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Chemical Composition, Medicinal Impacts and Cultivation of Camelina (*Camelina sativa*): Review

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Abstract: *Camelina sativa* is an oilseed crop and known as gold of pleasure and false flax. It holds promise as a source of human food and animal feed products and it is considered as a new source of essential fatty acids, particularly *n-3*(omega-3) fatty acids. The seed of Camelina can contain more than 40 % oil, 90 % of which is made up of unsaturated fatty acids, including a 30–40% fraction of alpha linolenic acid (18:3n-3), another 15–25% fraction of linoleic acid (18:2n-6), about a 15% fraction of oleic acid and around 15% eicosenoic acid. Tocopherol content is about 700 mg kg-1. The oil is capable of improving the n-6/n-3 fatty acids ratio in food. Alpha linolenic acid (18:3n-3) serves as a substrate for EPA (Eicosapentaenoic acid), DHA (Docosahexaenoic acid) and hormones with important functions in human organism, particularly in the maintenance of immunity. A cholesterol reducing effect of Camelina oil was confirmed in trials with volunteers. The reduction of cholesterol in blood serum was ascribed to the synergistic effects of alpha linolenic acid (18:3n-3) and antioxidants. An enrichment of food with α -linolenic acid appears extraordinary important for infants and children. Dietary α -linolenic acid promotes a healthy growth as well as optimal neurological development. The incorporation of Camelina oil in diet for children appears to be promising health promoting measure. Health promoting potential of Camelina oil has high contents of α -linolenic acid, tocopherols and other antioxidants make Camelina oil nutritionally very attractive.
Kay words: Camelina oil, dietary supplement, nutritional value, healthy food.

Introduction

Camelina sativa is a flowering plant in the family Brassicaceae and is usually known in English as Camelina, or false flax. Camelina is an oilseed crop belonging to family Brassicaceae with agronomic low-input features[1]. Camelina is a low-input oilseed crop with very high nutrient efficiency that can grow with limited nitrogen fertilization and often grown on marginal land. Camelina is a short-season crop that is well adapted to production in the temperate climate zone. It is generally grown as an early summer annual oilseed crop but can be grown as a winter annual in milder climates[2]. Camelina germinates at low temperature, and seedlings are very frost tolerant[3]. It responds well under drought stress conditions and may be better suited to low rainfall regions than most other oilseed crops[2]. Camelina is particularly competitive in semi-arid regions and in relatively infertile or saline soils, and it is extremely resistant to adverse environmental conditions (e.g., drought). Moreover, Camelina has a rather short vegetative period of about 4 months, and thus, it can be incorporated into double cropping systems during cool periods of growth. Camelina produces antimicrobial phytoalexins that confer resistance to plant pathogens and insect pests, and it is an allelopathic crop, producing and releasing into the environment secondary metabolites that inhibit the development of neighboring plants[4].

Due to high content of unsaturated fatty acids in Camelina oil its oxidative stability should be an important factor, Camelina oil was found to be more stable towards oxidation than highly unsaturated linseed oil but less stable than rapeseed, olive, corn, sesame and sunflower oils. Camelina oil has an unusual fatty acid profile, consisting of higher levels of alpha-linolenic acid and comparatively low concentrations of erucic acid[5]. Camelina oil can serve as an interesting source of n-3 (omega-3) fatty acid due to its cholesterol-lowering properties for the human diet[6]. The possible industrial applications of Camelina include its use in environmentally safe paintings, coatings, cosmetics and low emission biodiesel fuels[7,8]. Although the presence of polyunsaturated fatty acids make Camelina oil susceptible to lipid oxidation but it remains sufficiently stable during storage due to the presence of antioxidants in the seed[9,10]. Camelina seed contains oil contents between 320 and 460 g/kg[11] and concentration of alpha linolenic acid was in the broad range from 28 to 43% of total fatty acids[12,13,5]. Seed quality characteristics of Camelina are important features for processing and marketing of the crop in competition with other oilseeds. There are several reports that suggest Camelina is one of the most cost-effective oilseed crops to produce due to search for the new sources of essential fatty acids, particularly n-3(omega-3) fatty acids and multiple use values[14].

Uses of Camelina

The crop is now being researched due to its exceptionally high levels (up to 45%) of omega-3 fatty acids, which is uncommon in vegetable sources. Seeds contain 38 to 43% oil and 27 to 32% protein[15]. Over 50% of the fatty acids in cold-pressed Camelina oil are polyunsaturated. The oil is also very rich in natural antioxidants, such as tocopherols, making this highly stable oil very resistant to oxidation and rancidity. The vitamin E content of Camelina oil is approximately 110 mg/100 g. It is well suited for use as cooking oil. There are some researches in human nutrition and health have determined the relationship between the diet and the occurrence of various diseases among the population in the industrialized countries. The nutritional deficiency due to the disproportion of poly-unsaturated fatty acids can be alleviated by the addition of n-3 fatty acid rich oils in the diet. In such a situation Camelina oil can be an excellent source of poly-unsaturated fatty acids and n-3 fatty acid in particular. Camelina oil can enhance the biological value of diet by changing the proportion of n-6/n-3 fatty acids[16]. Camelina is being marketed in Europe in salad dressing and as cooking oil (it is not suitable as deep-fat fry oil). The specific dermatological effects of polyunsaturated fatty acids make Camelina oil suitable for cosmetic applications, such as cosmetic oils, skin creams and lotions[17].

The co-product (meal) obtained after oil extraction from the seed is valuable as animal feed[18]. To use Camelina meal as a potential animal feed requires information on its chemical composition, nutritive value, digestibility and product quality aspects. In this context, studies on using Camelina in the diet of beef heifers[19] and dairy cows[20] have been reported. Also, fish such as salmon, with the added benefit of increasing the omega-3 content of the resulting meat, eggs and dairy products[21,22,23]. Camelina meal is rich in protein, fat and essential n-3 and n-6 fatty acids, and could be incorporated into poultry rations as a source of energy, protein and essential n-3 and n-6 fatty acids.

Due to high levels of essential fatty acids, particularly the omega-3 fatty acid α-linolenic acid, Camelina oil is also being investigated as a food ingredient[10,24.] In 2010, Health Canada approved the use of cold-pressed, unrefined Camelina oil as a food ingredient in Canada. In some eastern European countries, Camelina oil is used in folk medicine for the treatment of burns, wounds, eye inflammations, as well as to cure stomach ulcers and as a tonic[25].

Camelina Cultivation

Soil preparation, seeding rate, method of planting and seeding depth are all factors that have been found to affect plant establishment and subsequent seed yields[26,27]. Camelina is drought-tolerant crop that can thrive and produce reasonable yields in low moisture conditions[1]. It has better spring freezing tolerance and drought tolerance compared to canola[28].

Seeding date is an important management practice that can be adapted to optimize Camelina production. Early seeding allows Camelina to flower before the usual summer heat and drought period that would help prevent pod abortion and increase seed yield. According to[28] the recommended seeding rate in Montana is 5.55 kg ha^{-1} for a uniform, dense crop stand. Broadcast trials were not successful for Camelina and resulted in poor and uneven crop establishment, which ultimately provided uneven stands and crop maturity at harvest. Camelina is usually seeded in the spring[15,29]. Winter seeding is also being investigated[1]. Seeds are planted at a shallow depth with good soil contact[30,3]. Seeds can be drilled using packer wheels to achieve this, or if broadcast, a roller harrow can be used to mix seed and soil together[30]. The recommended sowing rate ranges from 3 to 7 kg/ha (approximately 250 to 600 seeds/ m^2), with the objective of producing a stand density in the range of 125 to 200 plants/m^2 [31]. Higher seeding rates can increase the competitiveness of the crop and decrease time to maturity[31,32]. The rate of emergence for Camelina has been observed to range from 12% to 70%, with an average of approximately 40%, which is comparable to canola[31]. As with other brassicas, it is generally recommended that Camelina not be grown in a field more than once every three to four years[3]. Due to its short growing season, Camelina also has the potential to be incorporated into double cropping systems, particularly in warmer climates[1]. Like other crops in the mustard family, Camelina responds to nitrogen, sulfur, and phosphorus fertilizer application.

Camelina is a short-season crop that requires a modest amount of nitrogen[3]. Studies have shown that yield is improved through the application of nitrogen and the recommended application rate ranges from 60 to 100 kg N/ha[31]. Depending on soil levels, application of phosphorous and sulphur may also improve yield[32]; however, at this time the optimal application rate has not been determined. In the absence of this information, fertilizer application for Camelina may be modeled after canola production practices. Camelina can survive conditions of dry soil, low rainfall and frost due to a short growing season; for example, Camelina matures 21 days earlier than flaxseed[33]. Camelina being a low input crop does not require great amounts of fertilizers. It has low response to Nitrogen (N), Phosphorus (P) and Potassium (K)[28]. [34]reported that to achieve maximum yield in a study in Montana, Camelina required 78.5 to 100.9 kg N ha^{-1}. In Romania, seed yield of Camelina was increased by 14% and 27% with applications of 40 kg P ha-1 and 60 kg P ha^{-1}, respectively, while applications of 50 and 100 kg N ha^{-1}caused an increase of 37% and 58% in seed yield[35]. Further, phosphorus increased the oil content from 39.2 to 41.9% and nitrogen decreased oil content from 40.9 to 40.1% respectively. The highest dose of N significantly reduced oil content[36,37]. Different agronomic and quality parameters responded to nitrogen application. Plant height, total nitrogen content in plant tissue and seed yield increased with increased nitrogen application, but oil content decreased[38].

Camelina shows good weed competitiveness, especially when plant stands are dense, although this has not been directly measured. This may in part be due to the early emergence and rapid growth of this crop, as well as its cold tolerance, which allows it to be planted early[3]. Camelina can be swathed for field drying prior to harvest, or it can be direct combined if varieties that are resistant to shattering are used[3]. Swathing is recommended if there is a high degree of lodging or green weeds in the field[30]. Swathing should be done when two-thirds of the pods turn from green to yellow[3].

Early trials of Camelina conducted in Canada showed seed yields of 1200 to 1500 kg/ha[39]. Recent trials in Canada indicated that seed production may not be affected by seeding date but can be affected by seeding rate producing 1338 kg ha^{-1} at a seed density of 200 seeds m^{-2}, 1496 kg ha^{-1} at 400 seeds m^{-2} and 1599 kg ha^{-1}at 600 seeds m^{-2} [38]. Different seeding rates did not affect seed size significantly[29] Field trials in Germany indicated that seed production of Camelina was affected by seeding date and soil enrichment. Early seeded plants produced an average seed yield of 1600 kg ha^{-1} as compared to 1150 kg ha^{-1} with late sowing. Variation in thousand-seed weight ranged between 0.8 and 1.3 g[40]. In France, *Camelina sativa* cultivars produced a maximum yield of 2.3 t ha^{-1} with late sowing and nitrogen applied at 100 kg/ha[41]. [42]achieved a maximum seed yield of 3 t ha^{-1} through breeding for marginal, poor soil with nitrogen application rate of 80 kg ha^{-1}. Generally, the seeding and harvesting equipments used for canola and mustard crops are suitable for Camelina[15].

Chemical Composition and Nutritional Value of Camelina

Camelina oil is the main product from Camelina seeds and the average yield of oil from the seeds is about 40% on dry matter basis[43]. It is a golden yellow colour liquid with a mild nutty and characteristics mustard aroma. Some of the physical properties of Camelina oil reported are: refractive index 1.4756, density 0.92 g/cc both measured at 25°C, iodine number 105 (g I2/100 g oil) and saponification value 187.8 (mg KOH/g oil)[10].

Camelina oil is highly unsaturated. The oil contains about 64% polyunsaturated, 30% monounsaturated and 6% saturated fatty acids (FAs). Fatty acid (FA) content in Camelina oil depends mainly on the varieties and on the conditions under which the crop was grown[43]. The main FAs are: α-linolenic acid (18:3 n-3) (ALA), linoleic acid (18:2 n-6) (LA), oleic acid (18:1 n-9) (OA) and gondoic acid (20:1 n-9) (GA). The presence of GA is a curiosity of Camelina oil. The role of this fatty acid in human metabolism is not known. The content of erucic acid was 2.3-3.7%[43]. This was below the limit of 5.0% allowed in vegetable oils for human consumption[43]. The ratio of linoleic acid (LA) (15%) and α -linolenic acid (ALA) (40%) is unique among the common vegetable oils such as soya oil, sunflower oil, rape oil, olive oil etc. The oil also contains high levels of gamma-tocopherol (Vitamin E) which confers a reasonable shelf life without the need for special storage conditions. The total content of tocopherols in Camelina oil ranged 800-900 µg/g. This was higher than flax oil and rape oil. From the nutritional point of view, Camelina oil is a rich source of essential fatty acids (LA and ALA). Animal research suggests that Camelina oil may have a significant effect on the reduction of triglycerides and cholesterol in pig serum. [44]concluded that the Camelina oil diet increased omega-3 long chain FAs, in particular eicosapentanoic acid (EPA) and improved the ratio omega-6/ omega-3 FAs in plasma. Potential health benefits of omega-3 from Camelina oil are being evaluated in a breast cancer risk study for overweight or obese postmenopausal women. Because of its nutritional effects, the oil could attract considerable attention for use in the production of health promoting foods[10].

Camelina meal consists of 13% residual oil, 6% ash, 12% crude fibre, 30% crude protein, 27% non-nitrogenous matter and other substances such as vitamins etc. In Camelina meal, protein content is about 30-35% DM basis. A large part of this percentage is seed storage proteins. They constitute 60 and 20% respectively, of the total proteins in mature seeds[45]. In Camelina meal, carbohydrates of Camelina include monosaccharides, disaccharides, oligosaccharides, polysaccharides and fibre. Monosaccharides and disaccharides are easily digestible and in the human body provide easily metabolisable energy. The content in Camelina is very small, for example sucrose is about 5.5%, it was twice as high as flaxseed (2.8%) but lower than rapeseed (6.8%)[46]. Oligosaccharides: raffinose and stachyose are very low in Camelina (below 1%)[47]. Polysaccharides: starch, pectin and mucilage. Starch is a polysaccharide consisting of different chain length and straight chained amylase and branch chained amylopectin. The content in Camelina is very low (1%)[47]. Starch is incompletely digestible in the small intestine, but it is fermented by microbes in the large intestine. Pectin is a heteropolysaccharide consisting mainly by d-galacturonic acid linked with fucose, xylose and galactose. This fermentable fibre is very low in Camelina less than 1%[48]. Mucilage is a water soluble fibre that forms gel. Soluble fibres delay gastric emptying and transit through the colon. Soluble fibres interfere with the absorption of sugars and fats. They absorb potentially noxious carcinogenic compounds of the ingesta[49]. The content of mucilage in Camelina is 6.7%, lower than flaxseed (8%)[47]. Crude fibre, include cellulose and hemicelluloses. Cellulose is a non-digestible glucose polymer. It is found in the cell wall of all vegetation. Hemicellulose fibres are cellulose molecules substituted with other sugars such as xylan galactan, mannan, etc. Cellulose and hemicelluloses are microbially fermented in large intestine. A mixture of short chain fatty acids, such as acetate, butyrate and propionate are produced[48]. Lignin is a polyphenolic compound associated with dietary fibre. It is water insoluble and in the gastro intestinal system, it increases the amount of stool and absorption of water[50]. The content of lignin in Camelina is (7.4%)[47]. The content of crude fibre in Camelina meal is about 15% dry matter basis. The substantial part of crude fibre was cellulose. The proportionally high content of mucilage, crude fibre and lignin indicates that Camelina meal, when incorporated in food, can exert positive effects on gastrointestinal processes. A long term human consumption of bread with added Camelina meal confirmed that beneficial role of the ingredient in digestion[47].

Camelina meal is a good source of vitamins B1 (thiamin), B3 (niacin) and B5 (pantothenic acid). Thiamin in nature exists as thiamine pyrophosphate. It functions as a coenzyme in transketolation and is important in neural transmission. It is directly involved in maintenance of normal appetite and healthy attitude[51]. The content of thiamin in Camelina is considerable higher (18 µg/g) respect than flaxseed (6 µg/g) and rapeseed (8 µg/g)[47]. Niacin occurs in two forms as nicotinic acid and nicotinamide. It is widely distributed in nature but it does not occur in large amount in free form. Most often it is found as the coenzyme NAD+ (nicotinamide adenine dinucleotide) and NADP+ (nicotinamide adenine dinucleotide phosphate). Niacin is one of the most important vitamins in human and animal nutrition[52]. The content of niacin in Camelina (194 ìg/g) is predominant among the vitamins, it results also about twice as high as in flaxseed (91 µg/g)[47]. Panthotenic acid has diverse metabolic functions as a structural component of coenzyme A (CoA) and acyl carrier protein. The CoA supports the transmission of nerve impulses, haemoglobin synthesis, synthesis of sterols and steroid hormones, maintenance of normal blood sugar, formation of antibodies etc. [51]. The content of panthotenic acid is identical to flaxseed (11 µg/g) and lower than rapeseed (16 µg/g)[47]. Analyses of CS reveal a prevalently low content of macro-minerals. The highest content between 1.0-1.6 % is calcium, potassium, phosphorus[47]. Among micro-minerals, Camelina presents markedly high content of iron (329 µg/g), manganese (40 µg/g) and zinc (69 µg/g) [47]. Camelina meal is characterized by the presence of minor substances that affect the value of this by-product. Especially plant secondary metabolites such as glucosinolates (GSLs), sinapine, inositol phosphates and condensed tannins belong to widespread anti-nutritive compounds which are generally present in oilseeds. GSLs and sinapine have usually been associated with members of Brassicaceae whereas inositol phosphates and condensed tannins are more generally distributed in flora[53].

Health Promoting Application of Camelina Oil

Human body cannot synthesize α -linolenic acid (ALA) and its deficiency may result in clinical symptoms including neurological abnormalities and poor growth. Therefore, α -linolenic acid (ALA) should be included in the diet. α -linolenic acid (ALA) can be elongated to EPA (Eicosapentaenoic acid) and DHA (Docosahexaenoic acid), because their metabolic products have beneficial effects which help in preventing coronary heart disease, arrhythmias and thrombosis[54]. The consumption of Camelina oil can help to improve the general health of the population to the desired level[55,56,57]. Camelina oil is helpful in the regeneration of cells, skin elasticity and slenderness recovery[58]. The preventive and curative effects were ascribed primarily to a reinforced immunity of human organism. The immunity was apparently deriving from biochemical processes in which linoleic acid, α -linolenic acid, tocopherols and phytosterols were involved[59,60].

Both the linoleic acid and α -linolenic acid are precursors for pure unsaturated fatty acids (PUFA) and are the substrates for important hormones with various functions in the human organism[61,62]. Motivated by unique nutritional quality and beneficial properties of Camelina oil[43], flax oil in the diet was replaced with camelina oil. The major ingredients (ca. 80 percent v/v fermented milk and 20 percent v/v camelina oil) were mixed to obtain emulsion. The fermented milk was a source of essential amino acids and microorganisms e.g. Lactobacillus acidophilus, with well known positive dietary effects. The oil provided linoleic acid, α -linolenic acid, tocopherols, phenols, phytosterols, etc. During testing with adults, 8 table spoons of fermented milk and 2 table spoons of Camelina oil were used per serving. To improve the nutritional value and taste, oats flakes and seasonally available small fruits, minced fruits or vegetables, dry fruits, grape raisins, jam, sugar, etc., were mixed with the emulsion. The complex mixture was consumed with 2-3 slices of toast. The most convenient was the consumption of the diet at breakfast.

Cholesterol Reducing Effect of Camelina Oil

The high contents of α -linolenic acid (ALA), tocopherols and other antioxidants make Camelina oil nutritionally very attractive. Besides being a substrate in human metabolism, ALA is capable of improving the *n-6*/*n-3* fatty acid ratio in food[63]. A mixed fat product consisting of butter fat and Camelina oil (1: 1), was tested by mildly hypercholesterolemic subjects. The volunteers aged 25-75 years (14 males and 31 females) during 4 weeks consumed 50-60 g /d of the mixed fat. Their habitual diet was maintained, only fats (butter, margarine, oil) were substituted with the tested product. Blood analyses were performed during morning hours in the intervals of 2 weeks by using Reflotron Boehringer, Manheim. The initial mean content of total cholesterol in blood serum of the subjects was 6.3 ± 0.25 mmol/L. After 2 weeks on the diet, the volunteers experienced a decreasing cholesterol level. At the end of the trial, their cholesterol in blood serum was reduced to 5.8 ± 0.23 mmol/L. The cholesterol reducing effect was ascribed to Camelina oil. A similar cholesterol reducing effect of Camelina oil was achieved in a test with mildly and moderately hypercholesterolemic subjects. The volunteers consumed 33 mL Camelina oil per day during 6 weeks. Their total cholesterol in blood serum was reduced from 5.9 to 5.6 mmol/L and LDL (low density lipoprotein) decreased by 12.2 percent[6]. In another trial, volunteers during 4 weeks consumed 12 g/d α -linolenic acid in the form of ground flax seed (50 g/d) or flax oil (20 g/d).

The content of long chain n-3 fatty acids and erythrocyte lipids in blood serum of the subjects increased significantly. Simultaneously was lowered serum total cholesterol by 9 percent and LDL (low density lipoprotein) cholesterol by 18 percent[64]. A provision of functional oil with flax oil reduced the total cholesterol by 12.5 percent and LDL (low density lipoprotein) by 13.9 percent[60]. Meanwhile, unusually high content of cholesterol in camelina oil, amounting to 188 mg/g, was reported[65]. [6]Karvonen HM et al determined cholesterol reducing effect of Camelina oil in a test with mildly and moderately hypercholesterolemic subjects. The volunteers consumed 33 mL Camelina oil per day during 6 weeks. Their total cholesterol in blood serum was reduced from 5.9 to 5.6 m mol L^{-1} and LDL (low density lipoprotein) decreased by 12.2 percent. Experimental evidence, however, proves that Camelina oil possesses a cholesterol reducing property. Besides the effects of α -linolenic acid and tocopherols also phytosterols were found effective in lowering cholesterol[66]. Preliminary unpublished experimental results indicate that the amount of cholesterol in blood serum is not proportional to the dietary intake. The major determinants of cholesterol level in blood serum are saturated fatty acids (C12:0 - C16:0). The development of atherosclerosis actually is deriving from the oxidation of LDL (low density lipoprotein)[67].

Dietary Supplementation by Camelina Oil as a Source of α -linolenic Acid

Dietary supplementation of α -linolenic acid in European countries, USA and Canada was estimated to be between 0.8 and 2.2 g/d per person[68]. The dietary provision of α -linolenic acid was a subject of numerous investigations. Recommendations for dietary intake of α -linolenic acid, however, are somewhat inconsistent. A supplementation of ca. 2 g α -linolenic acid (20 g rape oil) and 7-10 g linoleic acid for the daily intake by healthy persons was suggested. The conversion of α -linolenic acid to EPA was found to be about (10 %)[69]. Other studies show that intake of 3.5 g/d α -linolenic acid increased the proportion of EPA (Eicosapentaenoic acid) but not DHA (Docosahexaenoic acid) in plasma phospholipids[70]. A supplementation of 4.5 and 9.5 g/d α -linolenic acid was used experimentally[71]. On the basis of studies with volunteers was proposed an intake of 12 g α -linolenic acid, corresponding to 20 g flax oil per day[64].

The exploitation of α -linolenic acid as a substrate for EPA (Eicosapentaenoic acid) depends on the n-6/n-3 fatty acids ratio. The conversion of α -linolenic acid to EPA (Eicosapentaenoic acid) can be inhibited by the excess of linoleic acid. An appropriate supplementation of α -linolenic is needed to ensure the conversion of α -linolenic acid to EPA (Eicosapentaenoic acid)[62,72]. An enrichment of food with α -linolenic acid appears extraordinary important for infants and children. Dietary α -linolenic acid promotes a healthy growth as well as optimal neurological development[73]. The incorporation of Camelina oil in diet for children appears to be promising health promoting measure. Health promoting potential of Camelina oil has high contents of α -linolenic acid, tocopherols and other antioxidants make Camelina oil nutritionally very attractive. Besides being a substrate in human metabolism, α -linolenic acid is capable of improving the n-6/n-3 fatty acid ratio in food. Experimental documentation shows that linoleic acid and α -linolenic acid are in human metabolism convertible to pure unsaturated fatty acids (PUFA) through desaturation and chain elongation metabolic pathway[63].

α -linolenic acid is a precursor for prostaglandins and other eicosanoids and hormones involved in wide range of body functions including the immune system[61]. Additional health effects may be ascribed to antioxidants and phytosterols in Camelina oil. Specific studies disclosed that phytosterols, incorporated in functional fat with flax oil, had beneficial effects on lipids and cholesterol in blood serum[60]. A dietary intake of 13.7 g/d α -linolenic acid from flax oil significantly increased the content of α -linolenic acid in blood serum. The concentration of α-linolenic acid increased approximately eightfold in the serum lipid fractions (phospholipids, cholesteryl esters and triglycerides) and 50 percent in the neutrophil phospholipids. The concentration of EPA (Eicosapentaenoic acid) in plasma phospholipids increased 2.5 fold. A supplementation of α -linolenic acid from vegetable oils can elevate EPA (Eicosapentaenoic acid) in tissues to concentrations comparable to those achieved with fish oil[74]. Another investigation shows a conversion of linoleic acid to n-6 metabolites ranging from 1.0 to 2.2 percent. The conversion of α -linolenic acid to n-3 metabolites was 11.0 - 18.5 percent and to DHA (Docosahexaenoic acid) it was 3.8 percent[62]. A significant increase of a-linolenic acid, EPA (Eicosapentaenoic acid) and DHA (Docosahexaenoic acid) in blood serum in a trial with volunteers was reported. At the same time, the saturated FA (C14:0, C15:0, and C16:0) decreased[6]. The trial demonstrated that a supplementation of Camelina oil had about the same effects as flax oil.

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