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THE EFFECT OF COLLAGEN ON THE STABILITY AND RHEOLOGICAL PROPERTIES OF COOKED SAUSAGES

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SUMMARY

Substitution of up to 40% of meat proteins by collagen - fat emulsion in comminuted sausage formulations increased the cooking losses and decreased the yield limit of product more than corresponding amounts of raw collagen. However, in properly prepared formulations such substitutions did not destabilize the system. The increase in temperature of the formulation in the cutter above 16°C caused instability of the products after cooking in controls and in both experimental systems. The effect of collagen on the stability and texture of sausages was independed on the composition of the mixture and thermal processing conditions.

The results of these experiments indicate that although collagen impairs the binding and gel forming capacity of the formulation by diluting the myofibrillar proteins in the system it must not necessarily cause texture deterioration in the sausages. It is possible to substitute a large part of meat proteins in a sausage formulation by collagen without abuse in quality of the product, by taking into account the functional properties of the meats.

INTRODUCTION

One of the most important technological properties of meat as raw material for cooked sausages of the bolonge or frankfurter type is its ability to form gels after heating in the presence of salt. The rheological characteristic of such gels depend primarily upon the concentration of muscle proteins and their physical- chemical state related to the ionic strength and pH of the environment. From among the three main groups of meat proteins the myofibrillar proteins play the most important role in the formation of a sausage emulsion and the uniform gelled structure of comminuted sausages. However the sarcoplasmic and stroma proteins also cotribute to the binding characteristics of meat.

Carcass parts rich in connective tissue are used extensively in the sausage industry. It could be assumed that collagen is the agent responsible for the high water holding capacity of sausages after heating. The results of several investigations (3,7,8) show that addition of raw or precooked connective tissue to sausage emulsions increases the elasticity of the cooked and cooled product and decreases the water released under pressure. Other authors reported that large quantities of high collagen meats present in sausage formulations caused defects, such as poor peelability, gel and fat pocket formation, and wrinkling of the outer skin in sausages. According to Kramlich (6) the amount of high collagen meats in a formula should be restricted to a maximum 25% of the meat block in order to prevent the occurrence of gelatin pockets. The results of Jones (5) indicate that stability problems can arise when meats rich in connective tissue are used above 15% of total meat input. Sadowska et al. (9,10) reported, that more than 10% Nx6,25 of collagen in fish and beef homogenates and sausages had a detrimental effect on the stability and texture of the products.

The above review indicates, that the connective tissue proteins effect in various ways the binding properties of the myofibrillar proteins. However, no detailed informations is available on the influence of pretreatment of the connective tissues and the parameters of Processing on the quality of the product. The objective of this investigations was to examine the interactions between collagen and other proteins in the sausage formulation under variable heat treatment parameters.

MATERIALS AND METHODS

Fresh beef meat from old animals, low in connective tissue were used in the experiments. The tendons and fat were carved out of the meat as carefully as possible. The meat and skinned pork jowls were ground separately in a meat grinder with a plate of 3 mm mesh diameter and frozen at -18°C, thus forming a supply of blended materials for the whole series of experiments. The collagen was isolated from the connective tissue sheats surrounding the beef round. The sheats, after very thorough mechanical defatting, were ground in a frozen state in a meat grinder with a 5 mm mesh plate. The accompanying noncollagenous constituents were extracted with distilled water followed by 1.1 M KI solution and ether:methanol mixture according to the procedure (1:1) described earlier (11). The collagen:water mixture was frozen and ground again through a plate of 1 mm mesh diameter and excess of water was separated by centrifuging.

The mixtures: beef meat, pork fat, and collagen or beef meat, fat, and collagen - fat emulsion, were used to prepare sausage formulations by cutting and mixing with water and 2% salt in a laboratory silent cutter. The collagen - fat emulsion was prepared in a colloid mill from collagen after 2 h heating at 100°C with water and fat in proportions 1:1:1. The content of total proteins and fat in these mixtures were changed from 11 to 15% and 16 to 35%, respectively. Meat proteins in the formulations were substituted by raw or precooked collagen in amounts up to 50%.

The sausages in collagen casings, 35 mm in diameter, were cooked in a water bath at 65 to 90°C during 30, 60 or 90 min, cooled to 10°C, and stored at 4±1°C.

The products were characterized by content of gelatin, free drip, expressible fluid, yield, and rheological properties. The Kjeldahl protein was determined by using the factor 6.25 for meat protein and 5.55 for collagen. The heat solubility of collagen was expressed as the ratio of hydroxypropline, contained in the formulation after extraction of gelatin with water, to the total hydroxyproline in the sample. The material was homogenized with water (1:5) 1 min at 6000 rpm, then heated 20 min at 40°C, and centrifuged. This procedure was repeated twice. Hydroxyproline was estimated in the sediment after 2 h hydrolysis of 50 mg of dry material in perchloric acid at 105°C (12) using the colorimetric procedure according to ISO (1). Free drip was determined after Bakunc and Bartanjan (2) and expressible fluid according to Shults and Wierbicki (14). The rheological properties were characterized by the yield limit of 15 mm thick slices measured in the Tilgner penetrometer with a flat punch, 8 mm in diameter.

The statistical significance of differences between two means of data was evaluated using the Student t test.

RESULTS AND DISCUSSION

Increasing the proportion of raw collagen in cooked sausage formulations, containing 12% of total protein and 32,4 % of fat, up to 50 % (in respect to Nx6.25) brought about a decrease in the yield limit as well as an increase in cooking losses in the product (Fig. 1). A similar but more pronounced influence on the stability and rheological properties of sausages was exhibited by precooked collagen present in the collagen-fat emulsion (Fig. 1 and Tab. 1). However, in properly prepared formulations such substitutions did not decrease the yield of sausages nor cause an accumulation of fat or loose gel under the casings. The instability of all sausage emulsions after cooking was caused by an increase in temperature of the formulation in the cutter above 16°C (Tab. 2). The character of the relation-

Fig.1. Effect of the pretreatment of collagen on free drip (——), expressible fluid (- - -) and texture of sausages
× - raw collagen
∘ - collagen- fat emulsion

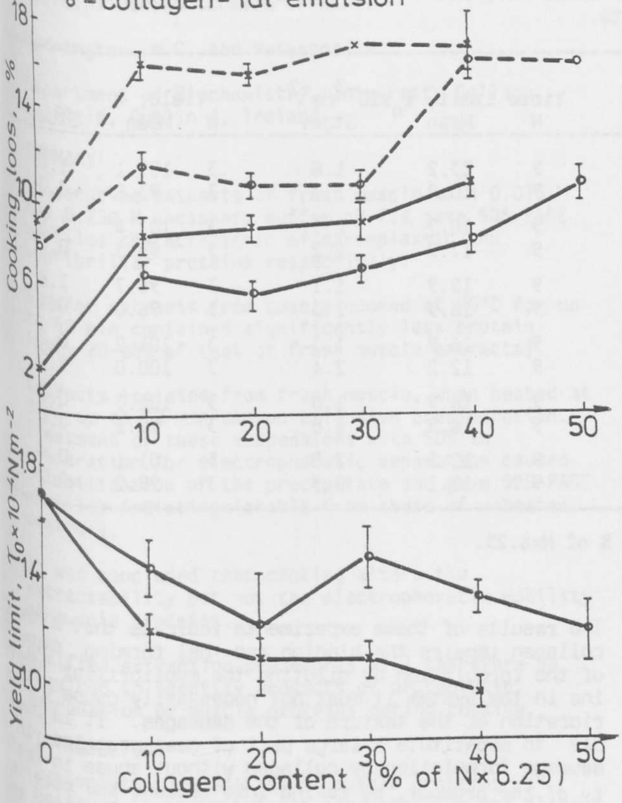

Fig.2. Effect of collagen concentration in 2.5% solution of NaCl on water binding at 75 -∘- and 85°C -×-

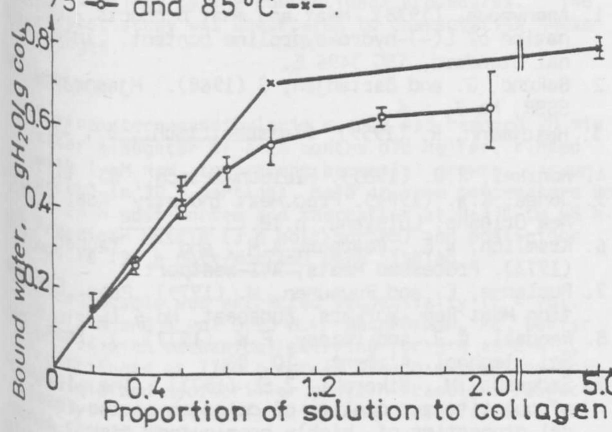

Table 3. The influence of temperature and time of heating of sausage formulations containing 20 % raw collagen in respect to N×6.25, on the solubility of collagen.

Temp., °C	0 N	0 Mean	0 Stdev	30 N	30 Mean	30 Stdev	60 N	60 Mean	60 Stdev	90 N	90 Mean	90 Stdev
65	3	0.6	0.20	3	0.5	0.07	3	0.8	0.03	3	1.4	0.10
70	3	0.4	0.20	3	0.7	0.10	3	0.8	0.09	3	1.6	0.07
80	3	1.0	0.10	3	1.5	0.04	3	1.6	0.06	3	2.1	0.08
85	3	1.1	0.09	3	0.9	0.20	3	0.8	0.04	3	1.6	0.20
90	3	1.8	0.05	3	2.0	0.01	3	2.5	0.08	3	2.5	0.06

Solubility of collagen, %; Time of heating, min

Table 1. The influence of temperature and quality of collagen substitution (20 % meat proteins) in sausage formulations on binding properties after cooking.

Free drip, %

Temp. °C	Control N	Control Mean	Control Stdev	Raw collagen N	Raw collagen Mean	Raw collagen Stdev	Collagen - fat emulsion N	Collagen - fat emulsion Mean	Collagen - fat emulsion Stdev
65	6	1.0	0.0	3	2.0	0.0	3	3.3	0.6
70	6	1.0	0.0	3	3.7	0.6	3	5.3	0.6
75	6	6.0	0.0	3	6.0	0.2	3	11.0	1.2
85	6	8.0	0.0	6	10.0	0.8	6	13.7	1.8

(Substitution of meat proteins)

ship existing between the collagen content in a formulation and the fluid losses or yield limit, presented on Fig. 1, differed from that obtained in a similar study (10) regarding a mixture of proteins and water without fat. This may be due to the difference in the viscosity of the liquid phase in the gel network. Although the degree of thermohydrolysis of collagen during cooking of the sausages was very small (Tab. 3), the concentration of gelatin increased with the content of collagen in the formulation. The rising of the viscosity of the liquid phase may decrease the rate of diffusion of the solutions out of the protein network. A similar effect on the stability of the product was exerted by the collagen-fat emulsion, which melted during cooking of the sausages.

The increase in the amount of water or fat per 1 g protein in the formulations (Tab. 4) at constant proportion fat: protein or degree of protein hydration, respectively, did not bring about any detrimental effects of collagen on the binding properties of meat proteins.

Table 2. Effect of the final temperature of sausage formulation in the cutter on the stability of sausages.

Losses, %

Temp. °C		N	0: Gel Mean	0: Gel Stdev	0: Fat Mean	0: Fat Stdev	20: Gel Mean	20: Gel Stdev	20: Fat Mean	20: Fat Stdev
15	1	6	1.0	0.0	0.0	0.0	3.7	0.0	0.0	0.0
	2	6	7.5	0.0	0.0	0.0	10.5	0.0	0.0	0.0
17	1	3	13.0	0.7	0.0	0.0	15.5	0.7	4.0	1.4
	2	3	17.0	1.7	11.3	0.6	17.5	0.5	6.3	0.6
20	1	3	13.0	1.4	11.0	0.0	17.5	2.1	12.5	2.1
	2	3	18.0	0.0	13.3	0.6	19.7	0.6	15.0	1.0

(Content of collagen, % N×6.25: 0 and 20)

1 - free drip, 2 - expressible fluid

Table 4. The effect of collagen at different proportions of water (W), fat (F) and total proteins (P) in formulations on the stability and texture of cooked products.

L/P	W/P	S^a	Free drip, % N	Mean	Stdev	Expres.fluid, % N	Mean	Stdev	Yield limit, ł$_o$ $\times 10^{-3}$ Nm^{-2} N	Mean	Stdev	Yield, % N	Mean	Stdev
1.07	4.47	0	6	10.0	0.0	6	19.0	2.8	9	23.2	1.8	3	101.1	1.0
		20	6	15.0	0.0	6	21.1	1.3	9	18.2	1.7	3	93.8	3.3
1.54	4.47	0	6	6.5	0.7	6	17.5	3.8	9	18.7	2.5	3	101.4	1.0
		20	6	14.0	0.0	6	16.5	2.1	9	17.9	2.2	3	98.3	0.0
2.07	4.47	0	6	13.2	4.5	6	17.0	0.0	9	15.9	1.1	3	96.7	1.6
		20	6	17.3	3.2	6	19.0	5.3	9	16.3	1.3	3	96.0	0.1
2.70	4.47	0	6	4.8	4.6	6	10.3	4.3	9	16.9	1.3	3	101.2	0.2
		20	6	9.3	3.6	6	15.5	3.3	9	12.2	2.4	3	100.0	2.0
2.70	3.8	0	6	10.0	0.0	6	10.0	0.0	9	16.9	1.0	3	102.3	0.0
		20	6	13.3	0.0	6	17.8	0.0	9	16.9	1.8	3	82.1	0.0
2.70	5.2	0	6	8.5	2.1	6	12.8	1.1	9	12.5	2.8	3	101.1	0.4
		20	6	10.5	2.1	6	15.2	0.5	9	12.1	0.9	3	99.2	0.2

a/ The level of substitution of meat proteins by collagen, % of Nx6.25.

Substitution of 20 % meat proteins by collagen in comminuted sausage formulations caused in all experiments a significant increase in cooking losses, regardless the composition of the mixture or temperature and time of heating of the sausages (Tab. 1 and 4). The results suggest that raw and precooked collagen bind the water molecules more weakly during cooking than the myofibrillar proteins. The water holding capacity of minced raw collagen increased after heating in a 2 % solution of NaCl at 85°C only by 40 % (13) and even less as the concentration of collagen in the mixture was increased Fig. 2 . In a sausage kept 90 min at 85°C only about 2.5 % of the total collagen was solubilized (Tab. 3). This means that during commercial sausage manufacture only a marginal proportion of the collagen turns into gelatin. Precooked collagen was more effective in causing instability of sausage formulations than raw collagen. High dissolution of collagen is a deteriorative factor as regards the stability of sausage emulsions (9).

The effect of collagen on the stability and rheological properties of sausages depends upon the concentration and binding properties of muscle proteins. Collagen in a concentration higher than 10 % in a mixture without fat, containing 11 % of total proteins, caused gel pocket formation and grainy structure of the cooked product. The detrimental effect of collagen can be reduced by increasing pH and the amount of NaCl in the homogenates above 6.8 and 2.0 % respectively (10).
The effect of collagen on the stability and texture of cooked sausages is significantly lower at high fat levels (Tab. 4). According to Honikel (4) fat improves the water holding capacity of lean sausage mixture. The small fat particles are surrounded by the lean mixture. When heat is applied the protein in the lean mixture coagulates around the fat particles. The coagulated protein is thus held in a loose lattice by the fat and therefore shrinks less than would a lean mixture or comminuted meat. This protein network can retain more moisture in its wide meshes after heating than would be possible without the fat. This suggests that interactions of hydrophobic groups in the proteins and fat in the network restrict shrinking of the structure during heating. Raw collagen, although it contains more hydrophobic groups than myosin, does not participate in fat binding, because it is insoluble and the collagen fibres are too large to protect the fat droplets in the sausage formulation.

The results of these experiments indicate that although collagen impairs the binding and gel forming capacity of the formulation by diluting the myofibrillar proteins in the system it must not necessarily cause a deterioration of the texture of the sausages. It is possible to substitute a large part of meat proteins in sausage formulation by collagen without abuse in quality of the product, by taking into account the material calculations and the functional properties of the meats.

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