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THE EFFECT OF THE FORMS OF STARCH PREPARATION ADDED TO REPLACE FAT ON THE RHEOLOGICAL PROPERTIES OF BATTERS DURING THERMAL TREATMENT

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A b s t r a c t. Temperature changes in batters, in the formulation of which 3% of fat was replaced with potato starch E1412 prepared in various ways, were investigated using the DMA method with the application of a mechanical relaxometer. In variant I, starch was added in the dry form during chopping, whereas in variant II it was added in the form of starch dispersion, and in variant III – in the form of gel. Batters with the basic formulation constituted the control sample (variant 0). At room temperature the solid phase of fat determined the rheological properties of batters, both the control one and those with starch preparation E 1412 added to replace fat (as dry mass, as suspension and as starch gel), irrespective of the mode of starch introduction. Increasing temperature induces at first changes in the continuous phase leading to liquefaction of fat and release of the water dispersed in the fat, which increases the system fluidity. Replacement of fat by dry starch preparation and its suspension does not have a significant effect on the conformational changes taking place in the hydrocolloidal-fat phase (40-60°C), so also on the structuralisation of batters. The starch preparation is not an elastic but a viscous factor. The final products with fat replaced by starch preparation (as dry mass, as suspension and as starch gel), irrespective of the mode of starch introduction, are characterised by greater elasticity than the unmodified product. The lowest plasticity and the highest elasticity are shown by the systems with fat replaced by starch gel.

K e y w o r d s: rheology, starch, hydrocolloid, elasticity

INTRODUCTION

It has been established beyond doubt that excessive intake of fat poses a risk of obesity, arteriosclerosis, angina pectoris, diabetes and some neoplasmic changes. The tendency, recommended by dieticians and motivated by health protection, to lower the intake of fat has prompted much effort towards development of reduced-energy food products, including low-fat meat products.

Meat products of reduced calorific value can be obtained by reduction of fat content in traditional products or by the use of fat substitutes of lower energy value [1].

Recently, much attention has been paid to substances of natural or synthetic origin known as hydrocolloids or structuralisation factors. They are mostly applied as components modifying the structure and texture of food products through densification, gelation or emulgation [2,7,8,10,11].

Total elimination of fat from meat products is impossible because fats, along with proteins and water, are the main components of meat. The fat determines the rheological properties of batters, texture of the final product, its taste and succulence [9,12], and has a significant effect on the stability of emulsion in highly refined meat products [5,6].

From the point of view of food technology, the mechano-rheological properties of a product are strictly related to its texture [3,14,15]. However, only a few authors have been interested in the relation between the changes in the molecular structure and the parameters describing macroscopic properties of polydispersed products of complex internal structure, such as meat products.

The aim of this study was to check the effect of the mode of hydration of starch preparation on the supermolecular structure of batters, and to determine the effects of the changes in the hypermolecular structure on the mechano-rheological properties of meat products on the example of highly refined sausages.

MATERIALS AND METHODS

The experimental material was prepared on a semi-technological scale. The raw product was pork meat of third class (48.71%), fine fat (20.88%), water at the level of 27.83% of the mass of meat and fat, additions (NaCl) (2%) and spices (0.58%). In the batters, fat was replaced by starch densifier E1412 added in 3% either as dry mass (1st variant) or as a suspension (2nd variant) or as starch gel (3rd variant). The control sample was batter without starch addition. The process of chopping lasted 8 minutes. The final temperature of the batters did not exceed 11-12^{o}C. The capacity of the cutter was 22 dm^3, the rotation rate of the knives was 3000 rpm, and the rotation rate of the cutter bowl was 20 rpm.

Temperature changes in the rheological properties of batters were studied by the DMA method using a mechanical relaxometer described by Rezler and Poliszko [13]. The quantities measured were: the components of the complex elasticity modulus: G_1 and G_2, the loss tangent $(tg\delta)$ in the range 20-85^{o}C. The frequency of free vibrations of the system was 0.363[Hz]. The measurements were made 15 minutes after the system had reached the desired temperature.

The results are mean values for three repetitions.

RESULTS AND DISCUSSION

Figure 1 presents the temperature dependencies of the elasticity modulus *(G_1)* of the batters studied with fat replaced by starch preparation in three forms (dry mass, suspension and gel) and for the control sample.

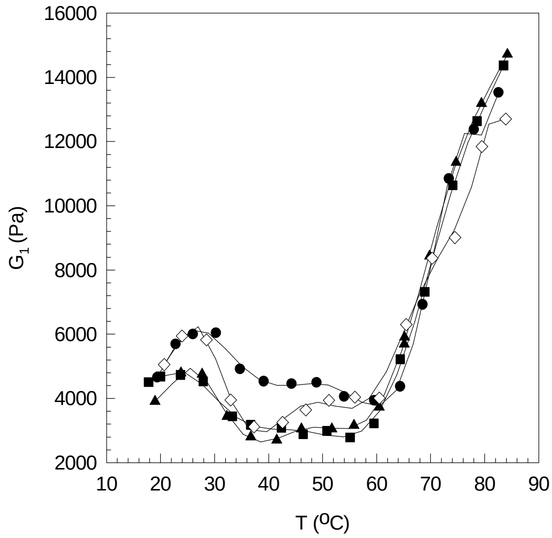

Fig. 1. Temperature dependencies of the real component of the elasticity modulus *(G_1)* for the batter samples with fat replaced by starch preparation in three forms: dry mass- square points, suspension – triangle points, gel – diamond points) and for the control sample – circle points

The temperature dependence of the elasticity modulus reveals three ranges of different characteristic behaviours of the modulus: from 20 to about 40°C, from 40 to 60°C and above 60°C. In the first range, 20 to about 40°C, the elasticity modulus *(G_1)* decreases with increasing temperature for all the samples studied, that is those with and without 3% of fat replaced. Further increase of temperature causes a small decrease of the modulus, and starting from about 60°C to 85°C its value rapidly increases.

The changes of the loss tangent with temperature are shown in Figure 2.

In the whole range of temperatures studied, the value of the loss tangent decreases, which indicates a decrease of the relative capability of mechanical energy dispersion. The fat replacement by starch preparation (irrespectively of the form) leads only to differences in the decrement and the level of the changes.

Along with water, fat is the main component of the continuous phase of batters. At 20°C it is in solid phase, thus at room temperature it determines the rheological properties of the batters. This is confirmed by the high value of the elasticity modulus (Fig. 4) for the control sample (~5800 Pa) and lower values for the samples with fat replaced by starch preparation in dry form and suspension, of 4400 and 3800 Pa, respectively. Comparable values of the elasticity modulus of the control sample and the sample with fat replaced by starch gel follow from the gel contribution to the elasticity of the system.

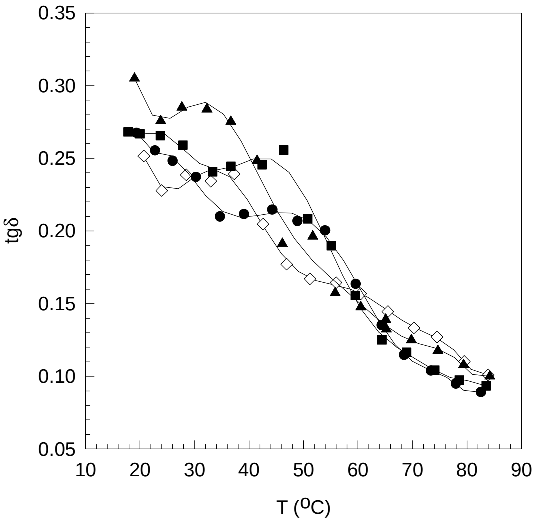

Fig. 2. Temperature dependencies of the loss tangent for the batter samples with fat replaced by starch preparation in three forms: dry mass- square points, suspension – triangle points, gel – diamond points) and for the control sample – circle points

The fast decrease in G_1 in the range 20-40°C (Fig. 1) is related to the fat phase transition. Liquefaction of fat increases the fluidity of the continuous phase and favours the release of water captured in the fat, which additionally increases the fluidity of the system and leads to significant changes in the dynamic viscosity (Fig. 3).

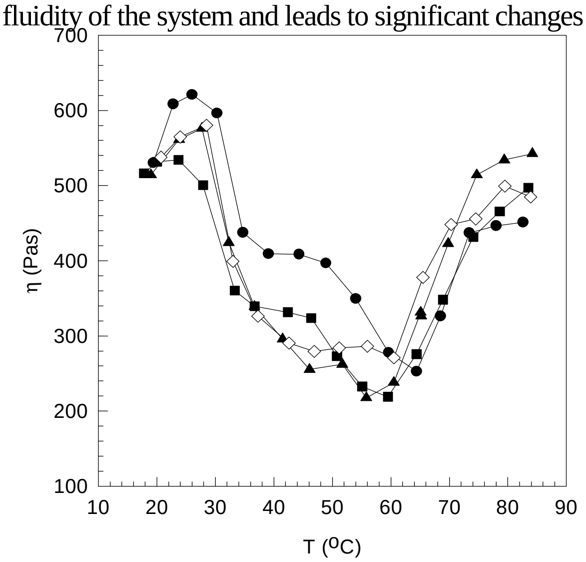

Fig. 3. Temperature dependencies of the dynamic viscosity for the batter samples with fat replaced by starch preparation in three forms: dry mass-square points, suspension – square points, gel – diamond points) and for the control sample – circle points

The molten fat and water released from the fat, together with proteins (mainly myofibril ones and some globular ones), cause the appearance of a hydrocolloidal continuous phase. The dispersed phase is made of the condensed components of the batters.

In the range of 40-60°C, the hydrocolloidal phase determines the elastic properties of all the batter samples studied only to a small degree. The elasticity modulus value of ~3000 Pa is determined by the resistance of the meat components of the batters, and the influence of starch is insignificant. In the whole temperature range analysed, the replacement of fat by starch preparation leads to a decrease in the loss tangent (Fig. 2) and in the dynamic viscosity (Fig. 3).

In the range 40-60°C, irreversible changes take place in hydrocolloids and they determine the rheological properties of batters subjected to thermal treatment and in the final products as well. The changes are reflected in the increase in the elasticity modulus G_1 and dynamic viscosity η observed above 60°C, and are related to the processes of denaturation of proteins taking place in the range of 50-60°C [2,4,11]. They are also manifested as a maximum in the temperature dependence of the loss tangent (Fig. 2). In those processes the polypeptide chains of proteins unfold. Such a conformational change favours the processes of structuralisation in the hydrocolloidal phase and association of water that can bind with the hitherto unavailable hydrophilous groups of the polypeptide chains forming cross-linked network supporting the water-fat emulsion [5,6]. The replacement of fat by starch preparation in the form of suspension or dry mass, provided that the amount of water in the system is preserved, does not lead to a decrease in the effective concentration of proteins responsible for the deve-lopment of the above described spatial matrix. This conclusion is drawn from the fact that the increase of the elasticity modulus above the temperature of denaturation (above 60^{o}C) is the same for all the systems studied (Fig. 1).

In the systems in which fat has been replaced by starch in the form of dry mass and suspension, the values of the loss tangent $tg\delta$ (Fig. 2) and dynamic viscosity η (Fig. 3) are higher than those for the control sample (unmodified). These observations suggest that when using starch preparation in those forms, the effects related to gelation and consequently cross-linking of starch are limited because starch mostly forms only viscous solution (water is bound only in the hydration shell) The starch preparation only plays a role of a filler of dissipative character.

Water plays the main role in the structuralisation of the continuous hydro-colloidal-fat phase. The replacement of fat by starch preparation in the form of gel leads to a reduction of the amount of available water as it is mostly bound with hydroxyl groups of cross-linked starch. This leads to weaker conformational changes in the polypeptide chains, to a decrease in the density of the protein matrix and thus to a delayed structuralisation of the batters. These changes are manifested as a lower increase of the elasticity modulus of the systems studied above the temperature of denaturation of protein components (60^{o}C), (Fig.1).

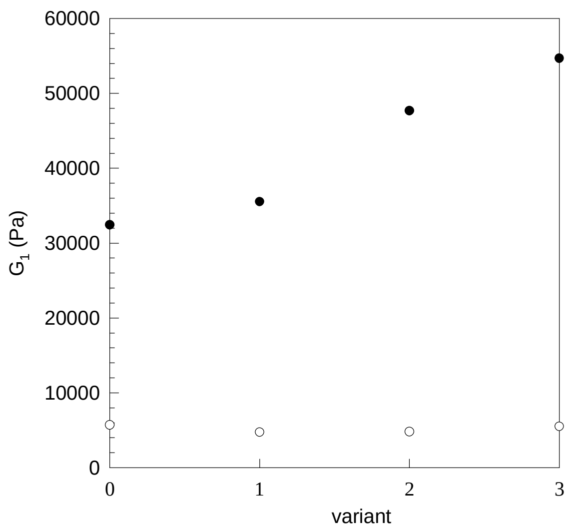

Fig. 4. The dependencies of the real component of the elasticity modulus *(G_1)* of batters subjected to thermal treatment (full dots) and raw batters (empty dots); control sample and samples with fat replaced by starch preparation (1-control, 2-dry mass, 3-suspension, 4-gel) at 20^{o}C

As follows from Figure 4, the elasticity modulus of the final product cooled down to room temperature is a few times higher than that of the batters that have not been subjected to thermal treatment, so a few times greater elasticity of the former. The greatest – more than 2-fold – increase in G_1 has been noted for the batters with 3% fat replaced by starch gel.

The increase in the elasticity of the final products with fat replaced by starch preparation is a result of the relatively weak processes of cross-linking of partly gelled starch (dry mass and suspension) and development of the matrix of gelled protein. The greatest elasticity is that of the final products in which fat has been replaced by starch gel, since in these products the cross-linking effects of the gelled starch are fully revealed.

CONCLUSIONS

1. At room temperature the solid phase of fat determines the rheological properties of all the samples of batters studied, i.e. the control and those with fat replaced by starch preparation in all forms considered.

2. With increasing temperature (20-40^{o}C), the fat component melts and the water dispersed in the fat is released, which results in an increased fluidity of the system.

3. Replacement of 3% of fat by starch preparation in the forms of dry mass or suspension does not have a significant effect on the structuralisation of the hydrocolloidal-fat phase, and thus of the batters as well. The starch preparation is not an elastic but a viscous factor.

4. The final products with fat replaced by starch preparation, irrespective of its form, are characterized by greater elasticity than the unmodified product.

5. The batters with fat replaced by starch preparation in the form of starch gel are characterized by the lowest plasticity and thus the highest elasticity.

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WPŁYW SPOSOBÓW DODAWANIA PREPARATU SKROBIOWEGO NA WŁAŚCIWOŚCI REOLOGICZNE FARSZÓW MIĘSNYCH W TRAKCIE OBRÓBKI CIEPLNEJ

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S t r e s z c z e n i e. W pracy badano temperaturowe zmiany właściwości reologicznych farszów, w których składzie recepturowym zastępowano 3% tłuszczu, różnie przygotowaną skrobią ziemniaczaną E1412. Badania wykonano metodą DMA przy użyciu relaksometru mechanicznego. W wariancie I, skrobię w postaci suchej dodawano podczas kutrowania, w II zaś w postaci dyspersji skrobiowej, natomiast w III w postaci żelu. Próbkę kontrolną stanowił farsz o podstawowym składzie recepturowym (wariant 0). W temperaturze pokojowej faza stała tłuszczu ma decydujące znaczenie w kształtowaniu właściwości reologicznych farszów kontrolnego jak i układów, w których tłuszcz został zastąpiony preparatem skrobiowym (w postaci suchej, dyspersji oraz żelu). Wywołane wzrostem temperatury zmiany w obrębie fazy ciągłej, farszów mięsnych na początkowym etapie prowadzą do rozpłynniania tłuszczów i uwalniania dyspergowanej w tłuszczach wody, co wywołuje wzrost płynności układu. Wymiana tłuszczu suchym preparatem skrobiowym oraz jego zawiesiną nie powoduje istotnego wpływu na zmiany konformacyjne zachodzące w fazie hydrokoloidalno-tłuszczowej (40-60^{o}C), a tym samym nie ma wpływu na struk-uralizację farszów mięsnych. Udział skrobi w kształtowaniu właściwości reologicznych farszów nie ma charakteru sprężystego. Skrobia stanowi czynnik lepki. Wyroby finalne z wymienionym tłuszczem na preparat skrobiowy (w postaci suchej, dyspersji oraz żelu) charakteryzują się większą sprężystością w porównaniu do produktu niemodyfikowanego. Najmniejszą plastycznością a tym samym największą sprężystością charakteryzują się układy z wymianą tłuszczu, kleikiem skrobiowym (żelem).

S ł o w a k l u c z o w e: reologia, skrobia, hydrokolid, elastyczność