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DYNAMIC-MECHANICAL AND THERMAL ANALYSIS OF THE HYDRO-COLLOIDAL PHASE IN MODEL MEAT EMULSIONS WITH THE ADDITION OF PEA CELLULOSE

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A b s t r a c t. The effect of temperature on the rheological properties of model meat emulsions with the fat being replaced by pea cellulose in different degrees has been studied. The temperature changes in the parameters describing the rheological properties have been determined. It was found that in the range 20-50°C, the rheological properties of meat emulsions are determined by the phase transition of fat. In the range 50-65°C the rheological properties are mainly determined by the structural changes in the hydrocolloid formed. Although the pea cellulose used in place of the fat does not take part in determining the elastic properties of meat emulsions, it is nevertheless important in the formation of its structure.

K e y w o r d s: rheology, pea cellulose, hydrocolloid

INTRODUCTION

The developing meat industry and the introduction of new meat processing technologies have brought about the requirement to use many non-meat components, the addition of which lead to quality improvement and impart new properties to the products. Increasingly, substances of natural or synthetic origin, known as hydrocolloids or structural additions, are used during processing or in the conservation of food products. They are mostly used as components which modify the structure and texture of food products through thickening, gelation or emulsification [2,5,7,9]. In order to change the unfavourable balance of meat and cellulose in the diet and to improve the nutritional value of meat products much effort has been made to develop products of reduced calorific value [1]. The most popular procedure is to replace fat by water and water binding substances of low calorific value, non-digested in human organism.

Fat is one of the main components of traditional meat products and essentially affects the mechano–rheological properties of the products and the stability of emulsion in fine meat products [8,4].

From the point of view of food technology, mechano-rheological properties are strictly related to the texture of food products [3,13,14]. However, only few works have done any investigation into the relationship between the changes in the molecular structure and the parameters describing the macroscopic properties of poly-disperse substances with complex internal structures such as meat products.

MATERIAL AND METHODS

The present study was performed on model meat emulsions in which the fat had been partly replaced by strongly hydrated pea cellulose ID 90 (ID FOOD IDIRC). The measurements were performed on samples each with a different content of pea cellulose: 0 sample – meat emulsions without pea cellulose, samples 1, 2, 3 – meat emulsions with 10, 15 and 20% of fat replaced by pea cellulose. Prior to use, the pea cellulose was hydrated in the proportion of one part of cellulose for four parts of water. The fundamental composition of the samples is given in table 1.

Table 1. The fundamental composition of the samples studied in g $(100g)^{-1}$ meat emulsion

Composition	Sample variants			
	0	1	2	3
Meat	50.0	50.0	50.0	50.0
Water	28.6	30.3	31.2	32
Fat	21.4	19.3	18.2	17.1
Cellulose	0.0	0.4	0.6	0.9

The temperature study of the rheological properties of meat emulsions was performed by the DMA method using a mechanical relaxometer described in [11]. The parameters measured were: the components of the complex elasticity modulus G_1 and G_2 and tgδ, in the range 20°C to 85°C. The frequency of the system vibrations was 0.343[Hz]. The results were read out 20 minutes after the system had reached the desired temperature.

The temperature changes in the components of the complex elasticity and the loss tangent reflect the changes taking place in the molecular structure of the substance studied. Component G_1 is related to this part of the potential energy of deformations which is preserved in periodical deformations and G_2 known as the loss modulus is related to the part of energy undergoing dissipation in the form of heat, tgδ is a measure of internal friction and describes the relative part of energy dissipated in the sample to the energy accumulated in a single cycle of deformations.

The results presented are the mean values of three repeated measurements.

RESULTS AND DISCUSSION

Figures 1 and 2 present the temperature dependencies of the elasticity modulus (G_1) and loss modulus (G_2) obtained for the 4 variants of the samples studied.

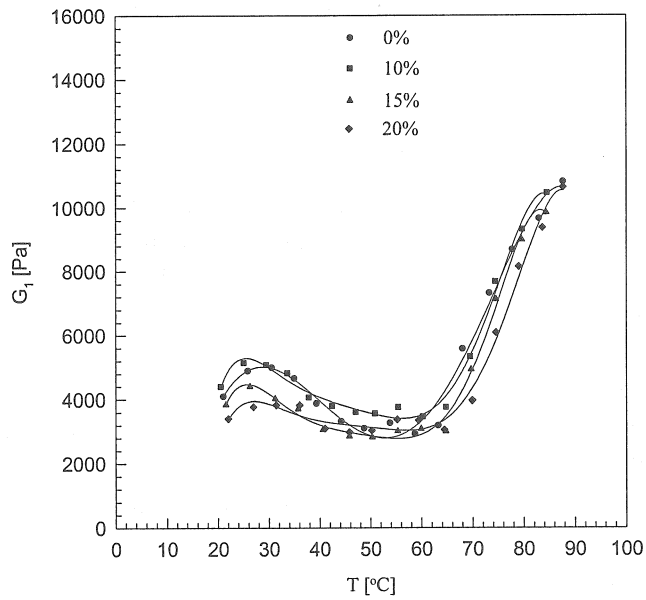

Fig. 1. Temperature dependence of the real component of the elasticity modulus (G_1) for the four variants of the samples studied (legend)

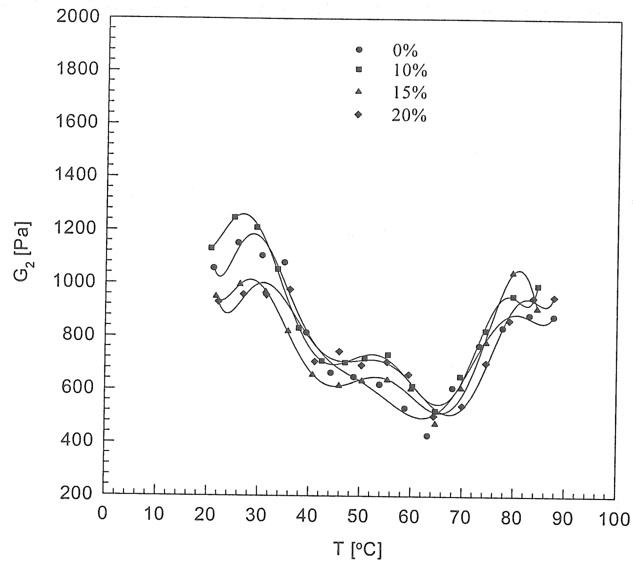

Fig. 2. Temperature dependence of the imaginary component of the elasticity modulus (G_2) of the four variants of the samples studied (legend)

On the basis of the dependencies, three temperature ranges can be distinguished in which the changes of the moduli have different characters: from 20 to about 50°C, from 50 to 65°C and above 65°C. In the first range 20-50°C the values of the elasticity modulus (G_1) and the loss modulus (G_2) decrease significantly with increasing temperature in all four variants of the samples (with and without cellulose). A further increase in temperature to about 65°C causes only a small decrease of the moduli. With a temperature increase from 65 to 85°C the values of both moduli rapidly increase.

The corresponding temperature changes in the loss tangent are shown in figure 3.

In the temperature range studied, the loss tangent value decreases with increasing temperature, which indicates the relative ability to dissipate mechanical energy decreases. The replacement of fat by pea cellulose leads to a decrease in the decrement, which is greater the greater the proportion of fat is replaced by cellulose (above 10%).

Meat emulsion contains fat, water, globular and myofibril proteins, both in the form dispersed in the hydrocolloidal – fat phase and in the form of larger fragments of muscle tissue. Thus, meat emulsion is a multiphase system in which particular components can occur in different states – from liquid to condensed.

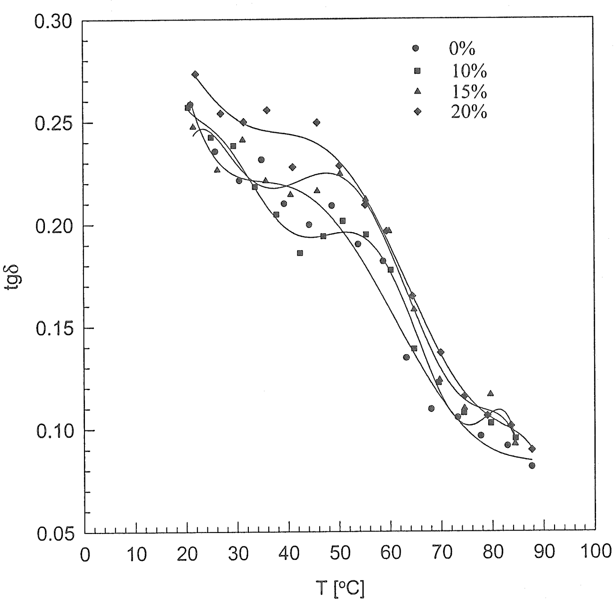

Fig. 3. Temperature dependence of the loss tangent of model meat emulsions for the samples studied

At 20°C, fat along with water, being the main component of the continuous phase of meat emulsion, is in the solid state, which gives high values of the elasticity modulus in all samples studied (~4000[Pa]). The fast decrease in the values of G_1 and G_2 where temperatures increase from 20 to 50°C, (fig. 1 and 2) is related to the phase transition of the fat.

The molten fat and released water with mainly myofibril proteins and some amount of globular proteins form the hydrocolloidal continuous phase. The dispersed phase is made of the condensed components of meat emulsions. In the range 50-65°C, the elastic properties of the meat emulsion samples with and without pea cellulose are – to an insignificant degree – determined by the hydrocolloid phase. The elasticity modulus at a level of ~3200[Pa] is determined by the other components of the meat emulsion and the content of cellulose is unimportant. In the whole temperature range studied, the replacement of fat by pea cellulose leads to increased energy loss (fig. 2).

The temperature dependence of the loss tangent reveals maxima (fig. 3) probably related to denaturation phase transitions of the forcemeat proteins taking place in the range 50-60°C [4].

The processes described above lead to an unfolding of the polypeptide chains. This conformational change favours development of the structure of the hydrocolloidal phase and the association of water absorbed by the cellulose, which can now bond to the previously unavailable hydrophilous groups of the polypeptide chains. In this way the presence of pea cellulose leads to an increasing density of the spatial structure and at the same time restricts the conformational changes of the polypeptide chains delaying the structural processes in meat emulsions. These effects are manifested by a much lower increment in the elasticity of the systems studied above 65°C (fig. 1).

These reconstituted products must show a specific texture. From the point of view of food technology, the texture of food products is determined by their mechano-rheological properties. At the present stage of the study it can be concluded that the rheological properties and thus the texture of the meat emulsions studied, are determined by the thermodynamic state and the contribution of the continuous phase and to a lower degree by the contribution and structural parameters of the dispersed phase containing fragments of muscle tissue and cellulose. This is reflected by the cohesion of the meat emulsions determined in the structural process.

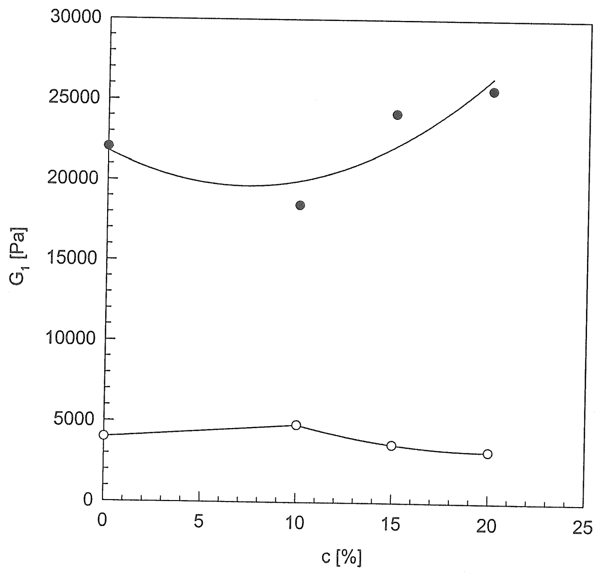

Fig. 4. The temperature dependence of the real component (G_l) of the elasticity modulus of model meat emulsions (after thermal treatment and original) as a function of the proportion of fat replaced by pea cellulose (empty boxes – original state, full boxes – after thermal treatment)

A comparison of the elasticity modulus of the final and original products at 22°C (fig. 4) reveals a more than fourfold increase in the final product and hence an increase in its elasticity. The replacement of 10% of the fat by cellulose leads to a decrease in the elasticity of the system and an increase in its plasticity, because of the specific interaction of the cellulose with fat.

CONCLUSIONS

1. The changes in the continuous phase of meat emulsions with increasing temperature lead, in the beginning, to a melting of fat and a release of the water contained in it.

2. The cellulose has little effect on the elastic properties of meat emulsion and plays mainly the role of a dissipating medium.

3. The replacement of fat by pea cellulose restricts the conformational changes of the polypeptide chains and leads to a delay in meat emulsion.

4. The processes of gelation of the earlier denatured protein components taking place above 65°C are manifested mainly by an increase in G_l and a decrease in tgδ, which indicates increasing elasticity and decreasing plasticity of the meat emulsions subjected to thermal treatment.

5. The elasticity of meat products subjected to thermal treatment and then cooled to room temperature is more than fourfold greater when compared with that of original meat emulsions at the same temperature.

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DYNAMICZNO-MECHANICZNA I TERMICZNA ANALIZA FAZY HYDROKOLOIDALNEJ W MODELOWYCH FARSZACH MIĘSNYCH Z DODATKIEM BŁONNIKA GROCHOWEGO

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Streszczenie. W pracy badano wpływ temperatury na właściwości reologiczne modelowych farszy mięsnych ze zróżnicowanym stopniem wymiany tłuszczu na błonnik grochowy. Określono temperaturowe zmiany wartości podstawowych parametrów charakteryzujących te właściwości. Stwierdzono, że w zakresie temperatur (20-50°C) o zmianach właściwości reologicznych decyduje przejście fazowe tłuszczu. W przedziale temperatur 50-65°C decydującą rolę w kształtowaniu właściwości reologicznych badanych układów odgrywają zmiany zachodzące w strukturze powstałego hydrokoloidu. Błonnik będący wymiennikiem tłuszczu, mimo, że nie bierze udziału w kształtowaniu właściwości sprężystych stanowi element strukturotwórczy farszy.

Słowa kluczowe: reologia, błonnik grochowy, hydrokoloidy