Chapter 1

Description and Composition of Flax

Understanding the composition of flax helps in recognizing its value in a healthy diet. The physical descriptors of flax or linseed, as it is sometimes called, distinguish it from other major oilseeds such as canola and sunflower. The following discussion provides a basis for considering the health benefits of flax.

Description

The botanical name of flax, *Linum usitatissimum* of the family Linaceae, recognizes its usefulness for a variety of purposes, not only as a food source. Flax is a versatile, blue-flowered crop. The seeds for food and feed uses are harvested and then sieved through fine mesh screens, resulting in a clean, uniform batch of whole seeds (considered 99.9% pure).

The seed itself is flat and oval with a pointed tip. It is a little larger than a sesame seed and measures about 2.5 x 5.0 x 1.5 mm (3). The seeds have a crisp and chewy texture and a pleasant, nutty taste (4).

Flax seeds range in colour from medium, reddish-brown to a light yellow (3). Seed colour is determined by the amount of pigment in the outer seed coat – the more pigment, the darker the seed. Seed colour is easily modified through simple plant breeding techniques.

Brown-seeded flax, which is rich in alpha-linolenic acid (ALA), an omega-3 fatty acid, is the most common flax grown in Canada. Yellow-seeded flax is one of two types. One type, a U.S.-developed variety

named Omega, is as rich in ALA as brown flax. The second is an entirely different flax called solin, which is low in ALA. Solin was developed for the cooking oil market. While brown and Omega flax are sold in health food stores and over the Internet, solin varieties are not sold directly to consumers. In Canada, solin is required to have a yellow seed coat to make it easier for growers and handlers to keep it apart from brown flax seeds at all stages of handling.

The terms "flaxseed" and "linseed" are often used interchangeably, although North Americans use "flaxseed" to describe flax when it is eaten by humans and "linseed" to describe flax when it is used for industrial purposes, such as linoleum flooring. In Europe, the term "flaxseed" describes the varieties grown for making linen.

Flax varieties grown for human consumption are different from flax varieties grown to produce fibre for making linen (5). All flax varieties grown for human consumption or other purposes were developed using traditional plant breeding methods and do not contain genetically-modified organisms (GMOs).

Composition

Flax is rich in fat, protein and dietary fibre. An analysis of brown Canadian flax averaged 41% fat, 20% protein, 28% total dietary fibre, 7.7% moisture and 3.4% ash, which is the mineral-rich residue left after samples are burned (6). The composition of flax can vary with genetics, growing environment, seed processing and method of analysis (7). The protein content of the seed decreases as the oil content increases (8). The oil content of flax can be altered through traditional plant breeding methods, and it is affected by geography – the cool nights of northern Canada improve oil content and quality. The composition of flax is provided in **Table 1**.

TABLE 1

Proximate composition of flax based on common measures[a]

Form of flax	Weight	Common measure	Energy	Total fat	ALA[b]	Protein	Total CHO[c,d]	Total dietary fibre
	g		kcal	g	g	g	g	g
Proximate analysis	100	–	450	41.0	23.0	20.0	29.0	28.0
Whole seed	180	1 cup	810	74.0	41.0	36.0	52.0	50.0
	11	1 tbsp	50	4.5	2.5	2.2	3.0	3.0
	4	1 tsp	18	1.6	0.9	0.8	1.2	1.1
Ground seed	130	1 cup	585	53.0	30.0	26.0	38.0	36.0
	8	1 tbsp	36	3.3	1.8	1.6	2.3	2.2
	2.7	1 tsp	12	1.1	0.6	0.5	0.8	0.8
Flax oil	100	–	884	100.0	57.0	–	–	–
	14	1 tbsp	124	14.0	8.0	–	–	–
	5	1 tsp	44	5.0	2.8	–	–	–

[a]Based on a proximate analysis conducted by the Canadian Grain Commission (6). The fat content was determined using the American Oil Chemists' Society (AOCS) Official Method Am 2-93. The moisture content was 7.7%.
[b]ALA = Alpha-linolenic acid, the essential omega-3 fatty acid.
[c]CHO = Carbohydrate.
[d]Total Carbohydrate includes carbohydrates like sugars and starches (1 g) and total dietary fibre (28 g) per 100 g flax seeds.

Fatty acids

Flax has historically been valued for its abundance of fat, which provides a unique mix of fatty acids. Fatty acids are organic compounds found in virtually all foods. Refer to **Table 2** for a description of common fatty acids.

TABLE 2

Types of fatty acids found in foods

Fatty acid	Number of double bonds	Saturation	Family name[a]	Formula[b]	Common food sources
stearic acid	0	saturated	–	18:0	most animal fats, chocolate
oleic acid	1	monounsaturated	Omega-9 (ω-9)	18:1n-9 or 18:1ω-9	olive oil, canola oil
palmitoleic acid	1	monounsaturated	Omega-7 (ω-7)	16:1n-7 or 16:1ω-7	beef tallow, lard
linoleic acid	2	polyunsaturated	Omega-6 (ω-6)	18:2n-6 or 18:2ω-6	vegetable oils like sunflower, corn, and safflower oils; meat from grain-fed livestock
alpha-linolenic acid	3	polyunsaturated	Omega-3 (ω-3)	18:3n-3 or 18:3ω-3	flax, flax oil, canola oil, soybean oil, walnuts, small amounts are found in meats like beef and pork and in eggs

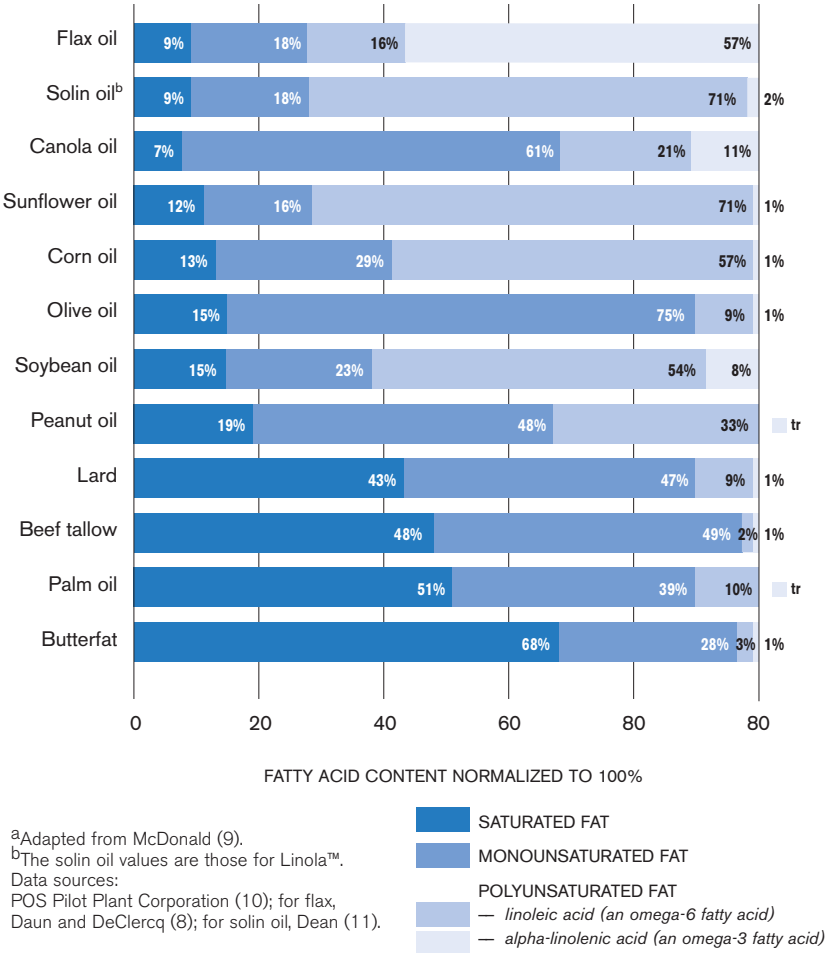
[a]The family name shows the position of the first double bond in the carbon chain or backbone of the fatty acid, marked from the methyl end with either an omega symbol ("ω") or with an "n". Thus, the first double bond in oleic acid occurs at the ninth carbon from the methyl end of the fatty acid.

[b]The fatty acid formula is read as follows: The number to the left of the colon shows the number of carbon atoms in the fatty acid chain. The first number to the right of the colon shows the number of double bonds in the carbon chain. The last three digits on the right show the family name. The formula for alpha-linolenic acid is 18:3n-3 or 18:3ω-3, meaning that it contains 18 carbons, has three double bonds and belongs to the omega-3 family.

Flax contains a mixture of fatty acids (see **Figure 1**). It is rich in polyunsaturated fatty acids, particularly alpha-linolenic acid (ALA or LNA, as it is sometimes abbreviated), the essential omega-3 fatty acid, and linoleic acid (LA), the essential omega-6 fatty acid. These two polyunsaturated fatty acids are essential for humans – that is, they must be obtained from the fats and oils in foods because our bodies cannot make them.

FIGURE 1

Comparison of saturated and unsaturated fatty acids in dietary fats and oils[a]



[a]Adapted from McDonald (9).
[b]The solin oil values are those for Linola™.
Data sources:
POS Pilot Plant Corporation (10); for flax, Daun and DeClercq (8); for solin oil, Dean (11).

In Figure 1, the fatty acid composition of flax oil is compared with other fats and oils (8,9,10,11). ALA constitutes 57% of the total fatty acids in flax, making flax the richest source of ALA in the North American diet. Linoleic acid constitutes 16% of total fatty acids. Flax oil and canola oil have the lowest levels of the nutritionally undesirable saturated fatty acids. The level of the desirable monounsaturates in flax oil is modest.

Solin oil is low in the essential omega-3 fatty acid, ALA. Solin oil was developed by plant breeders in Australia and Canada, who modified traditional flax oil to reduce the ALA content from 50–60% to less than 5% (11). Solin oil has a fatty acid profile that is similar to sunflower seed oil, making it a good choice for certain food applications like margarine (12). Other vegetables oils rich in ALA have been modified to lower the ALA content, as shown in **Table 3** (10,13–15).

TABLE 3

Alpha-linolenic acid content of traditional and modified vegetable oils

ALPHA-LINOLENIC ACID AS % OF TOTAL FATTY ACIDS

Traditional oil[a]		*Modified oil*	
Flax oil	57.0	Solin oil	1.9[b]
Canola oil	11.0	Low-linolenic canola oil	2.5[c]
Soybean oil	8.0	Low-linolenic soybean oil	3.7[d]

[a]POS (10).
[b]Kibiuk (14).
[c]Vaisey-Genser et al. (13).
[d]Warner and Mounts (15).

Protein

Amino acids are the building blocks of protein. The amino acid pattern of flax protein is similar to that of soybean protein, which is viewed as one of the most nutritious of the plant proteins. There appears to be little difference in the amino acid content of the proteins from two flax varieties shown in **Table 4**, even though they differ in seed coat colour (16–18). The essential amino acids are identified with an asterisk in Table 4. These are the ones that must be included in the diet because the human body cannot make them.

Gluten

Flax, like other oil seeds, is gluten-free (19). Gluten is a protein found in wheat, oats, barley and rye. The specific agent in gluten that causes the condition known as gluten enteropathy is gliadin, which is rich in the amino acids proline and glutamine. The term "prolamins" (*prol*ine + glut*amine*) describes extracts of gluten. The mechanism by which dietary gluten irritates the mucosal lining of the gastrointestinal tract in susceptible people is not well understood (20). Fortunately, people who are sensitive to gluten can enjoy flax in their diets.

TABLE 4

Amino acid composition of flax

Amino acid	Flax Cultivar[a]		Soy flour[b]
	Brown flax (NorLin)	Yellow flax (Omega)	
	g/100 g protein		
Alanine	4.4	4.5	4.1
Arginine	9.2	9.4	7.3
Aspartic acid	9.3	9.7	11.7
Cystine	1.1	1.1	1.1
Glutamic acid	19.6	19.7	18.6
Glycine	5.8	5.8	4.0
Histidine*	2.2	2.3	2.5
Isoleucine*	4.0	4.0	4.7
Leucine*	5.8	5.9	7.7
Lysine*	4.0	3.9	5.8
Methionine*	1.5	1.4	1.2
Phenylalanine*	4.6	4.7	5.1
Proline	3.5	3.5	5.2
Serine	4.5	4.6	4.9
Threonine*	3.6	3.7	3.6
Tryptophan*[c]	1.8	NR[d]	NR
Tyrosine	2.3	2.3	3.4
Valine*	4.6	4.7	5.2

[a]Oomah and Mazza (17).
[b]Friedman and Levin (18).
[c]Bhatty and Cherdkiatgumchai (mixture of NorLin, NorMan and McGregor cultivars) (16).
[d]NR = Not reported.
*Essential amino acids for humans.

Carbohydrates

Flax is low in carbohydrates (sugars and starches), providing only 1 gram (g) per 100 g (6). For this reason, flax contributes little to total carbohydrate intake.

Dietary fibre

Fibre occurs as structural material in the cell walls of plants. *Dietary fibre* consists of nondigestible plant carbohydrates and other materials that are found intact in plants. *Functional fibre* consists of nondigestible carbohydrates that have been extracted from plants and that have beneficial effects in humans. *Total fibre* is the sum of dietary fibre and functional fibre. Dietary fibre and functional fibre are not digested and absorbed by the human small intestine and, therefore, pass relatively intact into the large intestine (21).

Total fibre accounts for about 28% of the weight of full-fat flax seeds. The major fibre fractions in flax consist of cellulose, which is the main structural material of plant cell walls; mucilage gums, a type of polysaccharide that becomes viscous when mixed with water or other fluids; and lignin, a highly-branched fibre found within the cell walls of woody plants. Lignins are related to a similar-sounding compound – lignans. Both are part of plant cell walls and are associated with cell wall carbohydrates. *Lignins* contribute to the strength and rigidity of the cell walls. *Lignans* are phytochemicals (plant chemicals) whose role in human nutrition, particularly cancer prevention, is being actively studied (22).

These fibre fractions in flax can be classified as either dietary fibre or functional fibre. The classification depends on whether they are found intact in flax or are extracted from flax, purified and added to foods and other products (21). Thus, whole flax seeds and ground flax are sources of dietary fibre, while mucilage gums extracted from flax seeds and added to laxatives and cough syrups (5) are a functional fibre.

Phytochemicals

PHENOLIC ACIDS. Phenolic acids are among the phytochemicals (plant chemicals) found abundantly in plants. They appear to have antioxidant, anticancer and antimicrobial activities (23). Flax contains about 8 to 10 g of total phenolic acids per kilogram (kg) of flax (24). Because they occur in association with fibre in plant cell walls, some of them could play a role in the health benefits attributed to flax fibre (25).

LIGNANS. Plant lignans are phenolic compounds (25). They are biologically active phytochemicals with apparent anticancer and antioxidant potential. Flax is a particularly rich source of a lignan called secoisolariciresinol diglycoside (SDG). SDG is a plant lignan that is converted by bacteria in the colon of humans and other animals to mammalian lignans.

FLAVONOIDS. Flavonoids are polyphenols found in many fruits, vegetables and beverages such as wine and tea. These antioxidants bind certain metals, interact with enzymes and have anti-inflammatory actions (26). Flax contains about 35–70 milligrams (mg) of flavonoids/100 g (23).

Vitamins and minerals

Flax contains minor amounts of water- and fat-soluble vitamins, as shown in **Table 5** (27). Vitamin E, a fat-soluble vitamin, is present in flax primarily as gamma-tocopherol (28), which functions as an antioxidant. Gamma-tocopherol protects cell proteins, fats and DNA from oxidative damage by free radicals, which may help prevent chronic diseases like heart disease and stroke, and it promotes sodium excretion in the urine, which may help lower blood pressure (29). The tocopherol content of flax is affected by the variety, maturity of the seed, growing region, growing conditions and method of extraction. The gamma-tocopherol content can range from 150 mg/kg to 800 mg/kg flax (30).

Table 6 shows the mineral content of flax (27). One tablespoon of ground flax contains 34 mg of magnesium, about the same amount of magnesium found in a banana, a cup of 2% milk or half a fried chicken breast. The potassium content of ground flax is about 66 mg per tablespoon or about the same amount of potassium found in one slice of toasted pumpernickel bread, a 6-oz. mug of brewed tea or a hard-boiled egg. Flax is low in sodium.

TABLE 5

Vitamin content of flax[a]

Water soluble	mg/100 g	mg/tbsp ground flax
Ascorbic acid/vitamin C	0.50	0.04
Thiamin/vitamin B_1	0.53	0.04
Riboflavin/vitamin B_2	0.23	0.02
Niacin/nicotinic acid	3.21	0.26
Pyridoxine/vitamin B_6	0.61	0.05
Pantothenic acid	0.57	0.05
	µg/100 g	µg/tbsp
Folic acid	112	9.0
Biotin	6	0.5
Fat soluble	**mg/kg in oil**	**mg/tbsp in oil**
Carotenes	not detected	not detected
Vitamin E[b]		
Alpha-tocopherol	7	0.10
Delta-tocopherol	10	0.14
Gamma-tocopherol	552	7.73

[a]Composite sample of whole flax (27).
[b]Tocopherol values represent the average of four varieties (28). The following forms of vitamin E were not detected: beta-tocopherol and alpha-, delta- and gamma-tocotrienol.

TABLE 6

Mineral content of flax[a]

	mg/100 g	mg/tbsp ground flax
Calcium	236	19.0
Copper	1	0.1
Iron	5	0.4
Magnesium	431	34.0
Manganese	3	0.2
Phosphorus	622	50.0
Potassium	831	66.0
Sodium	27	2.0
Zinc	4	0.3

[a]Composite sample of whole flax (27).

Comparison of Brown and Yellow Flax

Brown and yellow (Omega) varieties of flax are virtually identical in their nutrient content (6), as shown in Table 7. The nutritional differences between them are small and likely result from differences in growing conditions. As mentioned previously, seed coat colour is determined by the amount of pigment present, a feature that can be changed through normal plant breeding practices. For consumers, the decision to buy a particular colour of flax can be based on price and appearance of the flax-containing food product, since the nutritional value of brown and yellow flax is similar.

TABLE 7

Comparison of brown flax and yellow flax[a]

Constituent	Brown flax	Yellow flax
	g/100 g	
Protein (% nitrogen x 6.25)	22.3	29.2
Oil/fat	44.4	43.6
	% of total fatty acids	
Specific fatty acids		
Saturated fatty acids	8.7	9.0
Monounsaturated fatty acids	18.0	23.5
Polyunsaturated fatty acids		
Alpha-linolenic acid	58.2	50.9
Linoleic acid	14.6	15.8

[a]Based on an analysis of a small number of samples conducted by the Canadian Grain Commission (6). Moisture content: brown flax, 7.7%; yellow flax, 7.0%.