Acta Agrophysica, 2007, 9(1), 221-231

EFFECT OF THE SUBSTITUTION OF MEAT BY A PROTEIN PREPARATION ON THE RHEOLOGICAL PROPERTIES OF FINELY-COMMINUTED SAUSAGE FORCEMEATS

Ryszard Rezler[1], Elżbieta Piotrowska[2], Włodzimierz Dolata[2], Michał Wojciechowski[2]

[1]Department of Physics, Agricultural University
ul. Wojska Polskiego 38/42, 60-637 Poznań
[2]Institute of Meat Technology, Wojska Polskiego 31, 60-624 Poznań
e-mail: rezler@owl.au.poznan.pl

A b s t r a c t. The aim of the performed investigations was to determine the influence of the substitution of the protein contained in meat tissue by the protein preparation AproPORK Plus 85-HF on the rheological properties of forcemeats and final products obtained with their assistance during their thermal treatment as exemplified by forcemeats used to manufacture finely-ground sausages of the 'hot-dog' type. Value changes of basic parameters characterising the above properties were determined with the assistance of the DMTA technique. It was found that rheological parameters and, consequently, the texture of the examined cuttered sausages were influenced by both the physical condition and the proportion of the continuous phase as well as by the structural parameters of the discontinuous phase of fragments of the meat tissue. This found its reflection in the consistency of the forcemeat, which was the effect of the structuralisation process. The reduction in the meat tissue proportion accompanied by increased water content in the forcemeat resulted in loosening of its structure. This was evident both in the level of values of basic rheological parameters and in the increase of scalding losses. In comparison with the unmodified products, the final articles modified with the applied protein extract were characterised by increased plastic properties.

K e y w o r d s: rheology, proteins, finely comminuted meat batters

INTRODUCTION

Proteins constitute an important building material of the human body and belong to the group of additives which do not go easily out of fashion. Proteins are food constituents characterised by high nutritive value and provide energy and amino acids indispensable for proper development and functioning of the organism. In recent years, application of various types of protein additives to processed meat product has become common practice in the meat industry (Cengiz and Gokoglu 2005).

Protein preparations can fulfil different functions in meat products. They enhance their quality by modifying sensory or physicochemical properties of the product, such as juiciness, binding or structure (Gajewska-Szczerbal *et al.* 2000, Hey and Sebranek 1996, Resurreccion 2004). Moreover, they supplement and improve the nutritional quality of the product either by increasing the quantity or by enhancing the quality of protein, e.g. by the addition of a preparation characterised by a high concentration of an amino acid limiting the nutritional value of the classical product. Sometimes, the purpose of their application is exclusively economic and is confined to the substitution of an expensive or deficit meat raw material by a cheaper or more available protein preparation (the so called substitution). Meat products, particularly finely- and moderately-comminuted ones, are complex food systems in which not only proteins but also other constituents can influence the quality and effectiveness of the finished product. As evident from review of literature on the subject, more and more attention is paid to the investigation of correlations between the structure of materials obtained from meat and different types of functional additives and their state preconditioned by the moisture content, temperature and the physical properties of food products (Allais *et al.* 2001, Brondum *et al.* 2000, Brunton *et al.* 2006, Hanne *et al.* 2001, Houska *et al.* 2001, Wonnop *et al.* 2005). This reflects the fact that raw materials are subjected to hydrothermal and mechanical treatments and these processes lead to significant structural changes at various stages of their molecular organisation. Despite the increasingly widespread application of rheometric techniques (Kerr *et al.* 2000, Kerry *et al.* 1999, Rezler *et al.* 2002), there are few papers devoted to interrelationships between changes in the molecular structure and values describing macroscopic properties of poly-dispersive materials of complex internal structure, such as products containing meat.

MATERIALS AND METHODS

The experimental material included sausage finely-comminuted forcemeats - control sample (K) and forcemeats in which meat (class III from the hock) was replaced by pork protein AproPORK Plus 85-HF. In the case of sample l (l) – 20% and in sample ll (ll) – 30% of meat (Tab. 1) was replaced by the AproPORK Plus 85-HF protein preparation (Tab. 2). The preparation was applied in such quantities as to maintain the content of protein.

The process of cuttering lasted 9 minutes. The final temperature of the forcemeat did not exceed 11^{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.

Table 1. Raw material composition of the examined forcemeats in %

Component	Control system	System I	System II
Pork meat of class III	58.22	46.58	40.75
Fine fat	26.09	26.09	26.09
Water	13.04	24.68	30.51
Curing mixture and NaCl	2.0	2.0	2
Spices	0.6	0.6	0.6
Sodium ascorbate	0.05	0.05	0.05

Table 2. Typical composition of the AproPORK Plus 85-HF preparation

Constituent	Content (%)
Protein	78%
Moisture content	10%
Ash	10%
Salmonella	None

Temperature changes in the rheological properties of the forcemeat were studied by the DMTA method using a mechanical relaxometer (Rezler and Poliszko 2001). It is a prototype oscillation rheometer developed at COBRABiD which operates on the principle of analysis of free vibrations of the reversed torsional pendulum. The quantities measured were the components of the complex elasticity modulus G_1, the loss tangent *($tg\delta$)*, and dynamic viscosity η in the range of 20-85^{o}C (the temperature was measured in the centre of the samples).

Analyses of the modelling sausage batters (at the temperature of 20^{o}C) were conducted 24 hours from the moment of cooling of the previously heated forcemeat (85^{o}C for 30 minutes). The frequency of free vibrations of the system was 0.363Hz. The results are mean values for three repetitions**.** The thermal drip was determined by heating at 70^{o}C for 30 minutes a certain mass of 30 g of forcemeat in a tube. Then the volume of the liquid forced out of the forcemeat on the thermal treatment was measured (the method developed by Kijowski and Niewiarowicz) (Kijowski and Niewiarowicz 1978).

The aim of the study was to ascertain the effect of the substitution of the protein contained in the meat tissue by the AproPORK Plus 85-HF protein preparation on the rheological properties of forcemeats during the thermal treatment and the obtained final products as exemplified by finely-ground forcemeats of the ‘hot-dog’ type of sausages.

RESULTS AND DISCUSSION

Figure 1 shows temperature relationships of the rigidity modulus (G_1) of the examined forcemeats, the control and with the meat replaced by the experimental protein preparation.

Within the entire interval of meat substitution (20-30%), together with the increase of temperature the values of the rigidity modulus were below the value for the unmodified forcemeat.

Irrespective of the modification method, the courses of temperature changes of the moduli values show different intensity and character of changes. Each of the three temperature areas (the first – from 20 to about 40°C, the second – from 40 to 65°C, and the third – above 65°C) is associated with different molecular changes which take place in the forcemeat under the influence of temperature.

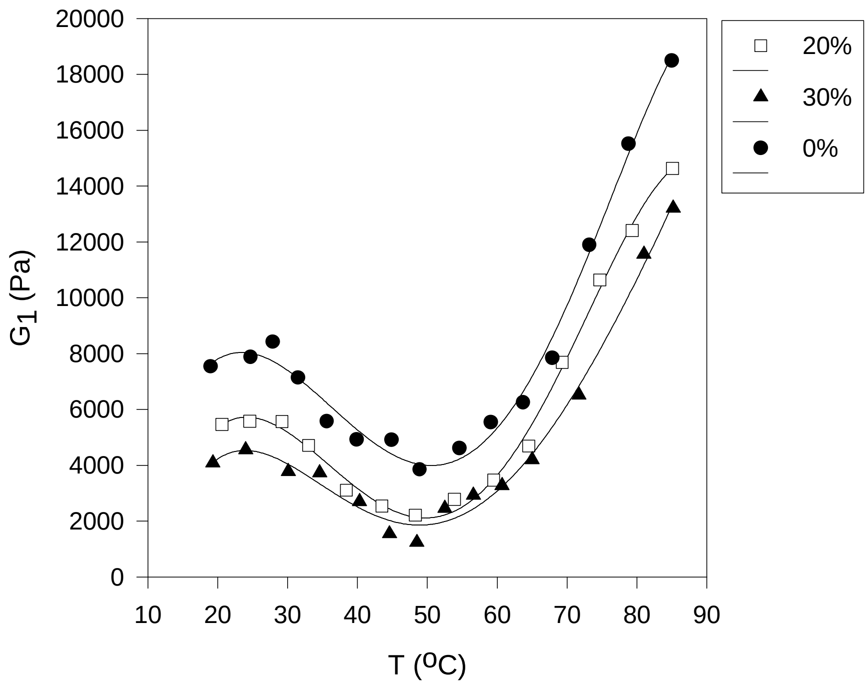

Fig. 1. Temperature correlations of the storage modulus (G_1) of the model forcemeats (control and with meat substituted by a protein extract)

Within the temperature interval of 20 to about 40°C, a clear value dispersion of the (G_1) modulus of rigidity can be observed. This occurred both in the control system and in the modified systems. Further temperature increases changed the values of the above mentioned modulus only slightly and it was only when the temperature increases reached the interval of 65°C to 85°C that the values of the modulus rose rapidly.

Correspondingly to the temperature changes in the values of the rigidity modulus, temperature changes of the courses of the loss tangent $tg\delta$ values were analysed (Fig. 2).

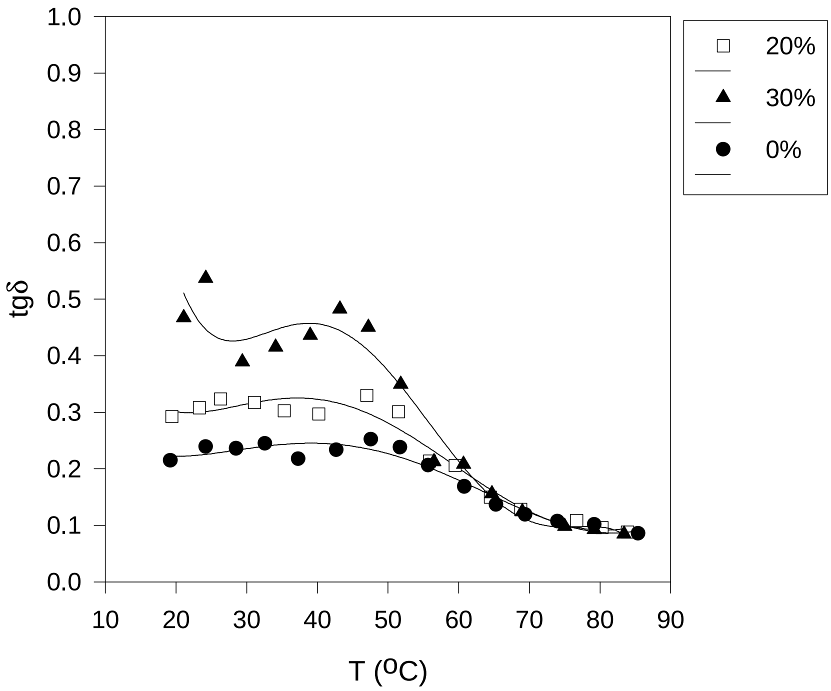

Fig. 2. Temperature correlations of the loss tangent *(tgδ)* of the model forcemeats (control and with meat substituted by a protein extract)

The systems show a declining capability to diffuse mechanical energy in the entire interval of the examined temperatures. The change in the degree of meat substitution by the applied protein extracts is reflected in decrement differences and in the level of changes of these changes.

Our earlier studies (Rezler *et al.* 2003, Rezler *et al.* 2004) showed that, apart from water, fat constitutes the main constituent of the hydrocolloid continuous fraction of the examined forcemeats. At room temperature (20°C), pork fat remains in the solid state. This exerts a crucial effect on the observed high values of the rigidity modulus (G_1) for the control forcemeat (about 8000 Pa) and for the modified forcemeats within the entire range of meat replacement (G_1~5800 Pa).

The observed dispersion area of the rigidity modulus G_1 during the initial interval of temperature changes (20-40^{o}C) (Fig.1) is associated with the phase transition of the fat.

Fat liquefaction leads directly to increased liquidity of the forcemeat continuous phase and, in addition, favours the liberation of water dispersed in them which, additionally, increases the liquidity of the system in the analysed temperature interval (20 to 40^{o}C) and leads to distinct changes in the value of the dynamic viscosity (Fig. 3).

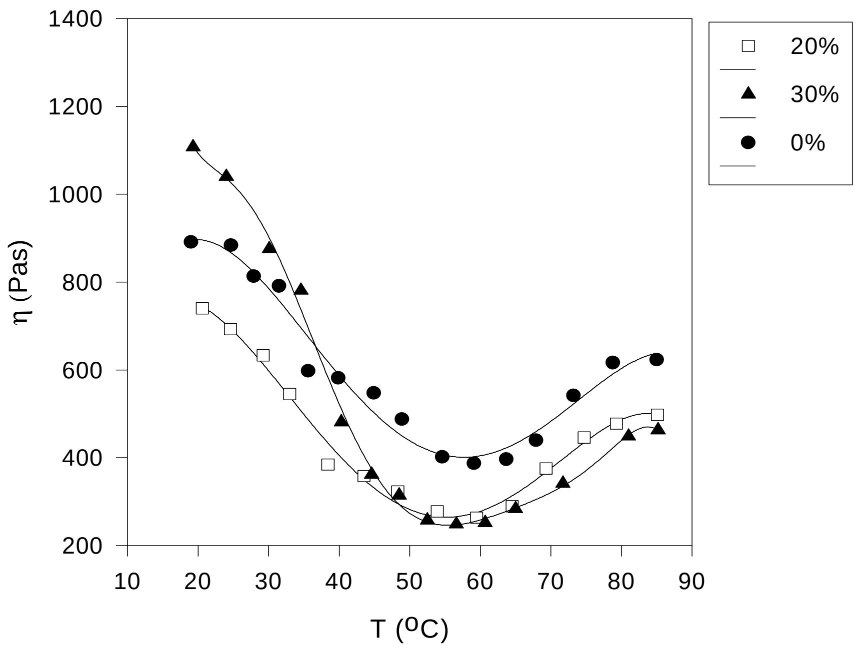

Fig. 3. Temperature correlations of the dynamic viscosity of the model forcemeats (control and with meat substituted by a protein extract)

Melted fat and liberated water, together with proteins, mainly myofibrillar and, to a lesser degree, globular contained in meat, result in the development of the hydrocolloid continuous phase. On the other hand, the discontinuous phase is made up of the condensed forcemeat constituents.

Within the temperature interval of 40 to 65^{o}C, the hydrocolloid phase affected the elastic properties of the examined forcemeats only slightly. This referred both to the control forcemeat and to the modified systems, and the elastic response depended on the resistance of the meat constituents of the forcemeat. Within the analysed temperature interval, the replacement of meat by the protein extracts led not only to reduced energy losses (Fig. 2) but also to lower values of dynamic viscosity (Fig. 3).

In addition, within the temperature interval of 40 to 65^{o}C, denaturation processes of the protein components of forcemeats also take place which are usually located within the range of temperatures from 50 to 60^{o}C (Boyer *et al.* 1996, Brondum *et al.* 2000). This is indicated by the increased values of the rigidity modulus G_1 (Fig. 1) above the temperature of 65^{o}C. This is also reflected in the curve of temperature correlations of the loss tangent *(tgδ)*, especially visible as the maximum in the systems modified by the applied protein extract (Fig. 2). Protein polypeptide chains unwrap as a result of denaturation. Such a change in the conformation increases the number of active sites in the polypeptide chains capable of linking with one another during the subsequent thermal treatment and of associating water which can now bind with the hitherto unavailable hydrophilic groups of the polypeptide chains. This enhances structuralisation of the hydrocolloid phase. Following the above-mentioned interaction, jellified proteins create a stable spatial matrix which maintains water-fat emulsion inside it (Carballo *et al.* 1996). However, a smaller proportion of condensed forcemeat components leads to the loosening of its structure. This is apparent in the decline of the rigidity modulus G_1 value (Fig. 1) which, at the accompanying increase of the value losses of the mechanical energy (Fig. 2) and dynamic viscosity (Fig. 3), indicates increased plasticity of such systems within the entire range of replacement and within the analysed temperature interval (40 to 65^{o}C).

The products undergoing restructuring must be characterised by a defined texture. From the point of view of food technology, the texture of food articles is connected with mechanical-rheological properties which also determine it to a considerable degree.

At the current stage of investigations, it can be stated that the rheological properties and, consequently, the texture of the examined forcemeats depend on both the physical condition and the proportion of the continuous phase as well as on the structural parameters of the discontinuous phase of the muscle tissue fragments. This manifests itself in the forcemeat consistency which is the result of the structuralisation process.

The final products modified by the protein extract, when compared with the unmodified articles, are characterised by increased plastic properties. This is evident in the comparable values of the rigidity modulus of the systems with meat replaced by the AproPork preparation with the control sample (Fig. 4) at the simultaneous increase of losses in mechanical energy observed in the modified systems (Fig. 5).

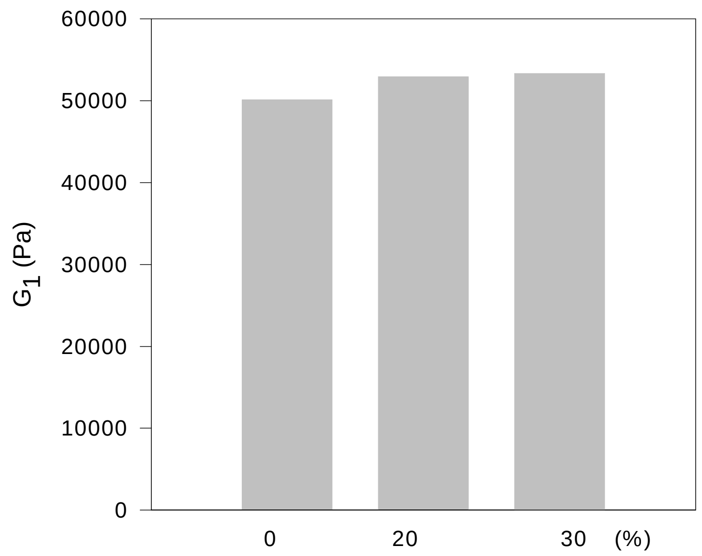

Fig. 4. Correlations of the storage modulus (G_1) of the model forcemeats subjected to thermal treatment at the temperature of 20°C with meat replaced by a protein extract

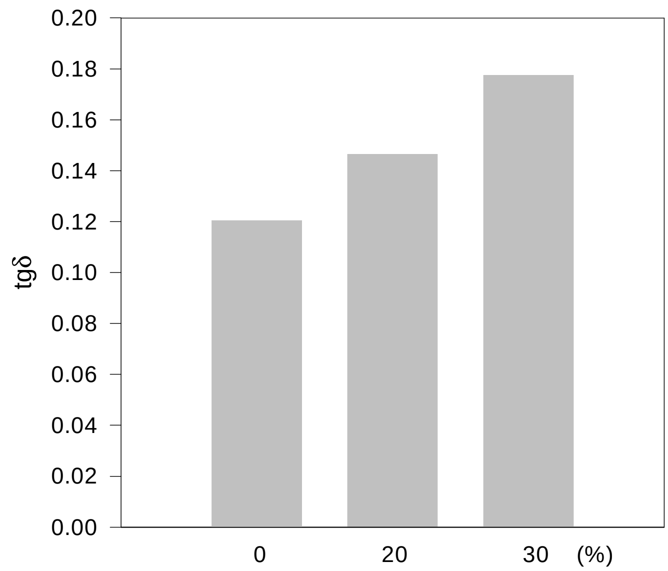

Fig. 5. Correlations of the $tg\delta$ of the model forcemeats subjected to thermal treatment at the temperature of 20°C with meat replaced by a protein extract

At the same time, it can be said that the substitution of structural protein contained in the meat tissue by the protein preparation results in a deterioration of water binding by the forcemeat together with the increase of the degree of meat replacement. The cause of this phenomenon is the increase in the ratio of water to protein (additional water required for protein hydration). This finds its reflection in the observed increase of the thermal drip in the final products which contain the AproPork preparation (Fig. 6).

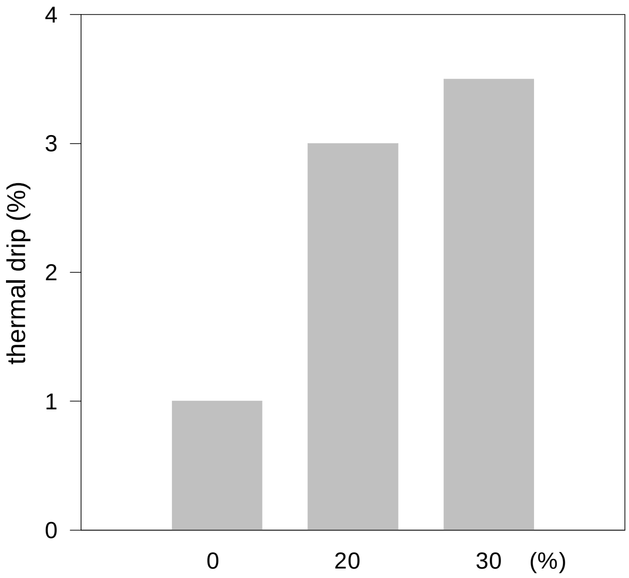

Fig. 6. Impact of meat substitution by the AproPork protein extract on the thermal drip, in %

The level of the scalding loss is important in the sense that it exerts a direct influence on the chemical composition of the final products. This, in turn, has an impact on their textural properties and sensory quality (Sampaio *et al.* 2004).

CONCLUSIONS

1. Rheological properties and, therefore, the texture of the investigated forcemeats are influenced by the physical condition and proportion of the continuous phase as well as by the proportion and structural parameters of the discontinuous phase of the muscle tissue fragments.

2. The structuralisation processes (jellification) of the protein components denatured earlier taking place at higher temperatures (60^{o}C) manifest themselves,

primarily, in the increase of the G_1 and decline of the tgδ as evidenced by the increasing elasticity and decreasing plasticity of forcemeats subjected to the thermal treatment.

3. The decrease in the proportion of the meat tissue, accompanied by a simultaneous increase in the water content in the forcemeat, results in the loosening of its structure. This is reflected both in the value level of the basic rheological parameters and in increased scalding losses.

4. The final products modified by the examined protein extract, when compared with unmodified products, were characterised by increased plastic properties.

REFERENCES

Allais I., Viaud C., Pierre A., Éric Dufour E. 2001. A rapid method based on front-face fluorescence spectroscopy for the monitoring of the texture of meat emulsions and frankfurters. Food Research Int., 34(2-3), 97-101.

Boyer C., Joandel S., Roussilhes V., Culioli J., Ouali A. 1996. Heat-induced gelation of myofibrillar proteins and myosin from fast- and slow-twitch rabbit muscles. J. Food Sci., 61, 6, 1138-1142.

Brondum J.; Munck L.; Henckel P.; Karlsson A.; Tornberg E., Engelsen B. 200. Prediction of water-holding capacity and composition of porcine meat with comparative spectroscopy. Meat Sci., 55, 177-185.

Brunton N.P., Lyng J.G., Zhang L., Jacquier J.C. 2006. The use of dielectric properties and other physical analyses for assessing protein denaturation in beef biceps femoris muscle during cooking from 5 to 85°C. Meat Sci., 72(2), 236-244.

Carballo J., Femandez P., Barreto G., Solas M.T., Colmenro F.J. 1996. Morphology and texture of bologna sausage as related to content of fat, starch and egg white. J. Food Sci., 61, 652-655.

Cengiz E., Gokoglu N. 2005. Changes in energy and cholesterol contents of frankfurter-type sausages with fat reduction and fat replacer addition Food Chem., 91(3), 443-447.

Gajewska-Szczerbal H.; Dolata W.; Mróz J; Jesionek M. 2000. The effect of hydration of protein on physical and chemical properties of protein-water-fat emulsion. Properties of Water in Food. Agr. Univ. Press, Warsaw, 198-207.

Hanne C.B.; Henrik J.; Anders H. 2001. Comparative study of low-field NMR relaxation measurements and two traditional methods in the determination of water holding capacity of pork. Meat Sci., 57, 125-132.

He Y., Sebranek J.G. 1996. Functional protein in lean finely textured tissue from beef and pork. J. Food Sci., 61, 6, 1155-1159.

Houska M., Nesvadba P., Mayer Z. 2001. Database of physical properties of foods: subgroup of mechanical and rheological properties. J. Texture Studies, 155-160.

Kerr W.L., Li R., Toledo R.T. 2000. Dynamic mechanical analysis of marinated chicken breast meat. J. Texture Studies, 31, 421-436.

Kerry J.F., Morrissey P.A, Buckley D.J. 1999. The rheological properties of exudates from cured porcine muscle: effects of added carrageenans and whey protein concentrate/carrageennan blends. J. Sci. Food Agric., 79, 71-78.

Kijowski J., Niewiarowicz A. 1978. Emulsifying properties of proteins and meat from broiler breast muscles as affected by their initial pH values. J. Food Technol., 13, 451-459.

Resurreccion A.V. 2004. Sensory aspects of consumer choices for meat and meat products. Meat Sci., 66(1), 11-20.

Rezler R, Poliszko S., Dolata W, Piotrowska E. 2003. Dynamic-mechanical and thermal analysis of the hydro-colloidal phase in model meat emulsions with the addition of pea cellulose. Acta Agrophisica, 2(2), 417-424.

Rezler R. Poliszko S. 2001. Dynamic mechanical analysis and thermal analysis of the hydrocolloid phase in model meat batters. I. The effect of temperature on rheological properties of model batters. Properties of Water in Food. Agr. Univ. Press, Warsaw, 184-193.

Rezler R., Poliszko S., Dolata W., Piotrowska E. 2004. The effect of the forms starch preparation added to replace fat on the rheological properties of batters during thermal treatment. Acta Agrophisica, 4(1), 161-167.

Rezler R., Poliszko S., Dolata W., Piotrowska E. 2002. Dynamic-mechanical and thermal analysis of the hydrocolloidal phase in model force-meat with addition of wheat fibre. Acta Agrophisica, 77, 117-125.

Sampaio G.R., Castellucci C.M.N., Pinto e Silva M.E.M., Torres E. 2004. Effect of fat replacers on the nutritive value and acceptability of beef frankfurters. J. Food Composition and Analysis, 469-474.

Wonnop V., Soottawat B., Atikorn P., Chonticha K., Apinya A. 2005. Influence of minced pork and rind ratios on physicochemical and sensory quality of Nham – a Thai fermented pork sausage. Meat Sci., 69(2), 355-362.

WPŁYW SUBSTYTUCJI MIĘSA PREPARATEM BIAŁKOWYM NA WŁAŚCIWOŚCI REOLOGICZNE FARSZÓW WĘDLIN DROBNO ROZDROBNIONYCH

Ryszard Rezler[1], Elżbieta Piotrowska[2], Włodzimierz Dolata[2], Michał Wojciechowski[2]

[1]Katedra Fizyki, Akademia Rolnicza,
ul. Wojska Polskiego 38/42, 60-637 Poznań 38/42, 60-637 Poznań
[2]Instytut Technologii Mięsa, ul. Wojska Polskiego 31, 60-624 Poznań
e-mail: rezler@owl.au.poznan.pl

Streszczenie. Celem badań było określenie wpływ substytucji białka zawartego w tkance mięśniowej preparatem białkowym AproPORK Plus 85-HF, na zmianę właściwości reologicznych farszów w trakcie obróbki termicznej oraz uzyskanych dzięki niej produktów finalnych na przykładzie farszów kiełbas drobno rozdrobnionych typu parówka. W celu określenia właściwości reologicznych farszów wykorzystano technikę DMTA Stwierdzono, że o właściwościach reologicznych, a tym samym o teksturze badanych wędlin kutrowanych decyduje zarówno stan fizyczny i udział fazy ciągłej oraz parametry strukturalne rozproszonej fazy fragmentów tkanki mięśniowej. Znajduje to swoje odbicie w spoistości farszu będącego efektem procesu strukturowania. Zmniejszenie udziału tkanki mięśniowej przy równoczesnym wzroście zawartości wody w farszu prowadzi do rozluźnienia jego struktury. Znajduje to swoje odbicie zarówno w poziomie wartości podstawowych parametrów reologicznych jak i wzroście ubytków parzelniczych. Produkty finalne modyfikowane ekstraktem białkowym w porównaniu do produktów niemodyfikowanych odznaczały się wzrostem właściwości plastycznych.

Słowa kluczowe: reologia, białka, farsze drobno rozdrobnione