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EFFECT OF THE REPLACEMENT OF MEAT BY THE CC400 PROTEIN PREPARATION AND FAT – BY WHEAT FIBRE ON RHEOLOGICAL PROPERTIES OF MEAT FILLINGS

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A b s t r a c t. The aim of the study was to examine the effect of temperature on the rheological properties of model meat fillings in which meat was partially replaced by a protein extract and fat – by wheat fibre. Using the dynamic-mechanical thermal analysis (DMTA), the authors determined the values of temperature changes of the basic parameters which characterise these properties. It was found that the rheological properties and, hence, the texture of the examined meat fillings were affected more by the continuous phase and less by the proportion of the dispersed phase of the meat tissue fragments and fibre. This was reflected in the consistence of the filling which was the effect of the structuring process. The final products modified by both the applied protein extract and with the simultaneous replacement of fat by the wheat fibre, in comparison with the non-modified products, were characterised by improved plastic properties and, therefore, by worse elasticity. This was confirmed by increasing values of the rigidity modulus accompanied by a simultaneous increase of losses of the mechanical energy.

K e y w o r d s: rheology, DMTA, water, fat

INTRODUCTION

The most popular method of reducing fat in meat products employed in the meat processing industry is its replacement with substitutes which bind and hold water, are low-caloric or do not undergo any digestion in the organism. Most frequently these replacers include various types of substances of natural or synthetic origin often referred to as hydrocolloids or structure-forming additives. In the majority of cases, they occur as components modelling the structure and texture of food products by way of thickening, jellifying or emulsifying [4,10,12]. However, complete fat elimination from recipe formulations of meat products is not possible because fat raw materials, together with protein and water, constitute the main components of meat products. Fat affects the rheological properties of fillings, the texture of the end-product, as well as its palatability and juiciness [13,19] and exerts a significant influence on the emulsion stability in finely comminuted sausages [5].

From the physical point of view, meat is a multi-phase system of complex internal structure (myofibrillar and globular protein, fats, water). The remarkably complex internal structure of this raw material is further complicated by a wide range of functional additives, the aim of which is to improve the quality of the end-product [7,11]. This has a significant influence on the mechanical-rheological properties which reflect the state of the material structure [3,18]. This can be attributed to the fact that, in the course of processing, the raw materials are subjected to hydrothermal and mechanical processing resulting in considerable structural alterations at various levels of molecular organisation. Despite the growing popularity of rheometric techniques [6,9], there are very few papers devoted to interrelations between changes in the molecular structure and values describing macroscopic properties of poly-dispersive materials of complex internal structure, including meat-containing products.

The objective of this research project was to determine correlations between different levels of meat substitution by a protein extract and of fat replacement by wheat fibre and the rheological properties of meat fillings subjected to thermal treatment as well as of final products as exemplified by sausage, finely comminuted fillings of the frankfurter type.

MATERIAL AND METHODS

The experimental material (Tab. 1) com-prised two samples of sausage, finely comminuted fillings with meat partly replaced by the CC440 protein extract (first sample). In the second sample, apart from the meat replacement, 20% of fat was substituted by the Vitacel WF 400 type wheat fibre rehydrated at the ratio of 1:6.

Table 1. Basic composition of the control sample of filling

Component	Content (%)
Pork meat, class III	48.71
Fine fat	20.88
Water	27.83
Curing mixture	0.97
NaCl	0.97
Herbs	0.58
Sodium ascorbianin	0.06

The CC400 protein extract was dehydrated at the ratio of 1:7.5. The preparation modified in this way was used to replace 5%, 10% and 15% of meat from the basic composition. The presented procedure shows that the amount of added water increased in each of the recipe modified fillings. Tables 2 and 3 present the water content in the examined samples. Characteristics of the CC400 protein extract is presented in Table 4.

Table 2. Percentage water content in fillings with the addition of the CC400 protein extract and of various levels of meat replacement

Water (%)	Meat replacement			
	0%	5%	10%	15%
	27.8	31.18	34.42	37.52

Table 3. Percentage water content in fillings with the addition of the CC400 protein extract, fat replaced by the wheat fibre Vitacel type WF 400 and of various levels of meat replacement

Water (%)	Meat and fat replacement			
	0%	5%	10%	15%
	27.8	34.69	37.52	40.87

Table 4. Physicochemical data of the CC400 protein extract

Protein	91%
Fat	9%
Moisture content	<5%
NaCl	<4%
Hydroxyproline	8.8%
Collagen	70%

The experimental fillings were manufactured in a cutter of 22 dm^3 capacity. The rotational velocity of knives was 3000 rpm and that of the bowl – 20 rpm.

Investigations of changes in the rheological properties of fillings in the temperature function were conducted using the DMTA method with the assistance of a mechanical relaxometer described in another article [17]. It is a prototype oscillation rheometer developed in COBRABiD which operates on the basis of the principle of analysis of free vibrations of the reversed torsional pendulum. In the course of the performed measurements, the following parameters were determined: component values of the combined rigidity modulus G_1 (storage modulus) and G_2 (loss modulus) as well as $tg\delta$ in the temperature interval from 20^oC to 85^oC. The frequency of the system's own vibrations was 0.363 Hz. The rate of heating was $1^oC\ min^{-1}$. The results are mean values for three replications.

RESULTS AND DISCUSSION

Figures 1 and 2 present temperature interrelationships of rigidity moduli (G_1) of the examined meat fillings, of the control filling as well as the fillings with meat replaced by a protein preparation and reduced fat content (20% fat replaced by wheat fibre). In the entire interval of meat replacement (5-15%) and in the identical treatments in which the level of fat was reduced, together with the increase of temperature, the value of the rigidity modulus was below that of the filling which was not modified.

Irrespective of the method of modification, the runs of temperature changes of moduli values showed different intensity and character of these changes. Each of the three temperature intervals (first – from 20 to about 40°C, second – from 40 to 65°C and third – above 65°C) was connected with different molecular changes occurring in the filling under the influence of temperature.

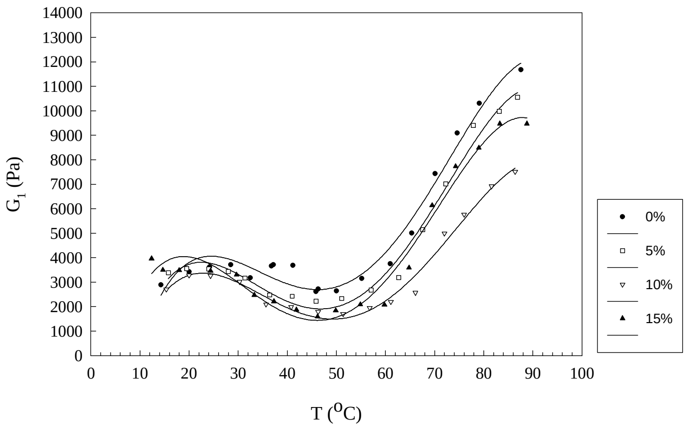

Fig. 1. Temperature relationships of the storage modulus (*G_1*) of meat model fillings: control and with meat replaced by protein extract, in %

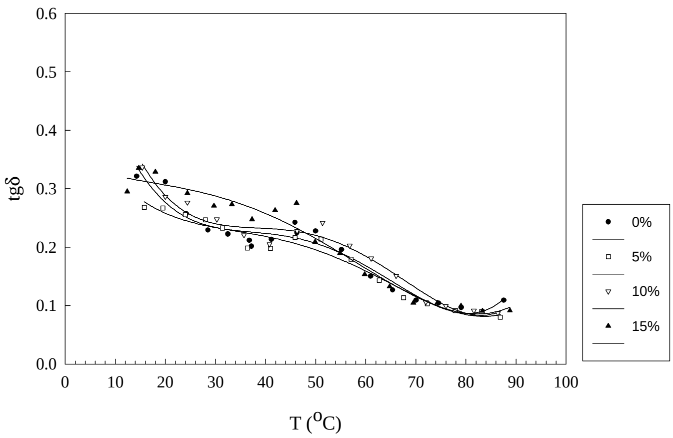

Fig. 2. Temperature relationships of the storage modulus (*G_1*) of meat model fillings: control and with meat replaced by protein extract and with the replacement of part of fat by wheat fibre, in %

In the temperature intervals from 20 to about 40°C, a distinct dispersion of the rigidity modulus value (*G_1*) could be observed.

This occurred both in the control treatment and in the modified system. Any further temperature increase resulted only in small changes in the values of the above-mentioned moduli. It was only when the temperature increased from about

65°C to 85°C that these values increased rapidly. Similarly to the temperature value changes of the rigidity modulus, the authors also analysed changes of the temperature runs of the tangent loss angle values $tg\delta$ (Fig. 3 and Fig. 4).

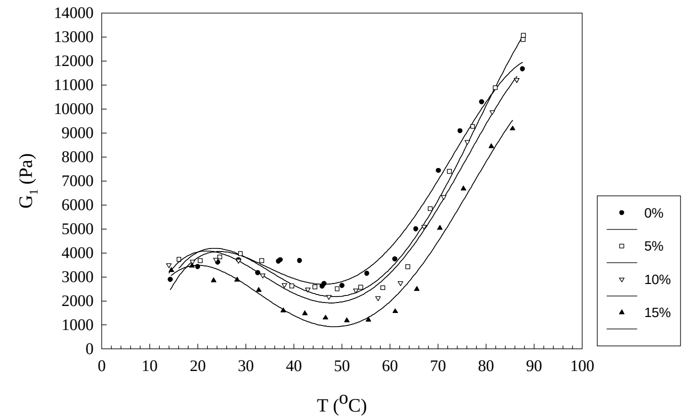

Fig. 3. Temperature relationships of the tangent loss angle of meat model fillings: control and with meat replaced by protein extract, in %

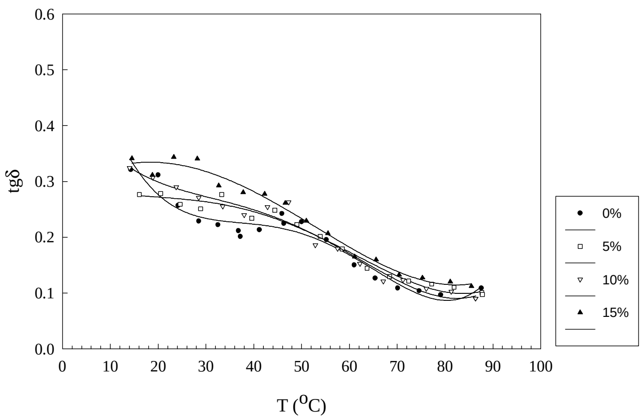

Fig. 4. Temperature relationships of the tangent loss angle of meat model fillings: control and with meat replaced by protein extract and with the replacement of part of fat by wheat fibre, in %

The systems showed a decreasing capability for the dispersion of the mechanical energy in the entire interval of the examined temperatures. The changes in the level of meat replacement by hydrated protein extracts were reflected by differences in the decrement as well as the value level of these changes. This also occurred in systems in which part of fat was replaced by wheat fibre.

Earlier investigations [14-16] revealed that fat (apart from water) constitutes the principal component of the continuous phase of the examined fillings. At room temperature (20°C), it is at the solid phase. This has a decisive effect on the observed high values of the rigidity modulus (G_1) for the control filling (about 4300 Pa) and for fillings modified by the two methods in the entire range of meat replacement (G_1 – 3800 Pa).

In the initial interval of temperature changes (20-40°C), the observed dispersion area of the G_1 rigidity modulus (Fig. 1 and Fig. 2) was associated with the fat phase transfer.

The liquefaction of fat leads directly to increased fluidity of the solid phase of fillings and favours the liberation of the water dispersed in it. This, in turn, additionally increased the fluidity of the system in the analysed temperature range (20-40°C) and led to distinct changes in the value of dynamic viscosity (Fig. 5 and Fig. 6).

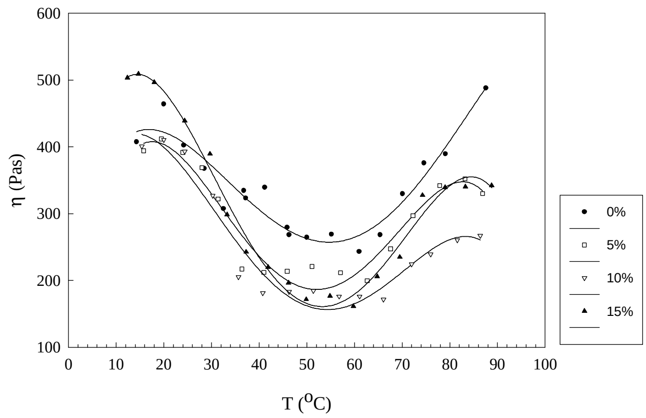

Fig. 5. Temperature relationships of dynamic viscosity of meat model fillings: control and with meat replaced by protein extract, in %

Systems with meat replaced by a protein extract were characterised by greater value changes of their viscosity in comparison with the fillings in which part of their fat was substituted by wheat fibre. This was caused by the fact that part of water was absorbed by fibre constituents (mainly cellulose), with the lower fat content acting as another contributory factor. Consequently, the examined systems differed from one another with regard to the degree of packing of the condensed filling components.

Melted fat as well as the liberated water and proteins, mainly myofibrillar and, to a lesser degree, globular, contained in meat led to the development of the hydro-colloidal continuous phase. The dispersed phase, on the other hand, was made up of the condensed components of the filling.

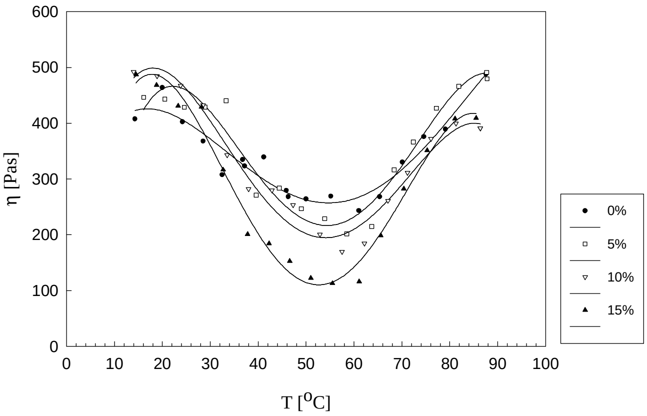

Fig. 6. Temperature relationships of dynamic viscosity of meat model fillings: control and with meat replaced by protein extract and with the replacement of part of fat by wheat fibre, in %

At the temperature interval of 40-65°C, the hydro-colloidal phase influenced the elastic properties of the examined filling only slightly. This referred both to the control filling and the modified systems (irrespective of the method). The elastic response at the level of approximately 2300 Pa was affected by the resistance of the meat components of the filling, and fibre had no part in it. In the analysed temperature range, the replacement of meat by hydrated protein extracts resulted in a decrease of both the energy losses (Fig. 3 and Fig. 4) and the value of the dynamic viscosity (Fig. 5 and Fig. 6).

During the initial range of the analysed temperatures (40-65°C), processes associated with the gellification of protein components took place. As a result of denaturation processes (located at the temperature range of about 50-60°C) [1,2,8] and development of new bonds, a new and more compact gel is formed, as evidenced by the increase of the G_1 rigidity modulus (Fig. 1 and Fig. 2) above 65°C. This is further confirmed on the curve of the temperature relationship of the tangent loss angle. This was particularly visible in the extracts modified by the protein extract (Fig. 3) in the form of the maximum. In the systems in which fat was replaced by fibre, these effects were masked by relaxation processes taking place at the range of temperature from 50-60°C associated with soluble polysaccharides contained in the wheat fibre (Fig. 5).

Following gellification and then denaturation, protein polypeptide chains developed and such conformation change favoured structuring of the hydro-colloidal phase as well as water association which could bind with the hitherto unavailable hydrophilic groups of polypeptide chains. The reduction of the meat tissue proportion in the raw material set and its replacement by the water and protein extract resulted in the increase of effective protein concentration responsible for the formation of networked spatial matrixes maintaining the water-fat emulsion. However, the lower share of the condensed filling components caused loosening of its structure. This became apparent in the decline of the value of the rigidity modulus G_1 (Fig. 1) which, at the simultaneous increase in the value of the mechanical energy losses (Fig. 3) and dynamic viscosity (Fig. 5), indicated lower elasticity of these systems within the entire range of replacements in the analysed range of temperatures (40-65^{o}C).

On the other hand, the reduced proportion of the fat tissue in the raw material and its replacement by hydrated fibre increased the total water content which took part in the development of spatial matrixes, whereas the fibre itself, forming elements of the special network, led to an increase of its density. Despite the increased density of the protein network, the elastic response of the system, in which the proportion of fats was reduced, was found to be on a lower level than in systems modified by protein extracts.

This can be attributed to the fact that a part of fat molecules was probably bound with fibre fibrils and, by doing so, they reduced the free energy of influence between chains which stabilise the spatial network of the protein gel. This, in turn, affected the already small contribution of fibres to the development of elastic reactions of the system. This happened because the fibre did not show elastic properties and acted as a “filler” of a dissipative nature, as evidenced by considerably higher values of losses of the mechanical energy in the systems in which fat was replaced (Fig. 4).

Restructured products must be characterised by a defined texture. From the point of view of food technology, the texture of food products is associated with mechanical-rheological properties which determine this property to a considerable extent.

At this stage of investigations, it can be stated that the rheological properties and, consequently, the texture of the examined meat fillings, were influenced by the physical state and the proportion of the continuous phase and, to a lesser degree, by the structural parameters of the dispersed phase of the fragment of the meat tissue and fibre. This was reflected by the consistence of the filling which was affected by the structuring process.

The final products modified by both the protein extract and the simultaneous replacement of fat by wheat fibre, in comparison with the non-modified products, were characterised by worse elasticity as evidenced by the increasing values of the rigidity modulus (Fig. 7) at the simultaneous increase of losses of the mechanical energy (Fig. 8).

Systems subjected to the modification by the protein extract and which, simultaneously, had their fat replaced by wheat fibre, exhibited worse elastic properties in comparison with the systems modified only by the protein extract. This can by explained by the fact that part of fat molecules bound with fibre fibrils, after cooling, solidified and stiffened them additionally. On the other hand, the fibre itself did not exhibit elastic properties and it served as a "filler" of a dissipative nature. This was evident in a considerably higher value level of mechanical energy losses in the systems in which fat was replaced (Fig. 8).

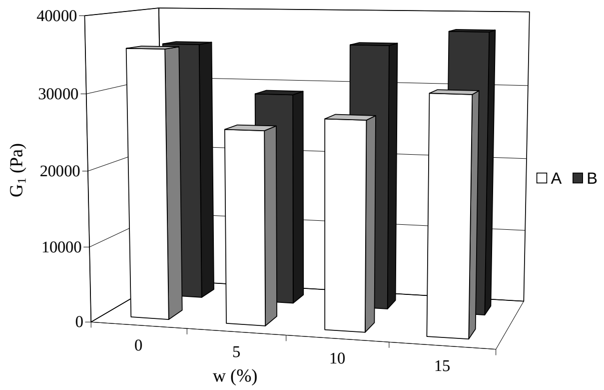

Fig. 7. Relationships of the storage modulus (G_1) of meat model fillings subjected to the thermal treatment after cooling at the temperature of 20°C with meat replaced by protein extract (A) and with the simultaneous replacement of part of fat by wheat fibre (B), in %

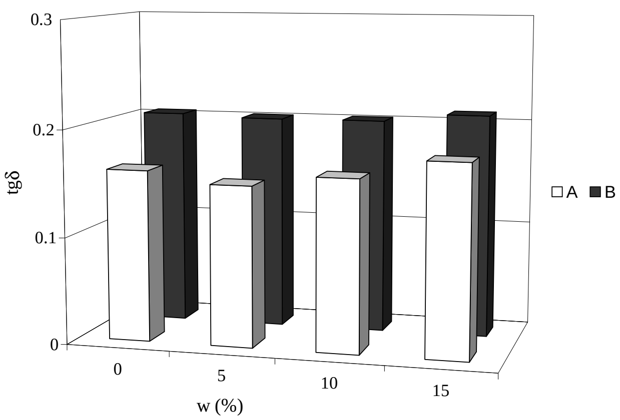

Fig. 8. The $tg\delta$ relationships of model meat fillings subjected to the thermal treatment after cooling at the temperature of 20°C with meat replaced by protein extract (A) and with the simultaneous replacement of part of fat by wheat fibre (B), in %

CONCLUSIONS

1. Rheological properties are affected more by the continuous phase and less by the proportion of the dispersed phase of fragments of the meat tissue and fibre.

2. The result of the gellification of the protein components of the meat fillings is the observed, at higher temperatures (above 60^{o}C), increase of the G_1 value and decline of $tg\delta$. This indicates the increasing elasticity of the fillings subjected to the thermal treatment.

3. The decrease in the proportion of the meat tissue in the filling led to the loosening of its structure. This was reflected in the level of basic values of rheological parameters.

4. The comparison of values of the rigidity modulus of the final products cooled to room temperature with fillings which were not subjected to the thermal treatment showed manifold increase of their values.

5. Final products modified both by the protein extract and simultaneously with fat replaced by wheat fibre, in comparison with the non-modified products, were characterised by a decrease of their elastic properties.

6. The interaction of fat molecules with the fibre fibrils resulted in greater stiffening and, hence, reduced the elastic properties of the final products in which fat was replaced by wheat fibre in comparison with the products modified only by the protein extract.

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WPŁYW WYMIANY MIĘSA PREPARATEM BIAŁKOWYM CC400 I TŁUSZCZU BŁONNIKIEM PSZENNYM VITACEL NA WŁAŚCIWOŚCI REOLOGICZNE FARSZY MIĘSNYCH

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S t r e s z c z e n i e. W pracy badano wpływ temperatury na właściwości reologiczne modelowych farszy mięsnych ze zróżnicowanym stopniem wymiany mięsa ekstraktem białkowym oraz tłuszczu błonnikiem pszennym na właściwości reologiczne farszy mięsnych poddawanych obróbce termicznej jak i produktów finalnych. Wykorzystując technikę DMTA (dynamiczno mechaniczna analiza termiczna) określono temperaturowe zmiany wartości podstawowych parametrów charakteryzujących te właściwości. Stwierdzono, że o właściwościach reologicznych a tym samym o teksturze badanych farszów mięsnych decyduje faza ciągła, a w mniejszym stopniu udział rozproszonej fazy fragmentów tkanki mięśniowej i błonnika. Znajduje to swoje odbicie w spoistości farszu będącego efektem procesu strukturowania. Produkty finalne modyfikowane zarówno ekstraktem białkowym jak i równocześnie z wymienionym tłuszczem na błonnik pszenny w porównaniu do produktów niemodyfikowanych odznaczają się mniejszą sprężystością. Świadczą o tym rosnące wartości modułu sztywności przy równoczesnym wzroście strat energii mechanicznej.

Słowa kluczowe: reologia, DMTA, woda, tłuszcz