Camelina sativa

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Camelina sativa (L.) Crantz, also called gold-of-pleasure, false flax, or linseed dodder, is an oilseed crop belonging to the tribe Camelineae of the mustard family (*Brassicaceae*). Camelina is a hardy plant that adapts very well to different types of soil and grows best in cool semi-arid climates. The great potential of this crop is also being exploited to obtain a sustainable feedstock for its different applications, and to improve dryland agriculture. Camelina can be used to improve the quality of foods, such as dairy products and meat, and the consumption of its oil has potential benefits for human health.

Keywords: Camelina sativa ; oilseed crops ; PUFA ; cover crop

1. Introduction

Camelina sativa (L.) Crantz, also called gold-of-pleasure, false flax, or linseed dodder, is an oilseed crop belonging to the tribe Camelineae of the mustard family (*Brassicaceae*) [1][2][3].

Plants are erect and typically reach heights between 30 and 90 cm. Rosette leaves are not lobed and are withered by the time of flowering. The stems are branched, woody when mature, and can be sparsely hairy. The leaves alternate on the stem and are lanceolate with a length of 2–8 cm and a width of 2–10 mm. Inflorescences are racemes with small flowers in terminal clusters. The flowers are pale yellow with four spatulate petals. The siliques are 7 to 9 mm long, leathery, smooth, and usually contain 5–15 golden brown seeds. Seeds are small, generally 2 to 3 mm long, brown in colour, rough, and have a rippled surface (**Figure 1**).

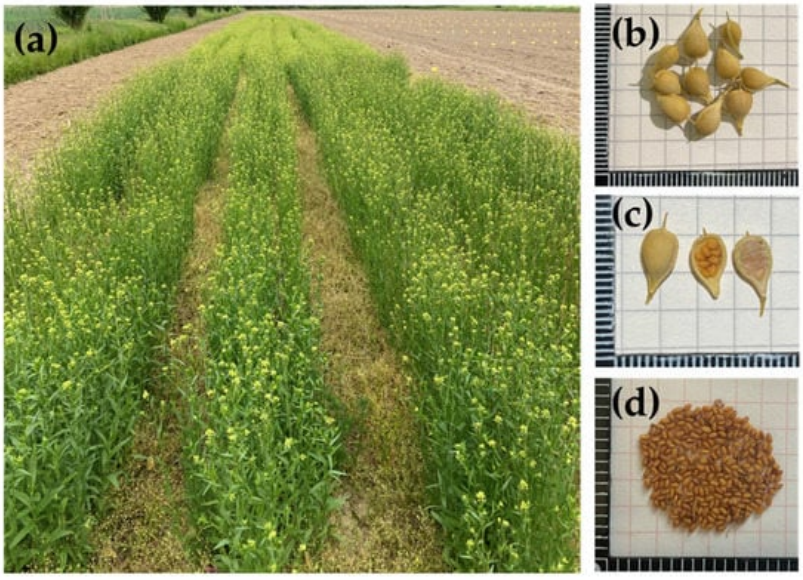

Figure 1. *Camelina sativa* crop. (**a**) Flowering plants; (**b**) silique; (**c**) opened silique; (**d**) seeds.

The weight of 1,000 seeds is in the range of 0.8 to 2.0 grams. The seeds contain 38 to 43% oil, and 27% to 32% protein. Camelina reproduces through seed and is primarily a self-pollinating species [4][5].

The possible centre of origin is located between Ukraine and Russia. The genetic diversity hotspot was identified in this region [6]. The distribution of camelina extends from Europe to southwestern Asia, and it was introduced in America and Canada as a contaminant of flax, hence the name false flax. *C. sativa* is a very ancient crop plant, and archaeological evidence suggests that its cultivation began in the Neolithic age in south-eastern Europe and during the Iron age, it was an important crop in most of Europe. In 1950 in Denmark, a mummified human body datable to this age was found from whose remains the contents of the last meal were identified: barley, flax, oats, and camelina. During the Roman Empire,

the oil extracted from the seeds of this plant was used for lamps, body care, and food. In 600 BC, camelina was cultivated in the Rhine valleys as a monoculture. Its cultivation continued until 1940 throughout France, Belgium, and Russia, where the oil was also used as fuel. Since 1950, this crop has been abandoned and replaced with more profitable crops [2][7][8].

2. Cultivation

Global climate change is leading to the deterioration of the sustainability of various economic sectors worldwide. In particular, the most affected sector that causes the greatest concern is the agricultural sector, which has been increasingly looking for crops that can be as resilient as possible to this irreversible climatic variability [9][10]. Crop diversification is used to promote better environmental, social, and economic sustainability of agri-food systems, maintaining their production capacity, providing ecosystem services, and promoting the efficient use of resources.

Camelina is a hardy plant that adapts very well to different types of soil and grows best in cool semi-arid climates. Camelina can tolerate drought conditions, although they can negatively impact sensitive growth phases, such as flowering [4][11]. Different works conducted in different countries worldwide on camelina seed yield were reviewed by Berti and co-authors [3]. Reported yields vary greatly depending on the climate, the cultivar used, and soil type. However, the highest seed yields have been registered in Mediterranean climates [2][9][12][13][14].

In the western Prairie provinces of Canada and the North and Central Plains in the USA, camelina may be economically competitive with other alternative oilseeds common to these areas, such as soybean (*Glycine max* (L.), flax (*Linum usitatissimum* L.), rapa canola (*Brassica rapa* L.), juncea canola (*Brassica juncea* L.), yellow mustard (*Sinapis alba* L.), oriental mustard (*Brassica juncea* L.), and Ethiopian mustard (*Brassica carinata* L.) [15]. In the upper Midwest Corn Belt region, camelina cultivation as a standalone crop could not be competitive with corn and soybean, and should be used in winter dual cropping to integrate the corn–soybean systems [16].

Its cultivation is also arousing growing interest in Italy [11][17][18]. In fact, a yield of 1200–3300 kg/ha in the Italian Lombardy Region was reported using seven different spring varieties (Calena, Ligena, Ukrajinskaja, Lindo, Zarja Socialisa, Soledo, and Morgesonne) [17].

The agronomic performance over two consecutive years of camelina sown in spring and autumn was evaluated in comparison with rapeseed (*Brassica napus* L.). The result showed, in general, the seed yield is similar to that of the rapeseed control and, on average, between 1340 and 1625 kg/ha. Furthermore, regarding the two sowing seasons, autumn planting allowed a better yield [17].

Camelina can be used in intercropping and rotation systems, especially in drier areas [1][3][9].

Winter genotypes are the best varieties for growing in winter to protect the soil. Concluding, using winter camelina as a cover crop prevents erosion and promotes carbon sequestration in the soil. Moreover, it can also be used to control weeds as it inhibits their growth [19][20].

3. Uses and Potential

In recent years, the interest in this plant has increased significantly as an oilseed crop for food, feed, jet fuel, and bio-based products [15][21]. Berti and colleagues reported the great potential of the crop and its numerous uses, particularly the oil properties and composition, which are useful for the purposes reported in **Table 1** [3].

Table 1. Uses of *Camelina sativa* (modified from Berti et al., 2016 [3]).

Uses	Details	References
Human nutrition	**Food** **Diet supplements**	**[20][22][23][24][25][26]**

Uses	Details		References
Animal feed	Bird	Chicken broilers	[9][27][28][29][30][31][32]
		Laying hens	
	Mammals	Cows	[33][34][35][36][37][38][39][40][40]
		Swine	
		Sheep	
		Rabbit	
	Fish	Swine	[41][42][43][44][45][46][47][48][49]
		Salmon	
		Trout	
		Other fish	
Chemicals	Polymers		[50][51][52][53][54][55][56][57]
	Adhesives		
	Resins		
	Cosmetics ingredients		
Fuels	Biodiesel		[1][3][5][21][57][58][59][60][61][62][63][64][65]
	Jet fuel		

Camelina can be used to improve the quality of foods, such as dairy products and meat, and the consumption of its oil has potential benefits for human health [66]. The oil is rich in essential omega-3 fatty acids (e.g., α-linolenic acid) associated with reducing the risks of coronary and inflammatory diseases. High polyunsaturated fatty acids content could reduce blood serum cholesterol levels [67], and improve serum lipid profiles [68] while protecting against cardiovascular risk factors. In folk medicine, camelina oil was used to treat skin wounds and burns [69].

In addition to the various benefits, the high levels of tocopherols and phytosterols with antioxidant activity increase the shelf life and stability of the oil [70][71].

Several studies have demonstrated the usefulness of camelina meal as a component of feed for broilers, cattle, dairy cattle, and fish, such as salmon (**Table 1**), with the added benefit of increasing the omega-3 content [43][72]. Camelina meal obtained from high-pressure seed crushing, or a pre-press solvent extraction process represents an important output with considerable economic value.

In animal feed, camelina flour and seeds are considered beneficial in limited quantities [9]. The presence of anti-nutritional compounds limits its use in zootechnical nutrition with a maximum percentage of 10% [73]. However, compared to other brassicas, the sinapine content (sinapines are alkaloids present in the seeds of *Brasssicaceae* that reduce the digestibility of proteins) is lower in the camelina meal. The glucosinolate content is mainly considered to evaluate the palatability, and it can be included with a content of 27–32 mmol/kg glucosinolates (GSLs) [74].

Additionally, considering the glucosinolates, camelina's accessions with a low content of erucic acid can be selected for animal diets. In the US Department of Agriculture's (USDA) National Genetic Resources Program collection, erucic acid content varies from 1.8–4.8% in camelina seed meal, and for feed, it is limited to a maximum of <2% [9]. Neupane et al. [9] evaluated the effects of camelina meal on different animals' diets. Adding camelina flour or seed oil to the diets of dairy cows led to an increase in the MUFA (monounsaturated fatty acid) and PUFA (poly unsaturated fatty acid) content in the milk with a consequent decrease in saturated fatty acids, without altering other parameters, such as the intake of dry matter, milk production, or digestibility.

In sheep diets, the addition of camelina flour increased the total omega-3 content and improved the omega-6/omega-3 ratio in both lamb meat and milk, the oxidative stability of the milk increased, and there was a reduction in atherogenic and thrombogenic indices. In pigs' diet, the inclusion of camelina seed meal by up to 18% increased the content of α-linolenic acid and reduced the cholesterol content of the meat, thus improving its quality. In addition to the quality of the final product, the animals' health improved. Camelina meal and oil are excellent substitutes for fish meal and fish oil in fish

feed. Several studies have shown an improvement in the total lipid content in salmon (*Salmo salar* L.) and cod (*Gadus morhua* L.) without affecting the sensory quality. The use of camelina in fish feed improved the content without adversely affecting the sensory quality of the fish fillets. Replacing fish oil with camelina oil had no effect on growth performance for most fish. It also tends to increase the omega-3 PUFA content in meat [41][43]. Another work published in 2020 reported the effect of different percentages of camelina cake in laying hens' diet.

The great potential of this crop is also being exploited to obtain a sustainable feedstock for its different applications, and to improve dryland agriculture [75].

In addition, the oil was used as a fuel for lamps and in various industrial applications, while the stems were evaluated for their fibre [4][8].

Currently, camelina oil is used as a raw material to produce biofuels, especially for the aviation industry, as it is rich in unsaturated fatty acids, and, consequently, it does not solidify at low temperatures [76]. Recently, in Italy, experiments on the cultivation of this crop for the production of biodiesel and the extraction of pure vegetable oil obtained promising results [77]. The results obtained as "camelina fuels" are encouraging, having successfully surpassed the techno-economic and life cycle analyses (LCA) as a second-generation biofuel [76][78][79].

Camelina also has a high application potential in the chemical industry due to the presence in its oil of a distinctive fatty acid composition. The predominance of polyunsaturated fatty acids means that their use is multiple in the production of biopolymers, bioactive molecules, lubricants, adhesives, varnishes, paints, pharmaceuticals, cosmetics products, and packing materials [80][81].

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