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DYNAMIC-MECHANICAL AND THERMAL ANALYSIS OF THE HYDROCOLOIDAL PHASE IN MODEL MEAT BLENDS WITH ADDITION OF WHEAT FIBRE

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Summary. The aim of the study was to check the influence of temperature on rheological properties of model meat blends in which different proportion of fat was replaced by wheat fibre. The temperature changes of the basic rheological parameters were measured. It was established that in the temperature range 20-40°C, the rheological properties were determined by the fat phase transition. In the range 40-60°C these properties were determined by changes in the structure of the hydrocoloid formed.

Wheat fibre does not show elastic properties, so does not affect the rheological properties, but is a structure formation agent of dissipative character and increases the dynamic viscosity of meat blends.

Keywords: rheology, wheat fibre, hydrocolloid.

INTRODUCTION

In order to change the disadvantageous balance of fat and fibre in the diet, much effort has been undertaken to develop products of diminished calorific value [1]. In meat industry the most often used procedure of reducing the amount of fat involves its replacement by other substances, which bind and retain water, and are of low calorific value or are not digested in the organism.

Fat is one of the main components of meat products and has significant effect on their mechanical and rheological properties, and on the stability of emulsion in highly refined meat products [3,6]. From the point of view of the food technology the mechanical and rheological properties are closely related to the texture of food products [2,14]. However, exact quantitative relations between the molecular, supermolecular structure, cell system structure and the macroscopic mechanical properties of food products have not been fully determined yet.

In literature much attention has been devoted to the relationship between the structure of meat products with different functional additions and their state determined by content of water, temperature and physical properties [5,7,8]. It is a consequence of the fact that the raw products are subjected to hydrothermal and mechanical processing, which leads to significant changes at different levels of molecular organisation. Despite the increasing use of rheometric methods [10,11,12], the relationship between the changes in the molecular structure and the parameters describing macroscopic polydispersive properties of products of complex structure such as meat products, has been a subject of relatively few works.

The aim of this study was to determine the role of wheat fibre in the supermolecular structure of meat blends and the effect of changes in this structure on the mechanical-rheological properties of final product sausage.

MATERIAL AND METHODS

The experimental material was prepared on a semi-industrial scale.
The initial raw material product was 3rd class pork (48%), fine fat (20.8%), water made 29% of the mass of the meat and fat, curing mixture (2.2%) and flavourings (0.4%). In the meat blend fat was replaced by wheat fibre Vitacel type WF 200, hydrated at the rate 1:5, and added in the amount making 5%, 7.5%, 10% of the total input mass. The control sample was meat blend without wheat fibre. The meat cutting grinding of mechanical cutters took 10 minutes. Wheat fibre added in the dry form was hydrated during the cutting, 2/3 of the wheat fibre was added after the 2nd minute and 1/3 after the 8th minute of the process of cutting. The final temperature of the meat blend did not exceed 11-12°C. The cutting bowl capacity was 22 dm^3, the rate of rotation of the knives was 3000 rev/min, and that of the cutting bowl was 20 rev /min.

Changes in the rheological properties of the meat blend as a function of temperature were followed by the DMA method with the use of mechanical relaxometer described in [13]. The components of the complex elasticity modulus: G_1 and G_2, and tgδ, were measured for temperatures ranging from 20°C to 82°C. The frequency of the free vibration of the system was 0.363 [Hz]. The measurements were made 15 minutes after a desirable temperature was achieved. The plots presented have been obtained on the basis of the mean values of three times repeated measurements.

RESULTS AND DISCUSSION

Figure 1 and 2 present the temperature changes of the elasticity modulus (G_1) and loss modulus (G_2), of the meat blend samples with the addition of wheat fibre and without it.

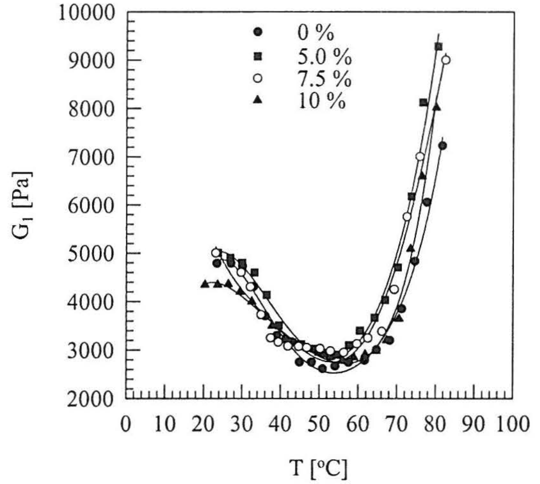

Fig. 1. Temperature dependencies of the real component of the elasticity modulus (G_1) of the meat blends samples studied: with and without wheat fibre.

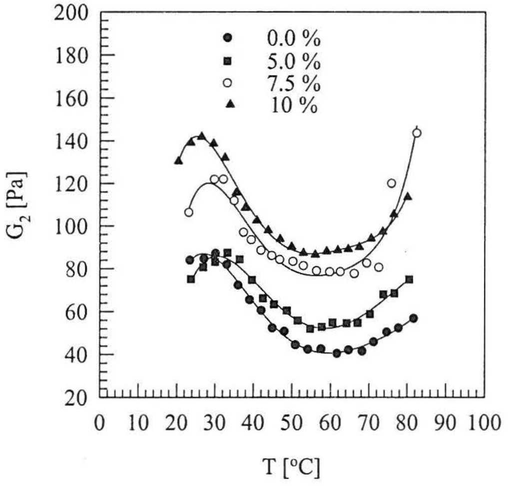

Fig. 2. Temperature dependencies of the imaginary component of the elasticity modulus (G_2) of the meat blends studied: with and without wheat fibre.

Three regions of the temperature changes of different character can be distinguished: from 20 to ~ 40°C, from 40 to 60°C and above 60°C.

In the first region 20 - 40°C the values of G_1 and G_2 decrease, in the sample with wheat fibre and in the sample without it. Further increase of temperature causes only slight decrease of these values. In the range 60°C - 82°C the elasticity modulus rapidly increases, while the loss modulus remains practically the same, although a small increase in its value can be noted near 82°C.

The temperature changes in the tangent of loss have also been measured and their course is illustrated in Fig. 3.

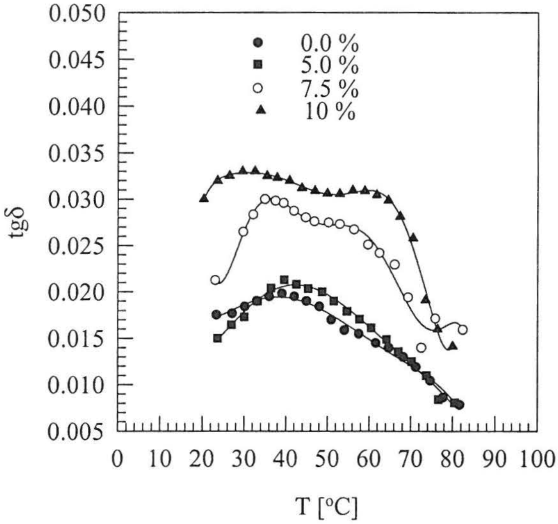

Fig. 3. Temperature dependencies of the tangent of loss in the model phases of meat blends in the samples with and without wheat fibre.

There are two temperature ranges in which tgδ shows a different character of changes: from ~20 to ~40°C and above 40°C. In the first range from 20 to ~ 40°C the values of tgδ significantly increase, which means that the relative ability to scatter the mechanical energy increases leading to maximum loss. Above 40°C, the values of tgδ decrease. In the range 40-60°C the tgδ changes in the samples with fat replaced with wheat fibre in the amount of 5%, show a much smaller decrement, which means that the maximum loss appeared close to 60°C.

Meat blends make complex systems composed of fat, water, globular proteins, myofibrin in the dissipated phase in the hydrocoloid-fat phase and in the form of large fragments of muscle tissue. Thus, the meat blend is a multiphase system whose particular components can occur in different physical phases: liquid or solid.

Fat is besides water the main component of the continuous phase of force-meat and at 20°C it occurs as a solid. Therefore, the elasticity modulus of the systems without wheat fibre and with small amounts of this component take high values 4.4 kPa and 5 kPa, respectively. The fast decrease of G_1 and G_2 in the range 20-40°C, (Fig. 1 and 2) is related to the phase transition of fat, as indicated by a decrease of the dispersion degree δ of G_1 (Fig. 4), observed in samples with increasing amount of fat replaced by wheat fibre.

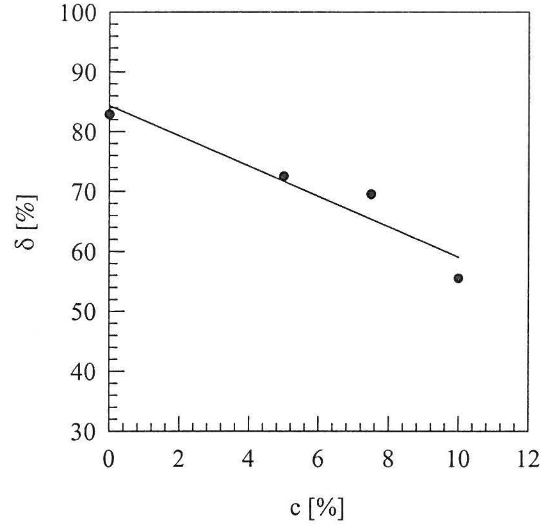

Fig. 4. Relative changes in the dispersion of the elasticity modulus in the model meat blends as a function of fat content.

Increasing fluidity of fat also favours the release of bound water, which additionally increases the system's fluidity in the range 20 - 40°C and leads to a significant decrease of the dynamic viscosity (Fig. 5).

The molten fat and released water together with proteins (mostly myofibril) are the components of the hydrocoloidal continuous phase. The dissipated phase are the solid components of the meat blends.

In the range 40 - 60°C, the elastic properties of the systems with and without wheat fibre are to a small degree dependent on the hydrocoloidal phase, and the elastic response at a level ~3 kPa is determined by the solid components, the effect of fibre is negligible. In the entire temperature range studied the replacement of fat by wheat fibre leads to an increase in the energy loss (Fig. 3) and dynamic viscosity (Fig. 5).

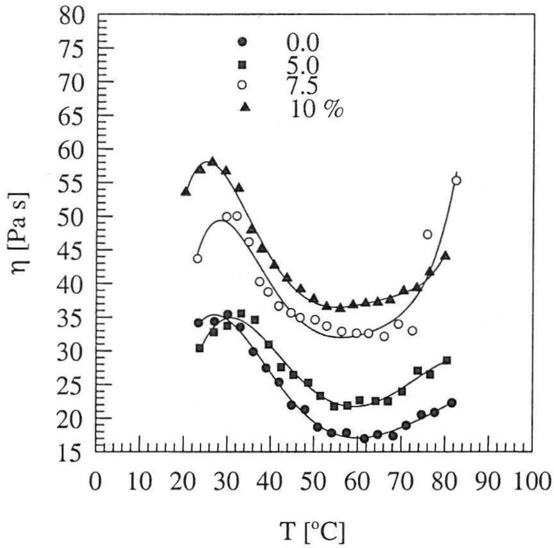

Fig. 5. Temperature dependencies of dynamic viscosity of the model meat blends with and without wheat fibre.

The temperature dependence of tgδ (Fig. 3) in the range 50°C-60°C, for the systems in which over 5% of fat has been replaced by wheat fibre, reveals new maxima related to the relaxation processes of the dissolvable polysaccharides being components of wheat fibre. The decrease of tgδ (Fig. 3) at a simultaneous increase of the elasticity modulus value G_I (Fig. 4) observed above 60°C has been assigned to the denaturation processes of proteins [3,4,9].

As a result of the above processes, the polypeptide chains of proteins unfold. Such a conformational change favours structuralisation of the hydrocoloidal phase and association of water absorbed by fibre, which can bind to earlier inaccessible hydrophilous groups of the polypeptide chains. That is why fibre, making elements of the spatial lattice, leads to an increase of this lattice density. This fact is manifested as an increase of the relative values of the elasticity modulus as a function of temperature (Fig. 6). The presence of wheat fibre probably also changes the pH of the system, leading to a decrease in the denaturation temperature of the proteins and favouring meat blends structure formation. These phenomena are manifested as a much greater increment of the increase of the elasticity modulus.

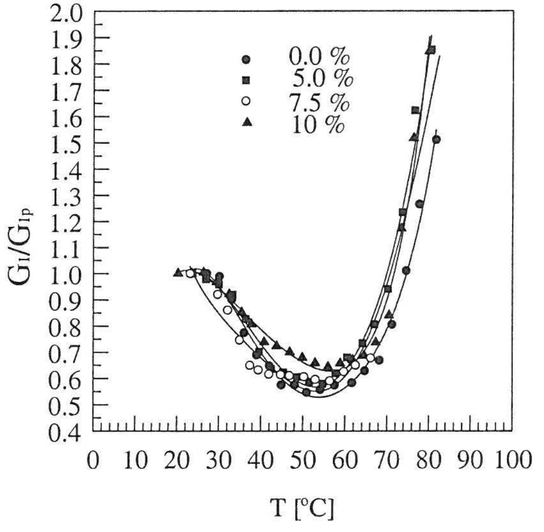

Fig. 6. Temperature dependencies of the relative values of the elasticity modulus obtained for meat blends samples with and without wheat fibre.

CONCLUSIONS

1. Thermal treatment of the meat blends in the range 20 - 40°C was found to change the rheological properties of the samples studies interpreted as due to fat melting.
2. Replacement of fat by wheat fibre leads to a decrease in the degree of dispersion of the rigidity modulus in the above temperature range.
3. In the range of the rigidity modulus minimum (40 - 60°C) the replacement of fat by fibre leads to an increase in the meat blends plasticity, which is manifested by a significant increase in the loss modulus.
4. In temperatures above 60°C an addition of fibre intensifies the processes of spatial arrangement.

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

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Streszczenie. W pracy badano wpływ temperatury na właściwości reologiczne modelowych farszy mięsnych ze zróżnicowanym stopniem wymiany tłuszczu na błonnik pszenny. Określono temperaturowe zmiany wartości podstawowych parametrów charakteryzujących te właściwości. Stwierdzono, że w zakresie temperatur (20-40°C) o zmianach właściwości reologicznych decyduje przejście fazowe tłuszczu. W przedziale temperatur 40-60°C decydującą rolę w kształtowaniu właściwości reologicznych badanych układów odgrywają zmiany zachodzące w strukturze powstałego hydrokoloidu.

Błonnik nie wykazuje właściwości sprężystych, tym samym nie kształtuje tych właściwości, aczkolwiek stanowi czynnik strukturotwórczy o charakterze dyssypacyjnym, zwiększając lepkość dynamiczną farszy.

Słowa kluczowe: reologia, błonnik pszenny, hydrokoloidy.