The influence of collagen on the rheological properties of meat homogenates

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The properties of homogenates containing up to 25% collagen in the total crude protein were characterized by flow curves and after cooking by elasticity and yield limit, as well as by the content of forced drip and gelatin . A substitution of up to 20% of meat proteins by raw pig skin collagen decreases the viscosity of the homogenate, the elasticity, and the yield limit by 40, 25, and 30%, resp. At higher concns. of collagen, of about 25%, a breakdown of the system was observed. In homogenates containing up to 15% of precooked pig skin collagen all rheological parameters were higher than in unsubstituted controls, regardless the degree of thermohydrolysis of the connective tissue. Increasing the proportion of meat with a high content of connective tissue brings about a decrease in viscosity of the raw mince as well as the elasticity and yield limit of the cooked product, more than corresponding addition of raw pig skin. In all investigated cases the quantity of drip decreased with increasing content of collagen in the formulation. In homogenates containing 13% of crude protein, 13% fat, and 2% NaCl the upper level of unmodified pig skin collagen, which does not depreciatingly influence the texture of the cooked product, is about 2,5%.

Der Einfluss von Kollagen auf die rheologischen Eigenschaften verschiedener Fleischhomogenate

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Homogenate die bezogen auf Gesamtprotein bis 25% Kollagen enthielten, wurden roh mittels der Fliesskurven und nach dem Kochen mittels der Elastizität, Fliessgrenze, Gelatinegehalt und Saftverlust charakterisiert. Die Ersetzung von bis 20% der Fleischproteine durch rohen Schwartenkollagen erniedrigt die Viskosität, Elastizität und Fliessgrenze der Homogenate um, entsprechend, 40, 25 und 30%. Höhere Konzentrationen von Kollagen, ca 25%, führen zu einem Zusammenbrechen des Systems. In Homogenaten mit bis 15% von vorgekochtem Schwartenkollagen sind alle rheologischen Parameter höher als in nichtsubstituierten Kontrollproben, unabhängig von dem Grad der Thermohydrolyse des Bundegewebes. Die Steigerung des Anteiles von Fleisch mit hohem Bindegewebegehalt hat eine Senkung der Viskosität des rohen Bräts, wie auch der Elastizität und der Fliessgrenze des gekochten Produktes zu Folge. Diese Veränderungen sind stärker als diejenigen die durch Zugabe von entsprechenden Mengen von rohen Schwarten verursacht sind. In allen untersuchten Fällen war der Saftverlust kleiner bei höheren Kollagenanteilen in der Rezeptur. In Homogenaten mit 13% Gesamtprotein, 13% Fett und 2% NaCl ist die maximale Zugabe von rohem Schwartenkollagen, bei der noch keine nachteiligen Einflüsse auf die Textur des gekochten Produktes bemerkbar sind, rund 2,5%.

6.5

L'influence de collagène sur les propriétés rhéologiques des homogénates de la viande

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Les propriétés des homogénates contenant jusqu'à 25% de collagène dans la totalité des protéinde crus ont été caracterisées par des courbes de débit et aprés la cuisson par l'élasticité /E/ et par la limite d'écoulement /τ_o/ aussi bien que par de WHC et contenant de gélatine. Une substitution jusqu'à 25% des protéines de la viande par collagène de peau crue de porc diminue la viscosité /η/ de l'homogénate, E et τ_o resp. de 40, 25 et 30%. Aux concentrations plus élevées d'environ 25% un effondrement du système a été observé. Dans des homogénates contenant jusqu'à 15% de collagène de la peau de porc précuite η, E, τ_o étaient plus élevés que dans des échantillons non substitués á n'importe qu'elle degré de la thérmohydrolyse du tissu. Lorsqu'on accroît les proportions de la viande dont la contenance en tissu conjonctif est plus élevée on observe la diminution de η de l'homogénate aussi bien que le E et τ_o du produit d'une façon plus large que la addition equivalent des peaux crues. Dans tous les cas examines la WHC accroît avec l'accroissement de la contenance de collagène dans sa formule. Dans les homogénates contenant 13% de proteines crues, 13% de gras, et 2% de NaCl, le niveau supérieur de collagène non modifié de la peau de porc qui n'influence pas d'une maniére dépréciable la texture du produit est de 2,5% environ.

Влияние коллагена на реологические свойства мясных фаршов

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Состав фаршов, содержащих до 25% коллагена по отношению к общим белкам, характеризовались кривыми течения, а после тепловой обработки модулом упругости и пределом напряжения сдвига, а также содержимостью свободной воды и желатина. Замена белков фарша коллагеном свиных шкур в количестве до 20% /N x 6,25/ уменьшает вязкость фарша, а также модул упругости и пределы напряжения сдвига соответственно на 40,25 и 30%. При участии коллагена порядка 25% имеет место расслоение системы. Зато в фаршах, содержащих шкуры, подвержённые тепловой обработке, /до 15% коллагена/ наблюдалось увеличение всех реологических показателей и стабильность системы несмотря на степень термогидролиза белков. Увеличение участия мяса с большой содержимостью ткани снижает вязкость сырого фарша, а также модул упругости и пределы напряжения сдвига подогреваемых фаршов в большей степени, чем соответствующая добавки свиных шкур. Независимо от качества коллагена количества свободной воды в подогреваемых фаршах уменьшается пропорционально концентрированию коллагена. В фаршах, содержащих 13% общих белков, 13% жира и 2% поваренной соли допустимо из-за текстуры продукта около 2,5% участие немодифицированного коллагена.

6.5

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Introduction

The role played by the myofibrillar proteins in the formation of the characteristic properties of sausage emulsions and of the uniform gelled structure of comminuted sausages has been investigated both in model systems and in various meat and fish homogenates and presented in details in reviews /1,6,7,10,12,16/. The complex interactions of the connective tissue proteins with other components during cutting, mixing, and cooking have been, however, less thoroughly examined and rather only generally treated in recent reviews /3,11/, although it is known, that in sausage manufacture collagen-rich carcass parts are used because of their high binding properties. As yet, however, there are no known relationships between the amount of collagen of different physico-chemical properties, present in the formulation, as well as the parameters of cutting and cooking, and the rheological properties of the final product. Preliminary results dealing with the role of connective tissue in the formation of the rheological properties of comminuted fish sausages have been presented in 1977 /15/. This study was undertaken to furnish more data, especialy in respect to meat sausages.

Experimental

The meats /table 1/ were ground separately in a meat grinder and frozen at -20°C, thus forming a supply of blended materials for the whole series of experiments. The homogenates produced as shown in Fig.1 contained 5,15,20, and 25% of connective tissue proteins in N x 6.25. The pig skins, which served as the source of additional collagen, were used raw

FIG1 THE PROCEDURE USED FOR PREPARING THE HOMOGENATES

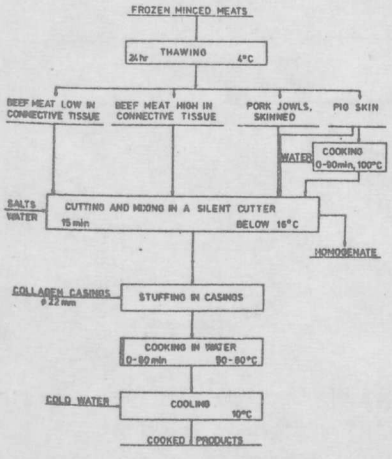


Table 1

The chemical composition of meats used for preparing the homogenates

Meats	Dry weight %	Proteins N x 6.25 %	Collagen Hyp x 7.46 %	Fat %
Beef meat low in connective tissue	26.1	22.8	0.9	3.3
Beef meat high in connective tissue	25.3	22.9	3.4	2.5
Pork jowls, skinned	84.1	5.1	1.8	79.0
Pig skin	51.4	24.5	20.3	26.9

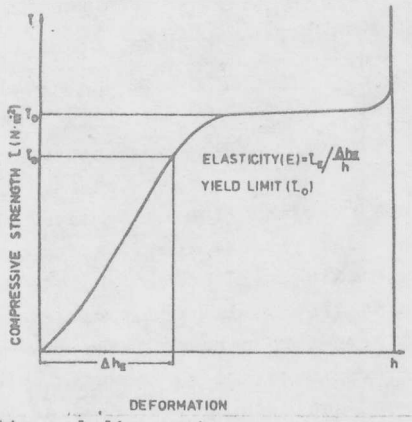
or after cooking in water for 30, 60, or 90 min. at 100°C.

The rheological properties of raw homogenates were characterized by flow curves, i.e. by the relationship between the shear stress /τ/ and shear rate /$\dot{\gamma}$/, determined in a capillary viscometer /17/, using shear stress values in the range of 354-714 Nm^{-2}. The apparent viscosity /η_{ap}/ was found from the formula

$$\eta_{ap} = \frac{\tau}{\dot{\gamma}}$$

at constant τ= 454 Nm^{-2}. The temperature of the homogenate during the measurements was 19 ± 1°C. The rheological properties of the cooked products were determined by measuring the deformation of slices, 15 mm thick /h/ under linearly increasing stress /1476 $Nm^{-2}s^{-1}$/ in a penetrometer with a flat punch, 14.5 mm in diameter. A typical rheogram of the cooked

FIG.2 A TYPICAL RHEOGRAM OF COOKED HOMOGENATES



homogenate is shown in Fig.2. The measured data were used for calculating the elasticity /E/ and yield limit /τ_o/.

The forced drip from the products was determined by the Grau-Hamm procedure /8/. The content of collagen or gelatin in the homogenates was assayed according to Stegemann and Stalder /2/ after 11 hrs of hydrolysis in 6n HCl. The content of gelatin in the presence of collagen was estimated by homogenizing 10g sample with 90g distilled water at 30°C, separating the solubilized gelatin on a Büchner funnel, and determining hydroxyproline in the supernatant.

Results and discussion

The influence of concentration and quality of collagen on the rheological properties of raw homogenates

The rheological properties of homogenates containing collagen of different quality in concentrations up to 25% of total protein can be described by the empirical Ostwald - de Waele equation:

$$\tau = K\dot{\gamma}^n$$

For homogenates with the lowest content of connective tissue the rheological parameter n = 0.3 and for that containing 20% of collagen from cooked pig skin n = 0.21. However, there was no evident relationship between the quantity and quality of collagen in the homogenates and the value of n /table 2/. Furthermore, both cited values are within the range

Table 2

The parameters K and n of the equation $\tau = K \cdot \dot{\gamma}^n$, characterizing the rheological properties of different homogenates

Source and pretreatment of collagen	Content of collagen % of N x 6.25	K N s^n m^{-2}	n
Collagen contained in lean beef meat	5	393	0.30
Collagen contained in beef meat rich in connective tissue	10	218	0.29
	15	220	0.25
Collagen of raw pig skins	15	353	0.29
	20	220	0.26
	25	331	0.25
Collagen of pig skins heated to 100°C			
0 min	15	545	0.26
30 min	15	571	0.25
60 min	15	589	0.22
90 min	15	676	0.21

0.19-0.3, found by several authors as characteristic for different meat and fish homogenates /5,14/. The parameter K decreases with the increase in the content of unmodified collagen in the formulation, depending also upon the source of the connective tissue. However, at 25% of pig skin collagen the relationship is somewhat obscured probably because at high concentration the coarse fragments of connective tissue decrease somewhat the flow rate of the system /9,13/.

Precooked collagen increases the viscosity of the homogenate, the raise in K being higher at longer cooking time /table 2/. Such behaviour may be caused by the presence of gelatin in the precooked material /table 3/ as well as by interaction of the denatured collagen with water, which is stronger than that of the myofibrillar proteins. Forthermore same increase in viscosity results probably from interaction of collagen with myofibrillar proteins /3,4/.

Table 3

The influence of precooking of pig skins on the rheological properties of homogenates, containing 20% of collagen /in respect to N x 6.25/, heated to 80°C.

Holding time at 100°C min	Relative change of forced drip %	Content of gelatin in the homogenate %	Elasticity E [N.m^{-2}] x10^4	Yield limit τ_o [N.m^{-2}] x10^4	Degree of hydrolysis of precooked collagen %	Degree of hydrolysis of collagen in the homogenate %
raw skins	100	0.2	5.94	4.91	0	8
0	78	0.7	10.00	6.73	13	28
30	66	1.0	10.88	6.91	29	39
60	60	1.1	9.05	5.71	39	44
90	49	1.5	8.52	5.56	55	57

The influence of concentration and quality of collagen on the rheological properties of cooked homogenates

Increasing the proportion of collagen in cooked homogenates up to 20% /in respect to N x 6.25/ brings about a decrease in elasticity and yield limit by 25 and 30%, respectivelly /Fig.3/ as well as an increase in gelatin concentration in the product /Fig.4/. The degree of thermohydrolysis of collagen during cooking of the homogenates was in all samples about 10%. However, the rheological properties of homogenates containing 25% of collagen in N x 6.25 differed from the above pattern. Furthermore, the product contained gelatin layers under the casing and had a grainy texture. A similar but more pronounced influence on the rheological properties of homogenates is exhibited by the connective tissue present originally in the beef meat /Fig.3/.

The elasticity and yield limit of the cooked product prepared by adding of precooked connective tissue to the mixture during cutting in the silent cutter, is higher than that

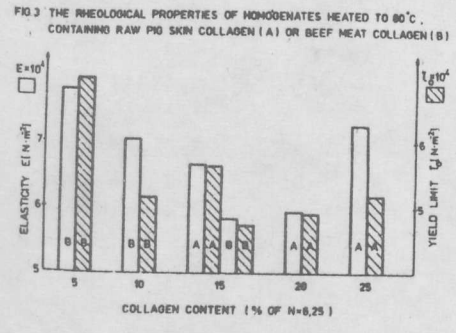


FIG.3 THE RHEOLOGICAL PROPERTIES OF HOMOGENATES HEATED TO 80°C, CONTAINING RAW PIG SKIN COLLAGEN (A) OR BEEF MEAT COLLAGEN (B)

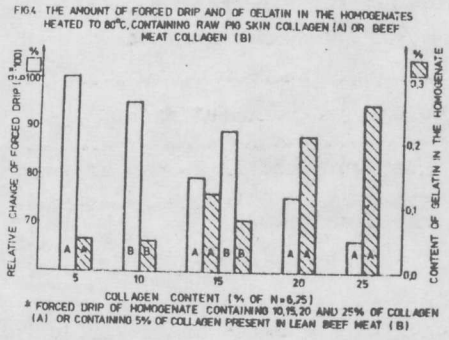


FIG.4 THE AMOUNT OF FORCED DRIP AND OF GELATIN IN THE HOMOGENATES HEATED TO 80°C, CONTAINING RAW PIG SKIN COLLAGEN (A) OR BEEF MEAT COLLAGEN (B)

* FORCED DRIP OF HOMOGENATE CONTAINING 10,15,20 AND 25% OF COLLAGEN (A) OR CONTAINING 5% OF COLLAGEN PRESENT IN LEAN BEEF MEAT (B)

of homogenates which were prepared with raw collagen /Table 3/ and of products containing no added collagen. The decrease in rheological parameters caused by prolonged heating is correlated with the content of gelatin in the product /Table 3/. The results presented in table 3 suggest that gelatin interacts during cutting and mixing in the silent cutter with the myofibrillar proteins to form structures, responsible for the characteristic rheological properties of the products. The unmodified collagen does not participate in these interactions to the same extent. Thus the gelatine which is formed later during cooking, not being a constituent of the original structure of the raw homogenate, forms kind of islets in the system and brings about a decrease in elasticity and yield limit.

The influence of temperature and time of cooking of homogenates containing added colagen

Raising the cooking temperature in the range from 50 to 80°C increases the solubility of collagen /Table 4/ and brings about a raise in the elasticity /Fig.5/ and yield limit /Fig.6/ as well as a significant decrease in forced drip /table 5/. All samples containing

Table 4

The influence of temperature and time of heating of the homogenates containing 5% of meat collagen /in respect to Nx6.25/ /a/ or 20% of raw pig skin collagen /b/ on the content of gelatin in the product

Temperature °C	Content of gelatin %					
	0		20		40	
	a	b	a	b	a	b
50	0.01	-	-	0.06	-	0.09
60	—	0.11	0.03	0.16	0.03	0.20
70	0.03	0.17	0.03	0.17	0.03	0.25
80	0.05	0.20	0.04	0.22	0.04	0.34

Table 5

The influence of temperature and time of heating of the homogenates on the amount of forced drip

Temperature °C	Time of heating $\frac{b}{a} \cdot 100\%$			
	0	20	40	60
50	122	91	87	80
60	107	91	71	66
70	74	76	77	63
80	75	67	77	75

a - Forced drip of homogenates containing 5% of collagen present in lean beef meat

b - Forced drip of homogenates containing 20% raw pig skin collagen /in respect to Nx6.25/

20% collagen, cooked at various temperatures, had a higher elasticity than the controls prepared without added collagen. However the reverse was true for the yield limid. Prolonged heating of the homogenates at different temperatures causes a decrease of the rheological parameters from the maximum values, which were obtained after about 40 min. /Fig. 5,6/.

FIG 5 THE INFLUENCE OF TEMPERATURE AND TIME OF HEATING OF THE HOMOGENATES, CONTAINING 5% OF COLLAGEN PRESENT IN LEAN BEEF MEAT (---) AND 20% RAW PIG SKIN COLLAGEN (IN RESPECT TO N×6,25) (——) ON THE ELASTICITY OF THE PRODUCTS

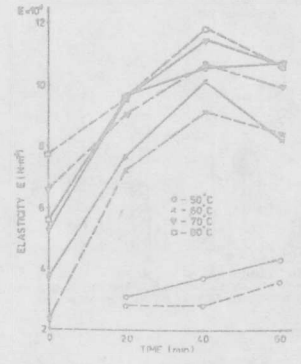
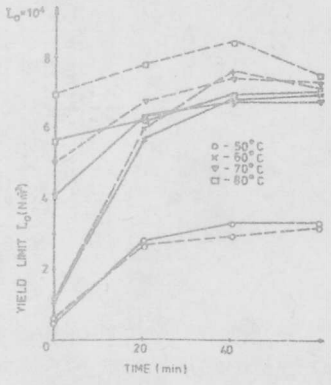


FIG.6 THE INFLUENCE OF TEMPERATURE AND TIME OF HEATING OF THE HOMOGENATES CONTAINING 5% OF COLLAGEN PRESENT IN LEAN BEEF MEAT (---) AND 20% RAW PIG SKIN COLLAGEN (IN RESPECT TO N×6,25) (——) ON THE PLASTIC PROPERTIES OF THE PRODUCTS



Conclusions

It has been shown experimentally that the rheological properties of comminuted sausages can be improved by addition of connective tissue, not exceding 2.5% of collagen in the cooked product. Higher concentration of connective tissue brings about a marked deterioration in texture. At different levels of collagen content the rheological parameters of homogenate and of the cooked product can be to same extent modified by the pretreatment of the connective tissue as well as by the time and temperature of cooking.

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