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EFFECT OF FAT SUBSTITUTES ON PHYSICO-CHEMICAL CHARACTERISTICS AND RHEOLOGICAL PROPERTIES OF MEAT PRODUCT

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Summary. The effect of cellulose preparations that were used in meat products instead of the recipe fat on shaping of physical-chemical parameters and rheological properties of the meat products, was studied. The following additives were used: potato and wheat cellulose preparations and inulin in the quantities: 0% (control), 5% and 10%. In the final product, chemical composition was analysed, the level of thermal drip was determined, the binding of the slice was evaluated and the rheological properties of the product were characterised. As a result of the conducted studies it was found that a type of the cellulose preparation used and the level of its addition had a significant effect on the determined parameters of quality. All the preparations caused – according to the expectations – a significant decrease of fat content in the products in relation to the control product. Application of a higher level of cellulose preparation had a significant influence on lowering of the fat and protein content and on the significant increase of water and salt level and on the size of the thermal drip. The level of the addition of the preparation used did not have any significant effect on the characterised rheological parameters. The product, containing preparation of wheat cellulose was characterised by the best binding of the product i.e. the lowest thermal drip and the highest tearing strength. The rheological characteristics of the inulin-containing product indicates that this substitute "imitated" fat in the examined product in the best way but it had a significant negative influence on binding of the product's bloc.

Keywords: cellulose preparation, fat substitute, meat product, binding of the product, rheological characteristics.

INTRODUCTION

Apart from nutrients, food products contain also the so-called non-nutritive substances but possessing health-promoting properties. The products that contain such substances are considered as functional foods. The functional foods include the products of all groups but they have to be characterised by a specific health-promoting effect, i.e. act in a prophylactic way in relation to certain diseases, retard ageing processes and help in maintaining a good physical and mental state [1,5]. Such tasks may be acquired by the products, containing such components as alimentary fibre, oligosaccharides, polyunsaturated fatty acids, polyhydroxide alcohols, peptides and proteins, glycosides, isoprenoids, vitamins, polyphenols, choline, probiotics and mineral components [2,3,5].

Such components include also alimentary fibre. Cellulose is not the uniform component but a group of compounds, being not metabolised by a human system and being resistant to enzymatic hydrolysis in the alimentary tract. Functional properties of alimentary cellulose are strictly related to its construction, percentage content of the particular fractions, primary material and the method of its obtaining. The most important properties of cellulose include: water absorbing, that is water holding capacity, binding of cations, sorption, that is capacity of binding bile acids and its salts in guts and viscosity [7,8]. It is simultaneously a prebiotic, texture-generating substance. It is recommended for use as sugar and fat replacer. It is also recommended for use in fats and meat industry in dietetic foods [7,11].

The aim of the work was to examine the effect of use of cellulose preparations as fat replacers and the level of its addition to the model meat product on its physical and chemical characteristics and rheological parameters.

MATERIAL

In the experiment, three different cellulose preparations were employed: potato, wheat and inulin, differing in origin and functional properties. Introduction of the preparation to the products had two functions: fortification of the product in health promoting substance and lowering of the level of fat, using the preparations as fat replacers. The preparations were introduced to the model products instead of the recipe fat, in the quantity of 5 and 10%. The studies were conducted with the finely disintegrated model meat product type "mortadela".

The formulation of raw material in the model meat product included the pork meat class III (21.4%), lean beef (28.6%), fine pork fat (21.4%) and water (28.6%).

The control product was manufactured from the batter with the basic recipe composition, without the addition of preparation (variant K). The recipe fat was replaced with the potato cellulose (P_P) and wheat (P_W) preparations, or inulin (P_I) in the quantities 5% and 10%, respectively. The scheme and marking of the experimental variants are given in Table1.

Table 1. Scheme and denotation of the experimental variants

The studied preparations		Control variant	Potato cellulose	Wheat preparations	Inulin
Denotation		K	P_P	P_W	P_I
The levels of the preparation, substituting animal fat	1	0%	0%	0%	0%
	2	5%	5%	5%	5%
	3	10%	10%	10%	10%

The raw materials for production of model batter at temperature of 0-2°C were disintegrated in the grinder with the screen with 3-mm mesh diameter, then they were chopped in the following sequence: meat, ice, cellulose preparation and fat. The time of chopping process was 10 minutes. A final temperature of the batter, obtained during the process, did not exceed 12°C. The batter was prepared in the chopper manufactured by Seydelman type 40 Ras, with 6-knives, with capacity of 0.04 m^3. Technical parameters of the chopper were as follows: rotations of the chopper's bowl- 30/min., revolutions of knife shaft – 3600/min., standard knives type EE with sliding coefficient $\lambda = 1.5$. The batter was filled in the cans of 400-g capacity, then they were pasteurised in water at temperature of 75°C till obtaining the temperature of 70°C in the can geometric centre of the product's bloc. Then, the cans were cooled down with a cold water and stored in the refrigeration room at temperature of 4-6°C. From this place, the samples were taken for the studies.

METHODS

In the model meat products, the following determinations were carried out:

- in the preserved meat bloc: water content (*W*) by the dryer method according to PN-73/A-82110, total protein content (*P*) by the Kjeldahl method using Kjeltec Analyser 1026 according to PN-75/A-04018, fat content by Soxhlet method (*F*), using Soxtec Fat Analyser HT-6 according to PN-73/A-82111, sodium chloride content (*S*) according to PN-73/A-82112, and the following indices were calculated: *W/P* – ratio of water (*W*) to protein (*P*) content and *F/P* – ratio of fat (*F*) to protein (*P*) content;

- the size of thermal drip (*TD*) exuding from the model product was determined by the weighing method [6];
- the evaluation of tearing strength of the slices (*SS*) was performed using an universal machine for resistance tests, Zwick model 1445 [9];

the rheological characteristics was studied by the CASRA method [10], using the unversal machine for resistance tests, Zwick model 1445, determining plasticity (*P*), elasticity (*E*) and fluidyty (*F*).

Each experiment was performed in 3 replicates. Chemical analyses was carried out in 2 or 3 replicates as well rheological analyses, thermal drip and strength of the slices were carried out in 8 or 10 replicates in each of the experiments. The results represent the means from all replicates.

The obtained results were statistically analysed, using Statgraphics program.

DISCUSSION OF RESULTS

The mean values of parameters, characterising the basic chemical composition of the products and the calculated indices *W/P* and *F/P* in the studied preserved meat blocs are given in Table 2. The obtained results show that the type of the used functional preparation as well as the level of its addition had a significant effect on the determined parameters and the calculated indices. The functional preparation of cellulose replaced a part of the recipe fat in the product and according to the expectations, the analytically determined fat content was lowered, from 26.2% in the control product to 21.9 – 22.1% in the products with the cellulose preparation. Together with the increase of the level of the preparation added, fat content in the final product was significantly decreasing, as compared to the control product: from 26.2% in the control product to 21.5% in variant, containing 10% addition of cellulose. Functional fat replacers had a significant effect on the increase of water content (from 61.0% in the control product to 65.5% in the product with the highest addition of the cellulose preparation), sodium chloride (from 1.57% in the control product to 1.69% in the product with the highest level of the preparation) and of the calculated index *W/P* (from 6.19 in the control product to 7.10 in the product, containing the highest level of the cellulose preparation), The addition of functional preparation caused a simultaneous significant decrease of protein content (from 10.0% in the control product to 9.2% in the product with the highest level of the cellulose preparation) and index *F/P* (from 2.62 in the control variant to 2.34 in the product with the highest additive of the cellulose preparation). The increased level of fat replacers in the product enhanced the statistically significant relationships.

Table 2. Chemical composition of model meat products

Factor	Water (*W*) (%)	Total protein (*P*) (%)	Fat (*F*) (%)	Sodium chloride (%)	Ratio *W/P*	Ratio *F/P*
type of the functional preparation						
K	61.9^{a}	10.0^{c}	26.2^{b}	1.57^{a}	6.19^{a}	2.62^{b}
P_P	65.1^{b}	9.4^{ab}	22.1^{a}	1.70^{b}	6.92^{bc}	2.35^{a}
P_W	64.8^{b}	9.5^{b}	22.1^{a}	1.70^{b}	6.84^{b}	2.33^{a}
P_I	65.5^{b}	9.2^{a}	21.9^{a}	1.79^{b}	7.16^{c}	2.39^{a}
NIR$\alpha \leq 0.05$	0.83	0.36	0.92	0.10	0.28	0.14
the level of additive preparation						
1	61.9^{a}	10.0^{c}	26.2^{c}	1.57^{a}	6.19^{a}	2.62^{b}
2	64.5^{b}	9.6^{b}	22.6^{b}	1.74^{b}	6.75^{b}	2.35^{a}
3	65.5^{c}	9,2^{a}	21.5^{a}	1.69^{b}	7.10^{c}	2.34^{a}
NIR$\alpha \leq 0.05$	0.65	0.28	0.73	0.06	0.15	0.09

$^{a, b, c}$ – means in the same column marked with various letters differ significantly ($\alpha \leq 0.05$).

The employed preparations had a variable influence on binding of the product (Tab. 3). The highest thermal drip in the quantity of 7.2% was found for the products, containing inulin preparation. On the other hand, the remaining cellulose additives – potato and wheat cellulose preparations – had a significant effect on its weakening. A higher level of the preparation's addition to the products instead of the recipe fat had a significant effect on the increase of the level of thermal drip. At the same time, the products containing inulin product were characterised by the lowest tearing strength of the slices. The level of the addition of the preparation to the product did not have any significant effect on this parameter. The examined fat substitutes had, therefore, a differentiated effect on shaping of the structure of final product. The inulin preparation, as being introduced instead of fat, created a delicate structure what was demonstrated by a weak water holding capacity and binding of water in the final product (the highest thermal drip and the weakest binding of the slices in the product, expressed as tearing strength). The produced bonds among the components of the batter and then, of the final product were too weak as to bind and hold water

which was introduced together with the preparation instead of fat. In spite of a differentiated origin, the preparations of wheat and potato cellulose possessed a similar characteristic in shaping of the structure of the model product.

Table 3. Mean values of slice strength and thermal drip of model meat products

Factor	Slice strength [N cm^{-2}]	Thermal drip [%]
type of the functional preparation		
K	2.0^{ab}	6.3^{ab}
P_P	1.99^{ab}	6.0^{a}
P_W	2.11^{b}	5.4^{a}
P_I	1.90^{a}	7.2^{b}
NIR$\alpha \leq 0.05$	0.19	0.85
the level of additive preparation		
1	2.0	6.3^{ab}
2	2.0	5.5^{a}
3	2.0	6.9^{b}
NIR$\alpha \leq 0.05$	0.16	0.71

$^{a, b, c}$ – means in the same column marked with various letters differ significantly ($\alpha \leq 0.05$).

The characteristics of the rheological parameters (Tab. 4) showed the individual texture-forming specificity of the preparations in the examined raw material system. The preparations of potato and wheat cellulose did not have any significant effect on the characteristic properties of elasticity and fluidyty and did not differ from the control product in relation to plasticity. On the other hand, the inulin preparation caused that the product with its additive was the least plastic and was characterised by the highest elasticity and fluidyty from among the studied variants; it differed significantly from the control variant and the products containing other cellulose preparations. The level of the addition of the used preparations did not have any significant effect of the characterised rheological parameters. The obtained results may indicate that the employed preparations created a structure similar to that one in the control product, or that the level of the additive was too low as to notice the significant changes in the formed structure.

Table 4. Mean values of rheologic parameters (CASRA method) of model meat products

Factor	Plasticity [x 10^5 N m^{-2}]	Elasticity [x 10^{-6} m^2 N^{-1}]	Fluidyty [x 10^{-8} m^2 $N^{-1}s^{-1}$]
type of the functional preparation			
K	1.55^{bc}	1.59^{a}	5.46^{a}
P_P	1.39^{b}	1.54^{a}	4.78^{a}
P_W	1.57^{c}	1.65^{a}	5.49^{a}
P_I	1.10^{a}	2.34^{b}	8.34^{b}
NIR$\alpha \leq 0.05$	0.16	0.20	0.82
the level of additive preparation			
1	1.55	1.59	5.46
2	1.43	1.77	6.15
3	1.28	1.91	6.59
NIR$\alpha \leq 0.05$	0.18	0.28	1.36

$^{a, b, c}$ – means in the same column marked with various letters differ significantly ($\alpha \leq 0.05$).

The results of the conducted analysis of correlation between the studied and calculated parameters, characterising physical-chemical and rheological properties of the products with the cellulose preparations introduced instead of fat, are given in Table 5. The parameters of the basic composition: water, protein, fat and the calculated indices *W/P* and *F/P* were correlated mutually on a very highly significant level. For fat and water, any relationship with the parameters, characterising binding of the product's slices and those ones, describing the rheological properties, was not found. Only protein and salt level correlated with the rheological parameters on a highly significant level.

The determined fat content in the products, containing cellulose preparations was very highly significantly correlated with water content (r = -0.960***), index *W/P* (r = -0.769***) and *F/P* (r = 0.874***), highly significantly with protein content (r = 0.528**) and significantly with the salt level (r = -0.370*). The relationship between fat content (*F*) and the mentioned above parameters had a linear character, described by the equation:

$$F = 109.516 - 1.246*W - 0.625*P - 0.276*S \quad (1)$$

and between fat and water (Fig.1):

$$F = 97.403 - 1.158*W \quad (2)$$

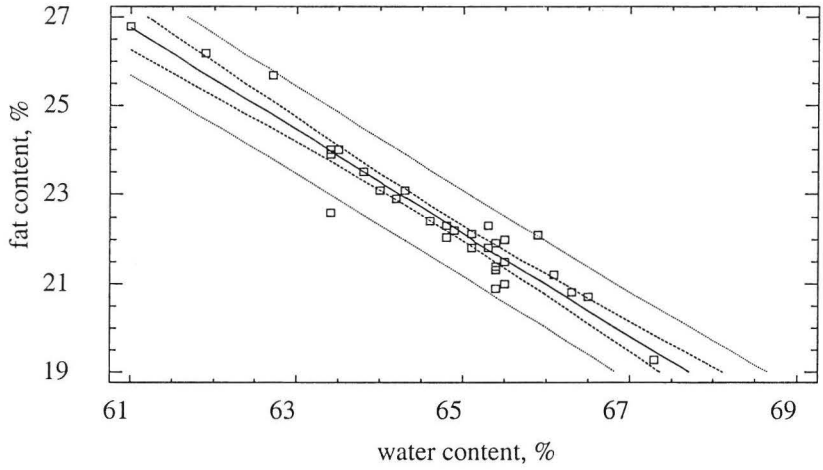

Fig. 1. The relationship between fat and water.

The obtained results indicate that each of the cellulose preparation used had the individual influence on the shaping of the examined physical and chemical parameters and on the rheological characteristics. Observations concerning potato cellulose do not confirm the results, obtained, among others, by [4] who found that the replacement of fat with potato cellulose in finely disintegrated product, irrespectively of the level of substitution, did not affect positively the binding of the batter components, being characterised by binding of the slices of the model meat preserves and their rheological characteristics. The conducted studies show that the product with the potato cellulose – apart from the advantageous differences in chemical composition such as fat decrease – created the structure similar to that one in the control product. Any significant differences in binding of the product and rheological characteristics were, however, not found. Similar observation included also preparation of wheat cellulose. The preparations of wheat and potato cellulose, in spite of the differentiated origin, possessed a similar characteristics in shaping of the structure of the model product.

Completely different structure was created by inulin preparation. The product with the addition of this preparation was least plastic and was characterised by the highest elasticity and liquidity but it had a negative effect on binding of the product's bloc. In the examined raw material, it created a delicate structure and "imitated" fat in the best way, what confirms other observations [11].

Table 5. Correlation between variables

	Water content	Protein content	Fat content	Sodium chloride content	Ratio *M/P*	Ratio *F/P*	Thermal drip	Slice strength	Plasticity	Elasticity
Protein content	-0.626***									
Fat content	-0.960***	0.528**								
Sodium chloride content	0.401*	-0.468**	-0.370*							
Ratio *W/P*	0.806***	-0.865***	-0.769***	0.451						
Ratio *F/P*	-0.773***	0.050	0.874***	-0.164	-0.410*					
Thermal drip	0.135	-0.195	-0.077	-0.220	0.213	0.006				
Slice strength	0.082	0.011	-0.141	0.153	0.106	-0.171	-0.410*			
Plasticity	-0.430	0.613***	0.246	-0.507**	-0.529**	-0.057	-0.144	-0.159		
Elasticity	0.351	-0.504**	-0.204	0.550**	0.436*	0.042	0.122	0.186	-0.845***	
Fluidyty	0.263	-0.456**	-0.137	0.474**	0.374*	0.092	0.158	0.138	-0.733***	0.951***

*** correlation very highly statistically significant at P≤0.001
** correlation highly statistically significant at P≤0.01
* correlation significant at P≤0.05
not significance P>0.05.

CONCLUSIONS

1. As a result of the conducted studies, it was found that the type of the cellulose preparation used and the level of its addition had an influence on the determined parameters of quality.
2. All the preparations caused a significant lowering, according to the expectations, fat content in the products in comparison to the control product, with the simultaneous decrease of protein content and significant increase of water and salt level in the product.
3. The application of a higher level of cellulose preparations had a significant effect on lowering of fat and protein content and significant effect on increase of water and salt content and rise of thermal drip. The level of the addition of the preparations used did not have any significant effect on the characterised rheological parameters.
4. The product, containing wheat cellulose preparation was characterised by the best binding of the slices in the product, i.e. the lowest thermal drip and the highest tearing strength.
5. The rheological characteristics of the product, containing inulin preparation shows that this substitute "imitated" fat in the examined product in the best way but it had a negative influence on binding of the product's bloc.

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WPŁYW ZAMIENNIKÓW TŁUSZCZU NA CHARAKTERYSTYKĘ FIZYKO-CHEMICZNĄ I WŁAŚCIWOŚCI REOLOGICZNE PRODUKTU MIĘSNEGO

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Streszczenie. Badano wpływ preparatów błonnikowych, które zastosowano w produktach mięsnych w miejsce tłuszczu recepturowego, na kształtowanie wyróżników fizyko-chemicznych i właściwości reologiczne produktu mięsnego. Stosowano dodatek preparatów błonnika ziemniaczanego, pszennego i inulinę w ilościach: 0% (wariant kontrolny), 5% i 10%. W bloku produktu analizowano skład chemiczny, określano wielkość ubytków cieplnych, oceniano związanie plastra oraz charakteryzowano właściwości reologiczne. W wyniku przeprowadzonych badań stwierdzono, że rodzaj zastosowanego preparatu błonnikowego oraz poziom jego dodatku miały istotny wpływ na oznaczane wyróżniki jakości. Wszystkie preparaty spowodowały istotne obniżenie, zgodnie z oczekiwaniem, zawartości tłuszczu wyrobów w stosunku do wariantu kontrolnego. Zastosowanie wyższego poziomu preparatów błonnikowych miało istotny wpływ w obniżeniu zawartości tłuszczu, białka, natomiast istotnym wzroście zawartości wody, soli i wycieku cieplnego. Wysokość dodatku zastosowanych preparatów nie miała istotnego wpływu na charakteryzowane parametry reologiczne. Wyrób zawierający preparat błonnika pszennego charakteryzował się najlepszym związaniem wyrobu tj. najniższymi wyciekami termicznymi i najwyższą wytrzymałością na zrywanie. Charakterystyka reologiczna produktu zawierającego preparat inuliny wskazuje, że zamiennik ten w badanym wyrobie najlepiej „naśladował" tłuszcz, lecz miał istotny negatywny wpływ na związanie bloku produktu.

Słowa kluczowe: preparaty błonnika, zamienniki tłuszczu, produkt mięsny, związanie produktu, charakterystyka reologiczna.