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Use of flaxseeds in the flour confectionery

[1*]Alexeev, G.V., [1]Krasilnikov, V. N., [1]Kireeva, M. S. snd [2]Egoshina, E.V.

[1]ITMO University, Department of Food Technologies and Engineering, Lomonosov St., 9, 191002, St. Petersburg, Russia
[2]ITMO University, Department of Innovation Marketing and Project Management, Birzhevaya st., 14, 199034, St.Petersburg, Russia

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Abstract

The article proposes expansion of the range of flour confectionery products using flaxseeds. The biochemical properties and composition of four different varieties of flaxseeds have been thoroughly studied and described. The rheological characteristics of different kinds of dough prepared from full-fat flax flour without yeast have been compared. The influence of a polysaccharide complex of flaxseeds on textural properties of products has been also assayed. The results of this research can be used for the development of recipes of sponge cake semifinished products for specialized and normal nutrition prepared from a full-fat flax flour as well as development of technological documentation for prepared flour confectionery.

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Introduction

Production of dietary foodstuff using vegetable raw material is one of the main objectives in the field of the healthy food formulated in the 80th years of the last century. Nowadays, it has become characteristic to create the food products for normal and specialized nutrition on the basis of raw material obtained from various cultivated and wild-growing forms of plants. Combinations of the numerous physiologically active agents in grain, fruits, vegetables and vegetative mass of plants, and their probable synergism with the main nutrients (which is still not deeply studied) provide adequate level of human requirements for these substances.

One of the most ancient economically important crops of many regions of Europe is flax. The pounded flax seed was widely used in medieval cookery in Russia as a food additive. Nowadays, flax seeds are considered to be an important functional ingredient being a source of alpha-linoleic acid, a high quality protein, phenolic compounds, food fiber and mineral substances (Gänzle, 2009). Nevertheless, technological properties of the main nutrients of flax seeds and their influence on consumer characteristics of flour products are studied insufficiently. In particular, flax seeds contain non-starch polysaccharides with high water connecting capacity that may be perspective for forming of textural properties of bakery and flour confectionery. The purpose of this work is to study the influence of biochemical properties of flax seeds on technological procedures of preparation and quality of finished flour confectionery.

Materials and Methods

Plant materials

The following sorts of flax seeds have been studied: flaxseeds of Russian sorts of oil grade "Snow White", "LM 98", "LM 97" and the Canadian sort "Norlin" of the harvest of 2000-2011. Samples of flax seeds are received from a collection of Russian Academy of Agrarian Sciences of Scientific Research Institute of flax in Torzhok city. The fatty-acid composition of flax seeds, considered as one of the most important characteristics, served as the criterion for samples selection. Another research objects were sponge-cake dough and baked sponge cake prepared on the basis of crushed flax seeds. A sponge-cake dough and baked sponge-cake of wheat flour, prepared according to the traditional recipe, were used as a control sample. Sample selection and preparation were performed according to the State

*Corresponding author.
Email: *gen.val.alexeev@yandex.ru*

standard GOST 5904-82. Composition of fats flax seeds lipids was determined by gas–liquid partition chromatography (GLPC) in accordance with GOST P 51483-99 and GOST P 51482-99.

Assessment of biochemical and rheological properties

Composition of proteins of flax seeds was determined by polyacrylamide gel electrophoresis (PAGE) by the Laemmli method (Laemmli, 1970). Water-soluble non-starch polysaccharides were extracted from flax seeds by the method of Hashimoto, Shogren, Pomeranz (Hashimoto *et al.*, 1986).

Hydrolysis of polysaccharides was carried out by the method proposed by Emaga, Rabetafika, Blecker and Paquot (Emaga *et al*.,2012) during 4 hours under the temperature 100°C with 2 M HCI solution.

Molecular weight distribution of water-soluble fraction of samples was carried out on Sephadex G15. Mobile phase was 0.3% water solution of ammonium sulfate.

Gas–liquid partition chromatography (GLPC) of monosaccharides was carried out by the method reported by M.I. Tsarev, V.I. Tsarev, I.B. Kartakov (Tsarev *et al*., 2000).

Dynamic viscosity of dough was determined on rotary viscometer "Reotest-2". Measurements were carried out at the room temperature (+20° C). Humidity of dough was determined by the method of acceleration.

Texture analyzer "Strukturometr ST-2" was used for determination of structural and mechanical properties of a product under loading. Deformation characteristics of a crumb of sponge-cakes produced with a full-fat flour of all 4 sorts of flax seeds and of a control flour sample were determined.

Organoleptic assessment was carried out using a profile method according to a developed system of characteristics which include: surface, view of the cut, taste, color, porosity. The nutritional value of sponge cakes was calculated according to the nutrient content tables. All the analyses were repeated three times.

Mathematical data processing was carried out using a software package EXCEL for Microsoft Office and the CurveExpert Ver 1.34.

Results and Discussions

Biochemical properties of flaxseeds of different sorts. Protein complex

All studied sorts of flaxseeds are close in structure and the ratio of the main protein components - 11 s and 7 s globulins. Some distinctions can be observed in minor components of albumin fraction as it is shown in Figure 1. The sorts LM 98 and the Snow White are identical in minor components which represent albumin fraction. The sort Norlin differs from them by the availability of polypeptides 1 and 2 in albumin fraction, and absence of the component 5. The sort LM 97 differs from the first two by weak manifestation of a component 4 in albumin fraction and stronger manifestation of a component 3.

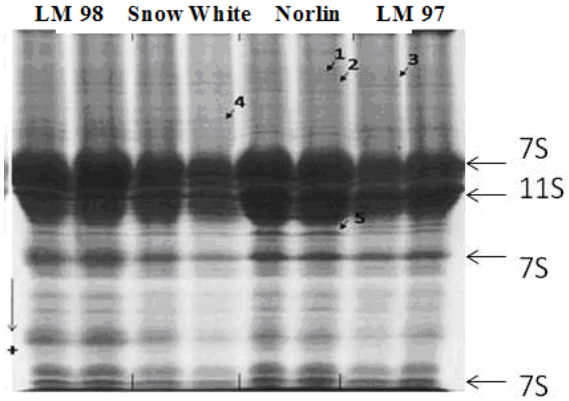

Figure 1. Protein electrophoresis of four sorts of flaxseeds

Possibility of using of a method of cryoprecipitation for obtaining protein isolates of flax was assayed. The method is based on a capability of storage proteins of plants to precipitate from a solution of a low ionic strength at low positive temperatures. Fractionation of reserve proteins under low temperatures (cryoprecipitation) allows getting separate fractions of globulins in a decently clean form. Taking into consideration the difference in physical and chemical parameters of 7 s and 11 s globulins of the seeds, it is possible to assume, that this method is of a certain interest for getting technologically functional protein ingredients and can have a prospective application for isolation of flax proteins.

Lipid complex

Lipid complex of the studied samples of seeds has been characterized based on total fatty acid composition (Table 1). The lipids of LM 98 seeds have a high content of linolenic acid (67,3%), lipid complexes of seeds LM 97, Snow White, and Norlin are characterized by high content of linoleic acid (60,1%, 53,7% and 61,5%, respectively) as well. The optimal ratio of omega-3 and omega-6 fatty acid complex (ω-6/ω-3) recommended by Institute of Nutrition of RAMS (the Russian Academy of Medical Science) in a diet of a healthy person should be (5-10):1 and in the preventive nutrition - (3-5):1 (Ipatova *et al*., 2009). None of four studied flaxseed oils correspond to the optimal ratio of omega-3 and omega-6 fatty acid complex ω-6/ω-3. Oil obtained from seeds Snow White, LM 97 and Norlin have

Table 1. Fatty acid composition of lipids of the studied sorts of flaxseeds

Fatty acids	Designation	Content of fatty acids in oil of seeds, % relative			
		LM 98 2009	Snow White 2002	Norlin 2011	LM 97 2000
Content of lipids	%	41,0	35,9	40,9	35,5
Palmitic	C 16:0	6,3	4,5	5,0	4,0
Hexadecanoic	C 16:1	0,1	0,1	0,1	Traces
Stearin	C 18:0	5,0	4,0	3,2	2,5
Olein	C 18:1	18,1	12,7	24,4	16,0
Linoleic	C 18:2	67,3	16,7	13,0	16,7
Linolenic	C 18:3	2,7	61,5	53,7	60,1
Arachidic	C 20:0	0,1	0,1	0,1	0,1
Eicosenoic	C 20:1	0,1	0,2	0,3	0,4
Behenic	C 22:0	0,2	0,1	0,1	0,1
ω-6:ω-3	-	25:1	0,28:1	0,25:1	0,27:1

similar ratio ω-6/ω-3 (0,25:1-0,28:1). Oil from flax seeds LM 98 differs significantly from the previous three having the ratio ω-6/ω-3 of (25:1). In order to get the lipid complex with the recommended optimal ratio of polyunsaturated fatty acids ω-6/ω-3 in the products developed from these flaxseeds, it is recommended to use blending of lipids from the seeds LM 98 with lipids from the seeds Snow White, LM 97, and Norlin.

Polysaccharide complex

The extracted carbohydrates are mainly presented by high-molecular polysaccharides with a molecular mass of more than 1000 Da (from 50 to 65%). The total fraction of carbohydrates with a molecular mass up to 500 Da constitutes 16-26% and is apparently presented by di - and trisaccharides. The pick-up fraction of carbohydrates (molecular mass 500-900 Da) is partially composed by some compounds of glycoside type such as flavones, anthocyanidins, etc., and some saccharides such as tetrasaccharides. The mass fraction of this pick-up fraction accounts for 19-23% in the studied seed samples. Nevertheless, it is known that the molecular mass of polysaccharides varies in case of association- dissociation reactions, which occur with different rate depending on temperature, ionic strength, pH of solution, and the duration of extraction. In the course of extraction polysaccharides are often hydrolyzed by own enzymatic system of seeds.

Distinctions in content of non-starched polysaccharides of individual monosaccharides are determined by a genotype of seeds. So, the seeds of Canadian sort Norlin, the lipids of which are rich with oleic acid, are characterized by low total content of monosaccharides, and approximately equal 1:1 ratio of polysaccharides of the amount of hexoses and pentoses.

On the contrary, the polysaccharides of seeds of other three sorts are characterized by high total content of monosaccharides and increased ratios of hexoses to pentoses (3:1 and more). It cannot be excluded that gels of these flaxseeds contain some amount of glucans considering the increased content of glucose. Water soluble gels are composed by two fractions of polysaccharides, neutral and acidic. Important to note a high content of neutral fraction of polysaccharides in the gel of seed of sort Norlin. For the gels of other three sorts it is characteristic the increased content of polysaccharides of acidic fraction (Snow White and LM 97), or approximately identical ratios of these two fractions (LM 98).

The chemical structure of polysaccharides can be presented by linear or branched forms. In case of non-starched polysaccharides the extent of branching can be estimated from the ratio of arabinose-to-xylose, and galactose-to- or fucose-to-rhamnose. Linear polymers should have limited ability, in contrast to the branched polymers, to form different associates needed for gel production. The above ratios are presented in the Table 2. The main skeletal polysaccharide of neutral fraction is arabinoxylan, and of the acidic fraction is rhamnogalactouronan. It is possible to estimate the extent of the branching of skeletal polysaccharides from the ratio of some lateral monoses to the monoses entering a chain of skeletal polysaccharides (Table 2). To the linear polysaccharides with rather small inclusion of lateral chains the polysaccharides of neutral fraction, extracted from Norlin seeds, are related. On the contrary, for the polysaccharides extracted from gels of other three seed varieties high extent of branching not only of the polioses of acidic fraction but also of the neutral is characteristic, which is proved by the increased ratios of some monoses to xylose and rhamnose.

Rheological properties of seed gels depend on the composition and chemical structure of

Table 2. Ratio of content of some monoses in polysaccharides of four seed gels

Ratios of monoses	Sort name			
	Norlin	LM 97	Snow White	LM 98
arabinose/ xylose	0,5	3,3	3,0	8,0
galactose / xylose	0,5	1,6	3,6	7,7
glucose / xylose	0,4	1,0	4,0	10,0
galactose / rhamnose	0,8	3,1	2,4	2,2
fucose/rhamnose	0,2	2,2	1,7	1,3
rhamnose/ xylose	0,6	0,5	1,6	3,5

polysaccharides (Cui *et al,*. 1996). According to some previously published data (Krasilnikov and Kireeva, 2011, Kireeva and Alekseev, 2014) the flax gels with increased content of neutral fraction, high content of xylose in polysaccharides, and a moderate ratio rhamnose-to-xylose in total polysaccharides have high viscous characteristics of dispersions. Based on our experimental data, the gels obtained from the studied seed varieties can be classified by their influence on viscosity of water dispersions as follows Norlin >Snow White >LM 97 >LM 98.

Rheological properties of dough

The developed recipe of a sponge cake prepared using full-fat flax flour is provided in the Table 3. From the provided data it is obvious that textural properties of products are created generally as a result of formation of polysaccharide complexes (of flax flour, starch, sucrose). Thus the effect of complexation is determined by initial emulsifying components of melange (polar lipids, egg albumine).

According to the colloidal chemistry, the basis for this technology is the process of formation of coagulation structures (gel) and their transition into condensation structures (colloidal solution) under humid thermal treatment. This process is determined by the chemical nature of natural polymers and modes of humid thermal treatment.

One of the features of preparation of sponge is the short duration of mixing of the beaten egg-and-sugar mass with the flour. Melange with granulated sugar is beaten to increase its volume by 2,5-3 times without heating. Before the end of beating, the flax flour mixed with potato starch are added, and mixed for no more than 15 seconds. Flour is added in 2-3 doses.

Flax sponge dough by its rheological properties is the non-Newtonian disperse system. Its flow curves are described by the equation of Ostvalda-DeVille: $\tau=a^{*}\gamma n$. Linear dependences in lg coordinates τ (viscosity) - lg γ (shift speed) for all samples of flax sponge are quite close which characterizes uniformity of formed gel structures. The flow index (n) for all samples of flax sponge are in the range of 1,0-0,83 which is characteristic for the disperse systems diluted under the shift. The coefficient of consistency (a) decreases in the following sequence: wheat dough >dough from flax seeds Snow White> dough from flax seeds Norlin > dough from flax seeds LM 97 > dough from flax seeds LM 98. It could be assumed that this dependence corresponds with high viscosity of dispersions of flaxseed gels with the increased content of xylose.

Rheological properties and preparation technology of sponge cakes using full-fat flax flour

It is suggested to bake the flax flour sponge cake in two phase temperature and moist mode. At the first stage (10-15 minutes), the temperature in the camera of combi-steamer is maintained at the level of 90 ^{0}C. Relative humidity of air remains at former level. The baked sponge cake is refrigerated during 20-30 minutes, then it is taken out from forms, and it remains at temperature of 15-20 ^{0}C during 8-10 hours.

Sponge cakes prepared using full-fat flax flour are comparable according to the physical and chemical characteristics with control samples of sponge cakes from wheat flour. Rheological profiles of sponges are provided in Figure 2. The studied samples could be classified by the decrease in general deformation as follows: sponge from seeds “LM 98” > sponge from seeds “LM 97”> sponge from seeds “Snow White” > sponge from seeds “Norlin”. The noted dependences correlate with content of xylose in flax polysaccharides as well as the ratio of arabinose-to-xylose. Based on the data presented it is possible to assume that this dependence is determined by the content of skeletal polysaccharide of neutral fraction, such as arabinoxylan, and extent of its branching. For gels of flax seeds “Norlin” it is characteristic the increased contents of linear forms of arabinoxylans with low extent of branching. For a polysaccharide complex of other three varieties of seeds high extent of branching of arabinoxylans and decrease in their content in total polysaccharides is characteristic.

When considering the change of plastic deformation of sponges it is necessary to take

Table 3. Sponge cake recipe prepared from full-fat flax flour

Raw materials	Content of solids, %	Raw materials used for 10 kg of finished goods, kg	
		Raw material	Dry weight
Flax flour	94,5	2,1	1,9
Potato starch	80	0,9	0,7
Sugar	99,8	2,9	2,9
Melange	26	4,8	1,3
Total	-	10,7	6,8
Output	63,7	10,0	6,3
Humidity		36 ±2,4%	

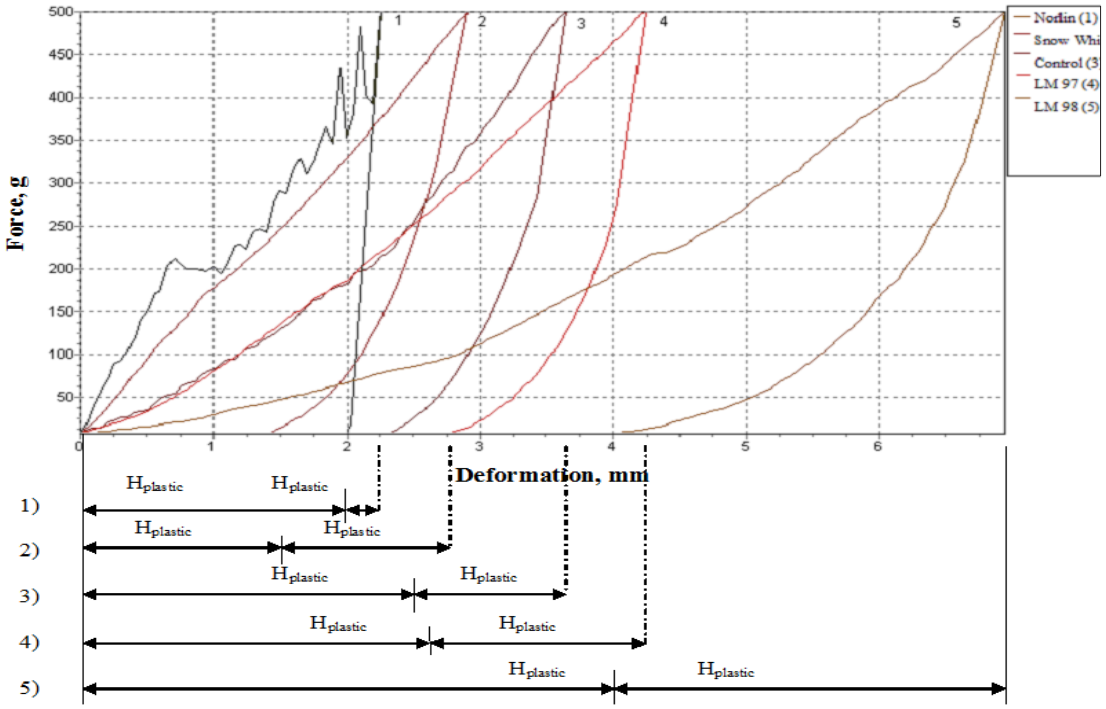

Figure 2. Rheological profile of sponges from the flax flour seeds "Norlin" (1), "Snow White" (2), wheat flour (control) (3), "LM 97" (4), and "LM 98" (5)

into account the molar-mass distributions of polysaccharides. Apparently, lower value of plastic deformation of sponges from seeds “Snow White” in comparison with sponges from seeds “Norlin” is caused by high content of polysaccharides with molecular mass more than 1000 Da in the latter. Elastic deformation of sponges correlates well not only with amount of branched arabinoxylans, characterized by the amount of pentoses, but also with extent of branching of rhamnogalactouronans which is proved by the ratios galactose-to-xylose, rhamnose-to-xylose, and glucose-to-xylose. Taking into account admissible acceptable values of the chosen descriptors, organoleptic profiles of sponges from flax flour are close to that of a control wheat sponge cake and are characteristic for this type of flour confectionery. From the point of view of sensory characteristics of products, it should be noted the original taste and smell of sponges from flax flour typical for fried almonds.

Nevertheless, for organoleptic properties of products the quality of initial flax seeds is of fundamental importance. In particular, the low numerical scores for the descriptors of smell and taste obtained for sponges from flax seeds with high content of polyunsaturated lipids (LM 97) is related to their oxidizing instability leading to formation of products of oxidation of linoleic and linolenic fatty acids characterized by bitter and rancid taste. Sponges from flax flour belong to category of specialized diet food. It does not contain prolamins, toxic in case of a gluten enteropathy. These products can be recommended for diets to compensate the deficit in polynonsaturated fatty acids and food fibers.

It is necessary to point out the varied chemical composition as well as colloidal and chemical

properties of food fibers (non-starch polysaccharides) of flax seeds of different varieties. The obtained data regarding their chemical composition allow assuming that non-starch polysaccharides of flaxseeds could be effective enterosorbents able to reduce serum cholesterol and cholesterol of lipoproteins of low density. They are also prebiotics stimulating the synthesis of the short-chain fatty acids in intestines. Food fibers content in 100 g of a sponge from full-fat flax flour provides 25-35% of recommended daily consumption (Buttriss, 2009).

Conclusions

Based on the assessed biochemical properties of different varieties of flax seeds, it is established that flaxseed can be considered as raw materials or as an effective food additive regulating a nutrition value, consistence, organoleptic properties, and storage term of flour confectionery for normal and specialized (dietary) nutrition. The carried research shows high variability of flaxseeds of different varieties by content and chemical composition of the main nutrients, especially lipids. The ratio ω-6/ω-3 fatty acids in lipids vary within the range of 0,25-25. The ratio of hexoses-to-pentoses varies from 1,1 to 5,1 in non-starch polysaccharides (food fibers) of studied flax seeds. This high biochemical variability of flax seeds could allow a combination of different varieties in order to obtain the required composition of nutrients.

It has been established that the storage globulins are uniform by their composition and the ratio of 11 s and 7 s-components in the studied samples of seeds. Some distinctions between the varieties of seeds are shown for minor components of proteins of albumin fraction. The high variability of soluble non-starch polysaccharides by the content of monoses (pentoses and hexoses) determines essential distinctions in rheological properties of dough and finished goods obtained using different varieties of flax seeds. It is shown that the viscosity of sponge prepared from full-fat flax flour increases in proportion to increase of xylose content in non-starch polysaccharides of studied flax seeds. It has been shown that general deformation of the sponges baked from flax flour, decreases in proportion to decrease in the arabinose-to-xylose ratio in non-starch polysaccharides. The elastic deformation of sponges decreases in proportion to decrease in the amount of pentoses in non-starch polysaccharides as well as in proportion to decrease of the ratios galactose-to-xylose, and glucose-to- xylose. It has been established that there is a direct proportionality between viscosity of dough and plastic deformation of the finished product. In the future research the analysis of micro-elements such as potassium, phosphorus, magnesium, manganesium, calcium, iron, zinc and copper should be conducted, as well as the estimation of the importance of the storage globulins for nutritional value or other properties of flaxseeds and finished products. The data about the impact on the nutritional value of food of these micro-elements may help finding new spheres of implementing the flax seeds for preventive and healthy nutrition. As a result of the current study, the technology of preparation of flax sponge cakes enriched with polyunsaturated fatty acids and food fibers for the specialized nutrition is developed.

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