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ROLE OF SELECTED WHEAT AND OAT CELLULOSE PREPARATIONS IN BINDING WATER IN FINELY COMMINUTED MODEL MEAT PRODUCTS

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A b s t r a c t. The effect of the substitution of pork fat with wheat or oat cellulose preparations and the application of these preparations as a functional additive in finely comminuted meat products was studied. Chemical composition of the preserved meat bloc was examined, water binding and sensory profile of texture was characterized, and sensory desirability of the products was evaluated. As a result of the conducted studies it was found that the applied wheat and oat cellulose preparations as a substitute for 20 and 30% of the standard fat content allow the obtaining of products which are not worse than the control product in respect of their quality. Fat substitution on the level of 40% caused the lowest evaluation of the consistency desirability and of the general desirability. As a result of the application of cellulose preparations as a functional additive, the products with the sensory quality similar to that of the control product were obtained. Ca. 1.5% addition of the cellulose preparations to the model product did not deteriorate its sensory characteristics, with the simultaneous introduction of health-promoting dietary fibre to the meat product, as being so desirable in the diet for a correct functioning of human alimentary tract.

K e y w o r d s: cellulose preparations, fat substitution, functional additive, meat products

INTRODUCTION

Water binding in meat products, one of the most important meat properties, has been the subject of many studies for many years [5,6,24]. Water holding, that is water binding capacity of the purely meat system, is dependent on such factors as pH, presence and concentration of salts, temperature and time duration since the slaughter moment etc. [4,5,24]. In finely comminuted meat batters, as obtained during the chopping process, water absorption, gel-forming and emulsification have an influence on the stability and texture of a final product. In the meat–fat batters, the interactions occur between the components; from the technological point of view, the protein –

water interactions belong to the most important ones [24]. Gel-forming ability is the most important technological property of meat proteins, especially of the contracting proteins of shrinking apparatus of actin and myosin. Owing to gel-formation, the desired texture of finely comminuted steamed meat products is generated. This phenomenon consists in the creation of an arranged, spatial structure of protein particles together with the solvent and dissolved substances [22].

In recent years, more and more studies have been oriented on the enrichment of foods in health-promoting components, including probiotics. This group includes cellulose, being also called dietary fibre, the role of which in human alimentary tract cannot be overestimated. Therefore, attempts have been undertaken to introduce cellulose to meat products, in which it does not appear in a natural state.

The preparations of wheat and oat cellulose of recent generation, with the shortest length and the smallest thickness of fibres, are characterised by a neutral flavour (taste and smell) and high water binding capacity. Owing to its chemical structure, cellulose may absorb water in its capillary system and distribute it throughout the whole volume of the product via the generated three-dimensional network. The network of fibres as formed from cellulose is situated in the matrix of finely comminuted batter. Apart from the undoubted functional properties, the cellulose preparations play also many health-promoting functions, which have an importance for the aware consumer [1].

THE AIM OF THE WORK

The aim of the work presented was to examine the possibilities of employing selected cellulose preparations in meat processing in two aspects: substitution of formulation fat and introduction as a functional additive to finely comminuted model product, and its enrichment with health-promoting product.

MATERIAL

The studies on the selected cellulose preparations were conducted on a finely comminuted, preserved meat model product. The evaluation of the application of the chosen cellulose preparations as fat substitutes was carried out by the substitution of 20, 30 or 40% of formulation fat. The functional role of the cellulose preparations in the system of finely comminuted meat product was studied when introducing them as a functional additive in the quantity of 1.43% in relation to the batter weight, and enriching the product in health-promoting substance.

Two cellulose preparations of recent generation were chosen: wheat (WF 600-30) and oat (HF 600-30). The basic physico-chemical characteristics of the preparations, as declared by the producer, are presented in Table 1. After introducing to the batter, the preparations were hydrated, maintaining the ratio of preparation and water at 1: 3.5. The control sample as fat raw material contained exclusively formulated fine pork fat (variant K). Presentation of the formulation raw materials and labelling of experimental variants is given in Table 2.

Table 1. Characteristics of dietary fibre preparations

Specification	Wheat fibre VITACEL WF 600-30	Oat fibre VITACEL HF 600-30
Water content (%)	–	< 8,0 *
Dietary fibre content (%)	97 *	> 96,0 *
Total protein content (%)	0,4 *	0,4 *
Fat content (%)	0,2 *	0,25 *
Ash content (%)	< 3,0 *	< 2,6 *
pH 10% solution	6,0 +/– 1*	6,0 +/– 1*
Physical traits	White powder, odourless	Cream-yellow powder
Water binding ability (g H_2Og^{-1})	3,5*	5,1*
Fat binding ability (g $oilg^{-1}$)	2*	–
Nutrition declaration	Wheat fibre*	Oat fibre*
Producer	Rettenmaier, Germany*	Rettenmaier, Germany*

– non-manufacturer's declaration, * manufacturer's declaration.

Table 2. Formulation of experimental variants

Raw materials (%)	Codes of variants				
	K	W-20 / O-20	W-30 / O-30	W-40 / O-40	Wa / Oa
Pork class III	21.4	21.4	21.4	21.4	21.4
Beef class II	28.6	28.6	28.6	28.6	28.6
Fine cut pork fat	21.4	17.1	15.0	12.8	21.4
Water	28.6	31.9	33.6	35.3	28.6
Preparation	–	0.9	1.4	1.9	1.4
Total	100.0	100.0	100.0	100.0	101.4
Ingredients	curing mixture (99.4% NaCl and 0.6% $NaNO_2$) – 1.8%, sodium ascorbate – 0.05% and sodium glutamate – 0.10% in relation to the weight of final product.				

K – control variant, W/O – variants containing wheat (W) or oat(O) dietary fibre as substitute, Wa/Oa – variants containing wheat (Wa) or oat (Oa) dietary fibre as functional additives, 20, 30, 40 – fat substitution level (%).

Finely comminuted model product was manufactured according to the production technology of sausage, employed in the meat industry. The duration of the chopping process was about 10 minutes. The final temperature of the batter, obtained in the process, did not exceed 12^oC. The batter was prepared in a Seydelmann, type 40 Ras, grinder with 6 knives and a capacity of 0.04 m^3. The technical parameters of the grinder were as follows: rotations of the grinder vessel – 30 min^{-1}, rotations of the knife shaft – 3600 min^{-1}, standard knives, EE type, with a slide coefficient $\lambda = 1.5$. However, instead of stuffing the casings with batter, tins of 400 g volume were filled and pasteurised in water at a temperature of 75^oC till the temperature of 72^oC in the centre of the bloc was reached. Then, the preserved meat products were cooled down with cold water and stored in a refrigerating room at a temperature of 4-6^oC till the moment of collecting the samples for tests.

METHODS

In the final product, the degree of the product binding was examined through the determination of the following parameters: the level of thermal loss, by the weight method [8], and the slice strength, using the Zwick apparatus model 1445 MOPS [23].

In the bloc of the preserved meat product, after the removal of fat and jelly, the chemical analysis of the basic composition was carried out and the following determinations were made: water content, by dryer method according to PN ISO 1442-2000; total protein content by Kjeldahl method, using Kjeltec Analyser 1026 according to PN-75/A-04018, fat content by Soxhlet method, using Soxtec Fat Analyser HT-6 according to PN ISO 1444:2000; sodium chloride content according to PN ISO 1841-1:2002; based on the basic composition balance, the energetic value of the product as expressed in kJ $(100g)^{-1}$ was calculated.

To determine the sensory characteristics of the texture, the method of profiling (PN ISO 11035:1994, PN ISO 41219:1998) was employed. The texture was characterised using selected parameters, such as hardness, product wetness and fatness. The intensity of the parameters was marked on a graphic scale with the appropriate extremes:

- hardness: soft (low level) → hard (high level)
- wetness: dry (lack of humidity) → wet (high level)
- fatness: little fat (low level) → fat (high level)

Also, desirability of consistency (texture) and overall consistency of the product (overall hedonic rating) was evaluated in hedonic categories. The evaluation was conducted by an 8-person team of trained judges at the Sensory Lab of the Meat and Fats Research Institute, using the computerised system ANALSENS. The laboratory meets the requirements of ISO 8589:1998.

Two experimental series were performed for all variants. Chemical determinations, evaluation of the texture and desirability profile, were conducted in two repetitions in each of the experiments, and the remaining determinations are the means from 5 (thermal drip) or 10 (tearing of the slices) unitary tests in each of the experiments. The results obtained were subjected to variance analysis and regression analysis, using the Statgraphics statistical program for Windows v. 3.1.

RESULTS AND DISCUSSION

The significant role of fat in creating the texture of meat products and their palatability and juiciness has been well known [2]. However, the reduction of fat content in the products by substitution with water increases the thermal drip during heat treatment [3,7] causes a lowering of the slice resistance to tearing, and a deterioration of the rheological characteristics [12,13] and a decline of yield and shortening of the shelf-life of the product. The organoleptic evaluations of such products reveal generally a low degree of sensory approval and are lowering together with the rise of the degree of fat substitution, as compared to the whole fat products, mainly due to deteriorated consistency [12].

Effect of the application of cellulose preparations as substitutes for the formulation fat

The mean results of water, fat, protein and NaCl content determinations, and of the calculated energetic value of the examined experimental variants, are given in Table 3. As the formulation fat (20, 30 and 40%) was replaced with increasing quantities of cellulose preparations, a significant linear increase in relation to the control preserved meat product without cellulose took place: that of the determined water content – from 63.9% in the control product to 66.0-67.0% in the products containing the highest participation of the cellulose preparations.

As a result of pork fat replacement with wheat or oat cellulose preparation, the analytically determined fat content was lowered, according to expectations, from 23.7% in the control product to 18.3-19.4% in the products containing the cellulose preparation.

At the same time, a decrease of NaCl content in the model product was observed, from 1.45% for the control variant to the level of 1.35-1.31% for the samples with 40% fat substitution. Fat substitution did not have any significant effect on the total protein content.

For the samples with the addition of wheat cellulose preparation, an increase in the total protein content was found: from the level of 10.3% to 10.5% and for the samples with the addition of oat cellulose, the rise of the protein content was somewhat higher and amounted to 10.8%.

Table 3. Chemical composition and mean values of thermal loss and slice strength of model meat products

Variants	Water content (%)		Protein content (%)		Fat content (%)		Sodium chloride content (%)		Calorie content (kJ (100g) $^{-1}$)		Thermal loss (%)		Slice strength (N m^{-2})	
Stat. meas.	$\overline{X}$	s.d	$\overline{X}$	s.d	$\overline{X}$	s.d	$\overline{X}$	s.d	$\overline{X}$	s.d	$\overline{X}$	s.d	$\overline{X}$	s.d
K	63.9	0.6	10.3	0.2	23.7	0.7	1.45	0.02	1247	35	3.84	0.82	3.08	0.30
P-20	64.4	0.5	10.2	0.1	22.2	0.4	1.39	0.02	1178	13	4.99	1.49	3.07	0.00
P-30	66.7	0.9	10.5	0.1	19.5	1.2	1.39	0.00	1078	49	6.91	0.59	3.07	0.21
P-40	67.0	0.6	10.5	0.1	18.3	0.6	1.35	0.07	1026	27	9.57	2.85	2.61	0.64
O-20	65.0	1.2	10.8	0.1	20.9	1.8	1.36	0.01	1158	62	6.50	1.12	3.23	0.01
O-30	65.5	1.3	10.6	0.1	20.2	1.5	1.33	0.01	1105	63	8.83	1.82	3.23	0.01
O-40	66.0	0.8	10.8	0.2	19.4	0.6	1.31	0.01	1079	28	10.64	2.63	3.34	0.27
Pd	62.8	0.1	10.1	0.1	23.4	0.4	1.46	0.03	1233	17	3.43	0.08	3.33	0.68
Od	62.0	0.4	10.1	0.2	23.8	0.2	1.43	0.02	1255	112	4.05	0.14	3.64	0.07

The calculated energetic value of the product for the control sample was equal to 1247 kJ (100g)$^{-1}$. The substitution of the formulation fat with the hydrated cellulose preparations caused a linear lowering of energetic value of the model products as compared to the control sample. With 40% substitution of fat, the energetic value was lowered by 14% for the samples with the participation of oat cellulose, and by 18% for the samples with the participation of wheat cellulose.

Increasing fat substitution with the cellulose preparations caused unfavourable changes in binding of the product bloc. A significant increase of the thermal leakage from the level of 3.84% for the control variant to 9.57% and 10.64% for the variants with 40 % fat substitution was found. The above mentioned data indicate that the employed cellulose preparations with lowering fat content and rising water content in the product and with the relatively low level of the total protein (10.3%) were not able to stabilise sufficiently enough the protein-fat-water system, which caused the drip from the product. However, only the samples with the addition of wheat cellulose were accompanied by the expected lowering of the resistance of slides to tearing: from 3.07 N m^{-2} to 2.61 N m^{-2}. It is consistent with the earlier studies on fat substitution [9-11,13]. On the other hand, in the samples with the oat cellulose, in spite of the increased thermal drip, an increase in the resistance of the slices to tearing was observed, up to the value of 3.64 N m^{-2}. This observation may be explained by the fact that in the case of somewhat higher thermal leakage from the samples containing oat cellulose, the content of total protein was higher by 0.3% and water content was lower by 1.0% in relation to the variant with wheat cellulose.

The results of the evaluation of the chosen parameters of sensory profile of texture and sensory desirability of the model products are presented in Table 4. The increasing fat substitution in the model product and the related changes in the basic composition and the bloc binding, as described above, have caused the decrease of sensory hardness and fatness sensation as well as consistency desirability and total desirability of the product. It seems interesting that the humidity sensation appeared at 20 % fat substitution and then it was observed to decline together with the rise of the substitution level; it is an evidence of shaping the desirable sensory properties of the model meat product by the cellulose preparations under evaluation.

Table 4. Mean values of sensory texture discriminants and overall hedonic rating of model meat products

Variants	Hardness (c.u.)		Wetness (c.u.)		Fatness (c.u.)		Consistency desirability (c.u.)		Overall hedonic rating (c.u.)	
Statistical measure	$\overline{x}$	s.d.	$\overline{x}$	s.d	$\overline{x}$	s.d	$\overline{x}$	s.d	$\overline{x}$	s.d
K	4.56	0.22	4.85	0.14	3.78	0.40	5.23	0.09	5.58	0.17
P-20	4.66	0.35	5.22	0.54	3.26	0.34	5.23	0.37	5.68	0.16
P-30	4.67	0.47	4.39	0.60	3.13	0.13	5.37	0.31	5.48	0.27
P-40	3.54	0.41	4.35	0.18	3.16	0.55	4.59	0.39	4.67	0.37
O-20	5.07	0.44	5.33	0.78	3.32	0.33	5.24	0.56	5.37	0.62
O-30	4.50	0.28	5.01	0.87	3.62	0.46	5.08	0.22	5.18	0.44
O-40	4.43	0.46	4.39	0.39	3.52	0.24	4.74	0.12	5.06	0.22
Pd	4.36	0.30	4.91	0.95	3.22	0.19	5.27	0.14	5.25	0.33
Od	4.32	0.63	4.85	0.65	3.61	0.51	5.37	0.32	5.48	0.26

The results of two-factor variance analysis of the evaluation of the effect of the level of formulation fat substitution (0, 20, 30 and 40%) and the type of the cellulose preparation employed (wheat, oats) on the examined parameters of the model product are given in Table 5. An at least significant effect of the increasing fat substitution with cellulose preparation on the rise of water content in the product, a lowering of fat and NaCl content, and a decrease of energetic value of the product was found. Fat substitution did not have any significant effect on the total protein content. From the bloc binding-decisive factors, only thermal drip was significantly increasing together with the rise of the degree of fat substitution. As the examined preparations revealed opposite directions of changes in respect of resistance to tearing (wheat preparation – lowering, oats preparation – increase), no definable effect on this parameter was found. Together with the rise of the degree of fat substitution, the texture desirability was significantly decreasing. On the other hand, the humidity sensation, after the initial rise at 20% substitution, was later significantly decreasing together with further rise of the level of fat substitution. No definable effect of fat substitution on the changes of the hardness parameter and of a general desirability of the product was found.

As a result of analysis of the effect of the type of cellulose preparation (wheat or oat) on the studied physico-chemical and sensory parameters (Tab. 1), it was found that both of the parameters examined had a similar effect in finely comminuted meat product and the observed differences in the evaluated parameters were not statistically significant.

Characteristics of sensory parameters, as given in Table 5, are an evidence that the sensory quality of the products subjected to fat substitution with the studied cellulose preparations, even at 40% fat replacement, was found on the level of the control sample quality (whole-fat sample). When comparing the obtained results with the results of earlier studies in this respect [12], it may be stated that the application of cellulose in substitution of formulation fat is more favourable in respect of sensory quality as compared to the earlier used protein-polysaccharide systems. On the other hand, the drawback of the use of cellulose preparations alone in fat substitution was a significant increase of thermal drip from the product, which was earlier confirmed by the studies of [3] and [7].

Effect of application of cellulose preparations as functional additives

The functional role of wheat and oat cellulose preparations in the system of finely comminuted meat product was examined, introducing the preparations mentioned as a functional additive in the quantity of 1.43% in relation to the batter weight, enriching the product with the health-promoting substance.

The results of one-way ANOVA analysis of the physico-chemical and sensory parameters of the model products studied: without preparation (variant K) and with the addition of wheat (variant Wa) and oats (variant Oa) cellulose preparation, are given in Table 6. A significant effect of the cellulose preparations on the parameters evaluated was found only in the case of water content in the product. The highest mean water content in the product (63.9%) was found in the samples of the control variant (K) and the lowest one (62.0%) – in the samples with the addition of oat cellulose (Oa). For the remaining parameters under study, no statistically significant differentiation between the variants was found. It results from the above fact that ca. 1.5% addition of cellulose preparations did not change significantly, except for water content, the physico-chemical characteristics and, what is most important – it did not deteriorate the sensory

Table 5. Multifactor ANOVA table

Factor	Value	Water (%)	Fat (%)	Total protein (%)	NaCl (%)	Thermal loss (%)	Slice strength (Nm^{-2})	Calorific Value (kJ(100g)$^{-1}$)	Hardness (c.u.)	Wetness (c.u.)	Fatness (c.u.)	Consistency desirability (c.u.)	Overall hedonic rating (c.u.)
Variant	0	63.9^{a}	23.7^{c}	10.3	1.45^{c}	3.84^{a}	3.08	1247^{c}	4.56	3.78	4.85^{ab}	5.23^{b}	5.58
	20	65.2^{b}	21.0^{b}	10.5	1.39^{b}	5.74^{b}	3.14	1134^{b}	4.86	3.24	5.28^{b}	5.24^{b}	5.52
	30	66.1^{bc}	19.8^{ab}	10.6	1.36^{ab}	7.87^{c}	3.17	1090^{ab}	4.18	3.38	4.70^{ab}	5.22^{b}	5.30
	40	66.5^{c}	18.8^{a}	10.7	1.33^{a}	10.10^{d}	3.12	1056^{a}	3.98	3.34	4.37^{a}	4.66^{a}	4.86
	LSD	1.24	1.4	0.6	0.05	1.86	1.02	54	1.06	0.59	0.62	0.42	0.74
Fibre prepa-ration	Wheat	65.8	20.6	10.4	1.40	6.33	2.94	1120	4.36	3.33	4.70	5.10	5.35
	Oat	65.1	21.0	10.6	1.37	7.45	3.32	1144	4.64	3.54	4.90	5.07	5.30
	LSD	0.9	1.0	0.4	0.04	1.32	0.72	39	0.75	0.42	0.46	0.29	0.52

Means in the same column with different superscript are significantly different ($P \leq 0.05$).

Table 6. One-way ANOVA table

Variant	Water (%)	Fat (%)	Total protein (%)	NaCl (%)	Thermal loss (%)	Slice strength (N m^{-2})	Calorific value (kJ(100g)$^{-1}$)	Hardness (c.u.)	Wetness (c.u.)	Fatness (c.u.)	Consistency desirability (c.u.)	Overall hedonic rating (c.u.)
K	63.9^{c}	23.7	10.3	1.45	3.84	3.08	1247	4.54	3.78	4.85	5.23	5.58
Wa	62.8^{b}	23.4	10.1	1.46	3.43	3.33	1232	4.36	3.22	4.91	5.27	5.25
Oa	62.0^{a}	23.8	10.1	1.43	4.05	3.64	1257	4.32	3.61	4.85	5.37	5.48
LSD	0.8	0.9	0.3	0.05	0.63	0.70	44	0.77	0.72	1.23	0.38	0.48

Means in the same column with different superscript are significantly different ($P \leq 0,05$), K – control variant without fat substitution, Wa – variant containing wheat dietary fibre as additive, Oa - variant containing oats dietary fibre as additive.

characteristic of the model product, with the simultaneous introduction of cellulose (dietetic fibre) to the meat product; this substance being a health-promoting component so much desirable for correct functioning of the human alimentary tract.

The conducted multi-factor regression analysis showed that water content in the product (W) was dependent on the fat (F) and total protein (P) content and, to a smaller degree, on the level of thermal leakage (TL). The equation representing the discussed relationship is as follows:

$$W = 89.44 - 0.705F - 0.837P - 0.076TL \qquad (r = 0.987) \qquad (1)$$

Similarly, it was revealed that the total desirability of the product (OHR) was dependent on water (W), fat (F), total protein (P) and NaCl content in the product and on the level of thermal leakage (TL), and the equation describing the discussed relationship is as follows:

$$OHR = 0.306W + 0.245F + 0.188P - 0.334TL - 14.119NaCl \quad (r = 0.999) \quad (2)$$

It may be concluded from the studies presented above that, while maintaining the favourable effect of the cellulose products on the sensory properties of meat products under the substitution, further work should be done, aiming at efficient and significant limitation of the size of thermal leakage from the product, thus improving the yield of the product.

CONCLUSIONS

1. The wheat and oat cellulose preparations employed to substitute 20 and 30% of fat composition allow the obtaining of products with the resistance of slices and sensory characteristics of the texture profile and desirability not worse than those of the control product.
2. Increasing fat substitution caused a significant rise of water content and an increase of thermal leakage and, on the other hand, a significant decrease of fat and NaCl content and, in consequence, of the calculated energetic value of the product
3. On the other hand, the application of the cellulose preparations alone as fat substitutes is a drawback, causing a significant increase of thermal leakage from the product.
4. As a result of the application of cellulose preparations as a functional additive, products with the sensory quality similar to that of the control products have been obtained.
5. Ca 1.5% addition of the cellulose preparations did not deteriorate the sensory characteristics of the model product, with the simultaneous introduction of health-

promoting (dietary fibre) component to the meat product, being so much desirable in a diet for the correct functioning of human alimentary tract.

6. To maintain the favourable effect of cellulose preparations on the sensory properties of the substituted meat preparations, it is necessary to limit the size of thermal leakage from the product in an effective and significant way in the future, improving the yield of the product.

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ROLA WYBRANYCH PREPARATÓW BŁONNIKA PSZENNEGO I OWSIANEGO W WIĄZANIU WODY W MODELOWYCH DROBNO ROZDROBNIONYCH PRZETWORACH MIĘSNYCH

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S t r e s z c z e n i e. Badano wpływ substytucji tłuszczu wieprzowego preparatami błonnika pszennego lub owsianego oraz zastosowanie tych preparatów jako dodatku funkcjonalnego do drobno rozdrobnionego produktu mięsnego. Badano skład chemiczny bloku konserwy, charakteryzowano związanie wody, sensoryczny profil tekstury oraz oceniano pożądalność sensoryczną wyrobów. W wyniku przeprowadzonych badań stwierdzono, że zastosowane preparaty błonnika pszennego i owsianego w miejsce wymiany 20 i 30% tłuszczu pozwalają na uzyskanie przetworów nie ustępującym jakościowo produktowi kontrolnemu. Substytucja tłuszczu na poziomie 40% spowodowała najniższą ocenę pożądalności konsystencji i pożądalności ogólnej. W wyniku zastosowania preparatów błonnikowych jako dodatku funkcjonalnego uzyskano produkty o jakości sensorycznej zbliżonej do produktu kontrolnego. Około 1,5% dodatek preparatów błonnika do produktu modelowego nie pogarszał jego charakterystyki sensorycznej, przy jednoczesnym wprowadzeniu do produktu mięsnego pro zdrowotnego włókna dietetycznego tak pożądanego w diecie dla prawidłowego funkcjonowania układu pokarmowego człowieka.

S ł o w a k l u c z o w e: preparaty błonnika, substytucja tłuszczu, dodatek funkcjonalny, produkt mięsny