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WHEAT FIBRE PREPARATION WF 400 LC AS A FACTOR AFFECTING THE RHEOLOGICAL PROPERTIES OF BATTER USED FOR FRANKFURTER-TYPE SAUSAGES MANUFACTURED UNDER INDUSTRIAL CONDITIONS*

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Key words: fat, wheat fibre, DMTA

The objective of this study was to determine relaxation macro-parameters describing the elasticity of the model sausage batter processed under industrial conditions. Experimental batters were subjected to different levels of fat replacement with rehydrated wheat fibre. Fat in the batter was replaced with rehydrated wheat fibre preparation Vitacel WF 400 LC manufactured by J.Rettenmaier & Sohne Company.

The experiments were carried out in three replications. The control batter, in accordance with the recipe formulation, contained 40% fat. In the model batches fat was replaced, in the amount of 25%, 35% and 45%, by rehydrated wheat fibre preparation. The dynamic-mechanical thermal analysis (DMTA) method was applied. The investigations made it possible to determine temperature-dependent changes (resulting from thermal treatment) in the values of basic parameters characterising rheological properties, *i.e.* modulus of elasticity (G_1), loss tangent tgδ and dynamic viscosity η.

The results showed that rheological properties of the experimental sausage batter are affected, first of all, by the physical condition and the proportion of the continuous phase and to a lesser degree by the proportion and structural parameters of the dispersed phase of muscle tissue fragments and rehydrated wheat fibre preparation. The replacement of fat in sausage batter by rehydrated wheat fibre and simultaneously used modified potato starch, increases their elastic and reduces plastic properties in comparison to the unmodified products.

INTRODUCTION

In order to alter the unfavourable balance of fat and dietary fibre in the diet, as well as enhance the nutritive value of processed meat products, investigations are being carried out to develop new processed meat products with reduced energy value [Colmenero, 2000]. The most common method applied in reducing the amount of fat in such products is fat replacement with water and/or by various substitutes binding and/or holding water, characterised by low energy value or indigestible. Total elimination of fat from the formula of minced (chopped) scalded, processed meat products, *e.g.* from the set of raw materials used in the production of finely comminuted scalded sausages and/or processed liver products is not possible. Fat plays a very important functional role and affects, among others, product texture, juiciness and is a carrier of flavour [Resurreccion, 2004; Wood *et al*., 2004]. From the point of view of food technology, mechanical-rheological properties are associated, in a definite way, with the texture of food (meat) products [Szczesniak, 1963, 1971; Bourne, 1982; Crehan *et al*., 2000]. However, until now, precise quantitative interrelations between the molecular and the structure of the cellular system and the mechanical properties of food products have not been fully recognised.

This refers, in particular, to meat and all kinds of meat derived products. From the physical point of view, meat constitutes a multi-phase system of complex internal structure (myofibrillar, globular and connective tissue proteins, fats, water *etc*.). This exerts a significant influence on mechanical-rheological properties, which reflect the structural condition of the material [Pietrasik & Shand, 2003]. It is evident from literature data that nowadays researchers are paying deserved attention to investigations of interrelationships between the structure of animal origin, mainly muscle and fat tissue, raw materials and different functional additives and their features depending on moisture content, temperature and physical properties of food products [Brondum *et al*., 2000a, b; Hanne *et al*., 2001].

Despite the increasingly wide-spread application of rheometric techniques [Kerr & Toledo, 2000; Rezler *et al*., 2002; Valdez *et al*., 2006], only several studies are devoted to interrelationships between alterations in the molecular structure and values describing mechanical properties of poly-dispersive materials of complex internal structure, such as meat-containing products.

The objective of the study was to determine the role of rehydrated wheat fibre preparation in the formulation of comminuted sausage batter on it spatial structure and to determine the effect of changes in this structure on the mechanical-rheological properties of the examined products as exemplified by the batter of finely comminuted sausages.

MATERIAL AND METHODS

The experimental material was batter of finely commi-

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nuted frankfurter-type sausages. Primary raw materials consisted of fine pork class III, ham and shoulder trimmings and skin emulsion (trimmed pork skins, subjected to brine treatment, next chopped in a grinder and homogenized). The raw materials were ground in a commercial 160 mm grinder (mincer) through a plate with mesh size of 3 mm. The WF 400 LC rehydrated wheat fibre was introduced into the silent cutter (bowl chopper) in order to replace fat at three levels: 25%, 35% and 45% of the 40% fat content in the sausage batter formulation. The wheat fibre, rehydrated at a 1:6 ratio, was added to the silent cutter at the end of chopping. Control batter was produced without rehydrated preparation of wheat fibre. Additional raw materials included phosphates (Almina), added at the beginning of chopping; curing mixture; modified potato starch LUBOSTAT (E 1412 – distarch phosphate), added to the chopper at the end of chopping; frankfurter spice mix by "Almi" (Table 1). The frankfurter production process was run under commercial scale conditions. Meat and fat were comminuted in a grinder with mesh size of 3 mm. Raw material comminuted in the grinder was chopped in a bowl chopper. Comminuted pork, spices, curing salt and 1/3 planned water/ice were added first to the chopper bowl (chopping of 3 min), followed by the addition of 1/3 planned amount of water/ice and skin emulsion (chopping of 1 min). In the next stage of the chopping process previously comminuted fat and the remaining amount of water/ice found in the formulation. Starch was added in the last stage of the process. Chopping was conducted until homogenous mass was obtained. Final batter temperature did not exceed 12°C. Thus obtained batter samples were placed in a relaxometer thermostat testing chamber.

TABLE 1. Formulation of experimental sausage batters.

Formulation	Control sample (kg)	25% Model batter I (kg)	35% Model batter II (kg)	45% Model batter III (kg)
Pork meat, class III	35	35	35	35
Pork fat trimmings	40	30	26	22
Skin emulsion	5	5	5	5
Water/ice	16	24.5	28	31.5
WF 400 LC fibre	-	1.5	2	2.5
Combi frankfurter seasoning	0.9	0.09	0.09	0.09
Ground white pepper	0.05	0.05	0.05	0.05
Ground sweet paprika	0.05	0.05	0.05	0.05
Almina	0.5	0.5	0.5	0.5
Curing mixture	1.8	1.8	1.8	1.8
Lubostat starch	3.0	3.0	3.0	3.0

Changes of the model sausage batter rheological properties in the function of temperature were determined by DMTA using a mechanical relaxometer, *i.e.* the prototype oscillation rheometer which operates on the basis of the principle of the analysis of free vibrations of the reversed torsional pendulum [Rezler & Poliszko, 2001]. The following rheological features were determined: values of modulus of elasticity G_1, tgδ and dynamic viscosity coefficient η at the temperature range of 20÷85°C. The frequency of free vibrations of the system amounted to 0.4 Hz and the rate of heating – 1°C/min. The results are mean values for three replications.

RESULTS AND DISCUSSION

Production of homogenized (emulsified) sausages involves an appropriate degree of comminution and uniform dispersion distribution of all raw material formulation components. Significant changes take place during mincing (chopping); a new physical system develops, causing changes in the initial structural parameters of all minced (chopped) constituents. This leads, primarily, to changes in properties of meat proteins and fat (Table 2). At the end of mincing, the obtained batter constitutes a dispersion system made up of two phases: (1) the hydrocolloid continuous phase (aqueous, colloidal solution of proteins and connective tissue, as well as emulsions of fat and proteins soluble in water or saline solutions) and (2) the dispersed phase made up of insoluble elements of muscle and adipose tissue. In its final form, the minced sausage batter constitutes a system of a diverse and dynamically balanced spatial structure. The purpose of the thermal treatment, among others, is to consolidate and preserve the developed system.

TABLE 2. Physico-chemical composition of WF 400 LC fibre preparation.

Component	Content
Fibre content	Min. 97% in dry matter
soluble	2.5%
non-soluble	94.%
Moisture content	max. 8%
Ash	max. 3%
Protein	0.4%
Fat	0.2%
Phytic acid	Negative assay
Fibre gluten	Negative assay
pH	6.5±1

Generally speaking, thermal treatment makes it possible to identify three areas of changes in modulus of elasticity G_1 under the influence of temperature. They differ both in the value and character of these changes. The first comprises a temperature range from 20 to about 40°C, the second – from 40 to 65°C, and the third – above 65°C. This results from differences in the intensity of the occurring physico-chemical processes affecting the rheological properties of sausage batter during thermal treatment.

Figure 1 shows temperature interrelations of moduli of elasticity (G_1) of the examined sausage batters, both the control and those in which pork fat was replaced with different quantities of rehydrated wheat fibre preparation.

The greatest dynamic changes of modulus of elasticity (G_1) was determined at the initial (20÷40°C) and final (65÷85°C) temperature ranges. In the case of the temperature range from 20 to about 40°C, a distinct dispersion could be observed in the values of modulus of elasticity (G_1). This occurs both in the control and in the experimental modified batter. A further increase of temperature results in only slight

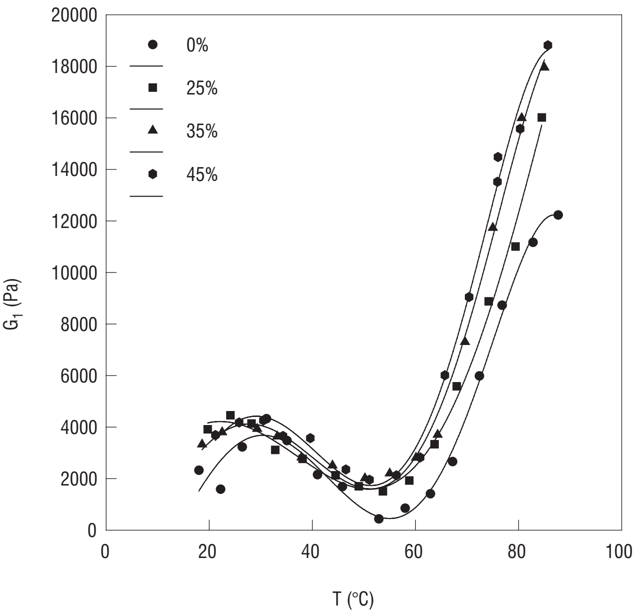

FIGURE 1. Values of temperature-dependent interrelations of modulus of elasticity (G_1) in model finely comminuted sausage batters: control and with the addition of rehydrated wheat fibre preparation.

changes in determined values of modulus and this takes place only when the temperature reaches 65÷85°C, resulting in a rapid increase in the value of the modulus (G_1).

Changes in the loss tangent tgδ values resulting from temperature courses are shown in Figure 2.

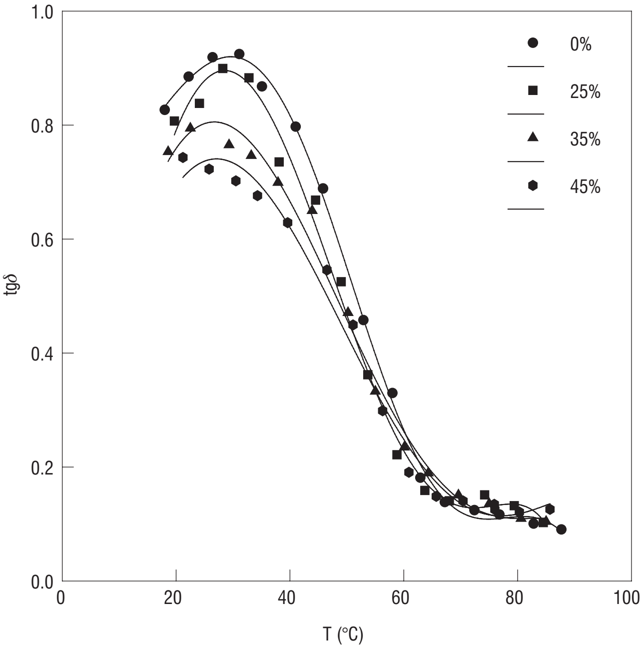

FIGURE 2. Values of temperature-dependent interrelations of the loss tangent tgδ of model finely comminuted sausage batters: control and with the addition of rehydrated wheat fibre preparation.

A downward trend of the tgδ value, indicating a declining relative capability to disperse mechanical energy, was observed both in the entire range of the analysed temperature and in the entire range of fat replacement with rehydrated wheat fibre preparation.

Earlier investigations [Rezler *et al*., 2003] showed that, apart from water, fat is the main constituent of the hydrocolloid continuous phase of the examined finely comminuted sausage batter. At room temperature (20°C), pork fat is at a solid state. This considerably affects the differentiation of modulus of elasticity (G_1) values for the control batter (about 1500 Pa) and for sausage batters in which fat was replaced with rehydrated wheat fibre preparation (G_1~2500 Pa).

The observed dispersion area of modulus of elasticity (G_1) at the initial range of temperature changes (20–40°C) (Figure 1) is associated with the transition state of fat.

Liquefaction of fat leads to increased hydrocolloid fluidity of the batter continuous phase and, in addition, also favours the release of water dispersed in them so far. This additionally increases the fluidity of the batter at the analysed temperature range (20÷40°C) and leads to changes in the value of dynamic viscosity (Figure 3).

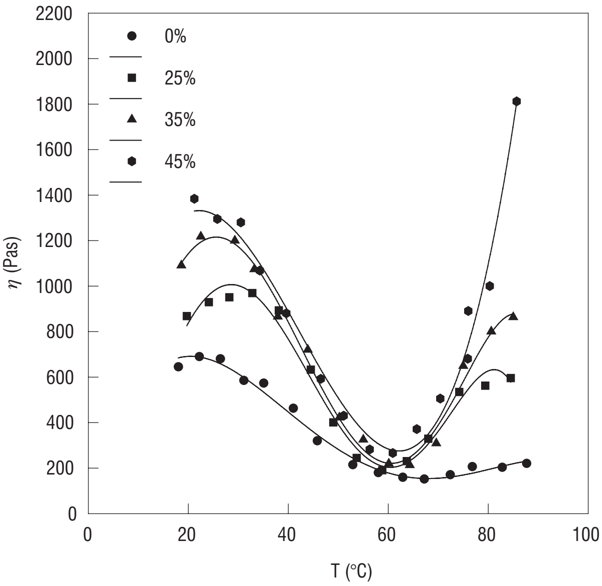

FIGURE 3. Values of temperature dependent interrelations of dynamic viscosity (η) of model finely comminuted sausage batters: control and with the addition of rehydrated wheat fibre preparation.

Spatial structure of the hydrocolloid continuous phase and the dispersed phase developed as a result of mincing is influenced, primarily, by the envelopes formed by soluble proteins around fat globules. These are mainly myofibrillar proteins (actomyosin, actin, myosin, *etc.*) released from muscle filaments. In the minced batter, these proteins form a spatial matrix supporting the water-fat emulsion.

Reduction in the proportion of fat and meat in the experimental, model batter formulation and partial fat replacement with rehydrated wheat fibre preparation results in an increase of the total water content. This, in turn, leads to the reduction of the ionic force in the water phase and a decrease of protein extractability and results in a less concentrated and less compact continuous phase of the hydrocolloid-fat emulsion. This has a considerable effect on changes in the effective concentration of the protein responsible for the formation of the network of spatial matrixes.

The applied heating process at the temperature range of 40÷65°C results in irreversible alterations in the hydrocolloid structure, having a crucial effect on the development of rheological properties of both batter subjected to thermal treatment and the final products.

Phenomena associated with the gelation of the previously denatured protein constituents (occurring at the temperature range of about 50÷60°C) take place in the initial analysed temperature range (40÷65°C) [Boyer *et al*., 1996; Hey & Sebranek, 1996; Brondum *et al*., 2000]. This leads to the structuring of the hydrocolloid phase and assists the process of association of water absorbed by fibre components of batter, which can bind with the groups of previously unavailable hydrophilic polypeptide chains. In other words, fibre being an element of the spatial network leads to its increased density.

Taking into consideration findings of our earlier investigations on the substitution of fat with wheat fibre preparation in the batter of comminuted, scalded sausages [Rezler *et al*., 2002], it can be stated that some fat particles bind with wheat fibre preparation, reducing the free energy of interactions between chains which stabilise the spatial network of the protein gel. This happens because fibre, not exhibiting elastic properties, constitutes a kind of 'filler' of dissipative character, leading to increased plastic properties of the system [Rezler *et al*., 2002].

No effects associated with plasticization were observed in the investigated batters. This can be attributed to the fact that all investigated batters have starch in their recipe formulation.

As modified potato starch soluble at high temperatures was applied, it is quite probable that following the formation of the starch gel lattice, the density of the developed spatial structure of sausage batter increased. Consequently, an increase was observed in the capacity to compensate for losses connected with the limited (as a result of the addition of rehydrated wheat fibre preparation) contribution of the protein matrix into the elastic response of the modified systems. The effectiveness of the contribution of the gelated starch to the elastic response of sausage batters increases with the degree of fat replacement with rehydrated wheat fibre preparation, probably due to increased quantities of water in experimental batters.

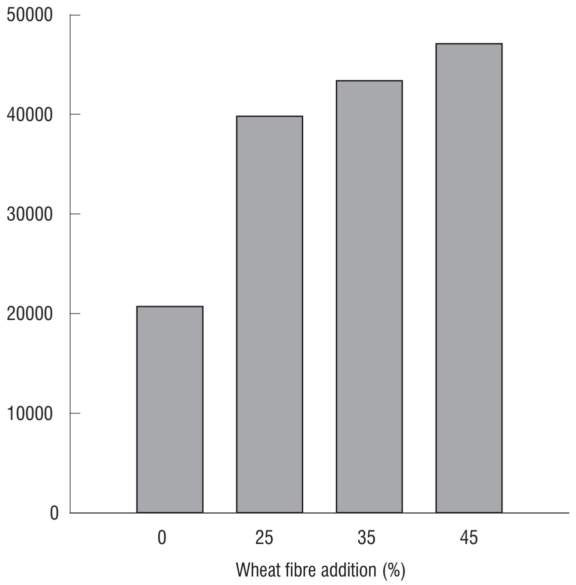

FIGURE 4. True component (G_1) interrelations of modulus of elasticity in model finely comminuted sausage batters subjected to thermal treatment at 20°C: control and with fat replaced with rehydrated wheat fibre preparation (%).

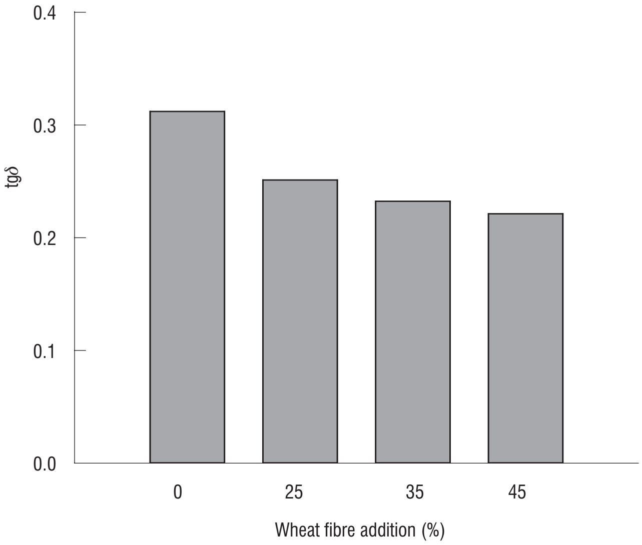

FIGURE 5. Tgδ interrelations of model finely comminuted sausage batters subjected to thermal treatment at 20°C: control and with fat replaced with rehydrated wheat fibre preparation (%).

These findings reflect changes of both modulus of elasticity (Figure 1) and the value of dynamic viscosity (Figure 3) dependent on the course of temperature. In the case of sausage batter in which fat was replaced with the rehydrated wheat starch preparation, values of both modulus of elasticity G_1 (Figure 1) and dynamic viscosity η (Figure 3) were observed to increase above respective values of the unmodified model batters. In the control batter, the effects connected with starch cross-linking occur to a limited degree, because added starch only partly gelates, developing a sticky solution (the amount of water is too small for the starch to gelate completely).

From the point of view of food technology, texture of food products is connected with mechanical-rheological properties, determining it to a considerable degree.

Taking into consideration the results obtained it can be said that the rheological properties and, hence, the texture of the examined model sausage batters depends mainly on the physical condition and proportion of the continuous phase and, to a lesser degree, on the share and structural parameters of the dispersed phase of the muscle tissue proteins and fragments. The substitution of fat with rehydrated wheat fibre preparation and the simultaneous use of modified potato starch in the formulation of experimental sausage batters results in an increase of elastic properties, and therefore poorer plasticity in comparison with the unmodified products (Figures 4. and 5).

CONCLUSIONS

1. Changes caused by an increase in temperature within the continuous phase of finely comminuted (emulsified, homogenized) sausage batter initially lead to fat liquefaction and the release of water dispersed in them and results in an increase of batter fluidity.

2. Rheological properties and, hence, the texture of the examined sausage batters are influenced by the physical condition and the proportion of the continuous phase and, to a

lesser degree, by the proportion and structural parameters of the dispersed phase of muscle tissue proteins and fragments.

3. Structuring (gelation) of the previously denatured protein components of sausage batter occurring at temperature >60°C manifests mainly in an increase of the G_1 value and a drop of tgδ, indicating the growing elasticity and declining plasticity of finely comminuted sausage batter subjected to thermal treatment.

4. Replacement of fat in emulsified sausage batters with rehydrated wheat fibre preparation, accompanied by the simultaneous application of modified potato starch in the recipe formulation, increase their elastic and reduce their plastic properties in comparison with those of unmodified products.

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REFERENCES

1. Benichou A., Aserin A., Garti N., Protein-polysaccharide interactions for stabilization of food emulsions. J. Dispersion Sci. Technol., 2002, 23, 93–123.
2. Bourne M.C.J., Food texture and rheology. Food Sci., 1982, 47, 440–444.
3. Boyer C., Joandel S., Roussilhes V., Culioli J., Ouali A., Heat-induced gelation of myofibrillar proteins and myosin from fast- and slow-twitch rabbit muscles. J. Food Sci., 1996, 61, 1138–1142.
4. Brondum J., Munck L., Henckel P., Karlsson A., Tornberg E., Prediction of water-holding capacity and composition of porcine meat with comparative spectroscopy. Part 1. Meat Sci., 2000a, 55, 177–185.
5. Brondum J., Munck L., Henckel P., Karlsson A., Tornberg E., Engelsen B., Prediction of water-holding capacity and composition of porcine meat with comparative spectroscopy. Part 2. Meat Sci., 2000b, 55, 177–185.
6. Colmenero J.F., Relevant factors in strategies for fat reduction in meat products. Trends Food Sci. Technol., 2000, 11, 56–66.
7. Crehan C.M., Hughes E., Troy D.J., Buckley D.J., Effects of fat level and maltodextrin on the functional properties of frankfurters formulated with 5, 12 and 30% fat. Meat Sci., 2000, 55, 463–469.
8. Hanne C.B., Henrik J., Anders H., Comparative study of low-field NMR relaxation measurements and two traditional methods in the determination of water holding capacity of pork. Meat Sci., 2001, 57, 125–132.
9. He Y., Sebranek J.G., Functional protein in lean finely textured tissue from beef and pork. J. Food Sci., 1996, 61, 1155–1159.
10. Kerr W.L., Li R., Toledo R.T., Dynamic mechanical analysis of marinated chicken breast meat. J. Texture Stud., 2000, 31, 421–436.
11. Pietrasik Z., Shand P.J., The effect of quantity and timing of brine addition on water binding and textural characteristics of cooked beef rolls. Meat Sci., 2003, 65, 771–778.
12. Resurreccion A.V., Sensory aspects of consumer choices for meat and meat products. Meat Sci., 2004, 66, 11–20.
13. Rezler R, Poliszko S., Dolata W, Piotrowska E., Dynamic-mechanical and thermal analysis of the hydro-colloidal phase in model meat emulsions with the addition of pea cellulose. Acta Agrophysica, 2003, 2, 417–424.
14. Rezler R., Poliszko S., Dolata W., Piotrowska E., Dynamic-mechanical and thermal analysis of the hydrocoloidal phase in model force-meat with addition of wheat fibre. Acta Agrophysica, 2002, 77, 117–125.
15. Rezler R., Poliszko S., 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. 2001, Agr. Univ. Press, Warsaw, pp. 184–193.
16. Szczesniak A.S., Classification of textural characteristics. J. Food Sci., 1963, 28, 385–391.
17. Szczesniak A.S., Consumer awareness of texture and of other food attributes. J. Texture Stud., 1971, 2, 196–202.
18. Valdez M.A., Acedo-Carrillo J.I., Rosas-Durazo A., Lizardi J., Rinaudo M., Goycoolea F.M., Small-deformation rheology of mesquite gum stabilized oil in water emulsions. Carboh. Polym., 2006, 64, 205–211.
19. Wood J.D., Richardson R.I., Nute G.R., Fisher A.V., Campo M.M., Kasapidou E., Effects of fatty acids on meat quality: a review. Meat Sci., 2004, 66, 21–32.

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ROLA BŁONNIKA PSZENNEGO WF 400 LC W KSZTAŁTOWANIU WŁAŚCIWOŚCI REOLOGICZNYCH FARSZÓW KIEŁBAS DROBNO ROZDROBNIONYCH TYPU PARÓWKOWA WYPRODUKOWANYCH W WARUNKACH PRZEMYSŁOWYCH

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Analizowano relaksacyjne makroparametry opisujące sprężystość modelowych farszów mięsnych wyprodukowanych w warunkach przemysłowych, w recepturze których wymieniano tłuszcz uwodnionym preparatem błonnika pszennego Vitacel WF 400 LC firmy J. Rettenmaier & Sohne. Doświadczenie wykonywano w trzech powtórzeniach. Próba kontrolna zawierała 40% tłuszczu. W farszach modelowych tłuszcz w ilości: 25%, 35%, 45% zastąpiono uwodnionym preparatem błonnika. Do oznaczenia parametrów reologicznych wykorzystano metodę dynamicznej reologii oscylacyjnej (DMTA). Oznaczono: zmiany wartości podstawowych parametrów charakteryzujących właściwości reologiczne (moduł sprężystości G_1, tangens kąta strat tgδ oraz lepkość dynamiczną η), jakie zachodzą podczas procesu ogrzewania (w przedziale 20÷85°C). Na podstawie uzyskanych wyników stwierdzono, że o właściwościach reologicznych farszów kiełbasianych decydują: stan fizyczny i udział fazy ciągłej, a w mniejszym stopniu: udział i parametry strukturalne rozproszonej fazy fragmentów tkanki mięśniowej i błonnika. Wymiana tłuszczu w farszach kiełbasianych uwodnionym błonnikiem pszennym (przy jednoczesnym zastosowaniu w składzie receptury modyfikowanej skrobi ziemniaczanej) skutkuje wzrostem właściwości sprężystych, a więc mniejszą plastycznością w porównaniu z produktami niemodyfikowanymi.