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PERSPECTIVES OF LINSEED UTILISATION IN BAKING*

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The aim of the study was to show the nutritional and health benefits implied by consumption of bread and pastry supplemented with linseed meal. Bread with 10 and 13% share of linseeds was characterised by higher amounts of protein, fat, dietary fibre, macro- and microelements in comparison to standard one. In the experiments on rats, a spectacular hypocholesteric effect of such bread was observed. Linseed pastry obtained high quality scores, irrespective of the linseed cultivar. A 3% increase in linseed in the recipe for flax hermit cookies and a 5% rise in flax muffins resulted in an increase in the amounts of proteins, dietary fibre, micro- and macroelements.

INTRODUCTION

In the last years, a growing interest has been observed in linseed (*Linum utisatissimum*) as a possible component of the so-called "healthy food" [Ratnayake *et al.*, 1992; Chen *et al.*, 1994; Chadha *et al.*, 1995]. This is caused by its unique chemical composition – the seeds contain in their dry mass (90%) approximately 25% of easily digested (85–90%) protein, about 40% of fat consisting mainly of polyunsaturated fatty acids (PUFA), more than 4% of minerals and around 30% of dietary fibre rich in pectins, β-glucans, gums and mucilage, that can bind different chemicals, such as cholesterol and cholic acids in the small intestine, thus reducing their absorption [Ratnayake *et al.*, 1992; Cunnane *et al.*, 1995; Bierenbaum *et al.*, 1993; Gambuś *et al.*, 1999]. Hypocholesterolaemic effect of linseed consumption is also related to high amount of α-linolenic acid (18:3, 3*n*-3) (ALA), that comprises above 50% of total fatty acids. Linseed is commonly regarded as the richest source of this valuable fatty acid, which is a precursor in synthesis of eicosanpentaenic acid ($C_{20:5, n-3}$) – EPA and docozahexaenic acid ($C_{22:6, n-3}$) – DHA [Bartnikowska & Kulasek, 1994] which are essential for synthesis of prostaglandins, prostacyclins, tromboxans and leucotriens. They also regulate metabolism of triglycerides and cholesterol, showing high antycholesterolic activity and inhibit hydroxy-methylo-glutarylo-coenzyme A reductase (HMg-CoA) in liver, which is responsible for cholesterol synthesis. [Drevon, 1992; Horrobin, 1990].

Due to a highly beneficial effect of *n*-3 PUFA on human health, products which contain them can be regarded as the so-called "functional food" and may be widely used in preventive medicine as well as therapy of many maladies [Kolanowski & Świderski, 1977; Oomah, 2001]. Their share in everyday diet should be enlarged, which can be obtained by supplementation of traditional food products in those acids. This is especially valid for European countries, such as Poland, where there is usually no balance between *n*-6 and *n*-3 fatty acids in a daily diet. The ratio of *n*-6 to *n*-3 acids is 30:1 or more, while it should be close to 6:1 [Kolanowski & Świderski, 1997; Ziemlański, 1997; Bartnikowska & Kulasek, 1994]. The ordinary method of correcting this proportion is to take raw or encapsulated fish oil, but such medicaments are used only in the cases of illness or reconvalescence [Drevon, 1992]. Prophylactic attributes of *n*-3 PUFA should be however utilised in a larger scale and this can be only achieved if there is a broad spectrum of quality nutrients containing them. Today, most of such products is produced on the basis of raffinated fish oil [Goldberg, 1994; Lauritzen, 1994], however it seems that bread supplemented with oilseed meal could be successfully introduced on the market [Gambuś *et al.*, 1999a, b]. Both bread and pastry are commonly used nutriments and after supplementation they can become a good source of *n*-3 PUFA in the diet.

MATERIAL AND METHODS

Wheat bread, in which 10 and 13% of total flour (type 650) was replaced with milled brown linseed (Opal cultivar), was baked using straight method [Gambuś *et al.*, 1999a]. Flax hermit cookies and bran flax muffins were prepared from milled brown linseed Opal and yellow linseed Hungarian Gold according to recipes of Flax Council of Canada.

The share of linseed in original recipe for cookies was 8% and in one trial it was increased to 11% which was compensated by the reduction of margarine (Table 1). Flax hermit cookies used for baking tests contained yellow or

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TABLE 1. Recipes for flax hermit cookies.

Ingredients	Original (g)	Modified (g)
Margarine	125	100
Sugar	160	160
Cold coffee extract	60	60
Egg	70	70
All-purpose flour	270	270
Milled linseed	60*	85**
Baking soda	2.75	2.75
Salt	3.3	3.3
Cinnamon	1.7	1.7
Nutmeg	0.75	0.75
Raisins	60	60
Chopped nuts	70	70

*) 8% of total mass; **) 11% of total mass

brown linseed. In total, 4 different types of cookies were obtained, which are later assigned as "C".

The share of linseed in original recipe for bran flax muffins was 4% and oat bran constituted 5% of total mass. The trial was made in which oat bran was completely replaced with linseed (Table 2). Muffins used for baking tests contained either yellow or brown linseed, so 4 different types of cookies were obtained, which are later assigned as "M".

TABLE 2. Recipes for bran flax muffins.

Ingredients	Original (g)	Modified (g)
All-purpose flour	250	250
Milled linseed	63*	146***
Oat bran	83**	-
Sugar	250	250
Baking soda	12	12
Baking powder	4.2	4.2
Salt	3.3	3.3
Cinnamon	6.6	6.6
Finely shredded carrots	380	380
Peeled shredded apples	180	180
Chopped nuts	70	70
Raisins	85	85
Milk	170	170
Beaten eggs	70	70
Vanilla	2	2
Canola oil	17	17

*) 4% of total mass; **) 5% of total mass; ***) 9% of total mass

The sensory evaluation of pastry was done using a five-point scale by assessing shape, colour, surface, consistency, cleavage, smell, and taste.

Chemical analysis of bread, cookies and muffins included: total protein, dietary fibre and raw fat, according to AOAC [1995]. The fatty acid profile was determined by gas chromatography using a Varian 3400 CX GC with FID detector (argon; DB-23 column of 30 m × 0.53 mm in diameter; column and detector temperature was 100–205°C and 240°C, respectively). The content of selected macro- and microelements was established by means of ASA (PU 9100, Philips, with deuterium lamp for the background correction).

To check the shelf life of flax hermit cookies, they were stored in glass jars for 2 months, and during that period the changes in fat were monitored, *i.e*. acid number and amount of peroxides according to Krełowska-Kułas [1993].

To prove the hypocholesteric effect of bread supplemented with linseed meal the experiment on albinotic rats (Wistar strain) was conducted. Twenty four male rats with average mass of 117 g were divided into 4 groups of 6 animals. Each rat was put in a separate cage. The animals were fed at the same time with appropriate diets, for 19 days. The daily portion contained 10 g (approx. 10% of rat weight), its composition was different for each group of animals (Table 3). Water was provided *ad libitum*. After the treatment, the animals were put to sleep with chloroform and after the injection of tiopental (diastolic activity), blood from heart was collected into test-tubes.

TABLE 3. Composition of diet applied for different groups of rats.

Group	Contents
I	Air-dried wheat bread (standard, in a form of water pulp)
II	Air-dried wheat bread (standard), 0.5% cholic acid, 1% cholesterol, 7% lard
III	Wheat bread supplemented with 10% linseed meal 0.5% cholic acid, 1% cholesterol, 7% lard
IV	Wheat bread supplemented with 13% linseed meal 0.5% cholic acid, 1% cholesterol, 7% lard

Blood samples analyses were done with an enzymatic method, using the analytical kits (Bio-Vendor, Czech Republic): triglycerides (TG) – catalogue number 12850, total cholesterol – catalogue number 10851, HDL catalogue number 10855, glucose level – catalogue number 11601. LDL was calculated as a difference between total cholesterol and its HDL fraction.

One factorial ANOVA was used to estimate the significance of differences between the obtained results. Calculations were made with a computer program Stat Skierniewice 1998.

RESULTS AND DISCUSSION

Linseed Opal contained more than 46% of raw fat in dry mass (Table 4). The rising of linseed meal share in wheat bread from 10 to 13%, resulted in a 3.0–4.8% increase in the raw fat content as compared to standard bread (Table 4). Fatty acid profile of brown linseed Opal was abundant in linolenic acid (51.5%) so in bread with their supplement the amount of this C18:3 acid was 8–9 times higher than in control. As it was already observed [Chen *et al.*, 1994], a small decrease in ALA was caused by baking – in bread with 13% share of linseed the loss was only 5% of the initial amount.

TABLE 4. Chemical composition of linseed and bread used in experiment (in dry mass).

Contents	Linseed cultivar		Kind of bread		
	Brown linseed – – Opal	Yellow linseed – – Hungarian Gold	Standard (wheat flour type 650)	Standard + 10% linseed Opal	Standard + 13% linseed Opal
Total Protein (N x 5.7%)	19.20 ± 0.30	18.40 ± 0.40	11.10 ± 0.10	12.10 ± 0.10	12.50 ± 0.10
Dietary Fibre (%)	32.70 ± 0.60	30.01 ± 0.40	0.65 ± 0.02	3.10 ± 0.10	3.55 ± 0.05
Mineral elements					
P (%)	0.64 ± 0.01	0.63 ± 0.01	0.13 ± 0.01	0.20 ± 0.01	0.22 ± 0.01
K (%)	0.95 ± 0.08	0.83 ± 0.03	0.20 ± 0.01	0.28 ± 0.01	0.30 ±0.01
Mg (%)	0.19 ± 0.01	0.18 ± 0.01	0.03 ± 0.00	0.07 ± 0.00	0.08 ±0.00
Fe (mg/kg)	66.60 ± 1.50	65.30 ± 1.10	No data	No data	No data
Zn (mg/kg)	74.50 ± 1.10	73.80 ± 0.50	11.00 ± 0.10	18.40 ± 0.10	19.50 ± 0.40
Cu (mg/kg)	11.30 ± 0.60	8.50 ± 0.50	1.25 ± 0.01	2.32 ± 0.02	2.55 ± 0.05
Raw fat (%)	46.70 ± 0.30	44.30 ± 0.20	0.42 ± 0.02	3.42 ± 0.02	5.20 ± 0.02
Percentage in total acids					
C16	6.20 ± 0.02	59.00 ± 0.05	20.04 ± 0.04	10.22 ± 0.02	8.32 ± 0.02
C18	4.64 ± 0.04	4.32 ± 0.02	5.17 ± 0.03	4.23 ± 0.03	4.17 ± 0.03
C18:1	27.86 ± 0.02	20.10 ± 0.06	32.96 ± 0.03	20.97 ± 0.03	21.51 ± 0.02
C18:2	14.47 ± 0.03	14.04 ± 0.04	26.18 ± 0.02	20.49 ± 0.03	19.64 ± 0.04
C18:3	51.50 ± 0.20	54.70 ± 0.20	5.04 ± 0.04	41.04 ± 0.10	45.54 ± 0.20

Bread with higher level of linseed contained also more protein and raw fibre (Table 4). The amount of protein in bread with 13% linseed meal was 1.34% higher than in control, which seems important as we take into account a low level of this component in cereal products. Moreover the coexistence of two plant protein systems in one product can result in a full utilisation of complementary amino acids [Gawęcki & Hryniewiecki, 1998].

The increase in dietary fibre (about 5 times at 13% of linseed) reduces digestibility which results in a lower nutritional value, but significantly improves dietary and wholesome characteristics of food [Ratnayake *et al.*, 1992; Cunnane *et al.*, 1995]. It seems that wheat bread's dietary characteristics can be significantly affected by pectins which are present in cereals in a very low amount, while their content in linseed is much higher [Ratnayake *et al.*, 1992; Oomah, 2001].

The presence of linseed in wheat bread enriched it in valuable minerals. Bread supplemented with linseed revealed much higher levels of P, K, Zn. Bread with 10% share of linseed had twice as much Mg and Cu (Table 4) as the standard one. The change in magnesium is important, as this element is needed for functioning of more then 300 intracellular enzymes. The balanced intake of Mg protects against cancer, atherosclerosis, urolithiasis and prevents premature births [Gawęcki & Hryniewiecki, 1998].

The evaluation of profits due to the enrichment of flax hermit cookies and flax muffins in linseed is only reasonable if such pastry is tasty and acceptable by consumers. Thus, the first applied test was the sensory one. The panel consisted of 15 persons with checked sensitivity. The tests have been successful in all cases, regardless of the form of linseed (Table 5). According to the point scale, all pastry has been qualified as more than good. Muffins were a little preferred, probably because of their soft and porous consistency, which obtained more points in comparison to cookies.

Similarly to bread, all pastry supplemented with higher amount of linseed was richer in protein, dietary fibre,

TABLE 5. Sensory analysis of cookies and muffins (averages from 15 panellists x importance factor).

Quality factor	Importance factor	CI*	CII	CIII	CIV	MI**	MII	MIII	MIV
Shape	0.10	0.42	0.42	0.40	0.38	0.45	0.45	0.44	0.45
Colour	0.10	0.39	0.40	0.42	0.43	0.46	0.48	0.48	0.48
Surface	0.15	0.66	0.61	0.61	0.51	0.66	0.67	0.68	0.68
Consistency	0.15	0.57	0.58	0.59	0.59	0.65	0.67	0.65	0.68
Cleavage	0.10	0.37	0.39	0.39	0.39	0.42	0.47	0.41	0.44
Smell	0.10	0.48	0.50	0.50	0.49	0.45	0.45	0.44	0.45
Taste	0.25	1.20	1.20	1.20	1.20	1.10	1.10	1.10	1.10
Total points		4.10	4.10	4.10	4.10	4.20	4.30	4.20	4.30

*) CI – cookies with 8% brown linseed, CII – cookies with 11% brown linseed, CIII – cookies with 8% yellow linseed, CIV – cookies with 11% yellow linseed; MI – muffins with 4% brown linseed, MII – muffins with 9% brown linseed, MIII – muffins with 4% yellow linseed, MIV – muffins with 9% yellow linseed

TABLE 6. Contents of total protein, dietary fibre and selected mineral elements in dry mass of examined flax cookies (C) and muffins (M).

Sample	Total Protein (N x 5.7)(%)	Dietary fibre (%)	Mineral elements					
			P (%)	K (%)	Mg (%)	Fe (mg/kg)	Zn (mg/kg)	Cu (mg/kg)
CI – 8% brown linseed	8.0 ± 0.3	4.0 ± 0.04	0.14 ± 0.01	0.28 ± 0.02	0.04 ± 0.00	24.4 ± 0.4	15.1 ± 0.2	3.24 ± 0.04
CII – 11% brown linseed	8.7 ± 0.3	4.6 ± 0.05	0.17 ± 0.01	0.29 ± 0.01	0.04 ± 0.00	26.2 ± 0.4	19.1 ± 0.2	3.68 ± 0.02
CIII – 8% yellow linseed	7.8 ± 0.3	2.9 ± 0.10	0.14 ± 0.01	0.27 ± 0.01	0.04 ± 0.00	22.7 ± 0.2	14.9 ± 0.3	3.38 ± 0.03
CIV – 11% yellow linseed	8.6 ± 0.2	3.6 ± 0.10	0.17 ± 0.01	0.28 ± 0.02	0.05 ± 0.01	25.6 ± 0.3	18.4 ± 0.2	3.72 ± 0.02
MI – 4% brown linseed	8.2 ± 0.2	4.8 ± 0.10	0.24 ± 0.02	0.42 ± 0.02	0.04 ± 0.00	30.3 ± 0.4	18.8 ± 0.4	3.36 ± 0.01
MII – 9% brown linseed	8.7 ± 0.2	6.6 ± 0.10	0.26 ± 0.01	0.46 ± 0.01	0.05 ± 0.01	37.1 ± 0.2	21.8 ± 0.3	3.90 ± 0.10
MIII – 4% yellow linseed	8.2 ± 0.2	4.1 ± 0.30	0.24 ± 0.02	0.45 ± 0.01	0.04 ± 0.0	29.9 ± 0.3	18.2 ± 0.3	3.26 ± 0.04
MIV – 9% yellow linseed	8.7 ± 0.1	6.5 ± 0.50	0.26 ± 0.01	0.50 ± 0.00	0.05 ± 0.01	35.3 ± 0.3	20.3 ± 0.2	3.72 ± 0.04

macro- and microelements (Table 6). Flax hermit cookies C II and C IV, where margarine was replaced with linseed, the increase in flax from 8 to 11% caused 0.7% rising of total protein, irrespective of linseed cultivar. This was accompanied by 0.5% increase in dietary fibre (Table 6). Even more favourable change in those compounds was observed in the case of muffins, where oat bran was replaced with linseed. The resulting increase in the linseed content from 4 to 9% provided 1.5% rising of dietary fibre and 0.5% of protein (Table 6).

A higher amount of dietary fibre in those cakes is interesting, if we take into account the fact that oat bran is commonly regarded as a rich source of dietary fibre. Its total content is about 16.6%, while its water-soluble fraction constitutes approximately 6% [Gąsiorowski, 1995]. Linseed however is more abundant in this component, it contains 30% of dietary fibre (Table 4) of which 40% is water-soluble [Ratnayake *et al.*, 1992]. It appears that linseed is a better dietary substrate than oat bran, because in the same amount it supplies also more protein.

Mineral composition of both linseed varieties was very similar (Table 4) and no significant differences were observed between the samples of pastry baked with their supplement (Table 6). Some discrepancies were found for Fe and Zn, both in muffins and cookies. Brown linseed provided more of these microelements (Table 4), however the improvement of mineral composition was significant irrespective of cultivar. Linseed proved to be a better source of microelements than oat bran.

As it was expected, cookies in which margarine was exchanged with linseed, contained approx. 2% less of raw fat, regardless of cultivar (Table 7) but more then 3% more of ALA (*n*-3 PUFA). The amount of linoleic acid C18:2, that composes 60% of fatty acids in margarine [Niewiadomski, 1993] was not affected. Similar trend in ALA was found in muffins (11% rise for both linseed cultivars), but in this case it was accompanied by an increase in the fat content. Yellow linseed was a little more beneficial in this aspect. Muffins can be classified as an instable pastry – their shelf life was about 5 days. To establish this parameter for flax hermit cookies, it was necessary to store them in glass jars and measure fat constants, which characterise their freshness (Table 8).

According to the Polish regulations, fresh margarine should be characterised by acid number less then 1.5 mg KOH/g of fat and the content of peroxides should not exceed 4 μg of active oxygen per l g of fat [Niewiadomski, 1993]. After 2 months of storage the content of peroxides was beyond these requirements, so flax hermit cookies cannot be stored longer then 2 months.

The increase in ALA (*n*-3 PUFA) observed for wheat bread as well as pastry supplemented with linseed meal seems to be a valuable achievement of this work. If such nutriments are included in a daily diet they may balance the ratio between *n*-6 and *n*-3 fatty acids [Kolanowski & Świderski, 1997; Ziemlański, 1997]. Hypocholesteric activity of raw flax seed eaten by humans and animals is already well documented [Bierenbaum *et al.*, 1993; Cunnane *et al.*, 1990, 1993, 1995; Oomah, 2001]. Here it was possible to demonstrate similar effect of bread supplemented with linseed on rats (Table 9). The highest concentration of cholesterol and its LDL fraction was found in serum of animals from II

TABLE 7. Raw fat content and fatty acid profiles in dry mass of flax cookies (C) and muffins (M).

Sample	Raw fat (%)	Percentage in total acids				
		C16	C18	C18:1	C18:2	C18:3
CI – 8% brown linseed	24.4 ± 0.1	15.50 ± 0.03	4.30 ± 0.02	49.4 ± 0.2	14.90 ± 0.03	10.00 ± 0.05
CII – 11% brown linseed	22.6 ± 0.1	14.30 ± 0.02	4.00 ± 0.05	48.1 ± 0.2	14.30 ± 0.02	13.40 ± 0.03
CIII – 8% yellow linseed	24.0 ± 0.1	15.50 ± 0.02	4.20 ± 0.04	48.1 ± 0.2	14.30 ± 0.02	11.00 ± 0.05
CIV – 11% yellow linseed	22.0 ± 0.1	14.00 ± 0.05	4.00 ± 0.04	47.1 ± 0.2	14.60 ± 0.04	14.80 ± 0.05
MI – 4% brown linseed	11.0 ± 0.2	9.90 ± 0.04	4.50 ± 0.04	55.4 ± 0.2	15.80 ± 0.08	12.80 ± 0.10
MII – 9% brown linseed	14.1 ± 0.2	8.30 ± 0.04	3.70 ± 0.03	47.8 ± 0.2	15.70 ± 0.06	23.50 ± 0.10
MIII – 4% yellow linseed	10.7 ± 0.2	8.90 ± 0.05	3.10 ± 0.05	56.4 ± 0.2	14.70 ± 0.10	15.50 ± 0.10
MIV – 9% yellow linseed	12.8 ± 0.3	8.40 ± 0.05	3.40 ± 0.05	46.0 ± 0.5	14.30 ± 0.08	26.60 ± 0.30

TABLE 8. Changes of the acid number and peroxide content of oil extracted from flax cookies during two months of storage.

Sample	Day of baking		Storage time (months)			
			1		2	
	AN*	PC**	AN	PC	AN	PC
CI – 8% brown linseed	0	1	0.32	1.36	0.62	4.40
CII – 11% brown linseed	0	0.84	0.47	1.72	0.84	4.60
CIII – 8% yellow linseed	0	0.85	0.36	1.30	0.72	3.98
CIV – 11% yellow linseed	0	0.94	0.42	1.42	0.78	4.50

*) Acid number (mg KOH / g of fat) **); Peroxide content (μg O_2/g of fat)

TABLE 9. Cholesterol, triglycerides and glucose contents of blood plasma of rats fed with bread (mmol/L).

Diet of rats	Total cholesterol	HDL cholesterol	LDL cholesterol	Triglycerides TG	Glucose
Group I wheat bread standard	2.39^{a*}	1.84^{b}	0.55^{a}	1.09^{b}	9.4^{b}
Group II wheat bread standard + 0.5% cholic acid + 1% cholesterol +7% animal fat	12.13^{c}	0.51^{a}	11.62^{c}	0.58^{a}	10.0^{b}
Group III wheat bread with the addition of 10% of linseed + 0.5% cholic acid +1% cholesterol +7% animal fat	6.57^{b}	0.46^{a}	6.11^{b}	0.41^{a}	8.5^{a}
Group IV wheat bread with the addition of 13% of linseed + 0.5% cholic acid +1% cholesterol +7% animal fat	6.36^{b}	0.48^{b}	5.88^{b}	0.40^{a}	9.6^{b}

*) The results marked with different letters are statistically different at the significance level of p=0.05

group, *i.e*. fed with standard bread and hypercholesterolic additives. Much lower increase in these constituents was observed in groups III and IV, where bread supplemented with 10 and 13% of linseed was used in exchange to standard one. All groups where hypercholesterolic additives were used (II–IV) revealed significantly lower level of blood triglycerides in comparison to group I. This reduction of energy carriers was accompanied by a shift in cholesterol composition favouring formation of its LDL fraction. Wheat bread alone did not cause similar alterations.

The results collected in Table 9 enabled a conclusion that differences in the impact of linseed supplementation level on lowering cholesterol fractions and triglycerides are statistically insignificant. Both 10 and 13% additions reduced the total cholesterol concentration in serum by 47% and its LDL fraction by 48.5% on average. The hypocholesteric effects of linseed on mammals reported previously were several times lower [Bierenbaum *et al.*, 1993; Cunnane *et al.*, 1993, 1995]. It can be explained by a synergic effect of ALA and dietary fibre present in linseed supplemented bread [Ratnayake *et al.*, 1992; Cunnane *et al.*, 1993; Oomah, 2001]. Bread seems to be a safe source of these components, as the cyanogenic glycosides which are present in raw flax seeds [Oomah *et al.*, 1992; Chadha *et al.*, 1995] decompose under thermal treatment such as baking [Chadha *et al.*, 1995; Cunnane *et al.*, 1995]. Morover the diet based on such modified bread can be easily applied due to its good taste and extended shelf life [Gambuś *et al.*, 1999b].

Unfortunately, the present study did not provide enough evidence for hypoglycaemic influence of dietary fibre contained in linseed products, because no statistically significant differences were found between glucose concentration in serum of rats fed standard and linseed-supplemented bread (Table 9). Probably 3% of dietary fibre was not enough to significantly inhibit glucose intake from bread, which provides it in a large quantity as it can be regarded as a concentrated starch gel [Gambuś, 1997].

CONCLUSIONS

1. Bread with 10 and 13% addition of linseed meal revealed elevated amounts of protein (1.1 and 1.4, respectively) and fat (3 and 4.8%) in comparison to standard bread. The fatty acid profile exhibited 8- -fold increase in α-linolenic acid (*n*-3 PUFA).

2. Linseed supplement improved dietary value of bread, enriching it with dietary fibre (5-fold increase in the case of 13% share), phosphorus, potassium, zinc and doubled the content of magnesium and copper.

3. Both applied linseed levels had a huge hypocholesteric effect on rats, fed supplemented bread – total cholesterol in blood plasma decreased by 47% on average and its LDL fraction by 48.5% in comparison to control.

4. A 3% increase in linseed in the recipe for flax hermit cookies and 5% rise in flax muffins did not influence their sensory assessment and improved their dietary and nutritional value, which was reflected by the amounts of proteins, dietary fibre, micro and macroelements.

5. The replacement of margarine and oat bran with linseed in pastry recipes had beneficial effect on α-linolenic acid content.

6. No significant differences in the dietary enhancement of pastry were found between brown linseed – Opal and yellow linseed – Hungarian Gold.

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PERSPEKTYWY ZASTOSOWANIA NASION LNU OLEISTEGO W PRODUKCJI PIECZYWA

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W chlebach pszennych mąkę pszenną typu 650 zastępowano zmielonymi nasionami lnu oleistego odmiany Opal, w ilości 10 i 13%. Do wypieku ciasteczek korzennych użyto brązowych nasion lnu odmiany Opal i żółtych odmiany Hungarian Gold, w ilości 8 i 11%, w tym drugim wariancie zastępując nimi część margaryny (tab. l). W babeczkach (muffins), opierając się na oryginalnej recepturze, zastosowano nasiona obu odmian w ilości 4%, a w drugim wariancie tę ilość zwiększono do 9% eliminując z ciasta otręby owsiane (tab. 2). W chlebach i pieczywie cukierniczym oznaczono zawartość: białka ogółem, tłuszczu surowego, włókna pokarmowego, wybranych makro- i mikroelementów oraz oznaczono profil kwasów tłuszczowych (tab. 4). Przeprowadzono także doświadczenie ze szczurami albinotycznymi, które karmiono chlebem standardowym i chlebem z udziałem nasion lnu oraz dodatkami powodującymi hipercholesterolemię (tab. 3). W chlebach z dodatkiem nasion lnu oznaczono większą zawartość wszystkich oznaczanych składników, w tym 8–9-krotny wzrost zawartości kwasu α-linolenowego, w porównaniu ze standardem (tab. 4). Chleby te wywarły silny hipocholesterolemiczny wpływ na szczury, zmniejszając stężenie cholesterolu całkowitego w surowicy krwi, średnio o 47% i jego frakcji LDL o 48.5%, w porównaniu z grupą kontrolną (tab. 9). Zwiększona ilość nasion lnu w pieczywie cukierniczym nie obniżyła oceny sensorycznej (tab. 5), natomiast spowodowała znaczny wzrost zawartości wszystkich ocenianych składników pokarmowych, a zwłaszcza włókna pokarmowego i kwasu α-linolenowego (*n*-3 PUFA) (tab. 6).