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QUALITY ASSESSMENT OF FINELY COMMINUTED SAUSAGES PRODUCED WITH THE ADDITION OF DIFFERENT FORMS OF MODIFIED STARCH

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Abstract. The study addressed the quality of finely comminuted sausages, in the formulation of which 3% fat was replaced with potato starch E1412 prepared in various ways. In variant 1, starch was added in the dry form during chopping, whereas in variant 2 it was added in the form of starch dispersion, and in variant 3 – in the form of gel. Sausage with the basic formulation constituted the control sample. Changes in rheological properties of batters depending on the temperature were investigated using the DMA method with the application of a mechanical relaxometer, whereas the water binding state and water dynamics were investigated using nuclear magnetic resonance. The texture of the sausages was determined through the following indexes: maximum force at the first compression – hardness I, force at the second compression – hardness II, elasticity, cohesiveness, threshold strain, force corresponding to threshold strain, maximum shear strength and shear work. Qualitative properties included in the sensory examination were: flavour, consistency, colour uniformity, slice binding and overall desirability. The method of potato starch rehydration had a statistically significant effect on the values of selected sausage texture indices in comparison to the control sausage. Sensory examination showed no statistically significant differences between the investigated variants of sausages. The parameter characterising slice binding was an exception in this respect. Fat replacement with starch preparation E1412, prepared in various ways, did not have a statistically significant effect on the production yield of the investigated model sausages.

Keywords: potato starch E1412, finely comminuted meat batter, fat replacement, rheological properties, nuclear magnetic resonance, texture

INTRODUCTION

Improper diet constitutes a serious socio-economic problem. According to the recommendations of FAO/WHO, dietary habits of the Polish society should be changed, especially the consumption of fat needs to be reduced [10,11]. In this

case the problem is connected with the so-called invisible fat, contained in numerous foodstuffs such as meat, sausages, milk and dairy products or sweets, as consumers frequently are unaware of its presence. In Poland very popular meat products are finely comminuted sausages of the wiener type, in which fat content may even exceed 30%. This results from the relatively low price of these products, their easy and fast preparation for consumption, lack of visible fat in the cross-section, and the false assumption that they are dietetic foodstuffs [20]. For this reason the meat industry faces the challenge of extending the offered assortment with products with lowered energy content, thanks to which the amount of fat consumed in everyday diet could be reduced. Consumers are going to demand low-fat foodstuffs with increasing frequency, as is already evident in all developed countries, where the number and assortment of such processed meat products are constantly increasing [1,9,15,21]. However, the development of the formulation for new assortments of sausages with a lowered energy content is not easy [8,21]. Being a carrier of taste, fat – apart from determining appropriate texture of the product and its juiciness – has a decisive effect on the mechanical and rheological, as well as sensory properties of the product, and on the stability of emulsion in finely comminuted sausages [8,10]. At present numerous fat substitutes, among them starch, are used in large quantities in meat industry. Starch is a natural storage polysaccharide in higher plants, i.e. potatoes, rice and maize. A common property of the above mentioned fat substitutes is their relatively high water binding ability and low energy content. The addition of starch as a fat substitute has been investigated in numerous research studies. Experiments conducted by Dolata *et al*. [8] showed that the replacement of fat with native starch in the amount of 2 and 3% did not result in the deterioration of the sausage texture in comparison to the control sample. The substitution of fat with rehydrated starch within the 2% to 5% range did not have a statistically significant effect on the results of sensory evaluation of processed meats.

Sausages with lowered fat content to be accepted and readily bought by consumers have to first of all exhibit proper sensory attributes, meeting the requirements of consumers [9,14,15].

The aim of this study was to evaluate the effect of the method, in which modified potato starch was rehydrated, on the quality of model meat products with lowered fat contents.

MATERIAL AND METHODS

Experimental material was prepared on a semi-commercial scale. The raw material for production was sinewy pork class III (48.71%), pork fat tissue (20.88%), the addition of water constituting 27.83% weight of meat and fat raw material, curing blend and spices (2.58%). During the process of chopping potato starch prepared in various ways was introduced to batters to replace 3% of fat. The batter of model

sausage with the basic formulation composition constituted the control sample (Tab. 1). The final temperature of the batter did not exceed 11-12°C. A chopper with the capacity of 22 dm^3 was used to produce batters. The rotational speed of the chopper knives was 3000 rpm, whereas that of the bowl was 20 rpm. The obtained batters were stuffed into natural casings with the diameter of 30 mm. After stuffing, sausages were dried at the temperature of 50°C, smoked at the temperature of 60°C and cooked at the temperature of 72°C in a smoking-scalding chamber. After 24h of cold storage, the sausages were subjected to tests.

Table 1. Composition of batters of finely comminuted sausages of the wiener type

Composition (%)	Control	Starch added		
		Dry form	Dispersion	Gel
Pork class III	48.71	48.71	48.71	48.71
Pork fat tissue	20.88	17.88	17.88	17.88
Water	27.83	27.83	27.83	27.83
Additives (spices, NaCl, E 250, E 301)	2.58	2.58	2.58	2.58
Starch preparation E 1412	0.00	3.00	3.00	3.00

Batters were analyzed on the day they were chopped. The investigations of changes in the rheological properties of the batters in the function of temperature were conducted using the DMTA method with the mechanical relaxometer described in the study by Rezler and Poliszko [19]. The real part G_1 is called the dynamic modulus and it is related to that part of the potential energy of strain which is saved during periodic deformations. The imaginary part G_2 of the modulus G^* is called the modulus of loss and is related to the part of energy which is dissipated in the form of heat. In the measurements, the values of components of the complex modulus of rigidity G_1 were determined, along with the loss tangent ($tg\delta = G_2 G_1^{-1}$) in the range of temperatures between 20°C and 82°C. The free vibration frequency of the system was 0.363 Hz. The measurements were conducted 15 minutes after the system reached the assumed temperature. The initial temperature was 20°C.

The contents and changes in the dynamics of water were determined on the basis of the measured spin-lattice relaxation times T_1 and spin-spin relaxation times T_2, using the nuclear magnetic resonance technique [12].

Sausage texture was tested using the universal testing machine Instron 1140, with the double compression test (the TPA test), where hardness I and II were determined, along with cohesiveness and elasticity, and shear test using the Warner-Bratzler knife, determining maximum force and work. With the application of the compression of the sample by 80% of its original height the following parameters were determined:

threshold strain, force corresponding to the threshold strain, final compressive stress, and yield point [4]. The tested sausages were cylinder-shaped with the diameter of 2.5×10^{-2} m and a height of 2.0×10^{-2} m. Sensory evaluation of the investigated sausages was conducted using the linear scaling method. The linear scale was a line segment with the length of 100 mm with boundary markings. Taste, consistency, colour uniformity, slice binding and overall desirability were quality factors [3,16,17].

The results obtained were subjected to statistical analysis. The bivariate analysis of variance (ANOVA) was applied at the level of significance $\alpha = 0.05$. In case of differences, Tukey's multiple comparison test was performed. The testing was conducted in two experimental series, for texture parameters in 10 replications. In the evaluation of consumer traits, the panel was composed of 50 persons each time.

RESULTS AND DISCUSSION

While analyzing the basic formulation composition it was found that the amount of protein conformed to the Polish Standard [18], whereas the content of fat in the sausages with the addition of starch prepared in various ways decreased in accordance with the assumptions of the experiment.

Table 2. The basic chemical composition of sausages produced with the addition of modified starch E1412

Parameters (%)	Starch added			
	Control	Dry form	Dispersion	Gel
Protein	11.83^{a}	11.05^{b}	11.02^{b}	11.51^{ab}
Fat	22.43^{a}	19.43^{b}	19.95^{b}	20.05^{b}
Water	62.40^{a}	63.84^{b}	63.40^{b}	63.03^{ab}

$^{a, b}$ – means in lines with different superscript are significantly different ($P < 0.05$).

The total water content in all the variants of the sausages analyzed was the same, which was also in accordance with the assumptions for this experiment (Tab. 2).

Table 3. Assessment of water binding state in sausages

Relaxation times (ms)	Starch added			
	Control	Dry form	Dispersion	Gel
T_1	469.82	465.51	471.86	485.09
T_{21}	45.67	64.27	55.00	45.25
T_{22}	139.74	175.15	142.41	136.05

The conducted measurements of the spin-lattice relaxation time T_1 and spin-spin relaxation time T_2 made it possible to evaluate the water binding state in the sausages.

Relaxation time T_1 makes it possible to determine the amount of water in the system. All the investigated variants showed slight changes in the values of this parameter. It is connected with the fact that in all the systems the amount of water did not change. The longest T_1 times were found in the variant in which some of the fat was replaced with previously cooked starch. Water forming the gel structure does not bind with the other batter components, especially protein. Additionally, the retrogradation process caused the removal of some water from the gel. The T_1 values closest to those for the control sample were obtained for the variant of the experiment in which some fat was replaced with previously rehydrated starch preparation.

Measurements of the spin-spin relaxation times showed that in the system two water fractions were found: bound water described by the short component T_{21} and free water described by the long component T_{22}.

The T_{21} values were the highest in case of variant 1. Bound water in this system was the most mobile. A lowering of the T_{21} value for variant 3 was caused by the binding of water participating in the formulation of starch gel. Free water also in this variant was the least mobile – it showed the shortest relaxation time. In comparison to the control sample, the system in which some of the fat was replaced with rehydrated starch preparation did not show significant differences in the values of both spin-spin relaxation times. The biggest differences – the longest T_{21} and T_{22} times in comparison to the control sample were obtained in the case of the application of fat substitute without its previous rehydration.

A comparison of the values of the modulus of rigidity in the case of final products with fat replaced with a starch preparation (in three variants), chilled to room temperature, with those for the non-modified product (Fig. 1) makes it possible to find an increase in its elasticity properties, and in this way – a decrease in its plasticity. The highest – more than 1.5 times higher – increase in the G_1 value occurred in the product with fat replaced by starch gel (in comparison to the non-modified product).

A decrease in the content of the adipose tissue in the formulation and the introduction of water and the preparation in its place resulted in a drop in the effective concentration of protein responsible for the formation of latticed spatial matrices supporting the water-fat emulsion [6,7] Gelled aggregates, formed with a lower protein content, exhibit a looser, less compact structure. The replacement of the adipose tissue with a starch preparation in the form of a suspension and in the dry form – while maintaining the unchanged amounts of water in the system – did not result in a decrease in the effective “concentration” of protein responsible for the formation of the above mentioned spatial matrices [2,5,3]. It is manifested in a slight differentiation in the values of the modulus of rigidity for the investigated systems (final products) in the variants of fat substitution with preparations in the dry form and suspension (Fig. 1).

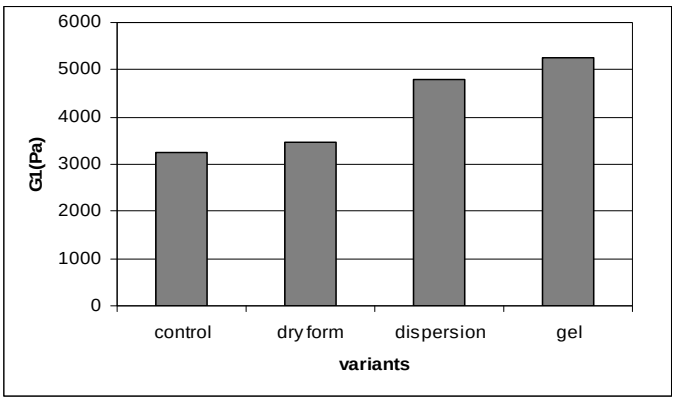

Fig. 1. The effect of starch re-hydration method on modulus of rigidity G_1

At the same time it can be seen that, in comparison with the control sample, in the products in which fat was replaced with the dry starch preparation and its suspension also a slight decrease in the values of the loss tangent tgδ was observed (Fig. 2), indicating a decrease in the relative mechanical energy diffusive power.

It leads to the conclusion that at such a method of fat substitution with starch preparations the effects connected with the cooking, and as a consequence with the crosslinking of starch, are observed in a limited range, as for the most part starch forms only a viscous solution (water is bound only in the hydratation envelope). The starch preparation itself plays only the role of a dissipative "extender".

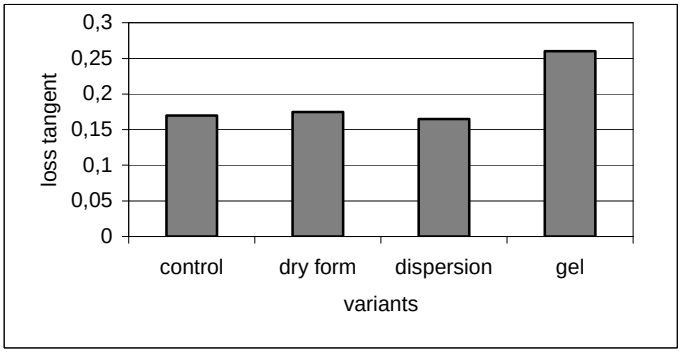

Fig. 2. The effect of the starch rehydration method on loss tangent

Water, and especially its redistribution, plays an essential role in the structuralization of final products. The replacement of fat with starch gel results in the reduction of its amount (most of the water is bound with hydroxyl groups of crosslinked starch). As a result it leads to less intensive conformation changes within polypeptide chains and a decrease in the density of protein network. It is manifested

in the increasing relative mechanical energy diffusive power (Fig. 2), and the participation of the crystal lattice of gelled starch compensates for the lower participation of the matrix of gelled protein in the elasticity reaction of the system, the result of which is a relatively higher elasticity of the final product.

The values of texture parameters in finely comminuted sausages, in which 3% of fat was replaced with modified starch, obtained in the TPA test, depended on the method of its preparation. Thus, the values of hardness I and II of sausages with starch added in the form of powder and dispersion did not differ in a statistically significant way from the control sausage. In contrast, sausage in which 3% of fat was substituted with starch gel showed lower values of hardness I and II, cohesiveness and elasticity than the other sausage variants. The differences were statistically significant, which suggests that this form of starch preparation (gel) causes disadvantageous changes in the texture properties of the final product. The added gel weakens the structure.

Fat substitution with starch preparation E1412, pretreated using different methods, had an effect on the values of threshold strain, yield point, force corresponding to threshold strain and on final compressive stress. It should be pointed out here that the product with starch added in the form of gel exhibited the lowest values of the investigated parameters in comparison to the sausages modified with starch added in the dry and dispersion forms. In comparison to the control sample, the values of threshold strain were 10.55% lower, the yield point 28.0% lower, the force corresponding to threshold strain 28.0% lower, and the final compressive strain was lower by 7.07%.

Table 4. Mean values of texture indexes for finely comminuted sausages produced with the use of modified starch

Parameters	Starch added			
	Control	Dry form	Dispersion	Gel
Hardness I (N)	34.78^{a}	34.17^{a}	34.19^{a}	28.50^{b}
Hardness II (N)	30.02^{a}	30.51^{a}	28.78^{a}	18.59^{b}
Cohesion	0.64^{a}	0.67^{a}	0.61^{a}	0.48^{b}
Elasticity (mm)	7.59^{ab}	7.71^{a}	7.51^{ab}	7.21^{b}
Deformation limit (%)	52.60^{ab}	54.25^{a}	50.85^{b}	47.05^{c}
Strain force (N)	42.56^{a}	40.31^{a}	40.36^{a}	30.64^{b}
Compressive stress (kNm^{-2})	86.66^{ab}	93.84^{bc}	97.68^{c}	80.53^{a}
Yield point (kNm^{-2})	85.38^{a}	80.85^{a}	80.96^{a}	61.46^{b}
Shear force (N)	3.52^{a}	5.33^{b}	3.98^{ab}	3.46^{a}
Shear work (J)	0.089^{a}	0.121^{a}	0.109^{ab}	0.092^{a}

^{a,b} – means in lines with different superscript are significantly different ($P < 0.05$).

The shear test showed that the biggest force had to be applied to cut the sample with fat replaced with starch preparation in the form of powder, whereas the smallest – for the sample containing starch in the form of gel. No statistically significant differences were found between the investigated samples in the shearing work.

The obtained results of the texture evaluation for sausages produced with the use of modified potato starch added to replace fat during the chopping process suggest that the method of preparing the starch preparation is important.

Sensory examination confirmed the trends observed during texture testing. The evaluated consistency of sausages, in which some of the fat was replaced with potato starch (the dry starch preparation – variant 1, suspension – variant 2 and gel – variant 3), did not differ statistically from the control sample. Statistically significant differences were found only in the evaluation of slice binding (Fig. 3).

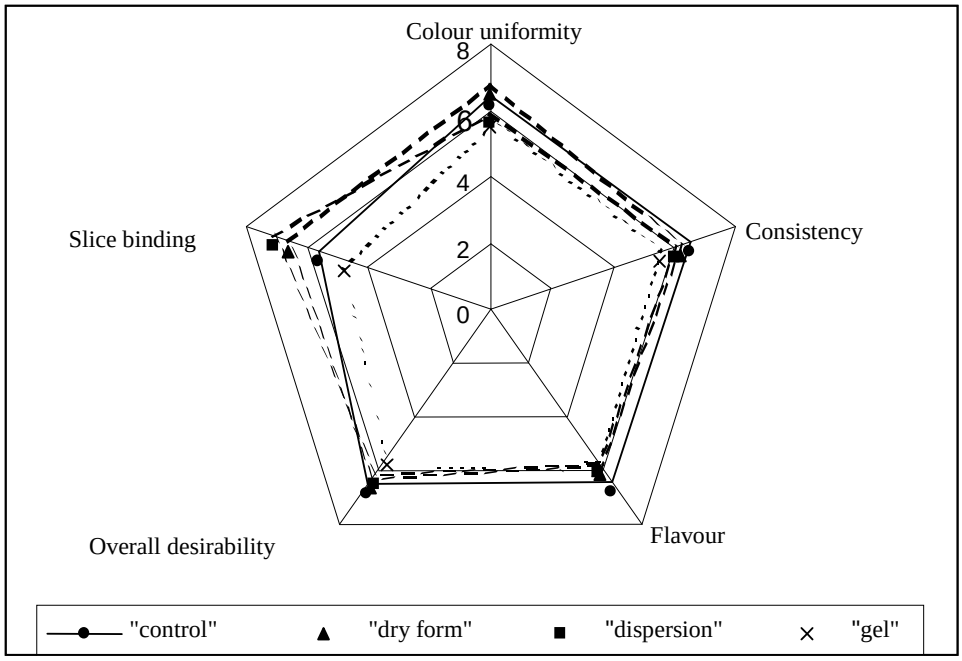

Fig. 3. Results of sensory examination

The lowest scores were given to the sausage with the starch preparation added in the form of gel. This sausage also had the lowest values of texture parameters measured objectively using the Instron universal testing machine. Scores for the cross-section colour and taste evaluation in the case of sausages produced with fat

substitution with starch were similar to those for the control sausage. In the case of overall desirability, the worst scores were given to the sausages in variant 3 – 5.45. The other sausages (variants 1 and 2) did not differ in a statistically significant way in their overall desirability scores from the control sausage.

Thus, it may be concluded that the sausages investigated (control and variants 1 and 2) received consumer acceptance. Overall desirability of the processed meat products amounted to 6.56, 6.32, and 6.15 in a 10-point scale.

The production yield of sausages, in spite of the differing experimental variants, did not differ in a statistically significant way from the control sausage (Tab. 5).

Table 5. Yield of finely comminuted sausages produced with the addition of starch

Type of sausage	Production yield (%)
Control	132.49[a]
Dry form	133.51[a]
Dispersion	135.23[a]
Gel	133.98[a]

CONCLUSIONS

1. The application of starch preparation as a fat substitute in finely comminuted sausages requires its preliminary rehydration. A statistically significant effect of the method of potato starch rehydration was found on the values of selected texture indices in comparison to the control sausage.
2. Sensory examination showed no statistically significant differences between the investigated sausage variants. The parameter characterizing slice binding was an exception here.
3. The experimental results obtained confirm the usability of modified potato starch as a fat substitute in finely comminuted sausages with lower energy content.

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OCENA JAKOŚCI WĘDLIN DROBNO ROZDROBNIONYCH WYPRODUKOWANYCH ZE SKROBIĄ MODYFIKOWANĄ DODAWANĄ W RÓŻNYCH FORMACH HYDRATACJI

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Streszczenie. W pracy oceniano jakość wędlin drobno rozdrobnionych, w których składzie recepturowym zastępowano 3% tłuszczu, różnie przygotowaną skrobią ziemniaczaną E1412. W wariancie 1, skrobię w postaci suchej dodawano podczas kutrowania, w 2 zaś w postaci dyspersji

skrobiowej, natomiast w 3 w postaci żelu. Próbkę kontrolną stanowiła wędlina o podstawowym składzie recepturowym. Badano zmiany właściwości reologicznych farszów w zależności od temperatury, metodą DMA przy użyciu relaksometru mechanicznego oraz stan związania i dyna-mikę wody za pomocą magnetycznego rezonansu jądrowego. Teksturę wędlin oznaczono poprzez następujące wyróżniki: maksymalną siłę pierwszego ściskania – twardość I, siłę drugiego ściskania – twardość II, elastyczność, spoistość, odkształcenie graniczne, siłę odpowiadającą granicznemu odkształceniu, maksymalną siłę cięcia oraz pracę cięcia. Cechami jakościowymi oceny sensorycznej były: smak, konsystencja, barwa na przekroju, związanie plastra oraz pożądalność ogólna. Stwierdzono statystycznie istotny wpływ sposobu uwodnienia skrobi ziemniaczanej na kształtowanie niektórych wyróżników tekstury wędlin w porównaniu z wędliną kontrolną. Ocena sensoryczna wykazała brak statystycznie istotnych różnic między badanymi wariantami wędlin. Wyjątkiem był parametr charakteryzujący związanie plastra. Wymiana tłuszczu, różnie przygotowanym preparatem skrobi E1412 nie wpłynęła w sposób statystycznie istotny na wydajność produkcyjną omawianych wędlin modelowych.

Słowa kluczowe: skrobia ziemniaczana E1412, farsz mięsny drobno rozdrobniony, właściwości reologiczne, magnetyczny rezonans jądrowy, tekstura