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Summary and Implications

Heating pork skin connective tissue (PCT) obtained from pork carcasses may enhance its water binding ability due to partial conversion of connective tissue collagen to gelatin. Upon cooling, the protein gel partially reforms, and may entrap added water. Incorporation of this recovered protein as a high added-water gel in reduced-fat products may improve product juiciness and palatability. The objectives of this study were to determine temperature and time variables that enhance conversion of connective tissue collagen to gelatin and determine basic properties of high added-water pork skin connective tissue gels. Heating PCT at 158°F for 30 minutes released more gel-water indicating conversion of connective tissue to gelatin. Added water (AW) levels of 100, 200, 300, 400, 500 and 600% were used to determine the water binding ability of heated PCT. Soluble collagen of these gels ranged from 100 to 25 mg/g, allowing the production of stable protein gels with as much as 600% AW. Increasing added water levels softened gel texture and lightened gel color. The potential exists to incorporate high added-water PCT gels into reduced-fat pork products to enhance product attributes.

Introduction

Reduction of fat in processed meats causes problems with product toughness, texture, flavor, juiciness, and color. Regardless of how important diet and health issues are to consumers, reduced-fat products will not be purchased if they have unacceptable palatability or appearance. Current technologies for fat replacement include adding water, protein-based, carbohydrate-based, or synthetic compounds, alone or in combination. The addition and retention of water by these fat replacers is effective in improving the palatability attributes of reduced-fat meat products. Pork skin connective tissue (PCT), a by-product of pork fabrication operations, may be used as a potential water binder to replace fat in reduced-fat meat products. The mechanism for this improvement may lie in the thermal denaturation of collagen during heating and its conversion to gelatin, a water binding agent. This study consisted of two experiments. The objective of Experiment I was to determine temperature and time variables that enhance conversion of pork connective tissue to gelatin. The objective of Experiment II was to determine basic properties of high added-water pork connective tissue gels.

Procedures

Experiment I

Pork skin connective tissue (PCT) was obtained by removing the skin from the loin, shoulder and ham regions of pork carcasses of market weight (about 220 lb) hogs. The skins were hand-scraped with a boning knife to remove excess subcutaneous fat and cut into strips approximately two inches wide and ten inches long. The strips of skin were frozen, coarse ground, refrozen, and flaked in an Urschel Comitrol. The PCT samples were placed in tubes (three per temperature x time combination) which were heated in a water bath at a single temperature (122, 140, 158 or 176°F) and removed at a specified time period (0.5, 1.0, 1.5 or 2.0 hours). Fluids released from each sample were decanted into graduated tubes. Each temperature x time treatment combination was averaged and reported as mL released fluids per 100 g sample. The experiment was designed as a split plot with a 4 x 4 factorial arrangement of treatments. Water bath temperature was the whole plot factor and time period the split plot factor. The experiment was replicated twice (n = 32).

(Continued on next page)

Table 1. Treatment formulations for the manufacture of PCT gels (Experiment II).

Treatment	Connective Tissue	Added Water
1	250 g	250 g (100%)
2	167 g	334 g (200%)
3	125 g	375 g (300%)
4	100 g	400 g (400%)
5	83 g	415 g (500%)
6	71 g	426 g (600%)

Experiment II

The PCT described in Experiment I was used to determine its ability to form a gel and bind added water. Appropriate amounts of PCT and distilled, deionized water were combined in 600 mL beakers to produce PCT gels weighing about 500 g and containing 100, 200, 300, 400, 500 or 600% added water (AW) (Table 1).

Based on the results from Experiment I, PCT x water treatments were heated at 158°F for 30 min. To enhance the uniform dispersion of flaked PCT throughout the PCT gel matrix, the beakers were removed from the water bath, placed on stirring plates and mixed with stir bars in a refrigerated cooler (43±2°F) at high speed until the gels thickened. The pH of each PCT gel was determined. Samples were obtained from each PCT gel treatment and used for HunterLab Colorimeter analysis (Illuminant A, 2° standard observer). Readings for HunterLab L* (lightness), a* (redness), and b* (yellowness) values were taken. The textural parameters of hardness, cohesiveness, springiness and chewiness were also determined per gram of gel. Analysis for hydration, a measure of water binding, was determined by dividing the amount of water retained by the amount of connective tissue contained in the gel sample, which varied among treatments (Table 1) and was expressed as g water held/g wet tissue. Variability in total amount of PCT contained in each gel treatment was accounted for by expressing hydration on a fat-free basis. Cook stability was determined by placing samples into a 120°F water bath and gradually increasing the water bath temperature until the internal sample temperature reached 156°F within 1.25 to 1.50 hours. The free liquid was decanted and cook stability expressed on a sample percentage and fat-free PCT basis. The experiment was designed as a randomized complete block design with a single factorial (AW) treatment. The experiment was replicated three times (n = 18).

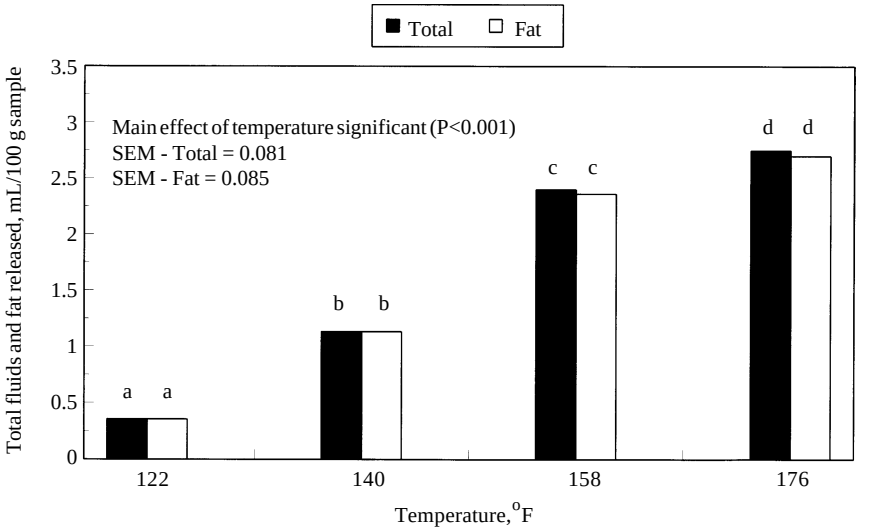

Figure 1. Main effect of temperature on total fluids and fat released from flaked, pork skin connective tissue heated at four temperatures. SEM = standard error of the mean.

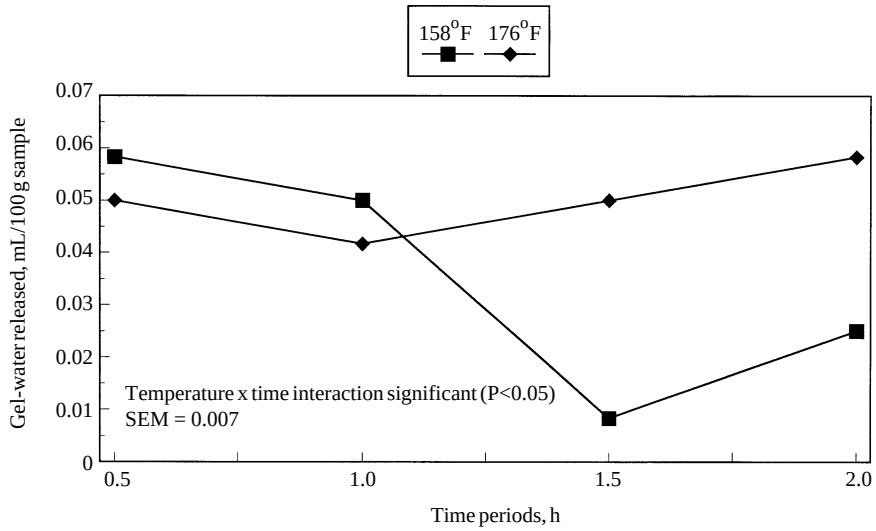

Figure 2. Lease squares means separation for released gel-water at 158 and 176°F within each time period for flaked, pork skin connective tissue. SEM = standard error of the mean.

Results and Discussion

Experiment I

The main effect of temperature increased (P<0.001) the volume of released total fluids and fat (Figure 1). A temperature x time interaction (P<0.05) existed for PCT for released gel-water (Figure 2). No gel-water was released at 122 or 140°F, indicating that these temperatures where not high enough to cause solubilization of pork skin connective tissue collagen to gelatin. Volumes of released gel-water were similar for PCT heated at 158 and 176°F, indicating solubilization of collagen to gelatin. Similar volumes of gel-water was released by PCT at 0.5 h for 158 and 176°F and at 1.5 and 2.0 h for 176°F (Figure 2). The observed decrease in released gel-water at 158°F as time periods increased may be due to the binding of water by solubilized connective tissue, thereby lowering the

Table 2. Proximate composition, soluble collagen content, hydration, and cook stability for high-added water pork connective tissue gels.

		Added Water Treatments (%)					
	SEM	100	200	300	400	500	600
Proximate composition (%)							
Moisture	0.66	71.33^{e}	80.47^{d}	86.81^{c}	89.62^{b}	90.40^{b}	92.81^{a}
Fat	0.56	12.17^{a}	6.90^{b}	4.30^{c}	3.89^{cd}	2.52^{de}	1.67^{d}
Protein	0.45	14.31^{a}	10.37^{b}	8.40^{c}	6.91^{d}	5.38^{e}	4.68^{e}
Collagen content (mg/g)							
Soluble	4.22	101.86^{a}	72.41^{b}	51.15^{c}	39.10^{cd}	32.92^{de}	23.46^{e}
Hydration (g H_2O held/g tissue)							
Sample	0.010	0.99^{ab}	2.02^{a}	2.95^{b}	3.89^{c}	4.79^{c}	5.53^{d}
Fat-free basis	0.016	1.13^{f}	2.17^{e}	3.09^{d}	4.04^{c}	4.92^{b}	5.63^{a}
pH	0.39	7.42^{c}	7.53^{bc}	7.69^{a}	7.61^{ab}	7.67^{a}	7.68^{a}
Cook stability (%)							
Sample	3.55	88.16^{a}	79.00^{a}	49.78^{b}	33.16^{c}	28.16^{c}	26.47^{c}
Fat-free basis	3.58	93.87^{a}	80.85^{b}	50.32^{c}	33.42^{d}	28.28^{d}	26.53^{d}

$^{a-e}$Means within row with different superscripts are different (P<0.05).

Table 3. Color values and textural attributes for high-added water pork connective tissue gels.

		Added Water Treatments (%)					
	SEM	100	200	300	400	500	600
Color							
Lightness (L*)	0.96	65.83^{b}	72.78^{a}	66.85^{b}	62.28^{c}	60.09^{c}	59.45^{c}
Redness (a*)	0.15	4.09^{a}	3.32^{b}	1.39^{c}	-0.32^{d}	-0.58^{e}	-1.19^{f}
Yellowness (b*)	0.27	10.77^{a}	10.03^{a}	6.63^{b}	4.29^{c}	2.17^{d}	0.80^{e}
Textural attributes							
Cohesiveness/g	0.013	0.112	0.093	0.084	0.074	0.067	0.071
Hardness (N/g)	3.08	136.62^{a}	76.72^{b}	41.98^{b}	22.02^{b}	13.55^{de}	7.68^{e}
Springiness (mm/g)	0.251	4.24	4.71	5.49	4.98	5.26	4.97
Chewiness (J/g)	3.025	64.53^{a}	34.32^{b}	20.30^{c}	8.19^{d}	4.93^{d}	2.98^{d}

$^{a-e}$Means within row with different superscripts are different (P<0.05).

amount of gel or water released from the PCT sample. Based on the results of Experiment I, it was concluded that heating PCT at a temperature of 158°F for approximately 30 min is sufficient to convert collagen to gelatin, thereby enhancing its potential capacity to bind added water.

Experiment II

Added water (AW) decreased (P<0.05) percent fat and protein, and increased moisture content (Table 2). Percentages ranged from 12.17 to 1.67% (fat), 14.31 to 4.68% (protein) and 71.33 to 92.81% (moisture), for 100 and 600% AW, respectively. The addition of water affected gel pH (P<0.05) with values ranging from 7.42 to 7.69. Increasing water decreased (P<0.05) soluble collagen content, with values ranging from 101.86 to 23.46 mg/g (100 and 600% AW, respectively). As AW increased, the amount of water bound (hydration) increased (P<0.05) from 0.99 (100 and 200% AW) to 5.53 (600% AW) grams of water held per gram of gel tissue. Expressed on a fat-free basis, hydration values ranged from 1.13 to 5.63 grams of water held per gram of PCT. Cook stability values decreased (88.16 to 26.47%) for 100 and 600% AW treatments, respectively, indicating solubilization of gelatin and subsequent release of water (Table 2).

Higher AW increased (P<0.05) L* (lightness) for 100, 200 and 300% AW treatments, but decreased for the remaining gel treatments (Table 3). Values for a* (redness), and b* (yellowness) decreased (P<0.05) as AW increased. Added water decreased (P<0.05) hardness and chewiness values per gram of gel, with 100% AW treatment approximately two times harder (136.62 N) than 200% AW treatment (76.72 N). Added water had no effect on cohesiveness or springiness. Springiness values ranged from 5.49 (300% AW) to 4.24 mm per gram (100% AW), while cohesiveness values ranged from 0.11 (100% AW) to 0.07 (600% AW) per gram (Table 3).

Based on the results from Experiment II, heating PCT allowed the production of high added-water protein gels. Softer texture, lighter color and ability to hold almost six times its weight in added water (hydration) and retain as much as 50 to 90% of this added water after reheating (cook stability) was observed for gels containing 100 to 300% AW. These functional properties may enhance overall product attributes if these protein gels are incorporated into reduced-fat products.

Results from this study indicate the feasibility of heating recovered pork connective proteins to form protein gels capable of binding large amounts of added water. The mechanism for this increase in water binding capacity appears to be due to the large amount of soluble collagen (gelatin) contained in these gels. Improvements in texture, color and palatability may result from the addition of gelatinized pork skin connective tissue protein gels into reduced-fat pork products. Additionally, economic benefits may be realized by using pork skin connective tissue protein gels to replace a percentage of the expensive lean tissue required for many reduced-fat pork products.

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