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REVIEW ARTICLE

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The golden discovery of *camelina sativa*: a pivotal study of ıts unique components and its multiple uses in various applications in science and industry

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Abstract

The increase in the global population causes a rapid increase in environmental pollution and energy consumption. Countries aim to increase the use of alternative energy sources as fossil fuels are limited and not universally accessible when generating their energy. In addition, research in the biofuels industry is expanding to include research on the use of vegetable oils as fuel. Camelina serves as a perfect illustration because of its abundant nutrients. Camelina, known as *Camelina sativa L.* Crantz, is a member of the cruciferous family and has been grown for its valuable characteristics for many centuries. Camelina seeds contain high levels of both protein (27-32%) and oil (38-43%). Camelina oil is rich in various components like phytosterols, phenolic compounds, tocopherols, and fatty acids, with omega-3 and omega-6 being the key ones. In the field of agriculture, growing this crop is appealing because it has a brief growing period and requires little water and fertilizers. Camelina is well-suited for arid regions because of its ability to withstand dry conditions and low temperatures. Due to its economic importance and easy cultivation in recent years, Camelina has many applications such as biofuel, food, agriculture, animal feed, cosmetics, and medicine. For example, Camelina is grown in the United States and Europe as a valuable crop that can be used to replace existing fuels. Future research aims to enhance its agricultural characteristics and view it as a substitute for existing fuels. This review focuses on the camelina plant, its oil, components, and properties, as well as its use in areas such as food, biofuels, animal feed, and agrochemicals.

Keywords: Brassicaceae; *Camelina sativa*; fatty acids; fuels; phenolic compounds.

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1. Introduction

Plant extracts have been used in many application areas such as medicine, cosmetics, and food since ancient times due to their aromatic and healing properties [1], [2], [3]. The structure of plant extracts includes flavonoids, steroids, phenolics, alkaloids, enzymes, amino acids, proteins, and saponins [4], [5], [6], [7]. All parts of plants such as seeds, stems, leaves, flowers, and fruits are used in the production of plant extracts. Filtering, microwave, Soxhlet, and boiling are the most important methods to obtain plant extracts [8], [9], [10], [11]. Several seed-bearing plants, including Camelina (*Camelina sativa*), groundnut (*Arachis hypogaea*), mustard (Brassica spp), and soybean (*Glycine max*), are excellent sources of oil. A few of these species are commonly utilized in the production of edible oil. However, Camelina stands apart from the rest due to its versatility [12]. Camelina oil is produced for a variety of uses, including food, medicine, and industry. Biodiesel is one application for this plant oil in the industry. One of the remarkable traits of Camelina is its minimal fertilizer requirements and its ability to flourish in marginal and impoverished soils. It has a short growth cycle of 85 to 100 days [13], [14], [15], [16]. Camelina is more resilient than other oil crops under abiotic stress, and studies have indicated that it may compete with other members of the Brassicaceae family, such as *Brassica. napus* and *Brassica. juncea* [17], [18].

2. History of the camelina species

Camelina is an old plant native to Central Asia and Europe [19]. Humans have cultivated and used it since the Iron Age in various daily activities. During the Iron and Bronze Ages, inhabitants of Scandinavia and Western Europe domesticated the camelina plant for use as food, cooking oil, and cattle feed, while its wild ancestors almost completely covered Europe and Central Asia. Additionally, some research suggests that it was present in eastern Turkey between the years 700 and 900 BCE [20], [21]. Although research on genetic diversity suggests that the origins of many species are likely in either Russia or Ukraine [22]. After being grown for centuries in Europe and North America, canola, a higher-yielding oil seed crop, replaced *Camelina sativa* in the 1950s [20], [21]. Currently, only a small amount of land in Germany, Poland and Russia is used for production [15].

3. Botanical features

Camelina sativa is a flowering plant and an oilseed source belonging to the Camelineae tribe of the Brassicaceae family [23], [24]. *Camelina sativa* goes by several names, including gold of pleasure and false flax [16], [23], [25], [26], [27]. Camelina is grown throughout Europe and Central Asia, as well as in Russia, where it is considered native. Its cultivation was stopped after World War II for economic and other benefits [19], [25], [28]. There are four species within the Camelina genus*: Camelina alyssum*, *Camelina microcarpa*, *Camelina rumelica*, and *Camelina sativa*. Among these species, *Camelina sativa* is one of the most used types [17]. Although the chromosome number of *Camelina* has been reported to be n = 6, n = 14, 2n = 12, 2n = 26, or 2n = 40, 2n = 40 is the most widely accepted, researchers from many regions of the world have reported varying numbers of chromosomes [21], [29]. Natural variation within populations may be the cause of variations in chromosome numbers [29], [30]. Camelina has simple hairy leaves arranged alternately on a straight, slightly rough stem [17]. The lance-shaped leaves have margins that are either smooth or lobed. It may have smooth or dichotomous bristles, typically 2-10 mm wide and 2-8 cm long [24], [29]. Leaves without petioles are arranged in an alternative position, usually touching each other. Camelina plants have a height ranging from 30 to 80 cm at maturity [29]. Camelina plants yield diminutive yellow flowers measuring 5-7 mm in diameter, featuring four petals arranged in a racemose configuration [31]. These floral structures bear resemblance to other Brassica flowers, yet are distinguished by the presence of delicate, lance-shaped leaflets. Camelina is mostly self-pollinating, characterized by its perfect anther flowers housing medium-sized pollen grains, which range from spherical to prolate in shape [17], [29]. The camelina fruit is shaped like a pear, orange-to-brown pod that is 10 to 25 mm wide and 5 mm long and is around one-fourth to one-half the size of canola seeds [17], [32]. Camelina has 8 to 15 seeds with color ranging from golden to brown [32]. Camelina has short roots, which allows it to draw water from shallow soil layers and is well adapted to fallow wheat production systems in arid regions [29].

Camelina seeds (Fig. 1) are quite tiny, measuring 2 to 3 mm in length [17], [32], and the weight of 1000 seeds is between 0.8 and 1.8 g [21], [29]. Camelina seed pods are siliques; globular and rounded, divided by a septum and typically contain 10 to 25 seeds at maturity. Seed pod changes their colour from green to yellow-reddish and then completely dry at full maturity [17], [24], and [29]. Camelina seeds contain 27 to 32% protein and 38 to 43% oil [16], [33], [34]. At harvest, the grain moisture level should be about 11%, and during storage, it should be around 8%. Unfavourable weather during harvest might result in a decrease in grain production. The germination period is 4 to 6 weeks, depending on the prevailing weather conditions [23].

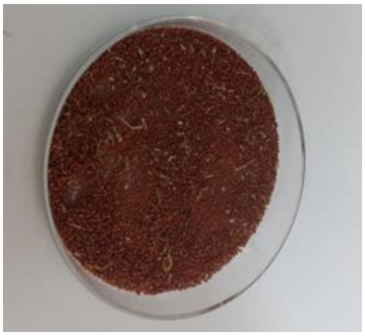

Fig 1. Camelina seeds.

4. Plant camelina and agricultural practices

Camelina is gaining an increase in economic importance in the field of the agricultural sector due to its different attributes [31], [35]. Its oil content in dry weight ranges between 30 and 48% [31], [35], [36]. These values are twice that of soybeans, which contain between 18 and 22% oil [37]. Because of its short growth cycle and minimal water and fertilizer requirements, interest in this crop has surged [14], [21]. Camelina contains many phytochemicals that increase its resistance to pests and diseases, which is another reason why it is a resilient crop [38]. Camelina can grow in hot and cold climate conditions, and this is what led to heightened attention in the agricultural sector [21], [39]. Compared to other oilseed crops, camelina seeds can germinate at 0°C, as their plants can tolerate very low temperatures [40], [41]. These features enable it to thrive in cold climates [42]. During seed growth, temperature rises more than 25°C may cause a significant drop in the amount of unsaturated fatty acid [43]. Camelina is usually sown in spring, but winter sowing is also possible. It is best to plant them in late October. Seeding rate, soil preparation, planting method, and seeding depth all influence seed yield and plant growth [44], [45]. Camelina might improve soil quality when grown in rotation with grains. Seeds are sown at a short depth with good soil contact. This can be performed by drilling seeds with packing wheels or disseminating seeds with a roller harrow [46]. The recommended planting rate is 3 to 7 kg/ha (250 to 600 seeds/m^2), with a stand density of 125 to 200 plants/m^2. Increased seeding rates can reduce the time to maturity and increase yield competitiveness. Row spacing is suggested for camelina production. The ideal row spacing for camelina cultivation is 20–30 cm, while 15 cm row spacing might be advised to prevent weed infestation [17]. Camelina emergence rates range from 12% to 70%, with a 40% average. Because of its limited growth season, it is advised that it be planted no more than once every three to four years. Camelina may be used in multiple cropping systems, particularly in warmer areas [34]. Camelina seeds react well to fertilizers high in nitrogen, sulphur, and phosphor [47]. The application of nitrogen fertilizer enhances crop yield but diminishes oil content. The nitrogen response of *Camelina sativa* is like that of *Brassica juncea* on Canadian prairies, so cultivators can use *Brassica juncea*'s soil recommendations for *Camelina sativa* production [48]. Camelina, a short-season crop, requires little nitrogen fertilizer, with suggested rates ranging from 60 to 100 kg N/ha [49]. Phosphor and sulphur may potentially increase yield, although the ideal treatment rate is uncertain. Camelina can tolerate dry soil, minimal rainfall, and cold temperatures, ripening 21 days earlier than flaxseed. It requires few fertilizers and has a sensitivity to nitrogen, phosphate, and potassium. In Montana, the highest yield was obtained with 78.5 to 100.9 kg N ha^{-1}. In

Romania, the yield of seeds rose by 14% and 27% with 40 and 60 kg P ha^{-1}, respectively. Phosphor increases oil content, but nitrogen decreases it. Nitrogen treatment enhanced plant height, total nitrogen content, and seed output, among other agronomic and quality metrics [34]. In new studies conducted by Hazrati and his friends on camelina crop, activated biochar can enhance soil quality for crop production under rainfed conditions. A split plot experiment with nine treatments and three replicates has been conducted to study the effects of supplementary irrigation and activated biochar on camelina growth. The results showed that Activated Biochar 10 and Activated Biochar at flowering stage increased seed and oil yield, unsaturated fatty acid content, seed yield (2751.8 kg/ha), 1000 seed weight (1.16 g), and oil yield (991.50 kg/ha) [50].

5. Camelina's most important applications

Many culinary and health items are made with camelina oil, where its usage rate reaches 80%. In addition, about 14% of camelina oil is used in industrial materials such as plastic softening compounds, cosmetics, detergents, lubricants, eco-fuels, phytochemicals, and adhesives [12]. Although the use of camelina as a cooking oil is largely limited, it plays an essential role in meeting the needs of increasing demand for bio-oils, especially in the biofuel industry. Camelina is characterized by a unique fatty acid profile, which allows it to be used in multiple industries such as medical, agricultural, nutrition, and the biofuel industry. Therefore, camelina has gained a good reputation in recent years due to its multiple usage and effectiveness in a variety of industries [14], [15], [34], [51].

5.1 Biodiesel

5.1.1 Biofuel manufacturing

Environmental pollution is mostly caused by the continued use of traditional non-renewable fuels. It results in the release of greenhouse gases, which have a detrimental effect on the environment. More generally, greenhouse gases such as carbon dioxide and nitrogen oxide cause climate change and increase global temperatures. Moreover, these high emissions lead to many other environmental problems, and therefore a lack of biodiversity [52]. Consequently, we should consider using renewable and sustainable energy sources as alternatives to traditional fuels to preserve the environment and reduce the effects of pollution. As a result, there is a growing interest in the manufacture of renewable fuels such as biodiesel, ethanol, and biomet fuel [53], [54]. Many feedstocks for biofuel production are being investigated, including seed oils, animal fats, algae, and low-value waste products (such as grease, cooking oil, and soap) [55], [56]. Although not all oilseeds are appropriate for production, some desirable qualities of vegetable oils in biofuel preparation include high seed yield, high oil content, unique fatty acids, consistent seed maturation rate, and flexibility in the local growing environment. In addition, it is especially desired to employ non-edible oilseed crops in the creation of biofuel to preserve the balance within the generation of food products and biofuel [20]. Many studies have examined the benefits of using Camelina oil extracts to produce diesel fuel [57]. Based on their previous research, scientists have emphasized the nutritional importance of camelina oil [36], [58], and on the other hand, they have emphasized its economic importance in the industrial sector due to its short life cycle compared to canola and soybean [59].

Camelina oil is transformed into methyl or ethyl esters of long-chain fatty acid by the alcohol esterification process. Low-emission biofuels have been created using these esters as a substitute for conventional fuels. The researchers found that adding camelina oil, which produces a high-iodine methyl ester similar to rapeseed, improved biodiesel fuel. For usage in diesel engines, transformed biodiesel's fatty acids profile must equal that of the original oil, and the pure form must adhere to the American Society for Testing and Materials D6751 (ASTM D6751) in North America and the European Standard 14214 (EN14214) in the European Union. Certain factors, such as cetane number, kinematic viscosity, distillation temperature, oxidative stability, and cold flow qualities, influence the fatty acid makeup of the original oil. The degree of unsaturation and the chain length of the original oil fatty acid esters have an impact on the characteristics of biodiesel. Checking the fatty acid profile is therefore essential for achieving the best biodiesel production [14], [60].

Various alcohols were mixed at 10% ratio with Camelina biodiesel for fuel analysis. Improvements in viscosity, density, calorific value, and cold flow properties were observed in all blends. Heptane, hexane, ethanol, and butanol blends have low flash points, while n-pentanol and iso-pentanol mixtures have higher flash points. High flash points are important for safe fuel transportation and storage. Blending camelina biodiesel with n-pentanol produced the most favourable results among the alcohols tested [61].

5.1.2. Hydroprocessed renewable jet fuel (HRJ)

The American Society for Testing and Materials (ASTM) International considers the Hydrotreated Esters and Fatty Acid (HEFA-SPK) or Hydrotreated Renewable Jet (HRJ) pathway as one of the most approved pathways for aviation biofuel production. Diversifying aviation fuel sources serves to achieve different goals; This includes reducing aviation emissions and reducing the cost of aviation fuel due to fluctuations in crude oil prices [61], [62]. These objectives are met with sustainable raw materials and production techniques. By utilizing sustainable, environmentally friendly materials and methods, HEFA-certified biofuels have the potential to lower operational expenses associated with fuel usage. Camelina presents itself as a potential raw material for hydrotreated renewable jet fuel. Camelina is being considered as a potential alternative to conventional jet fuel [58]. Agriculture and oil conversion operations demand a lot of energy and emit a lot of pollutants. Except in organic soils and heavy clay soil conditions, camelina matures in 80 to 100 days, depending on the soil type, making it a valuable plant [14], [63]. Camelina-derived jet fuel offers multiple environmental benefits for aviation, including substantial decrease in greenhouse gas emissions and energy utilization, and improved engine performance [64], [65]. The use of Camelina biofuel blends can lead to decreased emissions of carbon monoxide, unburnt hydrocarbons, and soot, although there may be a slight increase in nitrogen oxides [66]. Camelina-derived jet fuel can deliver 70% life cycle emission savings and improved thermodynamic behaviour in an operational gas turbine engine, resulting in 3-3.8% fuel savings [67].

5.2. Chemical byproducts

5.2.1. Bioadhesive

Recently, there has been an increased interest in producing ecologically friendly and renewable adhesives to replace formaldehyde-based resins which include Phenol-Formaldehyde (PF) and Urea Formaldehyde (UF), which are generated from non-renewable petrochemical sources [68]. Researchers investigated a variety of alternatives, including bio-based substances such as Camelina protein [26] and soybean-derived adhesives [69]. Canola and camelina proteins have the potential to replace conventional petroleum-based adhesives in several applications [26]. Globulin's compact shape results in weaker adhesion qualities and increased protein aggregation, whereas glutelin from defatted Camelina meal were reported to have superior adhesive strength than globulin [26]. Applications for pressure-sensitive adhesives include graphics, medical supplies, tapes, and labels, among others [70].

5.2.2. Alkyd resin

Polymeric alkyd resins are widely utilized in composites, adhesives, and coatings, among other industrial applications. These resins are synthesized from polyols and renewable vegetable oils. A novel source to produce these resins is camelina oil [14], [71]. In 2015, Nosal and associates developed an alkyd resin by alcoholizing oligomerized glycerol with camelina oil, employing renewable camelina oil and polyglycerol. The resins were produced by polycondensing the alcoholysis products of camelina oil with anhydrides of phthalic and maleic acids at temperatures ranging between 230°C and 250°C. The resulting resins exhibited drying periods and flexibility comparable to those derived from pentaerythritol and camelina oil. Additionally, alkyd resins were synthesized using camelina oil as a raw material and glycerol as a polyol, and their properties were compared to linseed oil-based products. The alkyd resins demonstrated characteristics like those of linseed oil-based polymers, highlighting their potential for a variety of applications [72].

5.2.3. Cosmetics and soaps

Oilseed crops are becoming increasingly important in the biorefinery industry due to their renewable and valuable feedstocks, particularly for pharmaceuticals, nutraceuticals, fine chemicals, cosmetics, agrochemicals, and biomaterials [16], [73]. Notably, vegetable oils have emerged as crucial ingredients in the cosmetic industry, particularly amidst a growing consumer inclination towards "Clean Beauty." This trend has led to a substantial increase, reportedly by 75%, in the utilization of "natural" raw materials in the cosmetic market [35]. In addition to industrial uses, camelina oil is useful in the manufacture of soap and cosmetics [74], [75]. Camelina oil's significant antioxidant capacity makes it suitable for usage in a range of cosmetic compositions. There are already a lot of commercial cosmetic goods, such as face and body lotions, shampoos, and other hair care items, that contain camelina oil in their formulation. Some companies, such as Springfield and Siberian Tiger Naturals, produce camelina oil-based soaps and distribute them in small markets. Cosmetics containing camelina oil are specially chosen by people who prefer to use vegetable oils in their beauty products [75].

5.2.4. Agrochemicals

Agricultural chemicals are important tools used to protect crops and enhance their growth and fertility. However, due to its irregular use, many problems such as pest resistance, health problems, and soil pollution have emerged [76]. The risks connected with synthetic pesticide usage have led to the use of organic pesticides (biopesticides), which are less expensive, environmentally friendlier, and more sustainable. Therefore, it is possible to replace these chemicals with plant-derived pesticides, which are considered a “green” alternative, as they decompose naturally and do not harm the environment [77]. Plant-derived insecticides are available in different forms, such as powders, pure plant materials, and extracts [78]. In field crops, camelina is a powerful insecticide, pesticide, and antifungal. It has been reported that when Camelina is applied to the soil at a rate of 5% and 1%, it inhibits the sclerotial germination and hyphae development of the *Phymatotrichopsis omnivorous* (Duggar) fungus, which causes cotton root rot and problems in cotton and alfalfa production. Secondary metabolites, such as Glucosinolates (GSLs), convert into nitrile, thiocynate, and isothiocyanate, which help protect plants [12], [21]. *Camelina sativa* has been revealed to exhibit allelopathic properties, which restrict weed development while indirectly affecting pathogen dynamics [31], [79]. It is discovered that the effects of varying concentrations of aqueous extracts from Brassicaceae cover crops on *Ambrosia artemisiifolia L* varied depending on the species and concentration. *Camelina sativa* had the greatest ability to restrict shoot, radicle length, germination, and fresh seedling weight. The study discovered 15 phenolic compounds in the Brassicaceae, with Camelina containing the most vanillin, chlorogenic acid, vanillic acid, caffeic acid, and syringic acid. These data indicate that Camelina is the most allelopathic species employed in the study, and its seeds are particularly high in allelochemical content [31], [80].

5.3. Therapeutic medicinal applications

Camelina Sativa has gained a prominent position among nutritional materials due to its components, which have a biological activity that plays an important role in preserving human health and protecting it from diseases [73]. Fatty acids such as Alpha linoleic acids and Linolic are the most important omega-3 fatty acids. In its natural state, our body cannot produce these acids, and therefore we must obtain them externally to prevent negative effects on nutrition and body health, such as poor growth and neurological disfunction. Docosahexaenoic acids and eicosapentaenoic acids are the most important alpha linoleic products, which have proven effective in preventing heart diseases [81], [82]. Camelina's richness in biological compounds gives it a very distinctive characteristic among natural oil plants. These compounds give it several activities, such as anti-viral, anti-cancer, and antioxidant activity. Tocopherol and eicosenoic acids are among the most important contents of Camelina, as they are present in varying proportions in the human body and contribute to its protection [83], [84]. Due to its distinctive activity against infections, it is included among the effective medicines for treating burns of various degrees and eye irritation [12], [85].

Phytosterols and tocopherols are fatty acids that are present in varying proportions in oil plants. Researchers have proven the effectiveness of these substances in preventing heart diseases caused by high levels of cholesterol in the blood. Camelina contains good amount of these acids, especially phytosterols, making it an important product that contributes to reducing harmful cholesterol levels in the body [86].

5.3.1. Edible camelina oil

Since ancient times, humans have relied on collecting plants and including them in their meals because of their advantages. Oil plants are one of these plants that have occupied a prominent position due to their richness in beneficial fatty acids such as Omega 3-6-9. These fatty acids constitute a large percentage of camelina oil, which is considered an alternative to current oils used in cooking [87], [88].

5.3.2. Camelina meal and cake

Camelina contains many organic substances, the most important of which are proteins, vitamins, and essential fatty acids. Camelina is used as a plant-based protein source in animal feed [89], [90]. Camelina meal can reduce thyroid activity in some animals, according to previous research [91]. Experiments investigating the effect of *camelina sativa* oil on blood metabolism characteristics in broiler chickens have shown that dietary intake containing camelina can affect plasma lipid profile. In a study published by Anca, the plasma lipid profile of broiler chickens fed a diet containing camelina oil have shown various levels of cholesterol decrease, as well as other changes in blood lipid content. In comparison, other studies have shown a tangible impact on plasma lipid levels when camelina oil is added to the diet. The results of the studies indicate that *camelina sativa* oil can contribute to reducing lipid levels, including cholesterol, in the blood [92], [93].

6. Camelina's bioactive components

Oil plants contain many active substances, such as phenolic acids, tocopherols, and others, in addition to essential fatty acids, which have many roles in the human body. These compounds play a role in enhancing the activity of the mind and protecting the body from cardiovascular diseases and other diseases [39], [94], [95]. Camelina also occupies an important position among these oils [39]. The principal product of the *Camelina sativa* plant is the oil produced by crushing and pressing the seeds, which comprises roughly 30 to 40% oil on a dry matter basis. 90% are unsaturated fatty acids. Camelina oil is a bright yellow liquid with a slightly nutty aroma and a distinct mustard odor. Camelina oil's physical qualities include a refractive index of 1.4756, a density of 0.92 g/cm^2 measured at 25°C, an iodine value of 105 (g I_2/100 g oil), and a saponification value of 187.8 (mg KOH/g oil) [88].

6.1. Content of essential amino acids

Camelina is an excellent source of protein. The protein content of various camelina feed components varies. Camelina seed has 24.78% protein, whereas seed byproducts such as cake have more protein. Camelina cake has a crude protein level similar to rapeseed meal (29.69-39.89%) but lower than soybean meal (43.0-56.3%) [96], [97]. It is well recognised that the essential amino acids composition of proteins indicates their biological importance. In camelina cake, the necessary amino acids range from 15.09 to 18.39%. Where it contains a minimum of 17 amino acids. The principal amino acids contents are isoleucine, leucine, lysine, phenylalanine, and valine. Protein in camelina seeds is abundant in non-essential amino acids such as glutamic and aspartic acids, serine, proline, and arginine, in addition to essential amino acids [98]. Camelina seeds contain many essential amino acids, especially arginine [99]. The fact that Camelina meal, which is extracted from its seeds, contains high levels of proteins makes it the best source of protein and energy for animals [91], [100]. The corresponding table shows the contents of *Camelina Sativa*'s essential amino acids (Table 1).

Table 1. Essential amino acids profile of *Camelina sativa* [35], [42], [101].

Amino acids	Content (g/100 g)
Aspartic acids	8.71–9.04
Phenylalanine	4.19–5.22
Cystine	1.94–2.12
Alanine	4.61–6.14

Glutamic acids	14.98–16.12
Glycine	5.25–6.06
Histidine	2.60–4.06
Isoleucine	3.96–4.62
Arginine	8.15–8.57
Leucine	6.63–7.12
Methionine	1.72–2.85
Lysine	4.46–4.52
Proline	5.09–6.07
Serine	5.04–5.96
Threonine	2.75–2.89
Tryptophan	1.21–1.32
Tyrosine	3.04–3.64
Valine	5.42–6.34

6.2. Composition of fatty acids

Recently, researchers have shown interest in *Camelina sativa* in various sectors, especially industry and agriculture, thanks to its chemical contents [52]. Camelina seeds are a raw source of essential oils, especially fatty acids, where they contain varying percentages of them. Camelina oil consists predominantly of saturated fatty acids, accounting for 64% of its composition, with low percentages of polyunsaturated and monounsaturated fatty acids, at 30% and 6%, respectively. The quality of fatty acids in camelina seeds is affected by climatic conditions and the quality of the crop [16], [39], [99]. Camelina oil contains elevated concentrations of alpha linoleic acid (18:3, 31–40%), oleic (18:1, 14–16%), linoleic (18:2, 15–23%), and eicosenoic (20:1, 12–15%) acids. Minor fatty acids such as palmitic (16:0), stearic (18:0), and erucic (22:1) acids. Camelina meal contains 0.17% myristic acids (C14:0), 7.19–9.12% palmitic acids (C16:0), 2.27–2.9% stearic acids (C18:0), 28.6–36.77% linolenic acids (C18:3), 13.5–28.5% linoleic acids (C18:2) and 14.4–19.9% oleic acids (C18:1) are among its constituents. Camelina seed contains significant amounts of palmitic acids (C16:0), myristic acid (C14:0), and stearic acids (C18:0). The fatty acids inside of camelina grains are 14.4–19.9% oleic acids (C18:1) and 13.5–28.5% linoleic acids (C18:2) [102], [103]. The ranges of camelina cake myristic acids (C14:0) ranges from 0.1 to 0.2%, whereas palmitic acids (C16:0) 7.19 to 9.46%. The percentage ranges of oleic acids (C18:1), linoleic acids (C18:2), and linolenic acids (C18:3) in camelina meal are 17.8–21.7, 24.35–28.8%, and 24.2–46.3%, respectively. One of the best natural sources of n-3 PUFA, especially alpha linoleic acids. The range of Camelina seed's polyunsaturated fatty acids (PUFA) content is 55.2-57.1%, monounsaturated fatty acids content is 32.1-36.16% and its Saturated Fatty Acids (SFA) content is 9.04-13.3%. Camelina oil consists of 55.2 % PUFA, 10.2 % SFA, and 34.6 % MUFA [51], [102]. The corresponding table displays the various percentages of fatty acids found in Camelina seeds (Table 2.)

Table 2. The various percentages of fatty acids found in Camelina seed [103], [104].

Fatty acids (%)	[105]	[106]	[107]	[108]
Arachidic acids	1.3	1.5	1.8	1.7
Behenic acids	-	0.3	0.8	0.4
Clupanodinic acids	-	0.2	0.4	-
Arachidonic acids	1.4	1.4	-	-
Docosatrienoic acids	-	0,4	-	-
Erucic acids	2.3	3.1	4.2	3.5
Eicosadienoic acids	1.8	2.2	1.9	1.8
Gadoleic acids	14	15	11.9	15.1

Lignoceric acids	-	0.2	-	-
Linoleic acids	18.5	19.1	18.7	18.5
Linolenic acids	35.8	33.5	28.6	32.8
Myristic acids	-	0.1	0.2	-
Nervonic acids	-	0.6	-	0.7
Oleic acids	16.1	14.4	17.6	15.7
Palmitic acids	6.1	5.5	5.1	5.7
Palmitoleic acids	0.1	0.1	0.3	-
Stearic acids	2.6	2.4	2.4	2.4

6.3. Phenolic compounds

Plant oils, particularly cold-pressed varieties, are an abundant source of biologically active compounds like the hydroxylated derivatives of cinnamic and benzoic acids coumarins, lignin and flavonoid compounds [109], [110], [111]. There are few investigations on the existence of natural phenolic compounds and antioxidant activity in *Camelina sativa* extracts [108], [111]. Camelina oil contains 760 mg of tocopherols, which are important antioxidants for the oxidative stability of vegetable oils. Other tocopherols include α-tocopherol (28.07–41.8 mg/kg) and delta-tocopherol (12.3–20.47 mg/kg). Pure camelina oil had a higher total tocopherol concentration (751–687 mg/kg) than rapeseed and flax oil [112]. Fresh camelina oil contains 123 mg of polar phenolic molecules, which are also known as chlorogenic acids. Camelina cake includes phenolic substances such as tocopherols, sinapine, and sinapic acids [111]. Several phenolic compounds were identified in camelina cake that may be responsible for the antioxidant effect. Tocopherols, sinapic and sinapine acids are the main antioxidants found in camelina cake, while flavanols also play a role in its antioxidant properties [113], [114]. Camelina contains large amounts of phenolic acids and flavonoids. The phenolic acids quantity in camelina in oil is from 681.89 to 892.12 mg/L and in seed ranges between 2043.6 to 3704.7 mg/kg, in the cake from 1148.67 to 1413.76 mg/kg dry matter. Flavonoids in camelina seed from 329.49 to 526.4 mg/kg, oil from 266.01 to 435.32 mg/L, and cake range from 37.69 to 73.13 mg/g [39].

6.4. vitamins, macroelements, and microelements in camelina

Camelina contains a significant amount of vitamin B1 (thiamine), B3 (niacin), and B5 (pantothenic acids). *Camelina Sativa* generally has higher levels of B-series vitamins when compared to the other seeds, except for pyridoxine (B6) [85], [115]. Vitamin B3 is the most abundant vitamin in camelina seed (194 μg/g) [94], twice as much as flaxseed's (91 μg/g) [85]. Camelina contains 18 μg/g of vitamin B1 and 11.3 μg/g of vitamin B5. Camellina has much more thiamine than flaxseed (6 μg/g) and rapeseed (8 μg/g). Pantothenic acids concentration in camelina is similar to flaxseed (11 μg/g) but lower than rapeseed (16 μg/g) [87], [116].

Camelina seed contains a trace of macrominerals. Potassium (K) (1.6%), phosphor (P) (1.4%) and calcium (Ca) (1.0%) are among the greatest concentrations. Additionally, camelina seed includes sulphur (S) (0.24%), magnesium (Mg) (0.51%), sodium (Na) (0.06%), and chlorine (Cl) (0.04%). The iron amount of camelina seed is substantial (329 μg/g), and it also contains large amounts of zinc (Zn) (69 μg/g). It includes 1.9 μg of nickel (Ni) and 9.9 μg of copper (Cu) per gram [87].

Camelina meals are composed of carbohydrates such as disaccharides, monosaccharides, polysaccharides, oligosaccharides, and fibre. Monosaccharides and disaccharides are easily digested and provide rapidly metabolizable energy in the human body. Camelina is characterized by a low concentration of carbohydrates. It contains 5.5% sucrose, which is twice the percentage of flaxseed (2.8%) but less than rapeseed (6.8%). Camelina contains very small amounts of oligosaccharides, such as stachyose and raffinose (less than 1%) [34]. For polysaccharides, which include starch, pectin, and mucilage, the percentage of starch and pectin does not exceed (1%). The mucilage content in camelina is 6.7%, less than flaxseed (8%) [87]. Camelina meal includes different secondary metabolites such as sinapine, inositol phosphates, glucosinolates, and condensed tannins, which are common antinutritional chemicals found in oilseeds. Sinapine and GSLs are often connected with Brassicaceae plants [116].

7. Conclusion

Recent studies have shown the importance of the *Camelina sativa* plant as a rich source of nutrients and active substances. According to available research, camelina seed oil has a special combination of vital fatty acids, making it beneficial for human health and many industrial applications. With further research and developments in agriculture and biotechnology, camelina are expected to have a significant impact in improving human food and improving environmental sustainability. Therefore, future research is important to discover the full potential of the camelina plant and make the most of its potential benefits.

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