PE4.86 Polyphosphate and Myofibrillar Protein Extract Promote Transglutaminase-mediated Enhancements of Rheological and Textural Properties of PSE Pork Meat Batters 309.00

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Abstract—The aim of the study was to compare functional, rheological and textural properties of batters prepared from normal (RFN) and PSE pork meat with formulations containing basic salt and curing ingredients (control) and/or microbial transglutaminase (TG) and/or polyphosphate (PP) and/or myofibrillar protein (MP, extracted from normal meat). Pork loins were incubated at high temperature 35ºC for 6 h to produce the PSE-like condition. Addition of TG with PP or MP to PSE meat batters enhanced their rheological (storage modulus, G') and textural properties to the level similar to or higher than those of the batters prepared with the basic curing formulations from RFN meat. It is suggested that the rheological and textural properties of denatured proteins in PSE meat can be partly restored by adding ingredients that allow more MP cross-linking by TG.

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Index Terms—PSE pork loin muscle, rheometry, texture, transglutaminase.

I. INTRODUCTION

The occurrence of PSE (pale, soft, exudative) meat is caused by many ante- and postmortem factors, and the reduced quality in PSE meat has a significant, negative economical impact. Genetic, biochemical, metabolic and environmental factors contribute to the problem [1, 2]. Therefore, while it is important to minimize the occurrence of this phenomenon, when PSE incidences do exist, food processors must develop processing strategies to restore the defective PSE meat to the quality level comparable or close to that seen in a normal meat. In particular, innovative ingredient manipulations to improve functional properties of myofibrillar proteins (MP) in PSE meat are highly desirable. There are different methods to improve poor quality of PSE meat, e.g., treatment of the meat by special curing formulations, mixing of PSE meat with normal meat, and adding different ingredients, including polyphosphates, TG, non-meat proteins, and polysaccharides during meat processing. These efforts are mainly directed to enhance functionality of MP which plays an essential role in producing the desirable texture and water binding in comminuted meat products, such as sausages and deli-type meats [3]. The concentration of proteins in formulated gels, batters or sausages strongly influences the protein functional properties. However, it is not always possible to predict these properties inherent to high-protein concentration formulations on the basis of low-protein concentrations that are often adopted in model systems [4]. Therefore, the aim of the present study was to estimate the effect of microbial transglutaminase (TG) alone or in combinations with sodium pyrophosphate (PP) and/or myofibrillar protein (MP) extracted from normal meat on rheological and textural properties of batters prepared from normal and PSE pork meat. The study tested the hypothesis that TG, PP and MP can enhance the rheological and textural properties of PSE pork meat batters to the level equal or higher to those of normal meat.

II. MATERIALS AND METHODS

A. Experimental design

Two repeated experiments were performed; in each, loins (Longissimus lumborum) were excised from one side of carcasses of two different pigs 30 min postmortem. Loins were divided into two equal parts and then stored, respectively, at 4ºC for 24 h (RFN), and 35ºC for 7 h followed by 4ºC for 17 h (PSE). Each loin was then sliced into ~1 cm-thick chops and the color parameters (Hunter colorimeter) were measured. Thereafter, PSE and RFN pork chops were placed in Cryovac bags, vacuum sealed, and stored in a -80°C freezer until use in less than 3 months. From the four loin samples collected (two from each independent experiment) and processed, duplicate RFN and PSE chops were analyzed for pH at 2 h and 24 h postmortem and for Hunter L* at 24 h postmortem. PSE samples had lower pH values than RFN after 2 h

(5.46/5.74) and higher L* values 24 h postmortem (54.9/49.1 and 58.1/53.0, respectively), indicating a PSE-like condition in the 35ºC treatment samples. Frozen meat was thawed at 4ºC overnight. Both RFN and PSE meat was trimmed of visible fat and connective tissue and then ground in a laboratory grinder through a 3 mm orifice plate. In four replications (two for 1st experiment and two for 2nd experiment) batters were prepared from RFN meat (control; TG; TG+PP) and PSE meat (control; TG; PP+TG; MP+TG). MP was extracted from RFN meat.

B. Preparation of raw and cooked meat batters

Three different RFN meat batters (RFN Control; RFN treated with TG; RFN treated with PP+TG) and four PSE meat batters (PSE Control; PSE treated with TG; PSE treated with PP+TG; PSE treated with MP+TG) (Table 1) were formulated as described below. First, MP was prepared from RFN meat at 2ºC according to Xiong [5]. For all batter processing, raw meat was chopped for 1 min. After addition of cold water with dissolved basic curing ingredients (NaCl, sodium nitrite, sodium erythorbate) and PP or MP, chopping was continued for 1 min. Meat homogenates were then blended with 0.5% TG for 1.5 min. Total mixing time was standardized to 3.5 min and the final temperature was below 10ºC in all cases. For MP treatment, the amount of added water and MP were calculated depending on MP concentration to maintain the constant close to 15% protein concentration in meat batters. Final meat batters (50 g each) were stuffed into two cylindrical plastic tubes (26 mm x 102 mm), which were closed with a lid, and centrifuged for 1 min at 2000 x g at 2ºC to remove air pockets. The batters were stored at 4ºC for 4 h to allow TG action before being subjected to cooking. Cooking, which transformed the meat batter pasts into gels, was done in a water bath that was heated from 20 to 76ºC at 1ºC/min. Cooked batters were cooled to rom temperature (20ºC) before textural evaluation as described below.

C. Dynamic rheological testing of raw meat batters

Rheological properties of raw RFN and PSE meat batter samples during thermal gelation were measured with the Bohlin VOR rheometer in an oscillatory mode equipped with two parallel plates set at 1 mm apart [5]. The meat batter gels were produced by heating from 20 to 76ºC at a heating rate of 1ºC/min, during which the samples were sheared at a constant frequency of 0.1 Hz with a maximum strain of 0.02. Changes in the storage modulus (G´, i.e. rigidity due to elastic response of the material) were recorded.

D. Textural properties of cooked batter gels

Textural profile analysis of cooked batters was performed using an Instron machine (Model 4301). Eight cores (diameter = 25 mm, height = 15 mm) of cooked samples from control and each treatment batter were compressed in two consecutive cycles to 20% of their original height between two parallel plates at a constant cross-head speed of 60 mm/min to measure hardness (the peak force required for the first compression). To determine breaking strength, eight samples of cooked batters (25 mm x 15 mm) were compressed all the way until the structure was disrupted. The breaking force was used to represent the breaking strength.

E. Statistical analysis

All the results were analyzed statistically using Statistica 8.0 program with one-way analysis of variance at the significance level of P≤0.05.

III. RESULTS AND DISCUSSION

The shear storage modulus (G´) increased during heating of the meat batters (data not shown). The value of G´ at the maximum transition temperature (49.9ºC) indicates the magnitude of the increase in the dynamic elasticity of the gelling batter, and the final G´ at the end of heating (76ºC) reflects the gel elasticity at the equilibrium. The specific G´ values for RFN and PSE meat batters are presented in Table 2. Incorporation of TG in the presence and absence of PP and MP into RFN or PSE meat batters promoted gelation, which was evident by the rapid development in G´ after 49.9ºC. The G´ values of PSE control meat batter and that with TG at temperature 49.9ºC were similar (P>0.05) to those of the corresponding RFN samples. The values of PSE gels at 76ºC were numerically lower than those of RFN samples; however, the differences were not significant. The G´ values of PSE meat batters with PP+TG at both the peak (49.9ºC) and the final (76ºC) temperatures were also not significantly different from that for RFN meat batters. The replacement of a small amount of PSE meat by MP extracted from RFN meat plus TG slightly enhanced the elasticity characteristics of the resulting PSE meat batters when compared with the control treatment. Unexpectedly, MP and TG together were not found to have a synergistic effect because G´ values for PSE meat batters with TG alone and with MP+TG were not

significantly different from each other. Differing from the dynamic rheological testing results, the breaking forces of cooked RFN control and PP+TG treatment meat batters were significantly higher than those of the counterpart PSE samples. Furthermore, the addition of TG or MP+TG to PSE meat batters improved the gel breaking forces to the level comparable ($P>0.05$) to those of control and TG-treated RFN batters. The textural improvements detected by the Instron compression test but not by the Bohlin dynamic rheological measurement can be explained because the former was done with set gels (cooled to room temperature after heating to 76ºC) whereas the latter tested the rheology of the gelling paste, not the final gel network strength. The incorporation of PP+TG to RFN and PSE meat batters resulted in exponential increases in gel breaking force in comparison with the controls or batters with TG only or with MP+TG. The result indicated that PP was critical in the extraction of myofibrillar proteins that served as the substrate for TG. On the other hand, cooked PSE meat batters with TG or PP+TG had significantly higher hardness than corresponding RFN batters. Both the additions of TG and MP+TG to PSE meat batters improved hardness in comparison with the PSE control batter. While TG had no effect ($P>0.05$) on cooked RFN batter hardness, it improved PSE batter harness by 15% ($P<0.05$). Hardness, like breaking force, of cooked RFN and PSE meat batters with PP+TG, was significantly higher than that from RFN and PSE control or with the addition of TG samples, respectively.

IV. CONCLUSION

Rheological properties of PSE pork meat batters with the addition of TG/MP+TG and PP+TG were similar to those of RFN pork meat batters produced with TG and PP+TG, respectively. Hardness of cooked PSE meat batters with TG and PP+TG was significantly higher than that of respective RFN meat batters. It is suggested that TG, PP and MP alone or in combinations have a positive impact on the textural qualities of PSE meat batters. On the other hand, cooked PSE meat batters with TG and PP+TG had a higher cooking loss (data not presented) and lower breaking force than that for cooked RFN meat batters. PSE and RFN cooked meat batters with PP+TG were darker (lower L* values) in comparison with other batter samples. The rheological, structural and technological properties of cooked PSE meat batters treated with MP+TG were similar in most cases to cooked PSE meat batters containing only added TG. More research should be conducted to reduce cooking loss of PSE pork meat batters; this can be done by adding ingredients that would work synergistically with TG and PP.

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Table 1. Formulation (g/100g batters) of samples from RFN and PSE pork meat

Treatment[1]	TG	Meat MP	Total	Water	NaCl	N/E[2]	TTP
	g/%	g/%	g/%	g/%	g/%	g/%	g/%
RFN Control		62.50		35.93	1.5	x	-
	0.0	-	100				
RFN TG		62.50		35.43	1.5	x	-
	0.5	-	100				
RFN PP +TG		62.50		34.93	1.5	x	0.5
	0.5	-	100				
PSE Control		62.50		35.93	1.5	x	-
	0.0	-	100				
PSE TG		62.50		35.43	1.5	x	-
	0.5	-	100				
PSE PP + TG		62.50		34.93	1.5	x	0.5
	0.5	-	100				
PSE MP + TG		54.17		24.12	1.5	x	-
	0.5	19.64	100				

[1] TG: transglutaminase; PP: polyphosphate; MP: myofibrillar protein (amount of meat and water in formulation depends on the protein concentration in MP).
[2] N/E: sodium nitrite 0.0156g/100g, mixed with sodium erythorbate ($C_6H_7NaO_6$) 0.055g/100g.