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ORIGINAL ARTICLE

Comparative analysis of fatty acid composition in 84 accessions of flax (*Linum usitatissimum* L.)

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Abstract

Introduction and objective. The aim of the study was to determine the content of five essential fatty acids in seed oil from 84 genotypes of flax (*Linum usitatissimum* L.) from the collection of genetic resources, stored at low temperatures of the long-term storage of the Plant Breeding and Acclimatization Institute in Radzików. The following fatty acids were evaluated: α-linolenic, linoleic, palmitic, stearic and oleic. The ranges of variability of fat content in flax seeds were also determined. In addition, it was calculated how many times the α-linolenic acid content is bigger than linoleic acid in seed oil of each accessions of flax.

Materials and methods. The research material consisted of 84 genotypes of common flax (*Linum usitatissimum* L.), collected and included in the samples. The fat content was determined by infrared analysis (calibration performed on the basis of a seed sample at IHAR-PIB in Poznań) by means of a NIRS 6500 spectrophotometer with a reflection detector within the range of 400–2500 nm.

Results. The ranges of variability of individual fatty acids of 84 flax accessions are as follows: α-linolenic acid: 48.4% – 58.9%, linoleic acid: 10.3% – 17.3%, palmitic acid 4.2% – 6.6%, stearic acid 2.6% – 5.1% and oleic acid: 17.0% – 26.7%. The fat content in the seeds of the evaluated accessions ranged from 39.8% – 44.8%.

Conclusions. Flax seeds from the collection of the genetic resources are an excellent ingredient in food because they contain a large amount of α-linolenic acid. Dietary supplementation with linseed, also containing large amounts of α-linolenic acid and small amounts linoleic acid, allows provision of the body with the necessary ratio of the diunsaturated (n-6) to the triunsaturated fatty acid (n-3). In order to protect health, it is necessary to supplement the diet with a unique α-linolenic fatty acid that are present in only a few food ingredients.

Key words

flax, *Linum usitatissimum* L., fatty acids, α-linolenic acid, health

INTRODUCTION

Flax (*Linum usitatissimum* L.) is one of the oldest cultivated plants in the world [1]. It is a dual-purpose crop, a source of seeds and fiber [2]. Some genotypes are grown mainly for fiber (fiber – type of use), others mainly for seeds (linseed – type of use) and some for fiber and seeds together (combined – type of use). In the world, tall fiber flax plants with long stems are grown in the north, while in the south shorter linseed plants of flax with numerous branches of the panicle with boll seeds, are grown [3]. Currently, flax is mainly grown to obtain seeds. [4]. The largest producer of flax seeds in the world is Canada [5] where it is the third major oilseed crop after canola and soybean [6]. A lot of flaxseed is also grown in China, USA, Russia, India and Ethiopia [5]. In Poland, flax is grown on a small area, although there are varieties that produce good yields and are resistant to Fusarium, the most important pathogen of this species (*Linum usitatissimum* L.) [7, 8]. Currently, the area of flax cultivation in Poland is 1.470 ha [5]. Farmers usually grow species that bring them the most income. In Poland, fiber flax is cultivated less frequently and linseed more often [9]. In 2019, there are nine flax varieties (*Linum usitatissimum* L.) on the Polish National List of Agricultural Plant Varieties. Four of them are linseed: Bukoz, Jantarol, Oliwin, Szafir, and five of them are fiber flax: Jan, Modran, Nike, Sara, Selena. Formerly, common flax *Linum usitatissimum* L. was often grown in Poland and the seeds were used because of their particularly beneficial effects on human and animal health [10]. Today, it is a marginal species.

In the situation of a great narrowing of biodiversity, it is very important to preserve local species gathered from places of their natural origin and old varieties that are characterized by specific morphological trials, biological features and natural composition of fatty acids in seeds. A characteristic of seeds of genetically modified varieties is a significantly lower content of α-linolenic acid, compared with traditional varieties. Programs based on the protection of genetic resources of flax are carried out in many countries in Europe and worldwide [11, 12].

The most important for human and animal health is α-linolenic acid, which is the most characteristic for flax (*Linum usitatissimum* L.), which is why stored accessions from the genetic resources of flax are of such great importance. In 2019, the Linum collection comprised 811 accessions of which 804 genotypes are stored in the National Center for Plant Genetic Resources at the Plant Breeding and Acclimatization

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Institute in Radzików, near Warsaw. According to the status of accessions, the Linum collection includes: wild species, landraces or primitive cultivars, breeding lines and advanced varieties of flax.

A healthy, nutrient-rich diet plays a very important role in preventing civilization diseases [13]. Many authors state that flax seeds are the richest source of α-linolenic acid, for example, Ganorkar at al. [4]. Consumption of flax (*Linum usitatissimum* L.) seeds is very beneficial for human and animal health [14, 15] also because they contain a lot of bioactive phenolics which demonstrate biological activity, including antiradical, antioxidant, antimicrobial and anticancer effects [16, 17].

The aim of the study is valorization of the qualitative (technological) features of 84 accessions from the flax collection (*Linum usitatissimum* L.) from the Plant Breeding and Acclimatization Institute in Radzików. The composition of the most important fatty acids, as well as the total fat content in oil seeds of flax genotypes, was determined.

MATERIALS AND METHOD

Materials

The passport data of the research material is presented in Table 1. The research material consisted of 84 genotypes of common flax (*Linum usitatissimum* L.), collected and included in the collection by the Institute of Natural Fibers (today, the Institute of Natural Fibers & Medicinal Plants). The international acronym of the institution that gathered new flax accessions (INSTCODE), the Institute of Natural Fibers, is the symbol POL026. After a three-year cycle of reproduction, these accessions were sent to the Plant Breeding and Acclimatization Institute in Radzików, where the long-term storage numbers (COLLNUMB) were assigned to them at the National Center for Plant Genetic Resources, under which they are deposited. Also, the Institute of Natural Fibers, as an institution that increased the collection of flax for new genotypes, gave 84 numbers to new accessions (ACCENUMB): IWN00447 – IWN00529 and IWN00558. The research material belongs to the genus Linum, species – (*Linum usitatissimum* L.), the representatives of which are popularly called – flax. All 84 accessions of flax (*Linum usitatissimum* L.) were included in the flax collection (ACQDATE) in 1988. The research material came from the following continents: Europe – 39 genotypes, North America – 25 accessions, South America – 13 genotypes, and 7 accessions of unknown origin. The country of origin of genotypes in Table 1 is shown in the column: (ORIGCTY). European genotypes came from Russia – 12, Hungary – 8, Portugal – 7, Germany – 6, Italy – 2, Bulgaria – 1, Czech – 1, The Netherlands – 1 and Norway – 1. North America is represented by 16 accessions from the United States and 9 from Canada. The genotypes of flax from South America came from 3 countries: Argentina – 7, Brazil – 3 and Uruguay – 3. The research material came only from 2 donors (DONORCODE). Most of the new flax accessions (*Linum usitatissimum* L.) were received from the Czech Republic – 73 genotypes, and 11 seed samples were brought from Russia. All flax genotypes in research are characterized by the morphological features according to the International Flax Database: plant life cycle – one-year (annual) and plant growth habit – erect [18].

Laboratory analysis

Laboratory analysis of 84 accessions from the flax collection were made at the Plant Breeding and Acclimatization Institute in Poznań. The following characteristics were determined: percentage fat content in seeds and percentage content of 5 fatty acids present in seed oil: α-linolenic (triunsaturated), linoleic (diunsaturated), oleic (monounsaturated) and saturated: stearic and palmitic [19]. The sum of the 5 fatty acids (with the largest share) was considered as 100% and the share of each of them was expressed as weight percent. The fat content was determined by infrared analysis (calibration performed on the basis of a seed sample at IHAR-PIB in Poznań) by means of a NIRS 6500 spectrophotometer (Foss – NIRS System, USA – now Denmark) with a reflection detector within the range of 400–2500 nm [20]. Fatty acid composition in oil (%) was determined using gas chromatography (Agilent 7890, USA) of fatty acid methyl esters by Hewlett Packard chromatograph type 3390A, Agillent Technologies 6890N Network GC System. The quantitative valuation of chromatographs was performed by integrating the areas under the peaks [21]. The method complies with Polish standards PN-EN-ISO 5508: 1996 [22] and PN-ISO 5509 [23]. The fat content and fatty acid composition were determined in seeds from 5 individual plants. Obtained results of biochemical analyzes are presented in Table 3. Statistical analysis was performed using an Excel spreadsheet.

Characteristics of the field experience

The field experiment was carried out from April 30 – July 31 in 2014 in Pętkowo (52° 13' 0" North, 17° 16' 0" East), near Środa Wielkopolska, and at the Experimental Station of the Institute of Natural Fibers and Medicinal Plants in Poznań. Weather summary for this period: average temperature – 16 °C (7–29 °C), average humidity – 71% (24–100%), average pressure (1005–1021 mbar). Flax seeds were sown with a manual seeder in an amount of 50 kg/ha in a field with an even slope on third class soil, with the following description: R III a 2D pgl. gl. The plots size was 2 m^2 (2.5 m / 0.8 m) and row spacing – 20 cm.

Methodology of International Flax Data Base

The Institute of Natural Fibres & Medicinal Plants takes part in the international program entitled "European Cooperative Programme for Plant Genetic Resources (ECP/GR). The purpose of this cooperation is to develop the International Database of Flax (IFDB). Multi-Crop Passport Descriptors (28 FAO/IPGRII) are used to develop the IFDB [24]. Assessment of fatty acid content has been developed for IFDB. Each fatty acid can have 5 levels of content: very low, low, medium, high and very high. Table 2 show which ranges of content of each acid, correspond to one of the 5 valuations, based on the Nôžková study) [25]. The content of each of the fatty acids of each genotype was valorized using descriptors (Tab. 2).

RESULTS

The total fat in the seeds of the 84 accessions from the collection of genetic resources of flax were found between 39.8% (Daros-166013) – 44.8% (C.I.1128–165998) (Tab. 3). The average fat content in flax seeds was 42.2%. The α-linolenic acid content of seed oil from the collection of genetic resources of flax (*Linum usitatissimum* L.) ranged from 48.4% (Can 2612-

A-165988) – 58.9% (C.I.2543 – 166002). The average α-linolenic acid content in breeding materials was 53.6%. Content of the linoleic acid content in seed oil of evaluated genotypes varied between 10.3% (C.I.1235 – 166001) – 17.3% (AL-CV-3-165963). The average linoleic acid content in the 84 flax accessions was 14.6%. The sum of polyunsaturated fatty acids in the research material of *Linum usitatissimum* L. ranged from 62% (Can 2612-A-165988) – 74.7% (C.I.1128), and the average sum of polyunsaturated acid of 84 genotypes – 68.1%.

The ranges of variability of other fatty acids of the 84 flax accessions were as follows: palmitic acid 4.2% (J.Lord -166031) – 6.6% (Calar C.I.464), stearic acid 2.6% (Record – 165970) – 5.1% (Swietocz – 165987), and oleic acid 17.0% (C.I.1128 – 165998) – 26.7% (Domaninśký Výnosnýj – 166017) (Tab. 3). The range of variation in the sum of saturated fatty acids: palmitic and stearic was 7.2% – 11%. The average of palmitic acid content was 5.5%, the average of stearic acid content – 3.5%, and the average of saturated fatty acids content of the 84 flax accessions (palmitic and stearic) – 9.1%.

In the flaxseed genotype (*Linum usitatissimum* L.), the α-linolenic acid content was higher than the linoleic acid content by a minimum of 2.8 times (AL-CV-3-165963) and a maximum of 4.5 times (C.I.1155-165999, Combras-166004, Endres kreu.-166025, Texbiles 7052 – 166042), because the ratio n-6 : n-3 ranged from 1 : 2.8 – 1 : 4.5. The average ratio of n-6 : n-3 in the research material was 1 : 4.1. This means that the amount of linoleic fatty acid, on average, was about 4 times smaller compared to the α-linolenic fatty acid amount of seed oil of flax. You can compare these results with others results [26, 27].

Table 4 presents data on 5 fatty acids for International Flax Data Base for the evaluation of this content using "Descriptor list for Flax "[25]. According to this, the content of acids in genotypes of flax can be: very low, low, medium, high and very high.

The content of α-linolenic acid was high in 80 flax accessions (95.2%) and very high in 4 flax genotypes (4.8%). The research material of all accessions of flax was characterized by a very low content of linoleic fatty acid. The palmitic acid content was medium for 66 flax accessions (78.6%) and low for 18 genotypes of research material (21.4%). The stearic acid content was medium for 74 genotypes (88.1%), high for 9 genotypes (10.7%) and low for 1 accession of flax (1.2%). The oleic acid content was medium for 78 genotypes (92.8%), low for 5 accessions (6%) and high for 1 accession (1.2%). Table 5 presents the mean values, ranges of variation and coefficients of variability of all 5 fatty acids and fat content in flax seeds separately for the following types: linseed, fiber, combined and unknown.

DISCUSSION

According to the WHO prognosis, until 2020, diet-related diseases will be a cause of almost ¾ of all deaths worldwide [28]. Civilization diseases are caused by improper diet and low physical activity [29]. Food ingredients affect gene expression and protein activity [30]. Incorrect selection of food products, that is, a diet with an excess or a shortage of specific ingredients can cause many diseases. The main diseases linked with unsuitable diet and low physical activity are: cardiovascular diseases, food-related cancers, obesity, lipid disorders, blood hypertension, type 2 diabetes, osteoporosis, tooth caries as well as anemia [31, 32]. Flax seeds are an excellent component of the diet with a unique, extremely valuable composition of seeds. Unfortunately, studies show that the decisive factor in purchasing a given product is its taste, which was indicated by 52% of the respondents [33]. Price is of lesser importance, including reduced price (10.7%) and need for good diet, which were indicated by only 8% of the interviewees [33]. It is agreed that in a balanced diet, 55–60% of the calories should come from carbohydrates, 25% from fats, and 10–15% from proteins [13]. Therefore, very important components of human diet are fats [34]. In the diet, less than 10% of the total fat should be saturated fat [35, 36].

In the presented study, the content of saturated acids in 73 of the 84 studied genotypes of flax from the genetic resources collection was lower than 10%, while in 11 flax genotypes – 10.1% – 11%. In this study, the sum of palmitic and stearic acid content in the group of 84 accessions was the highest – 9.1%, while in the group of 14 genotypes it was the lowest – 8.3% [27], in the group of 9 accessions it was 8.9% [20], in the group of 16 genotypes it was 9.0% [26]. Similarly, the average palmitic acid content was the highest in the group of 84 accessions – 5.5%, the lowest in the group of 14 – 5.2% [27] and 16 genotypes – 5.2% [26], the medium in the group of 9 accessions – 5.4% [20].

The average stearic acid content in studied group of 84 accessions (3.5%) was lower than in the group of 16 accessions – 3.8% [26], and higer then it in both groups of 14 genotypes – 3.1% [27] and of 9 genotypes – 3.4% [20].

Unsaturated fatty acids are divided into monounsaturated and polyunsaturated. Monounsaturated fatty acid is oleic acid that predominates in olive oil. Polyunsaturated fatty acids are diunsaturated linoleic acid (n-6 family) and triunsaturated α-linolenic acid (n-3 family). The content of polyunsaturated fatty acids is very often mentioned, for example, in bottles with linseed oil, but it is not known how much of the oil contains linoleic acid (n-6) and how much linolenic (n-3). Such knowledge is very important, because the WHO recommends that in order to maintain health, do not eat too much linoleic acid and too little α-linolenic acid. According to Matławska and Bylka [37], the ratio of fatty acids from the n-6 family to the fatty acids of the n-3 family (n-6 : n-3) is currently even 30 : 1 in the diet of Western countries, while the ratio of the n-6 family to the n-3 family recommended by the WHO, Simopoulos and Mińkowski [38, 39] is 4–5 : 1 and by Strączkowski [13] from 1 : 1 – 6 : 1. Information about the species whose seeds or fruits containing a large amount of acids from the omega-3 family is very important for designing a proper health-promoting diet. There are few food sources containing large amounts of α-linolenic acid; such products are: flaxseed (*Linum usitatissimum* L.), leafy vegetables, walnut, algae and deep-sea fish [37]. Other authors also mention flax seeds as the most important food source of α-linolenic acid [40]. Rudzińska and Wąsowicz, in addition to flax seeds, provide the following nutrients which are good sources of acids from the n-3 family: seeds *Camelina sativa* L.), krill, alga oil, fish meat: tuna, salmon and cod [40]. Huerta-Yepez [41] quotes Burdge [42] who reports on the following sources of fatty acids from the omega-3 family: green leafy vegetables, flaxseed *Linum usitatissimum* L., walnuts, canola oils [41, 42]. There are only 2 species that are characterized by a higher α-linolenic acid content compared to content of linoleic acid in seed oil: *Linum usitatissimum* L. and *Camelina sativa* L. In seeds from the collection of flax genetic resources, the amount of α-linolenic acid is higher

Table 1. Passport data of 84 accession of flax (*Linum usitatissimum* L.)

Collecting number **COLLNUMB** (long-term storage KCRZG –IHAR)	Accession name **ACCENAME**	Institution code **INSTCODE**	Acquisition date **ACQDATE**	Donor institution code **DONORCODE**	Donor number **DONORNUMB**	**GENUS**	**SPECIES**	Country of origin **ORIGCTY**	**ORIGIN**	**Type of use**	Accession number **ACCENUMB**
165960	AL-1200	POL026	1988	CZE122	2–202	*Linum*	*usitatissimum* L.	URG	--	--	IWN 00447
165961	AL-CII-2	POL026	1988	CZE122	2–250	„	„	BRA	4	L	IWN 00448
165962	AL-CII-6	POL026	1988	CZE122	2–51	„	„	BRA	--	F	IWN 00449
165963	AL-CV-3	POL026	1988	CZE122	2–53	„	„	BRA	--	--	IWN 00450
165964	Artikskij 7	POL026	1988	CZE122	2–532	„	„	RUS	3	L	IWN 00451
165965	Attana ZZOB	POL026	1988	CZE122	2–605	„	„	BGR	3	L	IWN 00452
165966	B 5128	POL026	1988	CZE122	2–208	„	„	USA	--	--	IWN 00453
165967	Bachmalskij 1056	POL026	1988	CZE122	2–537	„	„	RUS	3	L	IWN 00454
165968	Barbarigo	POL026	1988	CZE122	2–41	„	„	---	--	--	IWN 00455
165969	Barnaulskij 120	POL026	1988	CZE122	2–561	„	„	---	--	C	IWN 00456
165970	Bayerischer Springlein	POL026	1988	CZE122	2–496	„	„	GER	--	F	IWN 00457
165971	Bela Elek-F-118	POL026	1988	CZE122	2–304	„	„	---	--	C	IWN 00458
165972	Baladi C.I. 377–1	POL026	1988	CZE122	2–205	„	„	---	--	--	IWN 00558
165973	Benvenuto Real	POL026	1988	CZE122	2–206	„	„	ARG	3	L	IWN 00459
165974	Betta 88	POL026	1988	CZE122	2–393	„	„	HUN	3	L	IWN 00460
165975	Betta 200	POL026	1988	CZE122	2–395	„	„	HUN	--	L	IWN 00461
165976	Bison Boyena C.I.389	POL026	1988	CZE122	2–79	„	„	USA	--	--	IWN 00462
165977	Bison Can 2100	POL026	1988	CZE122	2–397	„	„	CAN	--	F	IWN 00463
165978	Biwing C.I.917	POL026	1988	CZE122	2–434	„	„	USA	--	C	IWN 00464
165979	Blaawe Ster	POL026	1988	CZE122	2–14	„	„	USA	--	--	IWN 00465
165980	Blenda-44205	POL026	1988	CZE122	2–512	„	„	PRT	--	F	IWN 00466
165981	Bolley Golden	POL026	1988	CZE122	2–494	„	„	URY	3	L	IWN 00467
165982	Börgen	POL026	1988	CZE122	2–28	„	„	NOR	3	L	IWN 00468
165983	Buck 113	POL026	1988	CZE122	2–93			ARG	3	L	IWN 00469
165984	Buck 114/7245	POL026	1988	CZE122	2–511	„	„	PRT	3	L	IWN 00470
165985	Buck 2/34	POL026	1988	CZE122	2–102	„	„	ARG	3	L	IWN 00471
165986	Buck 3/34	POL026	1988	CZE122	2–103	„	„	ARG	3	L	IWN 00472
165987	Calar C.I.464	POL026	1988	CZE122	2–243	„	„	USA	4	L	IWN 00473
165988	Can 2612-A	POL026	1988	CZE122	2–209	„	„	CAN	3	L	IWN 00474
165989	Can 2763-A	POL026	1988	CZE122	2–164	„	„	CAN	3	L	IWN 00475
165990	Can 2900-C	POL026	1988	CZE122	2–167	„	„	CAN	--	--	IWN 00476
165991	Can 3011-B	POL026	1988	CZE122	2–179	„	„	CAN	3	L	IWN 00477
165992	Capace	POL026	1988	CZE122	2–40	„	„	ITA	3	L	IWN 00478
165993	Cascade CAN 36	POL026	1988	CZE122	2–400	„	„	CAN		F	IWN 00479
165994	C.I.481-Winona	POL026	1988	CZE122	2–78	„	„	USA	--	--	IWN 00480
165995	Welsh C.I.645	POL026	1988	CZE122	2–433	„	„	USA	4	L	IWN 00481
165996	C.I. 917	POL026	1988	CZE122	2–434	„	„	USA	--	--	IWN 00500
165997	Victory C.I.1045	POL026	1988	CZE122	2–436	„	„	CAN	3	L	IWN 00501
165998	C.I.1128	POL026	1988	CZE122	2–244	„	„	USA	4	L	IWN 00502
165999	C.I.1155	POL026	1988	CZE122	2–246	„	„	USA	4	L	IWN 00503
166000	C.I.1247	POL026	1988	CZE122	2–425	„	„	ARG	F	F	IWN 00504
166001	C.I.1235	POL026	1988	CZE122	2–424	„	„	USA	4	L	IWN 00505

Collecting number **COLLNUMB** (long-term storage KCRZG –IHAR)	Accession name **ACCENAME**	Institution code **INSTCODE**	Acquisition date **ACQDATE**	Donor institution code **DONORCODE**	Donor number **DONORNUMB**	**GENUS**	**SPECIES**	Country of origin **ORIGCTY**	**ORIGIN**	**Type of use**	Accession number **ACCENUMB**
166002	C.I.2543	POL026	1988	CZE122	2–777	„	„	CAN	4	L	IWN 00506
166003	Colonel Brandhaun	POL026	1988	CZE122	2–196	„	„	---	--	F	IWN 00507
166004	Combras	POL026	1988	CZE122	2–516	„	„	PRT	--	L	IWN 00508
166005	Conceicao	POL026	1988	CZE122	2–515	„	„	PRT	3	L	IWN 00509
166006	Cresus	POL026	1988	CZE122	2–465	„	„	PRT	--	F	IWN 00510
166007	Crystal C.I.982	POL026	1988	CZE122	2–247	„	„	USA	--	F	IWN 00511
166008	Csikmind-szenti	POL026	1988	CZE122	2–576	„	„	HUN	--	F	IWN 00512
166009	Csikszentkirályi kékvirágu	POL026	1988	CZE122	2–578	„	„	HUN	--	F	IWN 00513
166010	Csóhai	POL026	1988	CZE122	2–163	„	„	HUN	3	L	IWN 00514
166011	Dacota 496	POL026	1988	CZE122	2–506	„	„	PRT	3	L	IWN 00515
166012	Dacota 36174	POL026	1988	CZE122	2–505		„	PRT	3	L	IWN 00516
166013	Daros	POL026	1988	CZE122	2–214	„	„	GER	F	F	IWN 00517
166014	Davis	POL026	1988	CZE122	2–162	„	„	USA	F	F	IWN 00518
166015	Diadem	POL026	1988	CZE122	2–460	„	„	HUN	3	L	IWN 00482
166016	Ditrói	POL026	1988	CZE122	2–579	„	„	HUN	--	F	IWN 00483
166017	Domaniński výnosnýj	POL026	1988	CZE122	2–231	„	„	CZE	--	--	IWN 00484
166018	Dona	POL026	1988	CZE122	2–37	„	„	ITA	3	L	IWN 00485
166019	Donskoj 166	POL026	1988	CZE122	2–546	„	„	RUS	--	--	IWN 00486
166020	Dorst-F6	POL026	1988	CZE122	2–181	„	„	NLD	3	L	IWN 00487
166021	Dufferin	POL026	1988	CZE122	2–783	„	„	CAN	3	L	IWN 00488
166022	E2-E3	POL026	1988	CZE122	2–251	„	„	URY	4	L	IWN 00489
166023	Eckendorfer 338/44	POL026	1988	CZE122	2–316	„	„	GER	--	C	IWN 00490
166024	Endres	POL026	1988	CZE122	2–618	„	„	GER	--	--	IWN 00491
166025	Endres kreu.	POL026	1988	CZE122	2–95	„	„	GER	3	L	IWN 00492
166026	Endres olejný	POL026	1988	CZE122	2–619	„	„	GER	3	L	IWN 00493
166027	Entre Rios 15445	POL026	1988	CZE122	2–517	„	„	ARG	--	--	IWN 00494
166028	Esterházi 822	POL026	1988	CZE122	2–704	„	„	HUN	3	L	IWN 00495
166029	Comun del Peru 1.5	POL026	1988	CZE122	K-6965	„	„	RUS	3	L	IWN 00496
166030	Flandes M.A.G.	POL026	1988	CZE122	K-6103	„	„	RUS	--	--	IWN 00497
166031	J.Lord	POL026	1988	CZE122	K-6942	„	„	RUS	--	L	IWN 00498
166032	K-6905	POL026	1988	CZE122	K-6905	„	„	---	--	L	IWN 00499
166033	Pale Blue	POL026	1988	RUS	K-4016	„	„	USA	3	L	IWN 00519
166034	Pieczerskij Kriarz	POL026	1988	RUS001	K-5408	„	„	RUS	--	--	IWN 00520
166035	Parchowskij Kriarz	POL026	1988	RUS	K-3764	„	„	RUS	--	--	IWN 00521
166036	Pergamino Puelche	POL026	1988	RUS001	K-6741	„	„	ARG	--	L	IWN 00522
166037	Redwood 65	POL026	1988	RUS	K-7200	„	„	USA	--	L	IWN 00523
166038	Record	POL026	1988	RUS	K-6879	„	„	---	3	L	IWN 00524
166039	Swietocz	POL026	1988	RUS001	K-5333	„	„	RUS	3	F	IWN 00525
166040	Scheyenne	POL026	1988	RUS	K-6305	„	„	USA	--	L	IWN 00526
166041	Tourneur	POL026	1988	RUS	K-6915	„	„	---	--	L	IWN 00527
166042	Texbiles 7052	POL026	1988	RUS	K-6945	„	„	RUS	--	--	IWN 00528
166043	Torżowskij 3	POL026	1988	RUS	K-7224	„	„	RUS	--	F	IWN 00529

– COLLNUMB – Collecting number: original number assigned by the collector(s) of the sample (Institute for Plant Breeding and Acclimatization).
– ACCENAME –Accession name.
– INSTCODE – Institution code: code of the Institute where the accession is maintained (codes consist of a 3-letter ISO country code, plus number).
– ACQDATE – Acquisition date: date the accession was included in the collection.
– DONORCODE – Donor Institution Code: code of the Institution from which the object was acquired for the collection.
– ORIGCTY – Country of origin: code of the country in which the sample was originally collected or bred.
– ORIGIN – Type of accessions based on its originating: 4-breeding line, 3-varieties.
– Type of use: linseed, fiber, combined.

Table 2. Descriptors states of fatty acids content of α-linolenic acid, linoleic acid, palmitic acid, stearic acid and oleic acid [%], according Nôžková

		Saturated		Nonounsaturated	Polyunsaturated	
Descriptor states		Palmitic acid C16:0	Stearic acid C18:0	Oleic acid n-9 (C18 :1)	Linoleic acid n-6 (C18 :2)	α-Linolenic acid n-3 (C18:3)
RANGES						
1	very low	< 3.9	< 1.5	< 14.1	< 20.7	< 11.1
3	low	3.9 – 5.2	1.5 – 2.6	14.1 – 19.0	20.7 – 33.5	11.1 – 24.5
5	medium	5.3 – 7.2	2.7 – 4.2	19.1 – 26.4	33.6 – 52.6	24.6 – 44.6
7	high	7.3 – 8.5	4.3 – 5.2	26.5 – 31.3	52.7 – 65.4	44.7 – 58.0
9	very high	> 8.5	> 5.2	> 31.3	> 65.4	> 58.0

Table 3. Characterization of the content of fat and fatty acids composition of 84 accessions of flax (*Linum usitatissimum* L.)

			Saturated fatty acids			Monounsaturated fatty acid	Polyunsaturated fatty acids			
Accename	Coolnumb	Fat [%]	Palmitic acid C16:0 [%]	Stearic acid C18:0 [%]	Total	Oleic acid C18:1 n–9 [%]	Linoleic acid C18:2 n–6 [%]	α-Linolenicacid C 18:3 n–3 [%]	Total	Ratio n–6/ n–3
AL-1200	165960	43.3	5.8±0.8	3.6±1.3	9.4	18.7±3.4	13.4±3.4	58.5±6.6	71.9	1:4.4
AL-CII-2	165961	42.8	5.3±06	4.1±1.5	9.4	22.8±4.5	15.3±2.4	52.5±5.9	67.8	1:3.4
AL-CII-6	165962	42.2	6.1±1.8	4.1±0.4	10.2	21.1±9.2	15.8±2.7	52.9±11.7	68.7	1:3.4
AL-CV-3	165963	42.7	5.5±1.7	3.8±1.2	9.3	24.9±11.8	**17.3**±6.9	48.6±16.3	65.9	**1:2.8**
Artikskij 7	165964	42.5	5.7±0.8	3.6±0.9	9.3	23.6±3.5	15.3±4.9	51.8±5.1	67.1	1:3.4
Attana ZZOB	165965	41.0	5.1±1.3	2.9±0.5	8.0	24.7±8.4	15.2±5.0	52.2±7.8	67.4	1:3.4
B 5128	165966	41.8	5.9±0.8	3.6±1.8	9.5	21.8±6.1	15.2±3.2	53.4±7.3	68.6	1:3.5
Bachmalskij 1056	165967	43.5	5.7±0.7	3.7±0.7	9.4	23.0±7.5	15.4±3.1	52.1±6.8	67.5	1:3.4
Barbarigo	165968	43.5	5.4±1.0	3.9±1.4	9.5	23.0±5.1	14.64.1±	52.9±4.1	67.5	1:3.6
Barnaulskij 120	165969	41.9	5.5±0.4	3.3±0.4	8.8	23.1±6.7	14.7±3.9	53.4±9.1	68.1	1:3.6
Bayerischer Springlein	165970	42.5	6.0±0.4	2.7±0.2	8.7	20.3±1.7	15.9±1.8	55.0±3.2	70.9	1:3.5
Bela Elek-F-118	165971	42.4	5.3±1.2	2.8±0.8	8.1	22.4±6.3	15.7±2.8	53.7±3.5	69.4	1:3.4
Baladi C.I. 377-1	165972	41.9	5.5±1.1	3.4±1.4	8.9	20.7±9.5	14.1±3.4	56.2±7.9	70.3	1:40
Benvenuto Real	165973	42.1	5.8±0.8	3.8±1.9	9.6	21.0±5.9	14.3±1.4	55.0±5.9	69.3	1:3.9
Betta 88	165974	43.5	5.5±0.5	3.2±1.4	8.7	25.78.3±	14.51.7±	51.1±7.1	65.6	1:3.5
Betta 200	165975	42.4	5.8±0.8	3.8±2.2	9.6	25.9±4.6	13.8±2.9	50.7±5.4	64.5	1:3.7
Bison Boyena C.I.389	165976	42.5	5.7±0.6	3.5±1.5	9.2	26.0±0.9	15.5±1.5	49.4±2.2	64.9	1:3.2
Bison Can 2100	165977	43.2	5.6±0.2	3.0±0.5	8.6	23.5±4.4	15.8±1.8	52.1±6.0	67.9	1:3.3
Biwing C.I.917	165978	42.8	5.9±0.4	2.90.8±	8.8	20.8±5.4	17.02.5±	53.5±7.1	70.5	1:3.2
Blaawe Ster	165979	42.7	5.3±0.3	2.8±0.5	8.1	23.3±2.9	15.0±4.1	53.6±2.5	68.6	1:3.6
Blenda-44205	165980	42.3	5.0±0.9	2.9±0.5	7.9	24.3±6.6	15.7±6.9	52.1±6.3	67.8	1:3.3
Bolley Golden	165981	42.8	5.9±0.5	4.0±2.1	9.9	20.7±7.9	15.0±2.9	54.4±12.2	69.4	1:3.6
Börgen	165982	43.3	5.8±0.7	3.8±1.2	9.6	23.6±5.2	15.3±2.3	51.7±2.2	67.0	1:3.4
Buck 113	165983	43.0	**6.6**±0.6	4.4±0.5	**11.0**	19.9±3.2	14.6±1.6	54.6±3.3	69.2	1:3.7
Buck 114/7245	165984	42.8	6.0±1.3	4.4±1.1	10.4	23.4±3.2	13.6±6.7	52.6±9.1	66.2	1:3.9
Buck 2/34	165985	41.9	5.3±0.6	3.5±1.6	8.8	22.0±6.2	14.3±2.9	54.9±7.5	69.2	1:3.8
Buck 3/34	165986	41.9	6.2±0.6	3.7±1.1	9.9	24.2±5.2	12.9±3.2	53.1±3.9	66.0	1:4.1
Calar C.I.464	165987	42.5	6.1±0.6	4.1±1.8	10.2	23.0±8.6	13.0±2.9	53.9±10.1	66.9	1:4.2
Can 2612-A	165988	43.6	5.6±0.7	3.6±1.9	9.2	28.7±13.1	13.6±5.1	**48.4**±10.0	**62.0**	1:3.6
Can 2763-A	165989	44.0	5.5±0.7	3.1±1.7	8.6	25.8±11.4	13.3±2.4	52.3±10.4	65.6	1:3.9
Can 2900-C	165990	42.6	5.6±1.1	3.8±1.8	9.4	23.9±8.3	15.0±1.0	51.7±9.1	66.7	1:3.4
Can 3011-B	165991	42.5	5.4±0.9	3.4±1.1	8.8	24.7±12.6	13.9±2.8	52.7±15.7	66.6	1:3.8
Capace	165992	41.4	5.1±0.3	3.0±0.3	8.1	22.3±4.0	15.5±2.0	54.1±4.0	69.6	1:3.5
Cascade CAN 36	165993	42.7	6.0±0.7	4.4±1.0	10.4	22.4±1.8	15.0±1.6	52.3±3.9	67.3	1:3.5
C.I.481-Winona	165994	40.1	5.4±0.6	2.9±0.9	8.3	22.5±4.5	13.7±2.9	55.42.8±	69.1	1:4.0
Welsh C.I.645	165995	42.5	6.0±1.2	4.6±0.9	10.6	20.4±5.6	14.9±2.9	54.2±6.1	69.1	1:3.6
C.I. 917	165996	42.6	5.7±0.2	2.9±0.8	8.6	20.9±3.9	14.6±1.5	55.8±3.5	70.4	1:3.8

			Saturated fatty acids			Monounsaturated fatty acid	Polyunsaturated fatty acids			
Accename	Coolnumb	Fat [%]	Palmitic acid C16:0 [%]	Stearic acid C18:0 [%]	Total	Oleic acid C18:1 n–9 [%]	Linoleic acid C18:2 n–6 [%]	α-Linolenicacid C 18:3 n–3 [%]	Total	Ratio n–6/ n–3
Victory C.I.1045	165997	42.7	5.8±0.5	3.3±1.9	9.1	18.0±5.7	14.3±2.0	58.6±5.9	72.9	1:4.1
C.I.1128	165998	**44.8**	5.3±0.2	3.0±0.2	8.3	**17.0**±3.2	17.4±2.2	57.3±4.1	**74.7**	1:3.3
C.I.1155	165999	41.0	5.8±0.5	2.9±0.2	8.7	19.6±3.0	13.1±2.2	58.6±4.5	1.7	**1:4.5**
C.I.1247	166000	41.5	5.6±0.5	3.6±1.2	9.2	23.7±8.6	14.0±3.2	53.2±6.9	67.2	1:3.8
C.I.1235	166001	42.8	6.1±0.8	4.9±2.0	**11.0**	24.3±4.1	**10.3**±1.0	54.4±5.6	64.7	1:5.3
C.I.2543	166002	43.2	5.7±0.2	3.1±0.4	8.8	19.0±1.1	13.2±1.4	**58.9**±2.3	72.1	1:4.5
Colonel Brandhaun	166003	42.5	5.0±1.3	3.1±1.1	8.1	21.9±11.2	13.6±2.5	56.5±11.7	70.1	1:4.2
Combras	166004	42.7	5.9±0.6	4.4±1.9	10.3	24.3±11.3	11.9±2.1	53.5±14.2	65.4	**1:4.5**
Conceicao	166005	42.1	5.3±0.6	3.4±0.4	8.7	25.9±7.1	15.7±1.7	49.6±6.7	65.3	1:3.2
Cresus	166006	42.6	5.8±1.0	4.1±1.5	9.9	21.0±4.2	14.4±2.2	54.6±4.6	69.0	1:3.8
Crystal C.I.982	166007	44.2	6.1±0.8	3.8±0.3	9.9	20.0±14.3	15.5±2.6	54.6±11.7	70.1	1:3.5
Csikmindszenti	166008	43.4	5.5±0.6	3.2±1.6	8.7	22.7±7.5	14.1±2.5	54.5±7.9	68.6	1:3.9
Csikszentkirályi kékvirágu	166009	42.6	5.7±1.3	3.3±1.5	9.0	23.6±10.0	14.0±3.5	53.9±9.6	67.9	1:3.8
Csóhai	166010	42.3	6.0±0.3	3.2±2.1	9.2	22.9±7.1	12.8±0.8	55.2±9.3	67.2	1:4.3
Dacota 496	166011	42.3	5.8±1.2	3.7±1.5	9.5	23.4±4.3	13.1±5.5	54.0±7.5	67.1	1:4.1
Dacota 36174	166012	42.2	5.9±1.0	2.9±1.1	8.8	23.5±4.8	16.1±2.4	51.6±5.3	67.7	1:3.2
Daros	166013	**39.8**	5.2±1.2	3.2±0.5	8.4	22.0±3.3	13.1±3.2	56.6±2.7	69.7	1:4.3
Davis	166014	40.9	4.7±0.7	2.8±0.8	7.5	22.0±6.4	14.7±3.5	55.8±5.5	70.5	1:3.8
Diadem	166015	43.0	6.2±0.7	3.8±2.6	10.0	23.5±6.7	14.2±2.6	52.3±5.7	66.5	1:3.7
Ditrói	166016	41.6	4.6±1.6	3.2±1.5	7.8	22.9±2.6	15.1±1.8	54.3±5.9	69.4	1:3.6
Domaniński výnosnýj	166017	41.7	5.5±0.7	3.7±1.4	9.2	**26.7**±8.1	15.3±6.3	48.8±8.3	64.1	1:3.2
Dona	166018	42.7	5.9±0.8	3.9±1.0	9.8	24.8±7.0	14.2±4.6	51.2±8.5	65.4	1:3.6
Donskoj 166	166019	42.8	5.3±1.2	3.7±1.3	9.0	23.9±9.2	15.1±3.0	52.0±10.3	67.1	1:3.4
Dorst-F6	166020	40.7	4.5±0.1	3.0±0.2	7.5	23.8±2.8	13.2±1.1	55.5±2.7	68.7	1:4.2
Dufferin	166021	42.1	6.0±0.5	4.3±0.6	10.3	20.9±5.1	13.4±1.6	55.3±5.9	68.7	1:4.1
E2-E3	166022	41.7	5.6±1.1	3.9±0.8	9.5	22.9±6.3	13.1±2.6	54.6±6.0	67.7	1:4.2
Eckendorfer 338/44	166023	42.4	4.9±0.5	4.7±1.6	9.6	25.2±10.1	15.9±1.8	49.3±10.6	65.2	1:3.1
Endres	166024	42.1	5.3±1.7	4.1±1.5	9.4	25.3±6.1	13.4±3.3	52.0±4.6	65.4	1:3.9
Endres kreu.	166025	43.0	5.9±0.9	4.2±1.9	10.1	22.1±4.4	12.4±2.6	55.4±4.7	67.8	**1:4.5**
Endres olejný	166026	40.8	5.7±0.7	4.4±1.6	10.1	25.2±10.8	15.5±2.4	49.2±12.6	64.7	1:3.2
Entre Rios 15445	166027	43.0	5.6±0.4	3.7±0.6	9.3	20.8±7.4	16.8±4.1	53.1±11.2	69.9	1:3.2
Esterházi 822	166028	43.2	5.7±0.2	4.3±2.2	10.0	23.4±6.8	13.9±2.8	52.6±9.9	66.5	1:3.8
Comun del Peru 1.5	166029	41.0	4.6±0.5	2.8±0.6	7.4	22.2±6.1	14.9±1.8	55.5±4.8	70.4	1:3.7
Flandes M.A.G.	166030	40.5	4.5±1.3	3.7±1.2	8.2	20.7±8.3	16.0±3.0	55.1±7.4	71.1	1:3.4
J.Lord	166031	40.9	**4.2**±0.9	3.0±0.7	**7.2**	22.4±4.8	15.3±4.4	55.1±4.5	70.4	1:3.6
K-6905	166032	41.0	5.0±0.6	2.9±0.5	7.9	23.5±3.5	15.6±3.1	53.0±3.5	68.6	1:3.4
Pale Blue	166033	41.3	4.4±0.2	2.8±0.4	**7.2**	23.7±3.7	14.3±3.1	54.8±5.3	69.1	1:3.8
Pieczerskij Kriarz	166034	41.4	4.8±0.7	3.3±0.6	8.1	24.1±7.3	15.0±4.4	52.9±9.6	67.9	1:3.5
Parchowskij Kriarz	166035	41.7	5.8±1.1	3.3±1.3	9.1	23.9±1.6	14.2±2.5	52.8±1.7	67.0	1:3.7
Pergamino Puelche	166036	43.2	5.6±1.2	3.4±2.1	9.0	22.7±9.4	14.9±4.3	53.5±8.8	68.4	1:3.6
Redwood 65	166037	42.7	5.8±0.5	3.0±1.6	8.8	19.0±5.9	14.2±3.7	58.0±5.0	72.2	1:4.1
Record	166038	41.7	5.9±0.5	**2.6**±0.3	8.5	26.2±8.6	15.0±1.1	50.3±8.7	65.3	1:3.4
Swietocz	166039	40.1	4.8±0.4	**5.1**±3.4	99	22.0±6.3	16.8±4.4	51.3±4.6	68.1	1:3.1
Scheyenne	166040	42.0	4.9±0.4	3.5±1.5	8.4	21.5±3.1	14.6±5.9	55.5±10.2	70.1	1:3.8
Tourneur	166041	41.8	5.0±0.4	3.1±0.5	8.1	21.6±3.5	15.3±2.0	55.0±5.2	70.3	1:3.6
Texbiles 7052	166042	40.9	5.1±1.1	3.4±1.4	8.5	26.1±12.8	11.9±4.8	53.6±9.6	65.5	**1:4.5**
Torżowskij 3	166043	40.8	5.0±0.6	4.2±1.8	9.2	21.4±7.6	15.1±3.3	54.3±3.3	69.4	1:3.6
Min		**39.8**	**4.2**	**2.6**	**7.2**	**17.0**	**10.3**	**48.4**	**62.0**	**1:2.8**
Max		**44.8**	**6.6**	**5.1**	**11.0**	**26.7**	**17.3**	**58.9**	**74.7**	**1:4.5**
Mean		**42.2**	**5.5**	**3.5**	**9.1**	**22.8**	**14.6**	**53.6**	**68.1**	**1:4.1**

Table 4. Characterization of the content of fatty acids in seeds from the collection of 84 genetic resources of flax (*Linum usitatissimum* L.), according Nôžková descriptors

Accename	Coolnumb	Saturated fatty acids		Monounsaturated fatty acid	Polyunsaturated fatty acids	
		Palmitic acid C16:0 [%]	Stearic acid C18:0 [%]	Oleic acid C18:1 n-9 [%]	Linoleic acid C18:2 n-6 [%]	α-Linolenic acid C 18:3 n-3 [%]
AL-1200	165960	medium	medium	low	very low	very high
AL-CII-2	165961	medium	medium	medium	very low	high
AL-CII-6	165962	medium	medium	medium	very low	high
AL-CV-3	165963	medium	medium	medium	very low	high
Artikskij 7	165964	medium	medium	medium	very low	high
Attana ZZOB	165965	Low	medium	medium	very low	high
B 5128	165966	medium	medium	medium	very low	high
Bachmalskij 1056	165967	medium	medium	medium	very low	high
Barbarigo	165968	medium	medium	medium	very low	high
Barnaulskij 120	165969	medium	medium	medium	very low	high
Bayerischer Springlein	165970	medium	medium	medium	very low	high
Bela Elek-F-118	165971	medium	medium	medium	very low	high
Baladi C.I. 377–1	165972	medium	medium	medium	very low	high
Benvenuto Real	165973	medium	medium	medium	very low	high
Betta 88	165974	medium	medium	medium	very low	high
Betta 200	165975	medium	medium	medium	very low	high
Bison Boyena C.I.389	165976	medium	medium	medium	very low	high
Bison Can 2100	165977	medium	medium	medium	very low	high
Biwing C.I.917	165978	medium	medium	high	very low	high
Blaawe Ster	165979	medium	medium	medium	very low	high
Blenda-44205	165980	Low	medium	medium	very low	high
Bolley Golden	165981	medium	medium	medium	very low	high
Börgen	165982	medium	medium	medium	very low	high
Buck 113	165983	medium	medium	medium	very low	high
Buck 114/7245	165984	medium	medium	medium	very low	high
Buck 2/34	165985	medium	medium	medium	very low	high
Buck 3/34	165986	medium	medium	medium	very low	high
Calar C.I.464	165987	medium	medium	medium	very low	high
Can 2612-A	165988	medium	medium	medium	very low	high
Can 2763-A	165989	medium	medium	medium	very low	high
Can 2900-C	165990	medium	medium	medium	very low	high
Can 3011-B	165991	medium	medium	medium	very low	high
Capace	165992	Low	medium	medium	very low	high
Cascade CAN 36	165993	medium	high	medium	very low	high
C.I.481-Winona	165994	medium	medium	medium	very low	high
Welsh C.I.645	165995	medium	high	medium	very low	high
C.I. 917	165996	medium	medium	medium	very low	high
Victory C.I.1045	165997	medium	medium	low	very low	very high
C.I.1128	165998	medium	medium	low	very low	high
C.I.1155	165999	medium	medium	medium	very low	very high
C.I.1247	166000	medium	medium	medium	very low	high
C.I.1235	166001	medium	high	medium	very low	high
C.I.2543	166002	medium	medium	low	very low	very high

Accename	Coolnumb	Saturated fatty acids		Monounsaturated fatty acid	Polyunsaturated fatty acids	
		Palmitic acid C16:0 [%]	Stearic acid C18:0 [%]	Oleic acid C18:1 n-9 [%]	Linoleic acid C18:2 n-6 [%]	α-Linolenic acid C 18:3 n-3 [%]
Colonel Brandhaun	166003	Low	medium	medium	very low	high
Combras	166004	medium	high	medium	very low	high
Conceicao	166005	medium	medium	medium	very low	high
Cresus	166006	medium	medium	medium	very low	high
Crystal C.I.982	166007	medium	medium	medium	very low	high
Csikmindszenti	166008	medium	medium	medium	very low	high
Csikszentkirályi kékvirágu	166009	medium	medium	medium	very low	high
Csóhai	166010	medium	medium	medium	very low	high
Dacota 496	166011	medium	medium	medium	very low	high
Dacota 36174	166012	medium	medium	medium	very low	high
Daros	166013	Low	medium	medium	very low	high
Davis	166014	Low	medium	medium	very low	high
Diadem	166015	medium	medium	medium	very low	high
Ditrói	166016	Low	medium	medium	very low	high
Domaniński výnosnýj	166017	medium	medium	high	very low	high
Dona	166018	medium	medium	medium	very low	high
Donskoj 166	166019	medium	medium	medium	very low	high
Dorst-F6	166020	medium	medium	medium	very low	high
Dufferin	166021	medium	high	medium	very low	high
E2-E3	166022	medium	medium	medium	very low	high
Eckendorfer 338/44	166023	medium	high	medium	very low	high
Endres	166024	medium	medium	medium	very low	high
Endres kreu.	166025	medium	medium	medium	very low	high
Endres olejný	166026	medium	high	medium	very low	high
Entre Rios 15445	166027	medium	medium	medium	very low	high
Esterházi 822	166028	medium	high	medium	very low	high
Comun del Peru 1.5	166029	Low	medium	medium	very low	high
Flandes M.A.G.	166030	Low	medium	medium	very low	high
J.Lord	166031	Low	medium	medium	very low	high
K-6905	166032	Low	medium	medium	very low	high
Pale Blue	166033	Low	medium	medium	very low	high
Pieczerskij Kriarz	166034	Low	medium	medium	very low	high
Parchowskij Kriarz	166035	medium	medium	medium	very low	high
Pergamino Puelche	166036	medium	medium	medium	very low	high
Redwood 65	166037	medium	medium	low	very low	high
Record	166038	medium	low	medium	very low	high
Swietocz	166039	Low	high	medium	very low	high
Scheyenne	166040	Low	medium	medium	very low	high
Tourneur	166041	Low	medium	medium	very low	high
Texbiles 7052	166042	Low	medium	medium	very low	high
Torżowskij 3	166043	Low	medium	medium	very low	high

Table 5. Range of variation and coefficient of variability of 5 fatty acids for linseed, fibre, combined and unknown type of flax (*Linum usitatissimum* L.)

Type	*Mean*	*Range of variation*	*Coefficient of variability*
Palmitic acid $C_{16:0}$			
Linseed	5.6	3.8–6.8	8.9
Fiber	5.4	3.9–7.4	11.1
Combined	5.,4	4.5–6.1	9.3
Unknown	5.4	3.6–6.3	9.3
F computational	4.8*		
Stearic acid $C_{18:0}$			
Linseed	3.6	2.2–5.9	22.2
Fiber	3.5	2.3–6.1	22.9
Combined	3.4	2.4–5.3	26.5
Unknown	3.5	2.4–5.1	17.1
F computational	0,7		
Oleic acid $C_{18:1}$			
Linseed	22.9	15.6–35.7	14.8
Fiber	22.2	15.5–30.8	13.9
Combined	22.9	19.3–31.0	14.0
Unknown	23.1	16.3–33.6	14.7
F computational	1,3		
Linoleic acid $C_{18:2}$			
Linseed	14.2	9.7–18.7	11.9
Fiber	14.9	11.2–19.8	10.1
Combined	15,8	12.5–18.4	8.2
Unknown	14,8	6.4–21.0	12.1
F computational	8,0**		
Linolenic acid $C_{18:3}$			
Linseed	53.7	42.4–61.3	6.7
Fiber	54.0	45.1–62.8	5.9
Combined	52.5	43.4–59.2	6.9
Unknown	53.2	40.4–61.4	7.3
F computational	1,3		
Oil content %			
Linseed	42.40	40.70–44.78	2.11
Fiber	42.06	39.81–44,24	2.84
Combined	42.38	41.89–42.81	0.88
Unknown	42,04	40.10–43.46	2.22
F cal.	0.89		

F computational * significant at level α ≤0.05 ** significant at level α ≤0.01

than linoleic from 2.8 – 4.5 times (n-6 : n-3 ratio is 1 : 2.8 – 1 : 4.5 (Tab. 3). In *Camelina sativa* L. seeds the content of α-linolenic acid content is higher than the content of linoleic acid from 1.57 [40] – 2.8 times (n-6 : n-3 ratio: 1 : 1.57 [40] – 1 : 2.8 [43]. Alfa-linolenic acid content ranged from 33% – 38.8% in seed oil from *Camelina sativa* L., and linoleic acid content varied between 13.8% – 21%. There are only flax seed oil and oil extracted from raspberry seeds on the list of bioactive compounds characteristic for plant oils [43] which are sources of α-linolenic acid. The following nutrients are rich in linoleic acid from the omega-6 family: afflower *Carthamus tinctorius* L., grape seed *Vitis vinifera* L., hemp *Cannabis sativa* L., corn *Zea mays* L., wheat germ, cotton seed, and soybean *Glycine* L [41,42]. In the oils listed below, the content of n-6 fatty acids (linoleic) exceeds the content of fatty acids from the omega-3 family (α-linolenic), as indicated by the ratio n-6 : n-3, the following number of times: in oil from *Rosa canina* L. – 1.4 times (1.4 : 1), in oil from rape seeds (*Brassica napus* L.) – 2.1 times (2.1 : 1), in oil from walnut – 5 times (5 : 1), in soybean oil – 9.4 times (9.4 : 1), in avocado oil – 14.6 times (14.6 : 1), in olive oil – 17.9 times (17.9 : 1), in wheat sprouts oil – 19.2 times (19.2 : 1), in hazelnut oil – 57.1 times (57.1 : 1), in sea buckthorn oil – 61.4 times (61.4 : 1), in sesame oil – 78 times (78 : 1), in almond oil – 95.4 times (95.4 : 1), in grape seed oil – 115.2 times (115.2 : 1), in sunflower oil – 118.9 times (118.9 : 1), in evening primrose oil – 143.8 times (143.8 : 1), in rice oil – 171.2 times (171.2 : 1) [44]. According to Obiedzińska and Waszkiewicz-Robak [43], the predominance of linoleic acid fatty acid over α-linolenic acid is even higher than results from the Łoźna [44] studies in the following vegetable oils: hazelnuts (n-6 : n-3 – 89 : 1), from sesame seeds (n-6 : n-3 – 113 : 1), grape seed (n-6 : n-3 – 134 : 1), peanuts (n-6 : n-3 – 138 : 1), with evening primrose seeds (n-6 : n- 3 – 239 : 1). In Cannabis sativa L. hemp oil, the α-linolenic acid content is 21.4% and linoleic acid content – 59.6% [45]; therefore, the ratio is in the line with WHO recommendations – n-6/n-3 – 2.8 : 1. The composition of fatty acids ranges depend on the variety, agrometeorological conditions, and also on the test method. Supercritical CO_2 extraction gave a higher average ALA content (60.5%), compared to the soxhlet extraction method (56.7%) [45].

The content of linoleic acid also depends on the maturity of the seeds, e.g. in the sunflower, it clearly increased with maturity [46].

A valuable collection of flax genetic resources has been collected in Poland. Seeds from the collection of genetic resources of flax (*Linum usitatissimum* L.) are the richest food source of the deficient α-linolenic fatty acid diet, because some of them come from their natural habitats while others are from old breeding lines and varieties. The flax accessions gathered mainly by the Institute of Natural Fibers (now Institute of Natural Fibres and Medicinal Plants) could achieve lower yields, but the quality of seeds is the highest due to the natural composition of fatty acids in seeds. They are stored in the National Center for Plant Genetic Resources of the IHAR. The most characteristic and most famous for flax is α-linolenic acid.

Due to its chemical structure, α-linolenic acid belongs to the so-called omega-3, which most people associate with marine fish [47].

Alfa-linolenic fatty acid is 18-carbonic and is a precursor of 20-carbonic eicosapentaenoic acid (EPA) and 22-carbonic docosahexaenoic acid (DHA), which are formed by elongation [40]. Jelińska states that long chain n-3 fatty acids are found in marine algae and phytoplankton, which synthetize the fatty acids in huge amounts, and are found later in fish living in cold seas (salmon, tuna, herring, mackerel and sardine) or warm seas [48]. Currently, another Nord Stream 2 pipeline is being built, which is not conducive to food security.

Jelińska reports that the reason for the ratio of n-6 : n-3 of 20–30 : 1 in the diet is the limit of fish consumption, and industrial production of animal feeds rich in seeds containing n-6 acids, which leads to obtaining meat in which n-6 acids dominate, and n-3 acids are present in small amounts [48]. Increased behavior of so-called lifestyle diseases result from the consumption of industrially processed food, which contains very small amounts of omega-3 fatty acids. Such food must have a long shelf life, which is achieved by lowering the α-linolenic acid content and increasing the linoleic content. From the end of the 20th century, flax breeding technologies developed more rapidly [49] and now include hybridization [50], introduced mutation, interspecific hybridization, utilization of male-sterility, ploidy breeding, tissue culture, gene transformation, marker assisted selection, etc. [49]. Lorenc-Kukuła and others report that flax oils with a low α-linolenic acid content are predominantly commercially available [51].

Only the consumption of linseed oil with a high content of α-linolenic acid protects the body against cancer [52]. The German doctor J. Budwig was very successful in the treatment of people with cancer. She developed a special diet, the purpose of which was to deliver α-linolenic acid to the body. It was a paste made of curd and linseed oil with a high content of α-linolenic acid.

Many articles inform about the therapeutic effect of omega-3 polyunsaturated fatty acids and the opposite effects of omega-6 polyunsaturated fatty acids on several diseases, including cardiovascular disorders, diabetes, neurodegenetative diseases and cancer [41]. The effect of protection against cardiological diseases of α-linolenic acid is described Rodriguez-Leyva et al. [53]. ALA (α-linolenic acid) and LA (linoleic acid) acids compete in metabolism with the same enzymes [40]. "Insufficient amount of α-linolenic acid and its derivatives (omega-3) and excess of linoleic acid and its derivatives in the diet favors the formation of tumors, especially breasts, colon and prostate" [48]. The consumption of α-linolenic acid should be about 1 g per day [40]. A diet high in n-6 acids promotes the formation of gallstones and can stimulate cancer processes, especially the breast and pancreas, and change the activity of enzymes and receptors [40]. The first variety of flax, which has the so-called inverted fatty acid composition, i.e. it has a very high content of linoleic acid and a small α-linolenic acid in seed oil, was Linola bred in Canada in 1994 [54, 55, 56]. Alpha-linolenic acid content in low ALA genotypes ranged from 1.10% – 6.60% [57]. High content of linoleic acid are typical for varieties with low content of α-linolenic acid [57]. Matławska and Bylka inform why the consumption of linoleic acid should not to be too large [37]. The linoleic acid family – omega-6 consists of the following acids: linoleic (LA), γ – linolenic acid (GLA), dihomo – γ – linolenic acid (DGLA), arachidonic acid (AA) [37]. Linoleic acid is transformed into GLA [37] which can be converted either to DGLA acid or to AA acid. The transformation of GLA to DGLA is beneficial to health [37], whereas the transformation of GLA to AA is not beneficial [37]. However, if there is too much linoleic acid in the diet, it is transformed into GLA and GLA to AA [37], which undergoes metabolic transformation into prostaglandin PGE1, a substrate for the pro-inflammatory eicosanoids: prostaglandins E2 and leukotriene B4 [37].

Flax seeds of 84 genotypes contain from 48.4% to 58.9% α-linolenic fatty acid in oil seed which makes them an excellent nutrient. It should be systematically eaten, preferably every day, linseed with a high content of α-linolenic acid or flaxseed oil from such seeds. This can increase the level of EPA and DHA in the tissues and at the same time lower the AA content [48]. EPA and DHA replaces AA in the lipids of tissues, serum and membrane of platelets of blood [48].

Due to the progressing pollution of the seas and oceans, marine fish that provide long-chain unsaturated fatty acids are not often bought and eaten, which is one of the reasons for the lack of omega-3 fatty acids in the diet [53]. An additional argument of eating flax seeds is that no erucic acid was found in them [39, 58]. Alpha-linolenic acid increases the absorption of long chain-polyunsaturated fatty acid, especially EPA and DHA and decreases the risk of several diseases [59]. As part of the long-term program on the conservation of genetic resources of flax, the public is informed about the pro-health significance of seeds from the *Linum usitatissimum* L. collection [32, 60, 61].

Among the evaluated 84 accessions of flax 80 genotypes (95.2%) are characterized by a high α-linolenic acid content in oil seed, varied from 48.4% (Can 2612-A – 165988) to 58.0% (Redwood 65-166037) and 4 of them are characterized by a very high α-linolenic acid content varied from 57.3 (C.I. 1128 – 165998 to 58.6 (Victory C.I. 1045 – 165997; C.I. 1155 – 165999). According to Nôžková [25] the high content of α-linolenic acid have genotypes which contains from 44.7% to 58.0 % of this acid and very high ones that contain more than 50% of this acid (Tab. 2). These genotypes can be used to breed new varieties, from which cold pressed linseed oil would be very beneficial to health functional food [57].

As a result of the conducted chemical analyses, it was found that the seeds from the collection of genetic resources of flax (*Linum usitatissimum* L.) are a very valuable source of α-linolenic fatty acid, the deficiency of which in the diet is currently a very serious problem of civilization.

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