Bovine Hide Collagen as a Protein Extender in Bologna

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Story in Brief

Slaughter of beef animals in the U.S. yields approximately 1.5 million tons of hide each year. The price paid for the "flesh" splits varies considerably; periods of low demand result in underutilization. Periods of low price have encouraged investigations into alternate uses for these splits. The USDA Eastern Regional Research Center has developed a process to manufacture foodgrade collagen from the "flesh" splits. This research reports the use of food-grade collagen to replace a part of lean meat in bologna formulations.

Coarse bologna was made with 0, 10, 20 and 30 percent replacement of lean meat with fibrous collagen. In the fine emulsion bologna, lean meat was replaced with fibrous collagen at 0, 4.7, 8.9 and 12.8 percent levels. Crude protein, lipid, moisture, pressed fluid, cooking loss, emulsion stability, pH, color and shear studies were conducted.

No adverse effects of added collagen were found on shrinkage, volume change, emulsion stability, free and total water or fat and protein content of coarse bologna as compared to that of control. Significant objective color and textural changes were noticed in the product with higher levels of collagen. However, such changes were not apparent upon visual inspection.

Replacement of lean meat with hide collagen in the fine emulsion bologna did not significantly affect the lipid, moisture, or crude protein in the raw or cooked emulsion. The pH, pressed fluid, cooking loss and color differences due to collagen replacement were also not significant. However, the peak force required to shear the bologna slices increased significantly but no visible textural changes were evident. Collagen also significantly decreased emulsion stability but not below acceptable levels.

Based on these results it was concluded that the use of bovine hide collagen in coarse bologna and fine emulsion bologna is feasible.

Introduction

Sausage products such as weiners and bologna are frequently made with less tender cuts (more collagen). Partially defatted tissue high in collagen is a common ingredient in such products. Sausage manufacturers use meat with high collagen content to reduce processing costs. However, the collagen content is often limited to 12 to 15 percent of the total meat ingredients to avoid major defects in the final product such as gel-pockets, gel-caps and poor peelability. Satterlee et al. (1973) reported the use of limed bovine flesh splits in sausage as a binder-extender. They found that hydrolyzed collagen preparations could be used to replace nonfat dried milk in meat emulsion. Whitmore et al. (1970) suggested that the binding and texturizing properties of fibrous collagen may have other functions in food. Elias et al. (1970) pointed out some possible use of collagen in fiber or granular form in meat products.

A process has been developed for the production of fibrous collagen from bovine hide for food uses (Komanowsky et al., 1974) which ensures its availability on a commercial scale. The use of this food-grade collagen as a protein extender offers great potential for the meat industry in the area of processed meats. The utilization of collagen in sausage would be advantageous from a labeling point of view since it could be listed under beef. This research reports the effects of food-grade fibrous collagen when used as a protein extender in coarse bologna and in a fine emulsion bologna.

Materials and Methods

Coarse bologna

Ground beef from a canner grade cow carcass and food-grade bovine hide collagen (USDA Eastern Regional Research Center, Philadelphia, Pennsylvania) having an average moisture content of 78.2 percent and an average solids content of 21.8 percent were the raw materials used. The chilled boned meat (48 hr postmortem) was ground (.54 cm plate) and blended in a paddle type mixer, frozen and stored at −20°C until use. The frozen ground beef and collagen were thawed overnight at 3.3°C. Food-grade collagen was added to the ground beef at levels of 0, 10, 20 and 30 percent (Table 1). The meat and collagen were mixed and ground twice (.32 cm plate), spices and water were added and the product was mixed for 5 minutes in a paddle type mixer. The seasoned batter was held in a cooler at 3.3°C for 22 hours and then stuffed into #2.5 Union Carbide fibrous casings using a Vogt hand stuffer, making approximately 1000 g sticks of bologna.

Table 1. Formulation of coarse bologna sausage, containing different levels of food-grade fibrous bovine hide collagen

Collagen %	Collagen added g	Ground beef g	Fat added g
0	0	4471.90	68.10
10	340.50	4063.30	136.20
20	681.00	3586.60	272.40
30	1021.50	3132.60	385.90

Each of the four batches was added with the following spices and additives: salt 136.0 g; white pepper 16.8 g; coriander 5.6 g; allspice 2.8 g; sage 2.8 g; garlic powder 0.7 g; onion powder 1.4 g; sodium nitrite 0.45 g; erythorbate 2.5 g; water (5 C) 1026 g. Lean: fat ratio was kept constant at 75:25.

Just before stuffing, samples were taken for emulsion stability of the batter. Each bologna stick was marked to keep the identity of front and back end to ensure that all the bologna sticks were placed in the oven for cooking in the same manner, and to ensure that slices were cut from identical locations for color and texture studies. The bologna was cooked in a Blodget convection air oven by following a heating schedule of 54.4°C for the first 90 minutes, 65.5°C for the next 60 minutes, 71.1°C for the next 60 minutes and 76.6°C for about 30 minutes until an internal temperature of 68°C was reached. The internal temperature was recorded by inserting thermocouples to the geometrical center of the product.

Table 2. Functional and chemical characteristics of cooked, coarse bologna containing different levels of food-grade bovine hide collagen

Characteristics	Food-grade hide collagen			
	0%	10%	20%	30%
Percent shrinkage[a]	7.19± 0.07	7.58± 0.13	7.51± 0.47	7.47± 0.38
Volume change[b]cc	9.37± 1.76	10.84± 2.54	9.07± 3.50	9.50± 1.84
Emulsion stability of raw[c]	5.63± 1.22	6.63± 0.52	6.75± 0.51	7.15± 2.63
Expressible juice[b]	54.60± 30.40	54.80± 20.60	54.60± 28.20	56.26± 37.20
Percent moisture[b]	62.23± 0.38	62.05± 0.31	62.36± 0.45	63.22± 0.84
Percent protein[b]	13.92± 0.09	13.67± 0.05	13.84± 0.12	14.04± 0.05
Percent fat[b]	20.24± 0.59	20.81± 3.18	19.81± 4.94	19.21± 1.28
Color value				
L value[b]	41.34± 0.64	41.98± 0.65	42.66± 0.99	42.52± 0.68
a value[b]	10.67± 0.28	10.52± 0.35	9.86± 0.64	9.43± 0.22
b value[b]	7.65± 0.22	7.67± 0.19	7.50± 0.19	7.43± 0.14
Texture				
Peak force[b] kg-f	22.69± 2.82	19.38± 2.94	21.40± 2.59	20.19± 2.54
Peak area[b] cm^2	2.30± 0.31	2.11± 0.29	2.26± 0.21	2.11± 0.32

[a]Number of observations = 48.
[b]Number of observations = 64.
[c]Number of observations = 16.

Table 3. Mean values of chemical composition of collagen #1

Collagen batch	Fat (%)	Moisture (%)	Ash (%)	Crude protein (%)	Soluble collagen (mg/g)	Insoluble collagen (mg/g)	Total collagen (mg/g)
1	0.23	74.01	0.17	21.98	22.51	161.08	184.09
2	0.28	78.81	0.16	20.41	23.18	157.10	184.77
3	0.26	75.48	0.18	19.89	21.10	159.14	182.75
4	0.25	78.97	0.19	22.07	22.14	158.91	184.00
5	0.27	74.50	0.15	21.08	23.01	159.61	182.31

Fine emulsion bologna

The source of raw meat was the lean and fatty tissue from an electrically stimulated bullock carcass. The lean and fat trim was ground (1.27cm plate) separately. The lean was throughly mixed in a paddle type mixer. The ground lean and fat trim was frozen separately and stored at −20°C until used. Bovine hide collagen #1 as described by Turkot et al. (1978) was used to replace lean in the sausage formula. This product was selected because its composition most closely resembled the lean meat to be replaced. Samples of lean, fat trim and collagen were analyzed for proximate composition. Based on this analysis, four different 9.08 kg sausage recipes were formulated using hide collagen to replace fractions of the non-lipid constituents. The lipid to non-lipid ratio was held at 25:75, making the non-lipid collagen levels 0, 4.7, 8.9 and 12.8 percent prior to the addition of water. Water was added to bring the moisture up to a level of 4 times the percent protein plus 10 percent (Table 4). Ground lean, fat trim and collagen were thawed at 1°C for 24 hours. The lean was chopped first in a cold silent cutter, then water in the form of ice and the seasonings (Table 5) were added, and the chopping was continued until the mixture reached 8°C. Then fat trim was added and chopping continued at high speed until the emulsion temperature reached 13°C. The emulsion was stuffed into 2.5 x 16 inch Union Carbide clear fibrous casings using a Vogt hand stuffer. Before the emulsion was stuffed, samples were taken for analysis. The sausage was cooked in a preheated (54°C)

Table 4. Bologna formulations (fine emulsion)

Nonlipid replacement level (percent)	Lean tissue (kg)	Fatty tissue (kg)	Collagen (kg)	Water (kg)
0.0	6.760	2.320	0.000	1.094
4.7	6.397	2.361	0.318	1.085
8.9	6.084	2.388	0.608	1.080
12.8	5.766	2.447	0.867	1.067

Table 5. Bologna ingredients* (fine emulsion)

Item	Grams
Sodium chloride	272.0
White pepper	33.6
Coriander	11.2
Allspice	5.6
Sage	5.6
Garlic powder	1.4
Onion powder	2.8
Sodium nitrite	0.9
Sodium erythorbate	5.9

*Added to each 9.08 kilogram formulation.

Blodgett model convection oven. The cooking schedule was 54°C for 1 hour 20 minutes, 66°C for the next 1 hour and 77°C until an internal temperature of 67°C was reached. The internal temperature in the sausage was monitored by inserting thermocouples to the geometrical center. After cooking, the sausage was cooled by immersion in ice water for 10 minutes, removed, dried with paper towels, wrapped in freezer paper and stored at 1°C for 48 hours.

Raw emulsion stability was tested by the method of Saffle et al. (1964), and pH was determined by the method of Sebranek (1978). Volume change was measured by Archimedes' principle of water displacement. Extractable lipid, crude protein, moisture and ash were determined following the AOAC methods (1970). Cooking loss was calculated by weighing the sausage before and after cooking and chilling. Color of the sausage was evaluated with a Hunter Lab Colorimeter as described by Hunter (1976). Results were recorded as L, a, b values. Textural changes were estimated using an Instron Universal Testing Instrument Model 1122 with a LEE Kramer Shear Cell. The resistance force experienced by the cell was expressed as kilograms of peak and area force. The water holding capacity was measured by the filter paper moisture absorption technique of Grau and Hamm (1953), modified by Urbin et al. (1962). The soluble and insoluble fractions of food-grade bovine hide collagen were determined as described by Wiley et al. (1979). The results were statistically analyzed by one-way analysis of variance (Steel and Torrie, 1960) and calculations made by the computer program of Barr et al. (1976).

Results and Discussion

Coarse bologna

The mean values for shrinkage (cooking loss), volume change, moisture percentage, expressible juice, fat and protein content of coarse bologna with 10, 20 and 30 percent hide collagen were not statistically different (Table 2) from the control (0 percent collagen). Color of the bologna showed a significant difference ($P<.05$) in the L value (lightness, darkness), a value (redness, greenness) and b value (yellowness, blueness) among the treatments. The lightness tended to increase whereas redness and yellowness tended to decrease with increase in collagen levels. This tendency may be due to the whitish color of the collagen.

The texture of cooked bologna was determined as a shear value obtained from the resultant force/distant curve (Figure 1). The force measured at the yield point A indicated firmness whereas the area under the shear curve indicated the total work performed by the Kramer cell to shear the bologna sample. The results on textural study (Table 2) indicated that firmness of bologna decreased at the 10 percent level, increased at the 20 percent level and decreased again at the 30 percent level of added collagen. The total area under the curve showed a similar trend. The changes in texture may be associated with the chemical changes in the collagen although relatively more gelatinization of collagen would be expected in cooked bologna containing higher levels of added collagen and, hence, a decrease in firmness. Although the data on emulsion stability did not reveal any significant differences (Table 2) between treatments, the emulsion stability values were generally higher than the acceptable levels for a true emulsion. According to Saffle et al. (1967) emulsion stability values up to 4 are within an acceptable range; beyond that a weak emulsion results. Even though coarse bologna is not an emulsion type sausage, the emulsion stability test was done to compare the effects of added collagen at different levels. The mean values for protein, fat, ash, soluble collagen, insoluble collagen and total collagen (Table 3) did not vary

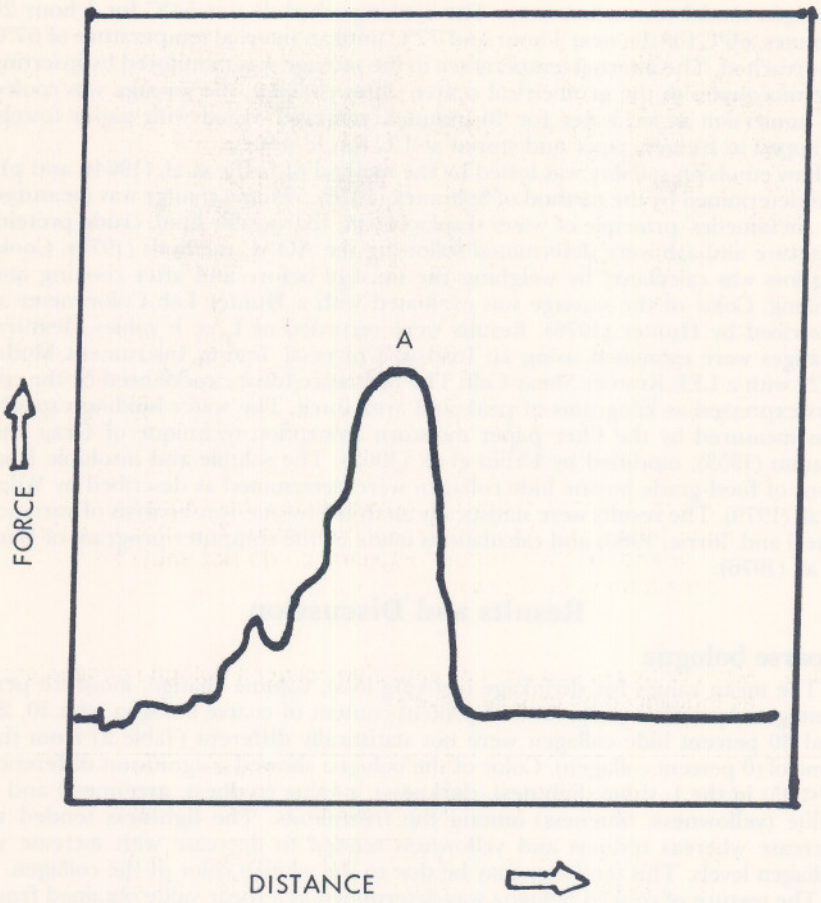

Figure 1. Typical force/distance curve for shear of bologna sausage (casing and about 10 mm peripheral portion was reamed before shear). A = yield point indicative of firmness.

significantly between cans of collagen used in this study. Figure 2 shows no deformations in the appearance of external surface of bologna. The physical texture and shape of the cross sectional area of the bologna did not show any gel-pockets due to added collagen. This supports the findings of Wiley et al. (1979) that only the soluble fraction of collagen is responsible for gel-pocket formation in the sausages.

Fine emulsion bologna

Replacing lean with hide collagen did not significantly ($P>.05$) affect the lipid, moisture or crude protein in the raw or cooked emulsion (Table 6). The press fluid, cooking loss and color differences in the cooked sausage were also deemed non-significant ($P>.05$). Collagen was also found to have no effect on the pH of

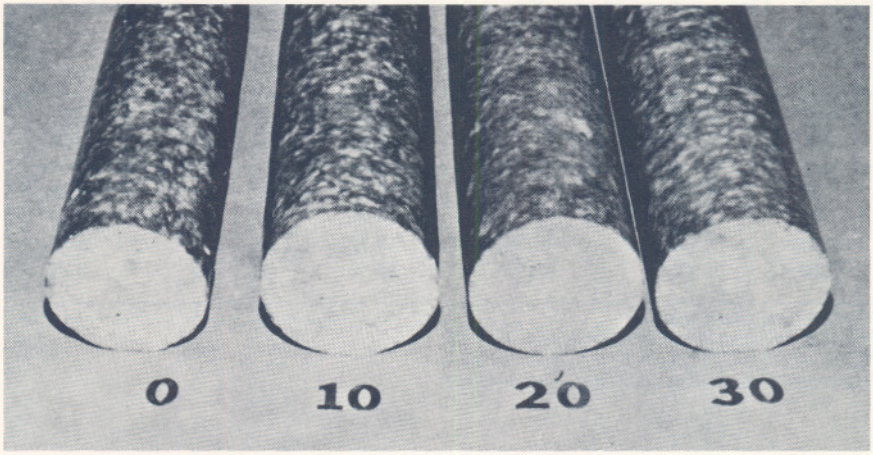

Figure 2. **Coarse bologna sausages, prepared from beef added with 10, 20 and 30% food-grade collagen from hide. The cross-sectional area and external surface appearance do not show any difference from control (0%).**

Table 6. Mean values of cooked, fine emulsion collagen-bologna parameters as influenced by collagen levels

Collagen level	Cookloss[3] (%)	Lipid[4] (%)	Moisture[4] (%)	Crude protein[5] (%)	pH[2,6] (cooked)	Pressed fluid[4] (%)	Peak shear[4] (kg)
0	5.78	20.75	60.18	14.77	6.07	47.68	16.16
4.7	6.04	20.65	60.28	14.96	6.09	46.18	16.91
8.9	6.12	20.59	60.12	14.76	6.04	43.03	20.93
12.8	6.00	20.66	60.21	14.71	6.06	44.40	22.30

[1]Nonlipid replacement level.
[2]Based on the mean hydrogen ion concentration.
[3]Based on 24 observations at each replacement level.
[4]Based on 96 observations at each replacement level.
[5]Based on 48 observations at each replacement level.
[6]Based on 12 observations at each replacement level.

raw or cooked emulsion. Emulsion stability testing revealed significant ($P<.05$) differences between the treatments; the control group was more stable while no difference was found between 8.9 and 12.8 replacements (Table 7). However, according to Saffle et al. (1964), emulsion stability values below 4 are acceptable. Collagen replacement significantly ($P<.05$) increased the peak force required to shear bologna slices (Table 6). The collagen added to the sausage formula in this study was of a fibrous nature with a low soluble fraction and may therefore have resulted in an increase in the force required to shear the slices. Again, the collagen which was incorporated into the aqueous phase of the emulsion might have been enmeshed in the web of myofibrillar proteins. Cooking would have

Table 7. Mean values of raw, fine emulsion collagen-bologna parameters as influenced by collagen levels

Collagen level	Lipid[2] (%)	Moisture[2] (%)	Protein[3] (%)	Emulsion stability[4]	pH[3] (raw)
0.0	20.14	62.17	14.07	0.77	5.78
4.7	19.73	62.29	14.26	1.84	5.79
8.9	19.87	62.30	14.18	1.57	5.78
12.8	19.60	62.30	14.16	2.86	5.79

[1]Nonlipid replacement level.
[2]Based on 90 observations at each replacement level.
[3]Based on 12 observations at each replacement level.
[4]Based on 72 observations at each replacement level.

fixed the insoluble collagen in the three dimensional overlap of myosin molecules, resulting in a higher tensile strength. However, it may be noted that the textural changes as well as the changes noticed in emulsion stability were not obvious upon casual inspection of the product but could only be detected objectively.

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