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Summary

Heating beef connective tissue (BCT) from desinewing operations may enhance its water binding ability due to partial conversion of connective tissue collagen to gelatin. Upon cooling, the gelatinized protein gel partially reforms, and may further entrap added water. Incorporation of this recovered protein as a gel in low-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 (Experiment I) and determine basic properties of high added-water beef connective tissue gels (Experiment II). Heating BCT at 158°F for 30 min released less gel-water and fat indicating binding of fluids by gelatin. Added water levels of 100, 200, 300, 400, 500 and 600% were used to determine how much water heated BCT could bind. Soluble collagen levels averaged 7% allowing the production of stable protein gels with as much as 400% AW.

Increasing added water levels softened gel texture and lightened gel color. The potential exists to incorporate high added-water BCT protein gels into low-fat beef products to enhance product attributes.

Introduction

Research in fat reduction of processed meats has recognized problems associated with removal of fat: toughness, rubbery texture, lack of flavor and juiciness, and a darker color. Regardless of the importance of diet and health issues to consumers, low-fat products will not be purchased if they have unacceptable palatability or appearance. Current technologies for fat replacement include the addition of 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 low-fat meat products. Beef connective tissue (BCT), a byproduct of desinewing operations, may be used as a potential water binder to replace fat in low-fat meat products. The mechanism for this improvement may lie in the thermal denaturation of collagen during cooking 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 beef connective tissue to gelatin. The objective of Experiment II was to determine basic properties of high added-water beef connective tissue gels.

Procedure

Experiment I

Beef connective tissue (BCT) that had been passed through a desinewing machine twice was obtained from a commercial beef slaughter facility. The BCT was frozen, coarse ground (0.5 in), refrozen and flaked (0.06 in) in an Urschel Comitrol, double bagged in polyethylene plastic bags and frozen (-26°F) until analyzed for proximate composition and released fluids. The BCT samples (17 g) were placed in tubes, 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). Additional BCT samples were used to monitor temperature by placing a thermocouple in the geometric center of the "test" samples. Time did not begin until the samples reached the appropriate internal temperature. Water bath and sample temperatures were monitored every 10 min and adjusted as necessary. Fluids released from each sample were decanted into graduated tubes, and the tubes centrifuged for 10 min at 5500 rpm. Total fluids, fat, gel-water and solids released were recorded. 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 × 4 factorial arrangement of treatments. Water bath temperature was the whole plot factor and time period the split plot factor. Fishers Least Significant Difference was used to separate significant main effects and interactions. The experiment was replicated twice (N = 32).

Experiment II

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

Based on the results from Experiment I, BCT x water treatments were heated at 158°F for 30 min. 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 and the stir bars could not move. This was done to enhance the uniform dispersion of flaked BCT throughout the BCT gel matrix. The stir bars were removed, beakers covered with parafilm and remained refrigerated 8-10 hr until analyzed. The pH of each BCT gel was determined. Samples were obtained from each BCT gel treatment by pushing a stainless steel coring device down the long axis of the gel to produce a sample cylinder that was then into 0.5 inch sections, producing samples measuring 1 inch (diameter) x 0.5 inch (height). Three sub-sample discs were used for HunterLab Colorimeter analysis (Illuminant A, 2° standard observer). One reading was taken on each surface of the sample discs for HunterLab L* (lightness), a* (redness), and b* (yellowness) values. Three sub-sample discs were used to compress each sample twice to 25% of average sample height. Hardness, cohesiveness, springiness and chewiness were determined. Analysis for hydration, a measure of water binding, was conducted by removing duplicate 25 gram (g) subsamples, placing them in centrifuge tubes and centrifuging at 15,000 rpm for 15 min at 36°F. Samples were removed and the expressed fluids collected. Hydration of each sample was determined and expressed as g water held/g wet tissue. Variability in total amount of BCT contained in each gel treatment was accounted for by expressing hydration on a fat-free basis. Cook stability was determined by placing 25 g samples into tubes, placing them in a 120°F water bath, and heating until the internal 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 BCT basis. The experiment was designed as a randomized complete block design with a single factorial (AW) treatment design. Fishers Least Significant Difference was used to separate significant main effects. The

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Table 1. Treatment Formulations for the Manufacture of BCT 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 was replicated three times (N = 18).

Results and Discussion

Experiment I

Proximate analysis showed BCT composition to be 56.92% moisture, 18.47% fat and 25.49% protein. A temperature x time interaction ($P<0.01$) existed for BCT for total released fluids (Figure 1) and released gel-water ($P<0.01$) (Figure 2). Less total fluids were released from BCT at 158°F than the other temperatures. The main effect of temperature was significant for released fat. No fat was released at 140 or 158°F (Data not shown). The observed decrease in released fluids may be due to conversion of connective tissue collagen to gelatin, which may absorb any moisture and fat released from the BCT sample. Least squares means of temperature x time interaction within the 158°F treatment means for each time period indicated no significant differences for released gel-water (Figure 2). Based on the results of Experiment I, it was concluded that heating BCT 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 percent fat and protein, while increasing moisture content. Percentages ranged from 7.88 to 2.66% (fat), 14.31 to 4.68% (protein) and 80.27 to 94.00% (moisture), for 100 and 600% AW, respectively. The addition of water did not effect gel pH. Increasing water decreased soluble collagen content, with values ranging from 14.94 to 0.67 mg/g and total collagen content from 85.69 to 27.18 mg/g (100 and 600% AW, respectively). Percent soluble collagen values ranged from 17 to 2% among the gel treatments (average value of 7.01%), indicating similar conversion of collagen to gelatin among treatments. As AW increased, hydration values increased ($P<0.0001$) from 0.95 (100% AW) to 2.88 (600% AW) g water held per g tissue. Fat-free hydration values increased ($P<0.0001$) from 2.37 (100% AW) to 4.71 (600% AW) g water held per g tissue. Cook stability values decreased (82.97 to 26.77%) for 100 and 600% AW treatments, respectively, indicating solubilization of gelatin and subsequent release of water. AW did not affect cook stability expressed on a BCT fat-free basis. Values ranged from 49.86% (100% AW) to 43.26% (600% AW) (Table 2). Only the 100, 200, 300 and 400% AW treatments produced gels firm enough to analyze for color and texture. Higher AW resulted in a linear decrease in L* (lightness), a* (redness),

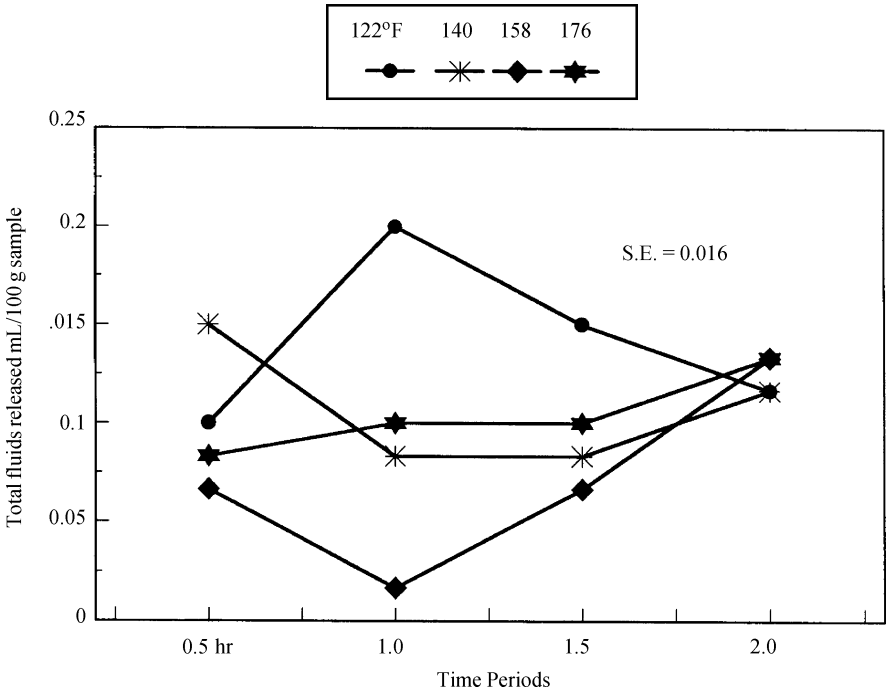

Figure 1. Least squares means separation for temperature ranges within each time period.

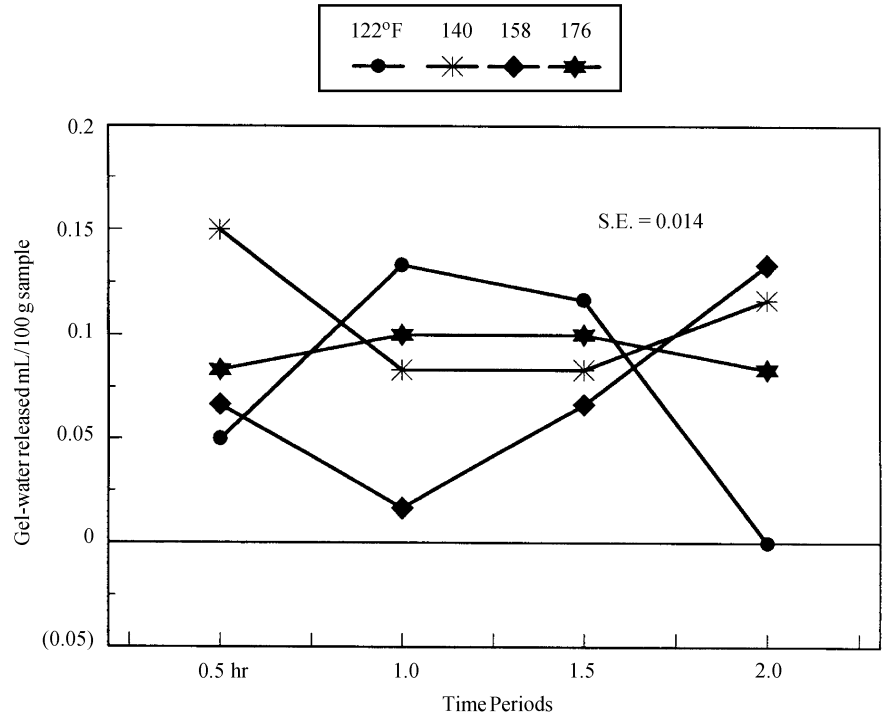

Figure 2. Least squares means separation for temperature ranges within each time period.

Table 2. Proximate Composition, Collagen Content, Hydration, and Cook Stability for High-Added Water Beef Connective Tissue Gels[f].

	Added Water Treatments (%)						
	SEM	100	200	300	400	500	600
Proximate Composition (%)							
Moisture	0.42	80.27[a]	85.48[b]	90.31[b]	91.67[cd]	93.12[d]	94.01[d]
Fat	0.28	7.88[a]	6.29[b]	4.41[c]	3.57[cd]	3.12[d]	2.66[d]
Protein	0.40	14.31[a]	10.37[b]	8.40[c]	6.91[d]	5.38[e]	4.68[e]
Collagen Content (mg/g)							
Total	4.44	85.69[a]	68.41[b]	51.70[c]	39.60[cd]	31.10[d]	27.19[d]
Soluble	0.73	14.94[a]	6.60[b]	5.10[c]	1.53[cd]	0.84[cd]	0.67[d]
Insoluble - (By difference)		70.75	61.81	48.60	36.03	30.26	26.52
% Soluble		17.43	9.64	5.99	3.86	2.70	2.46
Hydration (g H_2O held/g tissue)							
Sample	0.10	0.95[a]	1.82[b]	1.99[bc]	2.19[cd]	2.44[d]	2.88[e]
Fat-Free	0.15	2.37[a]	3.42[b]	3.71[b]	3.87[bc]	4.25[cd]	4.71[d]
Cook Stability (%)							
Sample	1.86	82.97[a]	58.67[b]	47.55[c]	36.48[d]	30.14[e]	26.77[e]
Fat-Free	1.86	49.86[a]	46.42[a]	43.47[b]	45.40[ab]	44.10[ab]	43.26[b]

[a-e]Means within row with different superscripts are different (P<0.05).

Table 3. Color Values and Textural Attributes for High-Added Water Beef Connective Tissue Gels.

	Added Water Treatments (%)				
	SEM	100	200	300	400
Color					
L *	0.84	63.12[a]	58.88[b]	59.15[b]	57.24[b]
a *	0.24	7.06[a]	5.29[b]	3.83[c]	2.95[d]
b *	0.14	6.17[a]	5.28[b]	4.58[c]	4.25[c]
Textural Attributes					
Cohesiveness	0.015	0.19[a]	0.13[b]	0.08[c]	0.11[bc]
Hardness (N)	11.31	52.17[a]	12.95[b]	4.38[b]	1.16[b]
Springiness (mm)	0.76	21.61[a]	13.40[b]	5.18[c]	3.36[c]
Chewiness (J)	0.061	0.25[a]	0.02[b]	0.002[b]	0.0007[b]

[a-e]Means within row with different superscripts are different (P<0.05).
[f]Sample temperatures for color and texture profile analysis were 36°F.

and b* (yellowness) values and tended to cause gels to become less cohesive and less springy. Added water decreased hardness values (P<.10), with 100% AW treatment approximately 4X harder (52.17 N) than 200% AW treatment (12.95 N). Chewiness values decreased linearly with increasing amounts of water (Table 3).

Based on the results from Experiment II, heating BCT increases its water binding capacity, allowing production of high added-water protein gels. The softer texture, lighter color and water binding capacity of these protein gels may enhance overall product attributes if incorporated into low-fat products.

Results from this study indicate the feasibility of heating recovered beef 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 conversion of ~7% of the connective tissue collagen to gelatin. Improvements in texture and color and palatability may result from the addition of gelatinized beef connective tissue protein gels into low-fat beef. Additionally, economic benefits may be realized by using beef connective tissue protein gels to replace a percentage of the expensive lean tissue required for many low-fat beef products.

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