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Flax Seeds–Source of Biomedical and Food Products

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Flax is a very important fibrous bast plant, both for valuable textile fibres and composites applications and for bioactive compounds used in folk medicine, nutraceuticals and functional food. Flax seeds are rich in valuable fatty acids, amino-acids, phytoestrogens, cyclolinopeptides, lecithin, waxes, lignin, pectin, mucilage, etc. ω-3 and ω-6 polyunsaturated fatty acids (PUFA) are effective preventing cardiovascular and heart diseases. Flax-seeds lignans, class of phytoestrogens with beneficial impact in treating hormone dependent diseases, have been investigated for anticancer, antibacterial and antioxidant properties.Flax-seeds mucilage is recommended for treating gastrointestinal, throat and skin diseases due to its protective, laxative and emollient properties.

Keywords Flax seeds; unsaturated fatty acids; lignans; mucilage; cyclolinopeptides

Introduction

Linum usitatissimum–the scientific name for flax, usitatissimum meaning in Latin most useful, is a worthy name for this plant used along history for food, fiber and many other purposes. Flax has been known for thousands years as herb for medical and cosmetic purposes. After mixing flax seed oil with sesame oil and olive oil ancient Egyptians created a soothing and rejuvenating balm for skin and hair. Flax seed oil has been applied in treatment of scalds, frostbites and care of dry, scaling skin with tendency for splitting. Nowadays, bast plant fibers are still of great interest for various eco-friendly applications such as bio-composite reinforcement and natural fabrics [1, 2]

Consumed by human as food for thousands of years, flax seeds have high nutrient value. Both basic flax seed varieties: brown and yellow or golden have similar nutritional

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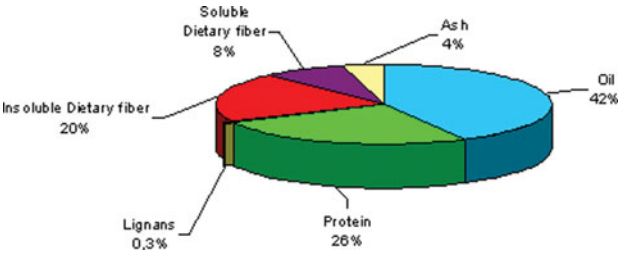

Figure 1. Nutritive components of flax seed.

characteristics. Flax seed oil represents ~42%, protein about 26% and dietary fibre about 28% [3]. The content of major nutritive components of flax seeds is presented in Fig. 1.

Chemical composition of flax seed is abundant in agro-fine chemicals like polyunsaturated ω-3 fatty acids (alpha linolenic) and ω-6 fatty acids (linoleic), valuable amino acids, mucilage, polyphenols including lignans (phytoestrogens), cyclolinopeptides, natural waxes, vitamins (A, B, E) minerals and squalene, recommending flax seeds for applications in pharmaceuticals, dietetic products and cosmetics.

The origin and biosynthetic pathways of various plant metabolites can be observed in Fig. 2.

Also, the defatted flax-seeds cake is a valuable ingredient for food and fodder, and lately a raw material for obtaining lignans [5] and polyphenolic extracts, that are very interesting due to their antibacterial and antioxidant properties [5, 6] (Fig. 3).

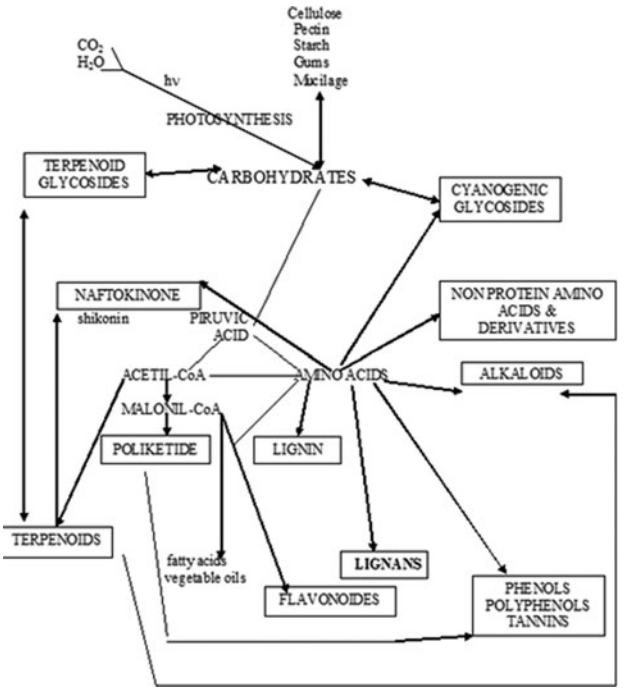

Figure 2. Origin and biosynthetic pathways of various plant metabolites (adapted after Balandrin & Flocke, 1988) [4].

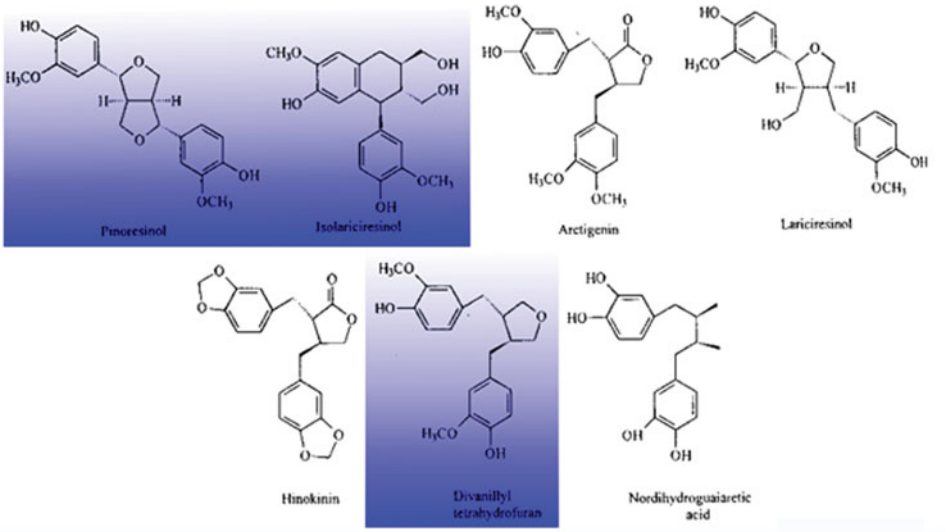

Figure 3. Structure of flax seed lignans.

Table 1. Edible sources of lignans

Source	The lignan content lignani (μg/100 g fresh weight)	Major lignan	Reference
Flax seed	301129–370987	Secoisolariciresinol	[12, 13]
Rye	10377	Syringaresinol	[14]
Wheat	7548	7-hydroxymatairesinol	[14]
Broccoli	1325	Lariciresinol	[12]
Strawberry	334–1578	Pinoresinol, secoisolariciresinol	[12]
Barley	1071	7-hydroxymatairesinol	[14]
Com	1049	7-hydroxymatairesinol	[14]
Sunflower seed	891	Sesamin	[14]
Green bean	273	Lariciresinol	[12]
Soy flower	130	Secoisolariciresinol	[18]
Bell peper (red)	113	Lariciresinol	[12]
Orange	78	Lariciresinol	[12]
Tea (English blend)	71	Pinoresinol	[12]
Roşie	58	Lariciresinol	[12]
Pea (jar)	34	Pinoresinol	[12]
Brown bean (jar)	26	Lariciresinol	[12]
Potato (boiled)	20	Lariciresinol	[12]
Coffee (brewed)	19	Secoisolariciresinol, lariciresinol	[12]
Lettuce (iceberg)	11	Secoisolariciresinol	[12]
Apple (Elstar)	1	Lariciresinol	[12]

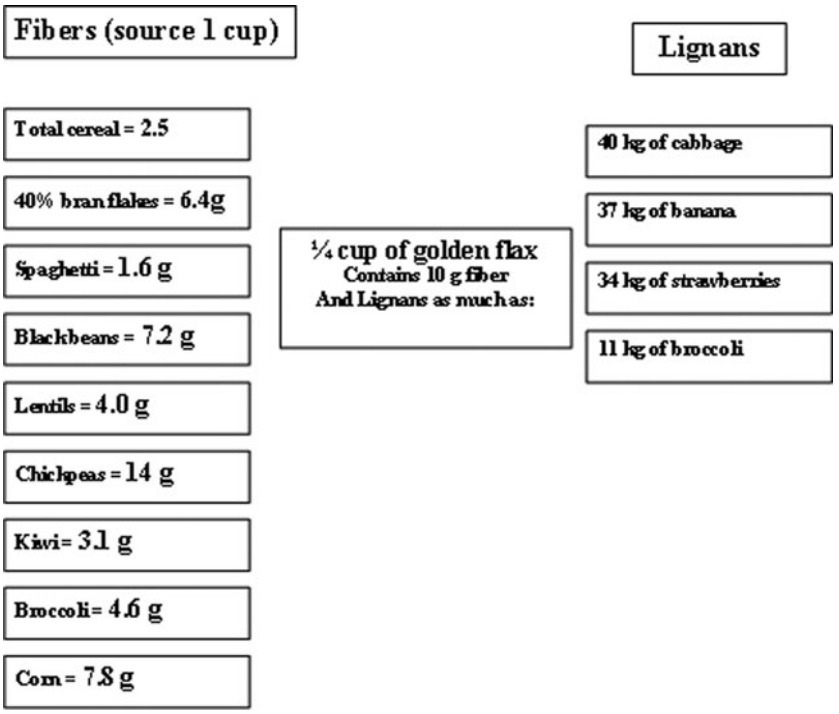

Figure 4. Comparing edible sources of lignans and dietary fibre (adapted after Mazur et al., 1996) [17].

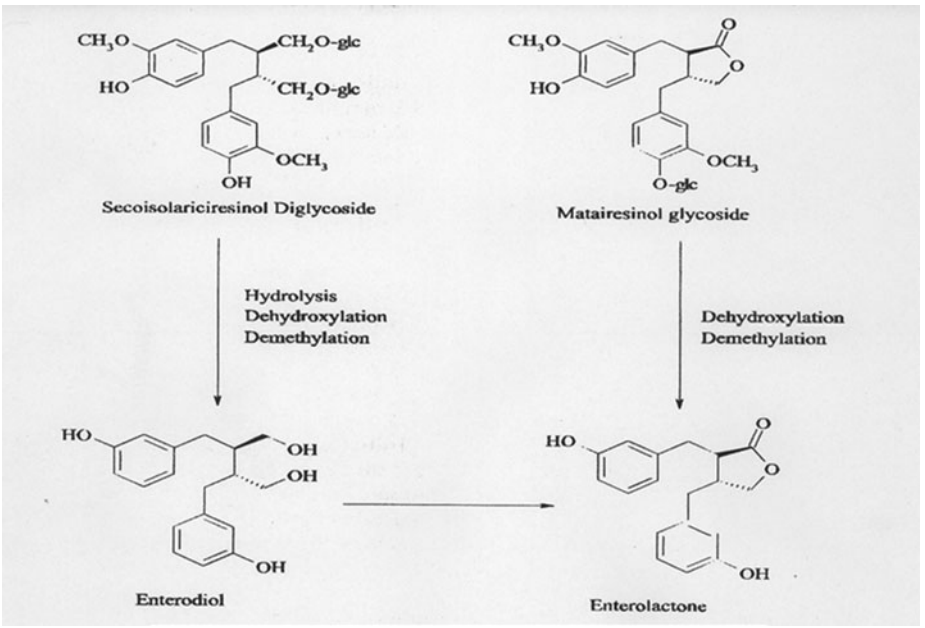

Figure 5. Lignans as precursors of mammalian hormones.

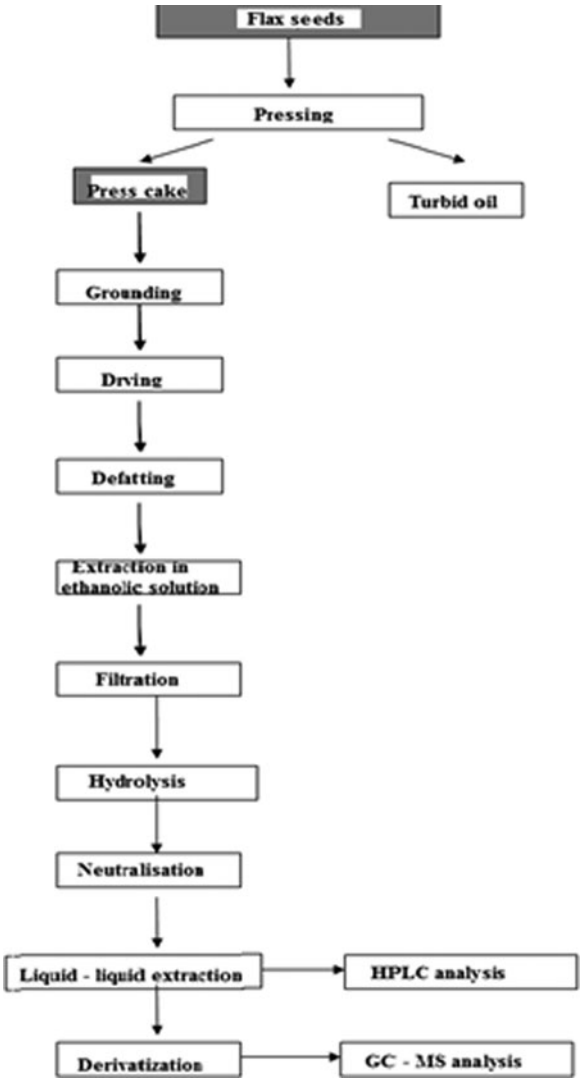

Figure 6. General scheme for extracting and analyzing lignans.

Flax-seeds 8-8'linked lignans are secondary plant metabolites developed from flavonoids precursor via phenyl-propanoid pathway, providing resistance to plants against pathogens [7, 8]. They are extensively investigated for their biological roles as antiviral, antibacterial, antifungal, antioxidant and antiestrogenic agents preventing the onset of hormone-related cancers [9–11].

Lignans, defined as compounds possessing a 2,3 dibenzylbutan structure, include matairesinol, secoisolariciresinol, lariciresinol, isolariciresinol, pinoresinol, olivil and other compounds, including diglucosides, are widely distributed throughout the plant kingdom [16]. Nevertheless, as can be seen from Table 1, flax seeds are the richest edible source of lignans [12].

Table 2. Essential amino acids composition of defatted flax seed (Thompson and Cunnane, 1995) [31]

Amino acid (g/100 g protein)	Flax seed	Rat requirement
Arginine	11.8	5.0
Histidine	2.9	2.5
Isoleucine	5.2	4.6
Leucine	6.8	6.2
Lysine	4.1	7.5
Methionine and cystine	6.0	5.0
Phenylalnineand tyrosine	8.2	6.7
Threonine	4.9	4.2
Tryptophan	1.8	1.2
Valine	5.6	5.0

Also, in Fig. 4 there is a suggestive comparison between the content of dietary fibres and lignans of different plants versus golden flax seeds.

The lignans structure as very important agro-fine chemicals from flax seeds and precursors of mammalian hormones is presented in Fig. 5 [18].

Recently, a lot of researchers signalise and confirm important and diverse curative properties of flax seed lignans: anti carcinogenic against estrogens dependent tumours, antibacterial, antifungal, antiviral, anti diabetic, lowers the risk of arteriosclerosis and relieves menopause symptoms [19, 20].

The procedure for extracting lignan from flax seed or flax seed cake and purifying the extract should be established depending on the analysis method we will use. Generally, lignans are extracted from defatted flaxseeds or defatted flax seed cake [5, 21–24].

Fat removing step is conducted using a non-polar organic solvent like n-hexane, dichloromethane or petroleum ether. Lignans extraction could be achieved using an alcoholic-water mixture, followed by an acidic, alkaline or enzymatic hydrolysis.

In order to analyse flaxseeds lignans one can choose to use GC-MS, HPLC, TLC and HPLC-MS.

Table 3. The composition in fatty acids of various oils

	Composition of fatty acids [% of fat]						
				Linolic			
Plant oils	Palmit 16:0	Stearic 18:0	Oleic 18:1	18:2 ω 6	α-linolenic 18:3 ω 3	γ-linoleic 18:3 ω 6	Stearidonic 184 ω 3
Hemp	−10	4–10	6–16	46–60	15–28	1–6	0–2
Flax	−8	1–4	15–30	10–30	0–68	—	—
Soybean	2–10	2–6	23–32	48–52	2–12	—	—
Sunflower	3–9	1–3	14–43	44–70	—	—	—
Olives	—	1–3	60–85	4–15	—	—	—
Palm	∼41	∼5	∼31	—	—	∼11	—

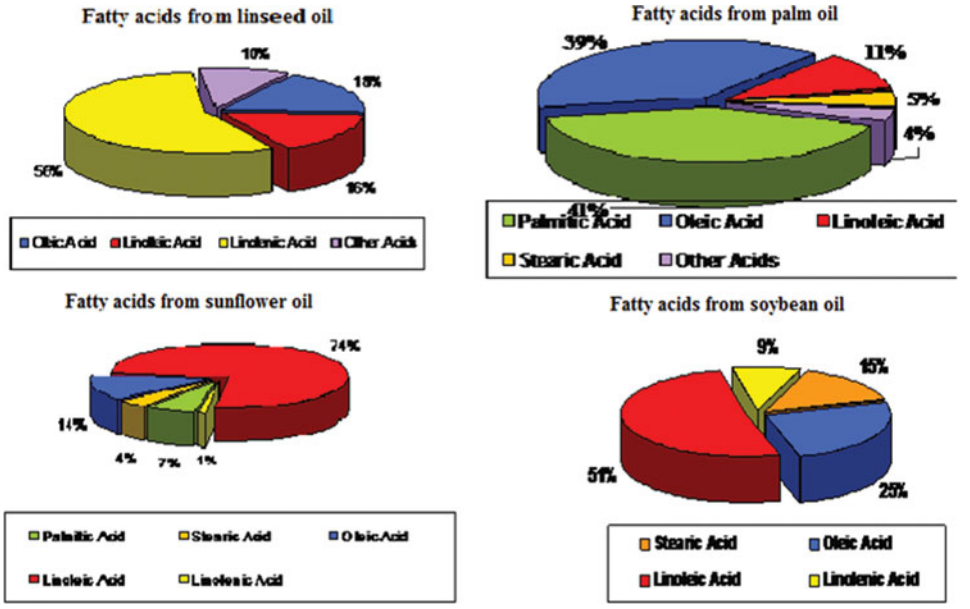

Figure 7. Comparison of some vegetable oils composition.

A general scheme of lignan extraction from flaxseed is presented in Fig. 6.

Protein found in flax seeds has significance to vegetarians relying on plant resources to meet their daily protein requirements, because of the numerous essential amino acids. Major storage protein of flax seeds are linin (11–12 S) and conlinin (2 S) those having molecular masses of 252–298 kDa and 16–17 kDa, respectively [25, 26]. Upon enzymatic hydrolysis flax-seeds protein generate bioactive peptides that potentially regulate blood pressure and lower cholesterol level [27, 28].

The main areas of application of flax-seeds protein are: as a stabilizing additive to food products such as: meat products, canned fish, ice cream and jellies; as an emulgator–an addition of protein flax seed extract to food enables to reach cream consistency of product and to eliminate unwanted flavours [29, 30].

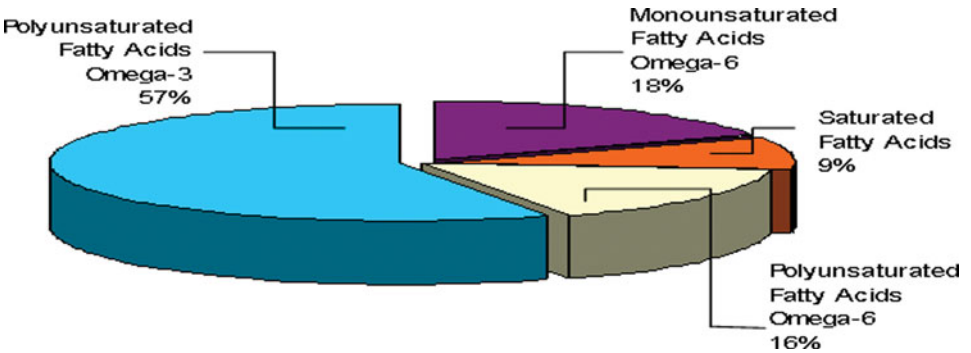

Figure 8. Fatty acid composition of flax seed oil low linolenic type–Linola® (Dribnenki et al, 2004) [32].

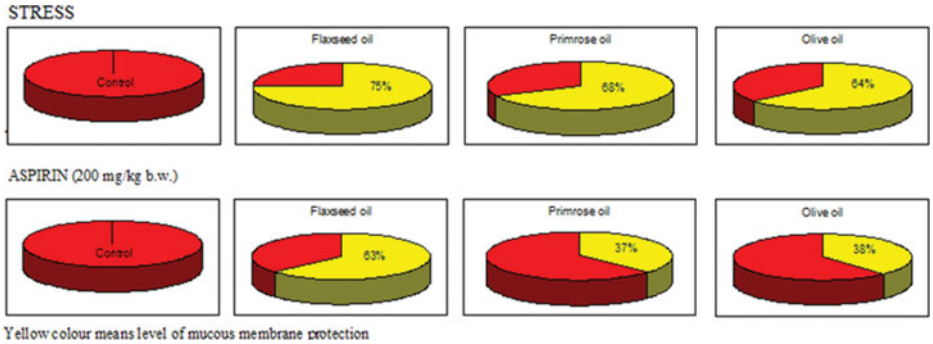

Figure 9. Gastro protective effect of flax seed oil in comparison to primrose and olive oil.

In Table 2 essential amino acids composition of flax seeds is presented.

In Table 3 the fatty acids from different oils are presented. Oils from flax seeds have the healthiest balance of fatty acids with low level of saturated fatty acids and are a source of $\omega 3$ and $\omega 6$ fatty acids.

Therapeutic properties of flax seeds are manifested against: cardiovascular and heart diseases, high level of serum cholesterol, different types of cancer, diabetes, nervous system diseases and brain malfunction, alimentary tract diseases such as ulcers, burns, constipation, throat diseases and bronchitis, dermal and skin diseases, menopausal symptoms [9, 33–35].

Gastro protective effect of flax-seeds oil against psychological and chemical stress, in comparison to primrose and olive oil is presented in Fig. 9 and some data about correlation between the doses of alpha linolenic acid in terminally ill patients' diet are presented in Table 4.

Cunnane 1995 established a correlation between the doses of alpha -linolenic acid in terminally ill patients' diet upon a clinical study on around 500 patients [31].

The most important omega-3 fatty acid for humans—and the one most frequently consumed in the average Western diet—is α-linolenic acid (ALA), which contains 18 carbons and three double bonds.

Many plant oils, such as canola, soybean, and flax seeds, contain large quantities of ALA. Our bodies can make a variety of other longer chain omega-3 fatty acids from ALA on a limited basis through condensation reactions via an acetyl-CoA intermediate.

Table 4. Data about correlation between the doses of alpha linolenic acid in terminally ill patients' diet (Cunnane, 1995) [31]

Level of ALA in % energy*	Cardiovascular diseases (CHD)	Cardiovascular diseases (CHD) excluded	Cancer	All analyzed disease cases
0.42	1.00	1.00	1.00	1.00
0.54	0.72	0.86	1.12	0.86
0.63	0.80	0.97	0.72	0.85
0.73	0.61	0.66	0.90	0.75
0.98	0.58	0.66	0.78	0.68

*The average consumption of ALA before the experiment was 1.7 g/d or 10% PUFA LA/ALA = 8/1.

Table 5. Composition of flax mucilage from extracted from 12 yellow and brown flax seed cultivar (after Cui, 2001) [37]

	Composition (%)	
Monosaccharide	Range	Mean
Rhamnose	13–27.2	19
Fucose	3–7.1	4.9
Arabinose	8.7–18.1	13.8
Xylose	21.1–44.4	35.1
Galactose	13.6–28.4	20.4
Glucose	2.6–13.8	6.2
Galacturonic acid	13.9–25.1	19.0

Longer chain omega-3 fatty acids include eicosapentaenoic acid (EPA; 20 carbons and five double bonds) and docosahexaenoic acid (DHA; 22 carbons and six double bonds). Although both EPA and DHA have received the moniker "heart healthy," the majority of health benefits appear to come from DHA. Both of these fatty acids are only found naturally in fatty fish and the algae they consume [36].

Another very important biologically active compound from flax seeds is mucilage. It consists in complex carbohydrates rich in galacturonic acid, differences between composition and rheological properties of dark and yellow flax seed being reported [37].

Flax seeds contains up to 9% of mucilage substances naturally soothing negative influence of irritating factors on mucous membranes of alimentary and respiratory tracts. It is therefore recommended in therapy of alimentary and respiratory tracts diseases or dermatological illnesses where it's covering, laxative, softening and soothing properties are used.

The composition of flax seed mucilage is presented in Table 5, whereas its applications are presented below, in Table 6.

Flax seed mucilage is a stabilizer and leaven for food products, for example it makes a very good substitute for egg protein in ice cream and bakery products, improving the tenacity of pastry, the volume, flavour and consistency of baked products [38].

Several properties make the flax-seeds mucilage a valuable ingredient for cosmetics and pharmaceutical products like: substitute for saliva, mild flavour preparations for sore

Table 6. The influence of flax seed flour addition upon quality of bread [30]

	Level of ground flax seed addition, %							
Technological properties	0	1%	2%	3%	4%	5%	7%	9%
Hygroscopicity of dough [%]	60.0	61.0	62.8	64.0	65.0	66.6	69.4	72.0
Number of bread value [points]	147	135	129	139	159	176	167	168
Coefficient of porosity [points]	95	93	95	93	100	100	98	98
Compressibility after 72 b [%]	63.8	66.8	70.0	69.6	66.4	67.0	65.6	70.4

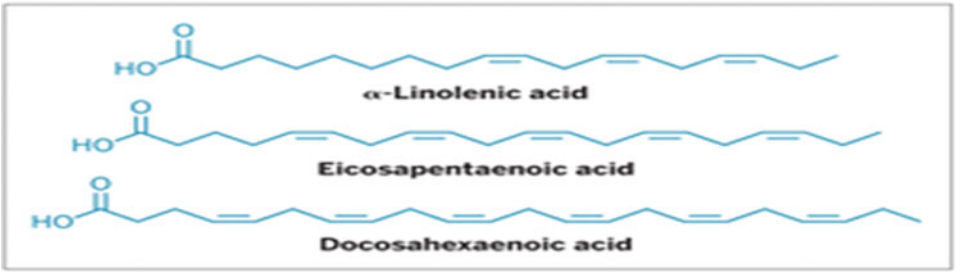

Figure 10. Important omega-3 fatty acids' structure.

throat and oesophagus, preparations for soothing cough, laxative preparations, carrier for oral pharmaceuticals of very moistening properties, ointments, etc. [3].

Both flaxseed and flax-seeds oil sooth skin irritations care about nails and hair preventing crushing and splitting up. Hydrophilic flax mucilage is an excellent coating material, covering and anti-inflammatory, in skin diseases. Due to its very strong hydrophilic properties it proves excellent in contracting and moisturizing skin [3].

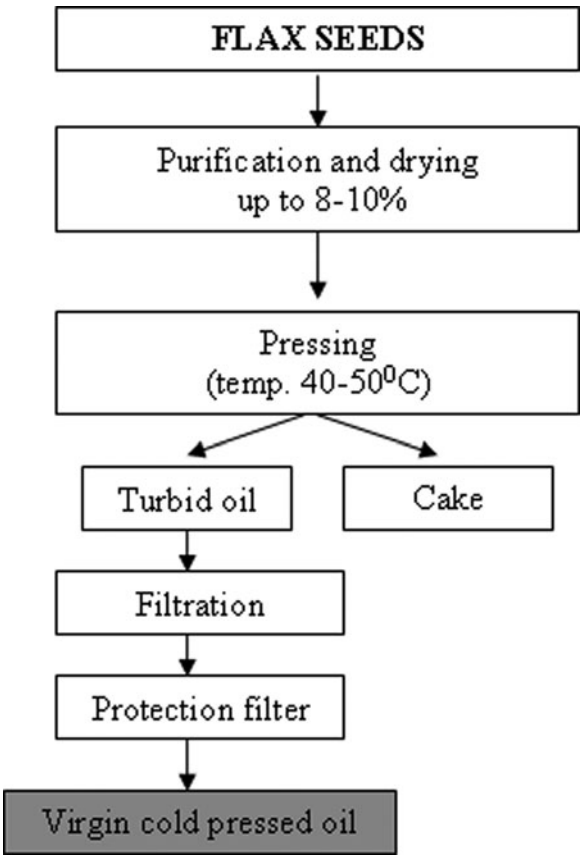

Figure 11. Technological steps to obtain cold pressed flax seed oil.

Table 7. Flax seed–mineral content [43]

Minerals (mg/g)		Minerals (μg/g)	
Sodium	0.6	Zinc	123.2
Potassium	12.1	Iron	207.6
Calcium	4.5	Copper	20
Magnesium	6.1	Manganese	58.5
Phosphorus	9.9		
Sulphur	4.0		

A wide spectrum of minerals like phosphorus, potassium, calcium, magnesium, sulphur and small amount of iron and zinc are present in flax seeds [37, 39, 40, 41]. The last one is a very important component of anandamide a neurotransmitter [42].

Mineral content of flax seed is presented in Table 7.

Another promising class of biologically active chemicals from flax seeds is that of cyclolinopeptides, that can be extracted from capsules of some selected flax cultivars which have flowers of intensively blue to dark blue colour.

The biological activities of cyclolinopeptides are confined to anti-inflammatory, anti-malaria actions and also immunosuppressant treatment in case of organ transplantation [30].

Flax-seeds waxes are mixtures of long chain alcohols C18–C30, aldehydes C24–C30, fatty acids C16–C32, esters of fatty acids with long chain alcohols. These compounds have interesting properties like: agents for plant perspiration control, barrier for pathogens, which make them useful antibacterial coatings and hydrophobic coatings [30].

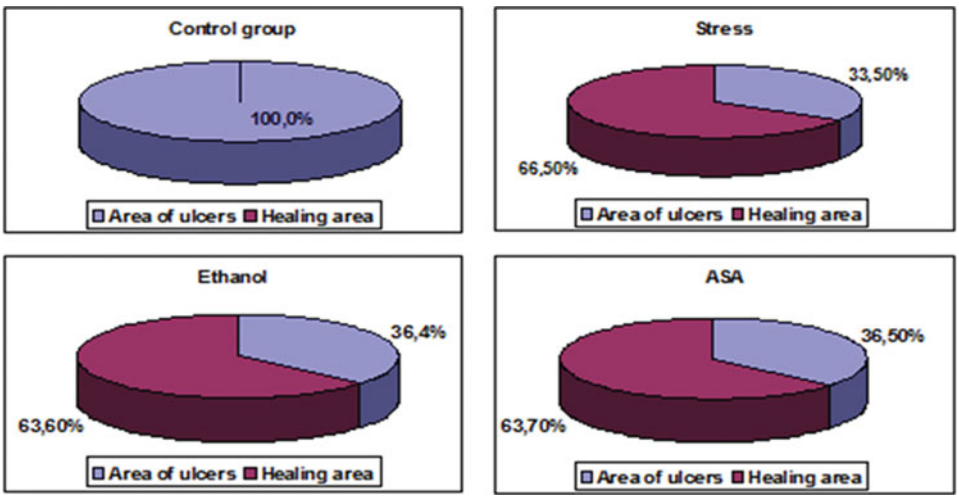

Figure 12. Protective properties of flax seed mucilage usable in preventing and treating stomach and duodenal illnesses.

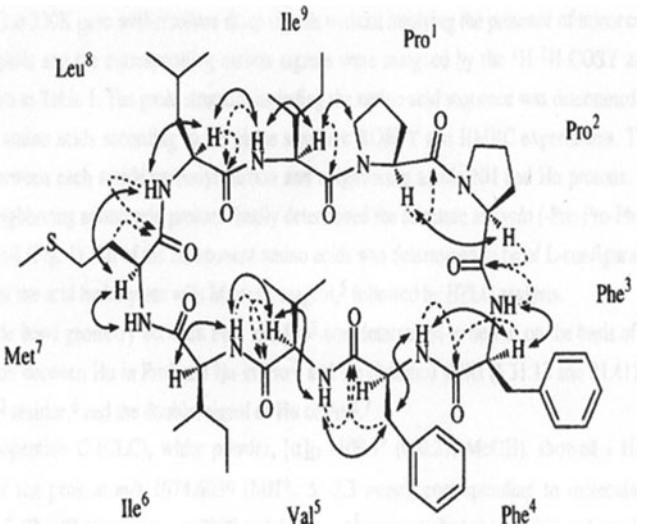

Figure 13. Cyclolinopeptyd B (CLB).

Conclusions

Flax seeds are now subject of sophisticated scientific and medical journals not by chance, or by fading fashion, but because of the abundance of valuable biologically active compounds included in their composition, making them worthy of being called "quintessential functional food".

Processing *Linum usitatissimum* whole plant as renewable resource for textile fibres, valuable edible oils and various agro–fine–chemicals makes flax not only one of the foundation crops of humankind but also the "bio-economy crop" of the 21st century.

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