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THE EFFECT OF THE PLANT FAT AKOROMA OM ON THE MECHANICAL PROPERTIES OF FINELY COMMINUTED SAUSAGE BATTERS

Ryszard Rezler

Department of Physics, Agricultural University
ul. Wojska Polskiego 38/42, 60-637 Poznań
e-mail: rezler@owl.au.poznan.pl

A b s t r a c t. The aim of the study was to investigate the effect of temperature on the rheological properties of model meat batters with different degree of replacement of animal fat with the plant fat Akoroma OM subjected to thermal processing as well as the final products manufactured from them. Using the DMTA (Dynamic Mechanical Thermal Analysis) technique, the author determined basic parameters at different temperatures. The application of the hydrogenated plant fat (Akoroma OM) as a pork fat replacer contributes, primarily, to a better dispersion of the fat and binds it with the structure of the finished product. This is apparent in the increase of the elastic properties of the final products and decrease of the cooking loss.

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

INTRODUCTION

It is possible to observe changes in the dietary habits of the Polish society, which is reflected in the fact that people pay increasingly more attention to appropriate nutrition. This is apparent in the increasing demand for meat products in which the dietary energy carrier – fat (especially fat of animal origin) - has been significantly decreased. The fat contained in the formulations of minced scaled meat products can negatively influence their properties. Fat raw materials have an extremely important functional role to play since they affect, among others, the texture and juiciness, and are carriers of palatability (Dolata *et al.* 2001, Resurreccion 2004, Wood *et al.* 2004)**.** The fat contained in food products reacts with flavour substances leading to their sensory stability. Many Polish consumers prefer finely-comminuted sausages (frankfurters type) in which, unfortunately, the fat content may exceed 30%. This is due to the fact that these sausages are relatively cheap. In addition, the absence of apparent fat on the cross-section of these sausages often gives a misguided conviction that these are dietary products.

However, it is not at all easy to prepare a formulation of new assortments of sausages of a reduced calorific value (Piotrowska *et al.* 2004, Tarrago-Tranni *et al.* 2006). In order to achieve the best functional and nutritional results, it is essential to select an appropriate fat substitute which can guarantee the correct quality and nutritional value of the final product. One of the methods to achieve it is to replace animal fat by plant fat.

The performed review of literature on the subject showed clearly that, currently, researchers pay more and more attention to investigations of interrelationships between the structure of meat-based materials and different functional additives depending on moisture content, temperature and the physical properties of food products (Allais *et al.* 2004, Brondum *et al.* 2000, Curt *et al.* 2004, Estevez *et al.* 2005, Hanne *et al.* 2001). Despite the increasingly wide-spread application of rheometric techniques (Borbas *et al.* 2003, Fabiane Guerra *et al.* 2005, Ker and Tolledo 2000), only few studies were devoted to interrelationships between the molecular structure and values describing the macroscopic properties of polydispersive materials which are represented by meat-comminuted sausages.

MATERIAL AND METHODS

The experimental materials comprised forcemeats of finely-minced sausages (control sample) – Table 1 – and batters in which the animal fat was replaced by the Akoroma OM fat (Tab. 2). This is a hydrogenated mixture of plant fats containing in their composition the n-3 polyunsaturated fatty acids (Tab. 3).

Table 1. Basic composition of the control sample of the experimental batters

Constituent	Content (%)
Pork meat of class III	48.7
Fat trimmings	20.9
Water	27.8
Curing mixture and NaCl	2.0
Spices	0.6
Sodium ascorbate	0.04

The process of cuttering lasted 9 minutes. The final temperature of the forcemeat did not exceed 11°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. The rheological properties of the batter at different temperatures were studied by the DMTA (Dynamic Mechanical Thermal Analysis) method using a mechanical relaxometer (Rezler and Poliszko 2001). It is a prototype oscillation rheometer which operates on the principle of analysis of free vibrations of the reversed torsional pendulum. In the course of the performed investigations, the author determined the component values of the complex rigidity modulus: G_1 (storage modulus), $tg\delta$ and dynamic viscosity coefficient η at the temperature range of 20-85^{o}C (the temperature was measured in the centre of the samples).

Table 2. Percentage content of pork fat trimmings and plant-derived fat Akoroma OM in the examined batters

Variant	K	I	II	III
Pork fat trimmings	100%	50%	25%	0%
Akoroma OM	0%	50%	75%	100%

Table 3. Basic composition of the Akoroma OM plant-derived fat (in %)

Protein	0
Carbohydrates	0
Saturated fat	41
Monounsaturated fat	44
Polyunsaturated fat	15
Cholesterol	<0.005
Trans fatty acids	<0.001
Fibre	0
Sodium	0

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 0.363 Hz. The results are mean values for three repetitions. The cooking loss content was determined using the method developed by Kijowski and Niewiarowicz (Kijowski and Niewiarowicz 1978).

The aim of the investigations was to determine the impact of the replacement of animal fat in the meat batter by the plant fat on the forcemeat rheological properties in the course of the thermal treatment and of the final products obtained using the experimental forcemeats.

RESULTS AND DISCUSSION

The essence of the production of finely-minced sausages lies mainly in ensuring the appropriate degree of comminuting all raw material constituents as a result of the cuttering process with the participation of water (ice). Important changes take place in the processed raw materials during the cuttering process. A completely new physical system is formed which alters the initial physical and chemical structure of all chopped constituents. This leads, primarily, to changes in the properties of meat protein and fat raw materials. Following the cuttering process, the obtained forcemeat constitutes a dispersion system consisting of the following two phases: continuous hydrocolloid phase (aqueous, colloidal solution of proteins and true fine-molecular compounds soluble in it) and discontinuous phase made up of condensed forcemeat constituents (fat and muscle tissue particles, micelles of dissolved and suspended protein together with electrolytes bound with them ionically). Consequently, the obtained forcemeat constitutes a system of varied and dynamically diverse balanced spatial structure. The application of the thermal treatment aims, among others, at the stabilization of the developed system.

During the applied thermal treatment, we can distinguish, basically, three temperature areas of value changes of the elasticity modulus G_1 which are characterized by varying courses regarding both the value and character of the changes; the first of them, from 20 to about 40^{o}C, the second – from 40 to 65^{o}C, and the third – above 65^{o}C. Each of them is characterized by different intensity of the physicochemical processes affecting the rheological properties of the forcemeats in the course of the thermal process.

The first figure presents temperature relationships of the rigidity modulus (G_1) of the examined forcemeats, the control, and those with the pork fat replaced by different amounts of plant fat.

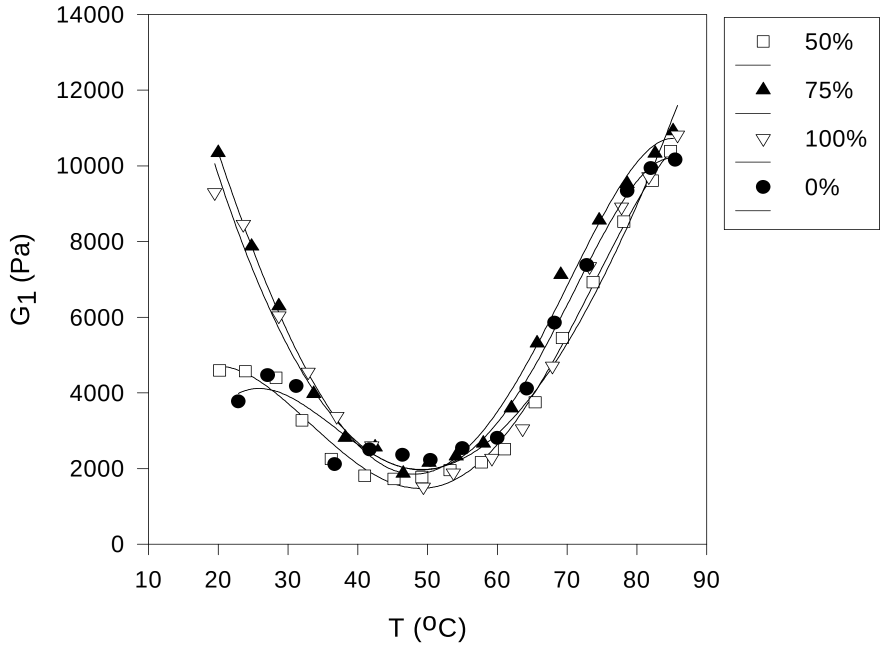

Fig. 1. Temperature interrelations of the storage modulus (G_1) of model forcemeats: control and with the replaced fat

The initial (from 20 to about 40^{o}C) and the final (65^{o}C to 85^{o}C) temperature intervals were characterized by the highest dynamics of value changes of the rigidity modulus (G_1). In the case of the 20 to about 40^{o}C interval, a distinct value dispersion of the rigidity modulus (G_1) can be noticed, and this occurs both in the control and the modified systems. Any further increase of temperature causes only slight changes of the value of the above mentioned modulus. It is only when the treatment temperature increases from about 65°C to 85°C that its value increases rapidly.

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

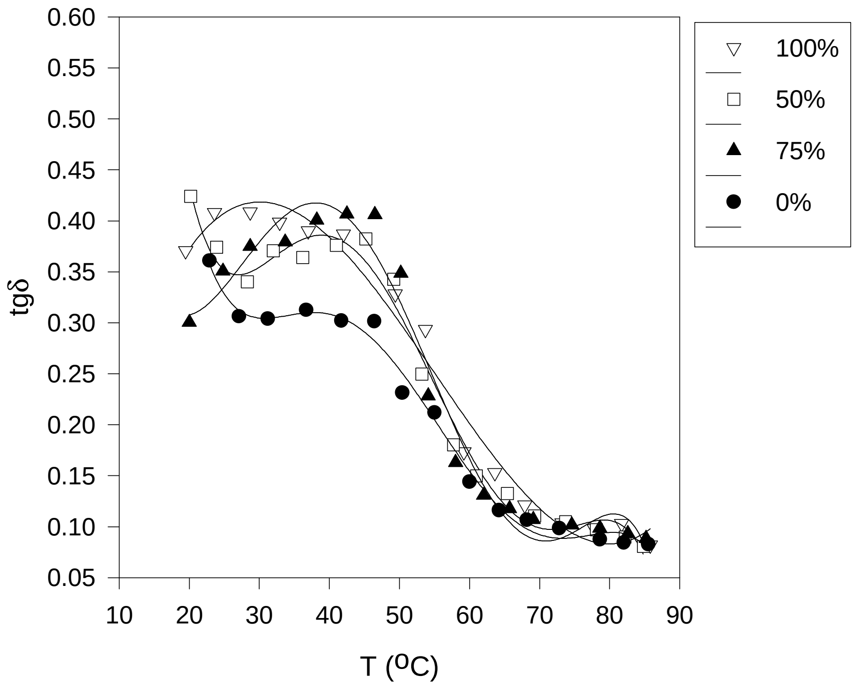

Fig. 2. Temperature interrelations of the loss tangent *(tgδ)* of model forcemeats: control and with the replaced fat

The systems show a declining capability to diffuse mechanical energy in the entire interval of the examined temperatures.

Our earlier studies (Rezler *et al.* 2003, Rezler *et al.*2003, Rezler *et al.* 2004) showed that, apart from protein and water, fat component is the main constituent of the hydrocolloid continuous fraction of the examined forcemeats. At room temperature (20°C), pork fat is at the solid state, in contrast to plant fat which, at this temperature, is primarily at the liquid phase (21% in the solid phase form). This exerts a crucial effect on the diversification of the value of the rigidity modulus (G_1) for the control forcemeat (about 4000 Pa) and for the forcemeat with the entire animal fat replaced by plant fat (G_1~10000 Pa). Fats which occur in a liquid form or grease (plant fats) disperse easier and are emulsified much faster than solid (animal) fats. Probably, this favours the development of a more compact spatial dispersion structure of all raw material components of the batter. This finds its reflection in the value changes of the dynamic viscosity (Fig. 3) which, together with the increase of the degree of the animal fat replacement by plant fat, increases its value in comparison with the forcemeat containing only pork fat.

The observed dispersion area of the rigidity modulus G_1 during the initial interval of temperature changes (20 to 40°C) (Fig. 1) is associated with the fat phase transfer.

Fat liquefaction leads directly to increased hydrocolloid 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°C) and leads to distinct changes in the value of the dynamic viscosity (Fig. 3).

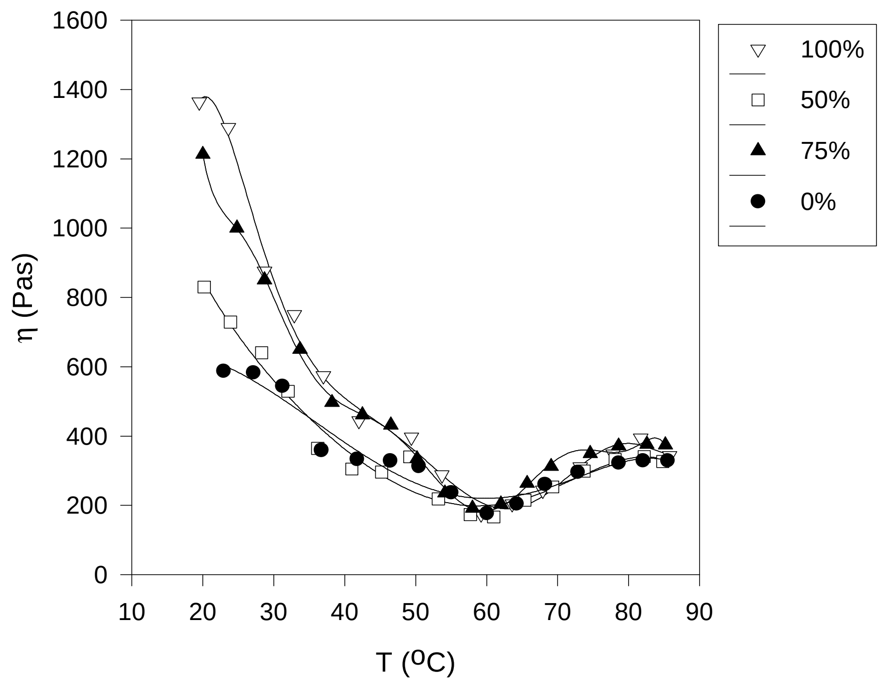

Fig. 3. Temperature interrelations of the dynamic viscosity of model forcemeats: control and with the replaced fat

It is the envelope formed by soluble proteins around fat particles that decides about the structure of the spatial hydrocolloid continuous and discontinuous phases developed as a result of cuttering. These are, primarily, myofibrillar proteins (actins and myosins) liberated from the structure of muscular fibres. These proteins form in the cutter batter spatial matrixes maintaining water-fat emulsion (Carballo *et al.* 1996).

In the temperature interval of 40-65^{o}C the elastic response at the level of about 4800Pa depends on the resistance of protein and meat particle components of the forcemeat. Therefore, the elastic reaction of the examined systems is not influenced by the substitution of fat.

Heating at the temperature interval of 40 to 65^{o}C leads to irreversible changes in the hydrocolloid structure which has a crucial influence on the development of the rheological properties of forcemeats subjected to the thermal treatment as well as in the final products.

In the course of the initial range of the analysed temperatures (40 to 65^{o}C), phenomena associated with the gelation of protein components take place.

Following denaturation processes and, later on, gelation (located at the temperature interval of about 50 to 60^{o}C) (Boyer *et al.* 1996, Brondum *et al.* 2000, Hey and Sebranek 1996) protein polypeptide chains undergo development. This type of conformation favours structuring of the hydrocolloid phase (above 65^{o}C) as well as water association which may bind with the hydrophilic groups of polypeptide chains which were until then unavailable. This leads to the development of new bonds and, therefore, formation of a more compact spatial structure of forcemeats, whereas proteins themselves act as meat-fat mechanical stabilisers. This is evident both in the increase of the rigidity modulus G_1 (Fig. 1) above the temperature of 65^{o}C as well as in the decrease of the capability for energy dissipation (Fig. 2).

The restructured products must be characterised by a specific texture. From the point of view of food technology, the texture of food products is associated with mechanical-rheological properties which also determine it to a significant degree.

The application of the hydrogenated plant fat (Akoroma OM) to replace pork fat results, primarily, in a considerably greater fat dispersion and its better binding with the structure of the finished product. This finds its reflection in the consistency of the forcemeat as affected by the structuralisation process as evidenced by the increase of the elastic properties of the final products accompanying increased level of replacement of the animal fat by plant fat.

This is confirmed by the increasing values of the rigidity modulus (Fig. 4) accompanied by a simultaneous maintenance of the same level of capabilities for the dissipation of the mechanical energy (Fig. 5).

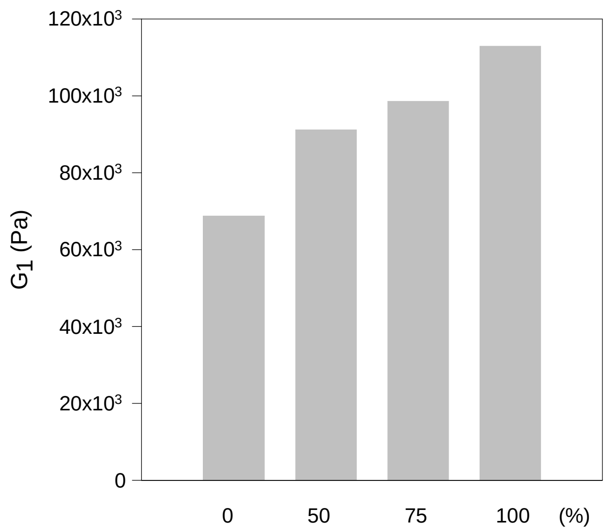

Fig. 4. Interrelations of the storage modulus (G_1) of model forcemeats subjected to thermal treatment, after cooling, with the replaced fat

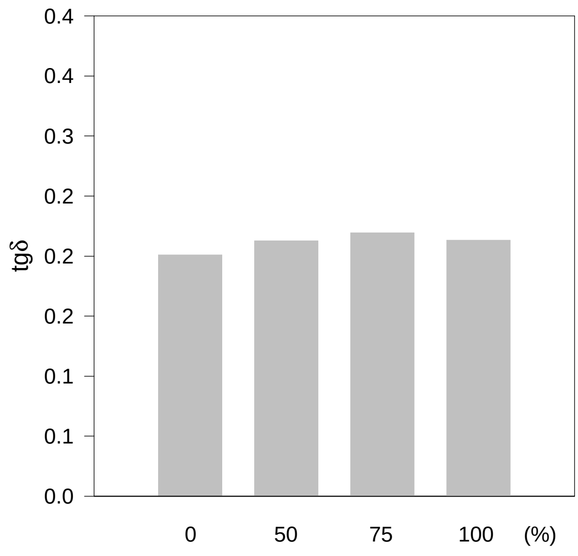

Fig. 5. Interrelations of the loss tangent *(tgδ)* of model forcemeats subjected to thermal treatment at the temperature of 85°C after cooling, with the replaced fat

At the same time, it may be said that the introduction of plant fat (Akoroma OM) as the swine fat replacer results in better water binding as reflected by a smaller cooking loss of the finished products containing the Akoroma OM fat (Fig. 6).

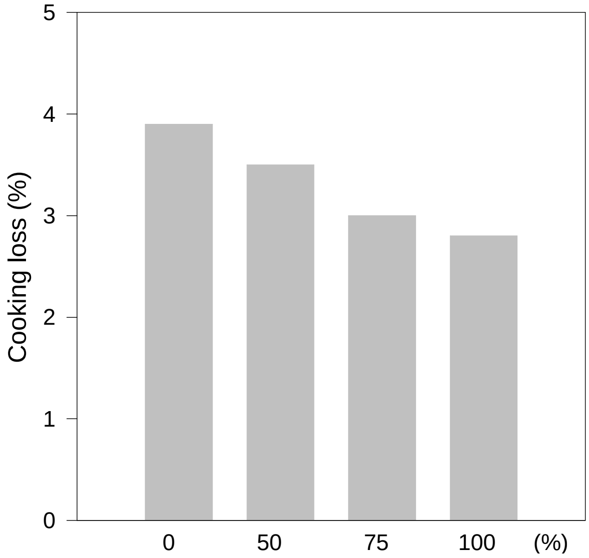

Fig. 6. Impact of the replacement of animal fat by the Akoroma OM plant fat on thermal drip, in %

CONCLUSIONS

1. Changes caused by the temperature increase within the continuous phase of forcemeats initially lead to fat liquefaction and liberation of water dispersed in them, which results in increased liquidity of the system.

2. The structuring (gelation) processes of the previously denatured protein components occurring at higher temperatures (above 60^{o}C) manifest themselves mainly in the increase of the G_1 value and drop of the $tg\delta$, which indicates growing elasticity of forcemeats subjected to the thermal treatment.

3. The application of the hydrogenated plant fat (Akoroma OM) as a replacer of pork fat results, first and foremost, in a better fat dispersion and binding with the structure of the finished product as evidenced by the increased elastic properties of the finished products.

4. The replacement of animal fat by plant fat reduces the amount of water and fat drip and, consequently, may result in increased production efficiency of finely-comminuted sausages.

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WPŁYW TŁUSZCZU ROŚLINNEGO AKOROMA OM NA WŁAŚCIWOŚCI MECHANICZNE DROBNO ROZDROBNIONYCH FARSZÓW MIĘSNYCH

Ryszard Rezler

Katedra Fizyki, Akademia Rolnicza
ul. Wojska Polskiego 38/42, 60-637 Poznań
e-mail: rezler@owl.au.poznan.pl

Streszczenie. W pracy badano wpływ temperatury na właściwości reologiczne modelowych farszów mięsnych ze zróżnicowanym stopniem wymiany tłuszczu zwierzęcego tłuszczem roślinnym Akoroma OM, poddawanych obróbce termicznej jak i produktów finalnych. Wykorzystując technikę DMTA (Dynamiczno Mechaniczna Analiza Termiczna) określono temperaturowe zmiany wartości podstawowych parametrów charakteryzujących te właściwości. Zastosowanie uwodornionego tłuszczu roślinnego (Akoroma OM) jako wymiennika tłuszczu wieprzowego przyczynia się przede wszystkim do lepszego zdyspergowania tłuszczu i związania go ze strukturą gotowego wyrobu. Przejawia się to wzrostem właściwości sprężystych produktów finalnych oraz zmniejszeniem ilości wycieku termicznego.

Słowa kluczowe: reologia, tłuszcz roślinny, drobno rozdrobnione farsze mięsne