium caseinate and plasma proteins for functionality in comminuted meat systems.

INTRODUCTION

The heat-induced gelling properties of muscle proteins are largely responsible for the stabilization of fat and water in comminuted meat products [Acton *et al.*, 1983; Asghar *et al.*, 1985; Gordon & Barbut, 1992; Smith, 1988]. Non-muscle proteins (NMP) and carbohydrates are often used as alternative gelling agents in comminuted meat products to enhance the yield by improving water binding properties. The addition of NMP and polysaccharides to the meat batters may compensate excess water addition and stabilize both fat and water in such emulsions [Shand & Schmidt, 1990; Keeton, 1996; Hoogenkamp, 1992].

Soy protein isolate is commonly used in processed meat products as a binder to reduce processing cost and water loss, to increase yield and to stabilize the emulsion of emulsion-type meat products [Keeton, 1994]. Blood plasma proteins are a promising source of soluble proteins. Moreover, plasma proteins have been reassessed as a useful ingredient in cooked meat products for its excellent gelling properties [Jarmoluk, 1997]. On the other perspective sodium caseinate cannot form self-supporting gels but rather acts as a paste in meat systems [Hermansson, 1976]. The functionality of carrageenan in meat products, on the other hand, is related to its thermally reversible gelation properties. Carrageenan dissolves throughout meat during thermal processing and gels on cooling. It improves water retention, consistency and texture of comminuted meat products [Trius & Sebranek, 1996].

Despite different characteristics these non-muscle proteins and polysaccharides are routinely used to enhance the texture and binding properties of comminuted meat products. However, little information is available on the effect of carrageenan on binding and textural characteristics of meat batters produced with combinations of carrageenan and other ingredients, including NMP.

Interactions between polysaccharides and proteins (muscle and non-muscle) occurring in biological systems play a role in determining the functional properties of these systems. The interactions are also important in determining meat product binding and textural properties and have been the subject of many investigations [Bernal *et al.*, 1987; Trius & Sebranek, 1996; DeFreitas *et al.*, 1997; Montero *et al.*, 2000]. However, the influence of non-muscle proteins in combination with carrageenan on the heat induced gelation properties of muscle proteins is not fully understood. A better understanding of the gelation properties of proteins (muscle and non-muscle) and carrageenan and their interactions in meat systems would contribute to improved utilization and processing qualities of these ingredients in meat products.

The present study was undertaken to examine the combined effects of carrageenan level and three non-muscle proteins on water binding and textural properties of cooked pork meat gels.

MATERIALS AND METHODS

Materials. Post-rigor pork meat (*Semimembranosus* muscles) was purchased from a local meat plant 48 h *post mortem*. The pork was trimmed of visible fat and connective tissue, then ground in a laboratory grinder through a plate

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with 3 mm diameter orifices. The ground meat was portioned, vacuum-packaged and frozen at -22°C until product formulation.

The protein concentration of the ground pork was determined by the AOAC [1990] procedures (981.10). Nitrogen values were converted to protein using a conversion factor of 6.25. The protein content of the meat was 22.24%.

The ingredients used in the homogenate formulations included curing mixture (containing 99.5% sodium chloride and 0.5% sodium nitrite), and sodium erythorbate (Fujisawa Pharmaceutical Co Ltd., Japan). Blood plasma (spray-dried porcine blood plasma powder) (BP) (VEPRO 75 PSC) was obtained from VEOS NV, Belgium. Soy protein isolate – SUPRO 595 (SI) was purchased as a commercial product from DuPont Protein Technologies, Ieper, Belgium. Sodium caseinate (SC) was purchased as a commercial product from PHZ SM "Lacpol", Poland. Carrageenan (SECOGEL MF) was purchased from BIOMAT, Poland. Non-muscle proteins were hydrated with chilled brine for 30 min prior to addition to meat ingredients.

Preparation of meat gels. Before processing, the meat was tempered at 4°C for 15 h prior to use. Meat protein content was adjusted to a constant level of 8% in all formulations. Shredded ice was added to the batters to ensure the same protein level. Treatments (200 g each) were prepared by mixing ground meat and non-muscle ingredients for 15 s using a BUCHI "MIXER B-400" (9000 rev./min). Levels of components tested are shown in Table 1. Concentrations of curing salt and sodium erythorbate in all formulations were set at constant levels of 2.0% and 0.1%, respectively. The final temperature of the homogenates never exceeded 7°C.

TABLE 1. Composition (% by weight) of pork batter formulations.

Formulation*	Meat	Water	NMP	κ-CGN	Others**
1	36.35	61.55	0	0	2.1
2	36.35	61.15	0	0.4	2.1
3	36.35	60.75	0	0.8	2.1
4	36.35	60.55	1	0	2.1
5	36.35	60.15	1	0.4	2.1
6	36.35	59.75	1	0.8	2.1
7	36.35	59.55	2	0	2.1
8	36.35	59.15	2	0.4	2.1
9	36.35	58.75	2	0.8	2.1

*NMP = non-muscle proteins (blood plasma, sodium caseinate or soy protein isolate); CGN = carrageenan; ** concentrations of cure salt (containing 0.5% sodium nitrite) and sodium erythorbate in all formulations were set at constant levels of 2.0% and 0.1%, respectively.

Immediately after homogenate preparation, the batters were stuffed into three cylindrical plastic tubes (30 mm x 115 mm). The tubes were closed and heated isothermally at 75°C to a final internal temperature of 72°C in a water bath, and thereafter cooled down in ice water until a core temperature of 20°C was reached. Internal temperature was measured using thermocouples inserted in the geometrical center of the samples. The gel samples were stored at 4°C until analyzed.

Water binding properties

Cooking loss (CL). Following overnight storage each chilled gel was removed from the plastic tube, blotted dry with a paper towel and weighed for a cook yield. Overall cook loss was calculated as a percentage based on the raw stuffed weight.

Expressible moisture (EM). The modified Hamm [Grau & Hamm, 1957] procedure was used to measure the expressible moisture (EM). Briefly, a gel sample (~0.3 g) was placed on filter paper (Whatman No. 1) and pressed for 5 min between two glass sheets using a 2 kg weight. EM was expressed as the percentage ratio of moisture released from the sample to the initial gel sample weight.

Textural properties. Textural characteristics of gels were analyzed according to the texture profile analysis (TPA) method [Bourne, 1978] using a STEVENS- QTS 25 texture analyzer (CNS FARNELL Quality and Test Systems, England).

Five center cores (25 mm in diameter, 15 mm height) of gel samples were compressed twice to 25% of their original height at a constant cross-head speed of 60 mm/min. The TPA parameters, namely hardness (peak force on first compression [N]), cohesiveness (ratio of the active work done under the second force-displacement curve to that done under the first compression curve [dimensionless]), springiness (distance the sample recovered after the first compression [mm]), and chewiness (hardness x cohesiveness x springiness [N x mm]) were computed.

Experimental design and statistical analysis. The experiment was replicated three times. Statistical analysis of results was performed using a Statistica package (Statistica 5.1 for Windows, StatSoft, Poland). Data were analyzed as a 7x3 factorial design with three different NMP each at two levels (1 and 2%) and three carrageenan levels (0.0, 0.4 and 0.8%) as main factors. Fisher's Least Significant Difference test at p=0.05 was used to determine differences between treatment means.

RESULTS AND DISCUSSION

Water binding properties

Generally, increased addition of non-muscle proteins improved the hydration properties of gels, resulting in significantly lower cooking losses as compared to samples containing only 8% muscle proteins (Figure 1). The effect of

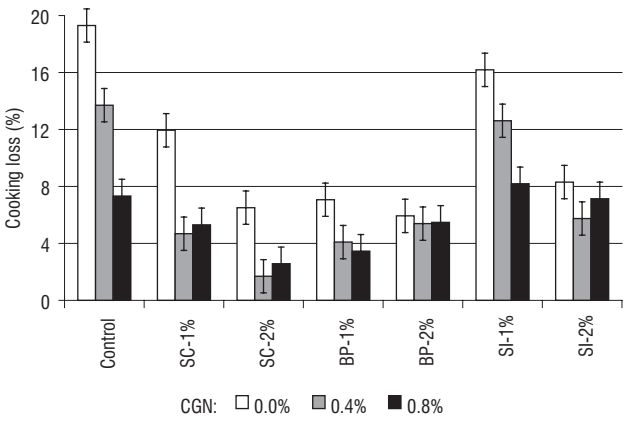

FIGURE 1. Cooking loss of pork gels as affected by the ingredients (SC – sodium caseinate, BP – blood plasma, SI – soy isolate, CGN – carrageenan). The vertical bar shows the confidence interval (95%).

increased NMP addition was observed only for treatments without CGN or with 0.4% addition. Of the NMP analyzed, SC and BP exhibited more effective water binding properties than the soy protein isolate. Soy proteins including the two major globular fractions, glycinin and beta-conglycinin, are remarkably resistant to denaturation [Feng & Xiong, 2002] and do not exhibit appreciable structural changes under the normal meat processing conditions. The lack of interaction with muscle proteins is considered as a major factor limiting the role of soy proteins as a functional component intended for assuring physical stability of comminuted and emulsified meats [Feng & Xiong, 2002; McCord *et al.*, 1998].

Jarmoluk [1997] reported that blood plasma proteins contribute to formation of the protein network thus enhancing thermal stability of batters and hence provide substantial technological advantage in processing of homogenized meat products. It has been suggested that BP addition may allow more favourable interactions with muscle proteins, thus producing a stronger, better-ordered three-dimensional gel, a type of structure which influences the binding properties of meat emulsions [Jarmoluk, 1997; Cofrades *et al.*, 2000].

Although SC lacks the gelation ability on heating and unlike BP cannot form a three-dimensional matrix, it has been reported to contribute to formation of the protein network [Su *et al.*, 2000] and as in our study to enhance thermal stability of reduced-fat batters. Hung & Zayas [1992] also indicated that SC helped to stabilize batter and may be advantageous in increasing hydration properties.

Atughonu *et al.* [1998] studied the quality characteristics, and microstructure of frankfurters prepared with 2% sodium caseinate and showed that SC was able to bind to the meat protein and fat, forming a protein-fat matrix with a better retention of water. A microstructure study showed that sodium caseinate stabilized the meat emulsion during cooking due to immobilization of fat globules by a protein membrane as well as their physical restriction by a sodium caseinate matrix [Su *et al.*, 2000]. However, in meat batters with extremely low fat content, the water retention capacity of SC may play a greater role rather than emulsion formation in determining the stability of the products. Addition of sodium caseinate to the meat batters may compensate excess water addition and stabilize both fat and water in such emulsions.

Water binding properties were also markedly improved by addition of carrageenan, but the effect of increasing levels of CGN was strongly dependent on NMP addition. The greatest improvements occurred for treatments processed without NMP addition. The higher the NMP content, the less marked was the improvement of cook yield when CGN content was increased. Similarly the effect of increased NMP addition was observed only for treatments without CGN or with 0.4% addition (Figure 1).

Addition of carrageenan also decreased the percentage of EM from gel samples. CGN improved water retention of meat gels and made the greatest contribution to the gels' water holding capacity in treatments processed without NMP (Figure 2).

The beneficial effect of CGN on hydration characteristics in this study is in agreement with our previous findings [Pietrasik & Li-Chan, 2002] and results reported by other authors that water binding properties are strongly influenced by CGN addition to processed muscle foods [Candogan & Kolsarici, 2003; Trius & Sebranek, 1996; Shand & Schmidt, 1990; De-Freitas *et al.*, 1997; He & Sebranek, 1996; Trius *et al.*, 1994].

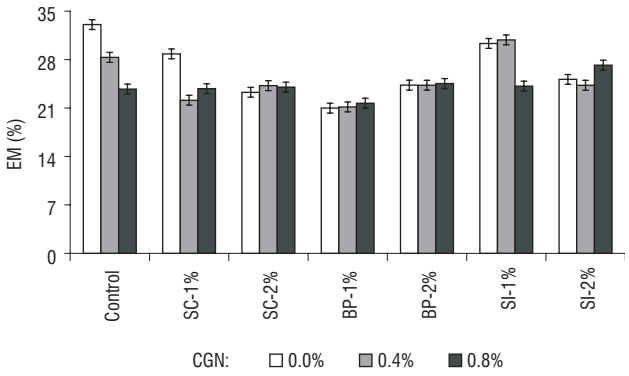

FIGURE 2. Expressible moisture (EM) from pork gels as affected by the ingredients (SC – sodium caseinate, BP – blood plasma, SI – soy isolate, CGN – carrageenan). The vertical bar shows the confidence interval (95%).

Our results indicated that the matrix formed in those gels had a greater ability to entrap water than that of other gels. DeFreitas *et al.* [1997] investigated effect of CGN on ultrastructure of heat-induced meat gels and found the microstructure of gels corresponded to the differences in water holding capacity. They suggested that a well-structured matrix and a fine, uniform structure with numerous small pores observed in the gels containing CGN would result in more absorptive capacity and better retention of water.

Textural properties

The effect of CGN on gel strength varied with NMP type and level addition. The hydrocolloid increased hardness of control gels and those containing sodium caseinate and blood plasma but had detrimental effect on strength of the gels produced with soy protein isolate (Figure 3).

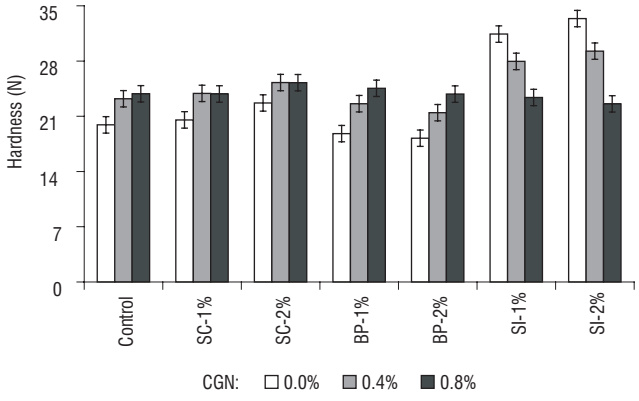

FIGURE 3. Hardness of pork gels as affected by the ingredients (SC – sodium caseinate, BP – blood plasma, SI – soy isolate, CGN – carrageenan). The vertical bar shows the confidence interval (95%).

Treatments with 1 or 2% SP had progressively lower hardness with increasing CGN level, suggesting that soy proteins might have interfered with CGN and this could account for the decrease of gel strength.

Gels processed with CGN were significantly less cohesive (Figure 4) and springy (Figure 5) than control samples without any additives.

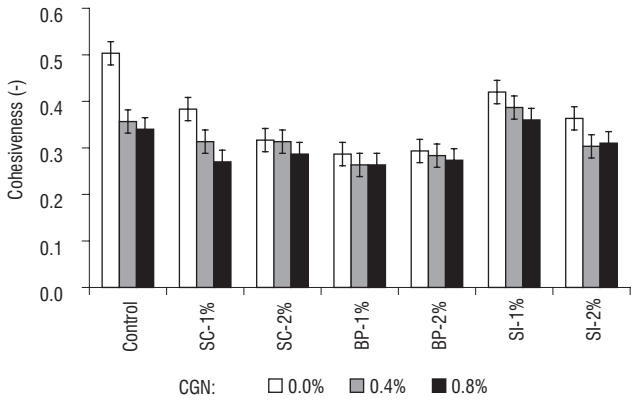

FIGURE 4. Cohesiveness of pork gels as affected by the ingredients (SC – sodium caseinate, BP – blood plasma, SI – soy isolate, CGN – carrageenan). The vertical bar shows the confidence interval (95%).

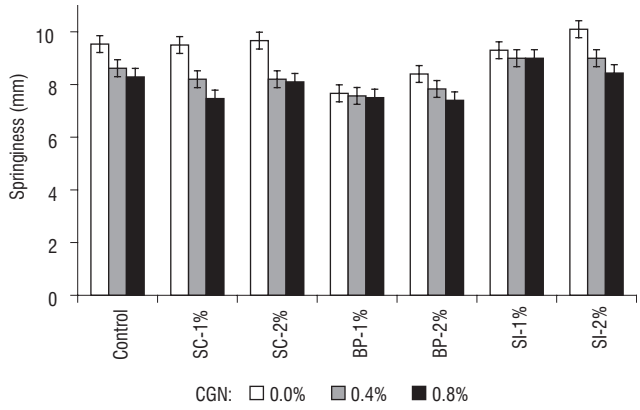

FIGURE 5. Springiness of pork gels as affected by the ingredients (SC – sodium caseinate, BP – blood plasma, SI – soy isolate, CGN – carrageenan). The vertical bar shows the confidence interval (95%).

Carrageenan gel networks are formed by a series of polymer chain associations to give rise to a three-dimensional helix framework [Trius & Sebranek, 1996] and this three-dimensional gel network is introduced into the heat-induced protein gel system. Therefore, carrageenan can increase hardness or stiffness, but cannot dramatically improve springiness or cohesiveness.

The effect of CGN on texture of gels shown in our study was consistent with other published reports. Shand [2000] reported that carrageenan addition decreased cohesiveness but had no effect on hardness of low-fat pork bologna. Addition of CGN at 0.5% level has been reported to increase hardness and chewiness but to decrease cohesiveness of beef gels [Pietrasik & Li-Chan, 2002]. It has also been reported that addition of carrageenan increased gel strength of salt soluble meat protein (SSMP) gels in model systems [DeFreitas *et al.*, 1997], hardness and bind strength of 1% salt beef sausages [Xiong *et al.*, 1999] and hardness of low-fat frankfurters [Candogan & Kolsarici, 2003].

The specific mechanism of CGN effects on meat product texture and interactions in a meat-carrageenan multicomponent gelling system is not fully understood. The effect of CGN addition on texture of comminuted meat products is probably not due to molecular interaction between proteins and the hydrocolloid but rather may be related to physical rearrangement of CGN and meat protein molecules [Bernal *et al.*, 1987; DeFreitas *et al.*, 1997].

Of the NMP used, only addition of sodium caseinate at 2% level and soy protein contributed to improved hardness of meat gels, but the effect was diminished by increased CGN level (Figure 3). The harder texture of gels with SPI could possibly be attributed to greater moisture release during cooking. Increased hardness of reduced-fat meat batters due to SPI has also been reported by Lin & Mei [2000].

Sodium caseinate cannot form self-supporting gels but rather acts as a paste in meat systems, indirectly contributing to water retention and texture of an emulsion [Hermansson, 1976]. However, it increases gel strength and can be regarded as an ingredient that may enhance elasticity of the meat batter [Hoogenkamp, 1992].

Su *et al.* [2000] reported that the hydrated sodium caseinate in the meat batters stabilized the meat emulsions during cooking and contributed to a firmer texture of frankfurters produced with its addition. Hung & Zayas [1992] also reported that shear force and firmness of frankfurters increased as SC was added.

Type of NMP also appeared to affect cohesiveness and springiness. Addition of blood plasma produced the least firm, springy and chewy texture.

Hermansson [1982] found that blood plasma proteins become reactive at temperature above that of meat protein gelation. The fact that blood plasma proteins in a meat batter form a gel too late in the processing to be integrated into the meat protein gel structure may results in mixed gels which are weaker than gels formed by MP alone.

Generally, none of the tested ingredients was able to yield gel cohesiveness equivalent to the control containing 8% muscle proteins (Figure 4).

CONCLUSIONS

Carrageenan favorably affected hydration properties and thermal stability, yielding lower cooking loss and higher water holding capacity for meat gels, but the effects were attenuated by increased NMP addition. Carrageenan also increased hardness of treatments containing sodium caseinate and blood plasma but not soy protein. The combination of carrageenan with NMP was unable to improve springiness or cohesiveness and led to the formation of harder but more brittle gels. Non-muscle proteins differed in their effect on various textural and stability properties, but generally were found to be inferior to CGN for functionality in comminuted meat system. BP and SC either alone or in combination with carrageenan presented superior textural characteristics in comparison to soy protein.

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WŁAŚCIWOŚCI TEKSTURY I ZWIĄZANIE WODY W HOMOGENNYCH ŻELACH MIĘSA ŚWIŃSKIEGO WYTWARZANYCH Z DODATKAMI BIAŁEK NIEMIĘSNYCH I KARAGENU

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Oceniono wpływ udziału karagenu, CGN (0, 0.4, 0.8%) oraz 1 i 2% dodatku trzech rodzajów białek niemięśniowych, NMP (plazmy krwi BP, kazeinianu sodu SC oraz izolatu białek soi SI) na stopień związania wody i parametry tekstury homogennych żeli wytwarzanych z mięsa świńskiego. Wykazano korzystny wpływ dodatku karagenu na stabilność termiczną homogenatów oraz na stopień uwodnienia żeli, odzwierciedlający się zmniejszeniem wycieków cieplnych oraz poprawą zdolności utrzymywania wody. Skutki te były osłabiane w miarę zwiększania dodatków białek niemięsnych. Rosnący udział karagenu powodował wzrost twardości żeli z dodatkami kazeinianu sodu i plazmy krwi, natomiast dla białek soi nie obserwowano tej zmienności. Nie obserwowano poprawy sprężystości i spoistości żeli wytwarzanych z różnymi mieszankami CGN i NMP. Żele te były natomiast bardziej twarde i kruche. Reasumując, wyniki badań wskazują, że ww. funkcjonalne cechy mieszanin białek soi z karagenem w homogennych systemach mięsnych w porównaniu do tych otrzymywanych z udziałem kazeinianu sodu i plazmy krwi są gorsze.