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Agro-biochemical Characterisation of *Camelina sativa*: A Review

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ABSTRACT

Camelina sativa- an oil seed flowering plant that originated in North Europe and Central Asia is known by many names: gold-of-pleasure, false flax, wild flax and German sesame. Belongs to the Family Cruciferae, genus Camelina and it includes several species. Camelina has several favorable agronomic characteristics, it can be cultivated both in winter and spring season, having a remarkable capacity to adapt and resist to difficult climate conditions and pests. *Camelina sativa* contains 30-48% oil and 33-47% protein and adequate micronutrients with unique properties for industrial and nutritional applications. In addition, Camelina is a promising oilseed crop for production of edible oil, seed meal for animal feed rations and/or biodiesel feedstock. The high amounts of unsaturated fatty acids (about 90%) make camelina oil fast-drying which can be used for making polymers, varnishes, paints, cosmetics and dermatological products. *Camelina sativa* seed meal consisting of up to 50% crude protein– can be sold asan ingredient for cattle and chicken feed, adding further value to producing camelina. Overall, Camelina oil, due to its composition, has multiple uses in various industries: feed technology, biodiesel production, biopolymer industry, cosmetic industry (skin-conditioning agent), in food products due to its high omega-3 fatty acid content and low erucic acid content and as milk fat substitution.

Key words: Animal feed, *Camelina sativa*, Feedstock, Oilseed.

Camelina [*Camelina sativa* (L.) Crtz.] is an important oilseed crop with several excellent qualities that are contributing tothe rising interest in its use for food, feedstock, pharmaceuticals, biofuel and other industries (Betancor *et al.*, 2015; Haslam *et al.*, 2016), its history goesback to the Bronze Age (Putnam *et al.*, 1993). Although camelina has been cultivatedin Europe for over 2000 years for oil and livestock fodder, the crop has gained increased popularity recently as abiofuel source due to its oil content. Although widely grown up to the early 1940's commercial production ceased with the introduction of oilseed rape (Putnam *et al.*, 1993). In addition, Quezal and Santa (1962) indicate the presence of *Camelina microcarpa* in the High Plateaus of Algeria as wild plant. The lower cost of hydrogenating rape oil and the lack of knowledge on the value of oils containing a high percentage of polyunsaturated fatty acids were the main causes of the lack of interest in camelina. There are two cultivated forms such as winter and summer, but the winter forms yielding higher than summer (Mosio-Mosiewski *et al.*, 2015). In addition, the camelina crop canbe grown on marginal farmland, with relatively low inputs and no irrigation. This plant also has very high resistance against pests such as cockroaches and pollen eating that is common in oil seeds. Underfavorable conditions, camelina crops yield >2 t/ha, but lower yields (1.2 to 2.2 t/ha) are observed under conditions of limiting nutrients or water (Crowley and Frohlich, 1998; Gehringer *et al.*, 2006). The particular value of camelina oil is given by its content in polyunsaturated fatty acids (50-60%), by its content in omega 3 (35-40%) and by its content in omega 6 (15-20%). Due to these properties, camelina oil is one of the richest vegetal sources of omega 3. Extraction of oil from camelina seeds by mechanical expeller yields a meal that consists of approximately 10% residual oil, 45% crude protein, 13% fibers, 5% minerals and other minor constituents such as glucosinolates and vitamins, which in turn has prompted studies for its use as an aquaculture and animal feed supplement. Present review covers various aspects of *Camelina sativa* research including its origin,classification and genetics, morphology, minimum inputs to grow camelina, allelopathic potential and camelina products and applications.

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Origin of Camelina

Camelina sativa is an ancient crop that is believed to have evolved as a weed in fields planted with flaxseed (Chaturvedi *et al.*, 2019); it is originated from Southern Europe and South-West of Asia (Berti *et al.*, 2016), although the exact region remains uncertain. In adition, a molecular analysis of a number of *Camlina sativa* accessions of Russian-

Ukrainian origin revealed that this region is a hotspot for genetic diversity in *Camlina sativa*, suggesting that it could be the centre of origin for this species (Ghamkhar *et al*., 2010).Known as “gold-of pleasure” or “false flax”, after losing any prominence in Europe during the 1940s, camelina breeding research started again in Germany in the 1980s (Vollmann *et al*., 2005).

Classification and genetics

Camelina [*Camelina sativa*(L.) Crantz] is a summer or winter growing annual herb in the family Brassicaceae, Class of Dicotyledons and is related to *Arabidopsis thaliana*, a much researchedspecies. As illustrated in the Fig 1, *C. sativa* (2n=40), is an ancient oilseed crop with a new found application as an aviation biofuel and omega-3 rich feedstock. The genus Camelina, represented by seven or eight species (Brock *et al*., 2019), belongs to one of the most karyo logically variable crucifer genera, with chromosome numbers ranging from 2n = 12 to 40 (2n = 12, 14, 16, 26, 28, 32, 36, 38 and 40) and a threefold genome size variation (Hutcheon *et al*., 2010; Brock *et al*., 2018).

Morphological description

Morphologically, camelina has a smooth or hairy steam, whose height may be between 65 and 110 cm (Fig 2A) (Berti *et al*., 2016). Rosette leavesare not lobed and are withered at flowering, leaves on stems are alternate,lance-shaped, lacking a petiole and usually clasping,they are typically 2 to 8 cm long and 2 to 10 mmwide and may be smooth or have a few, primarily forked, hairs (Francis and Warwick 2009). The inflorescence is composedof small pale-yellow flowers (Fig 2B), which are made up offour petals that further develop pear-shaped silicles (Fig 2C). The final number of pods per plant can range from approximately 60 to 115 and it is positively and negatively correlated with increased N fertilization and increased sowing density, respectively (Czarnik *et al*., 2018). Camelina seed pods are siliques; globular and rounded, divided by a septum and typically contain 10 to 25 seeds; at maturity, seed pod change their color from green to yellow-reddish and thencompletely dry at full maturity(Jankowski *et al*., 2019). Camelina seeds are brown to light brown with a thousand kernel weight (TKW) of 1 to 2 g (Meakin, 2007).

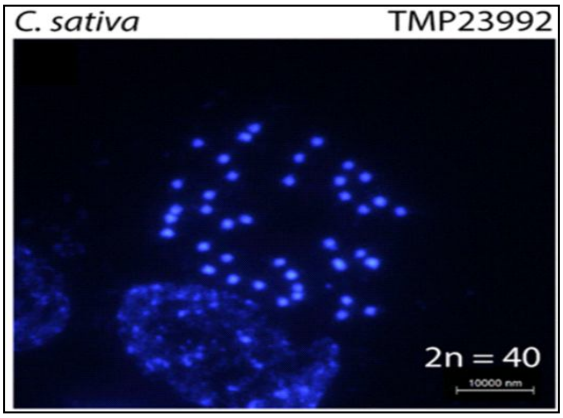

Fig 1: Chromosome counts of *Camelina sativa*.
Source: Chaudhary *et al.* (2020).

Minimum inputs to grow camelina

Camelina is an annual crop which can be cultivated both in spring and in winter seasons (Dobre *et al*., 2014; Berti *et al*., 2016), winter varieties showing a high resistance to harsh climate conditions. In addition, camelina has modest requirements for agro-ecological conditions; an important feature of camelina is its high level of resistance against insect pests and plant pathogens and low doses of nutrients (Volmann *et al*., 2005). Kim *et al.* (2015) proved that the Camelina cultivation requires low water and fertilizers compared with other crops from the same family.Moreover, it was noted the adaptability of Camelina to different medium conditions (Berti *et al*., 2016) and its capacity to grow in marginal lands (Kim *et al*., 2015, Petre *et al*., 2015). Camelina is well adapted to cool temperate semi-arid climates (Mulligan, 2002) and it is more tolerant of drought and spring freezing in comparison with other crops from the same family (Krzysztof *et al*., 2019). Due to the small seed size (Fig 3), camelina is planted at shallow depths (6-8 mm) to ensure plante mergence and good stand establishment.In addition, seeding rate of 5-7 kg seeds ha^{-1} is adequate to ensure good dense stand. Camelina can be grown under conventional tillage or

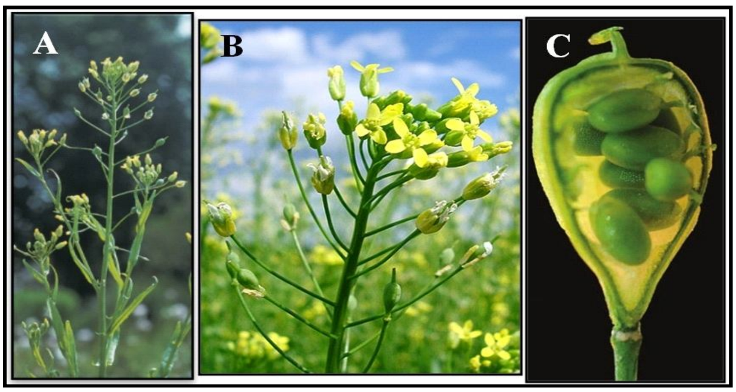

Fig 2: Details of the Camelina plant.
A) Camelina branches, B) Camelina inflorescences and C) Camelina seeds pod.

no-till conditions (Enjalbert and Johnson, 2011). However, excessive crop residue can reduce seedling emergence with no-till,therefore seeding rates need to be increased under no-till (Enjalbert and Johnson, 2011).

Allelopathic - *Camelina sativa*

Allelopathy is expected to be an important part of integrated weed management as a supplementary tool for weed control in the agro-ecosystems because of increasing public concern about harmful effects of pesticides on the environmentand human health as well as increasing rate of weed resistant to known chemicals (Uremis *et al*., 2009). Selective breeding has been done to improve the allelopathic activity in some crops: rice, wheat and barley (Bertholdsson, 2007; Kong *et al*., 2011). Brassicaceae family plants are frequently cited as allelopathic (Jafariehyazdi and Javidfar, 2011) and include oilseed [canola (*Brassica napus* L.), camelina [*Camelina sativa* (L.) Crantz.], mustard (*Brassica rapa* L.)] and vegetable crops [broccoli (*Brassica oleracea* L.) and radish (*Raphanus sativus* L.)]. In addition, Brassica species contain allelochemicalcompounds as glucosinolate and their corresponding degradation products that are, under special conditions, released to environment and affects seed germination and plant growth (Bones and Rossiter, 1996). Leaves are the main source of allelopathic inhibitors and the focus of many allelopathic investigations; Lovett and Duffield (1981) reported positive effects of *Camelina sativa* leaf washings on flax growth, which observed no significant increase in flax root or shoot weight in response to Camelina leaf washings.

Camelina sativa in rotation cropping systems

Leclère *et al*. (2018), reports that the *Camelina sativa* was identified as a possible summer cover crop in double cropping systems, this type of approach tremendously widens the opportunities of Camelina to pass from thestatus of niche crop to cash cover crop in Europe. One new potential use of Camelina is as a cover crop in maize soybean rotations in the Midwest USA; winter Camelina can be direct sown following the harvest of short-season cereals such as wheat (*Triticum aestivum* L.) (Berti *et al*., 2015) and ithas the potential to be established by broadcasting into longer seasonstanding crops such as maize and soybean. On the contrary, Previous cropping systems research reported growing Camelina in place of fallow in a Wheat-Fallow rotationshowed minimal reduction in winter wheat yield (6%) in wet years (Hess *et al*., 2011). However, in drier years, winter wheat yields following Camelina were 13%-30% lower than yields after fallow (Chen *et al*., 2015; Hess *et al*., 2011).

Fig 3: A) Camelina silicles (pods) near maturity and B) Camelina seeds.

Camelina products and applications

The high oil content of Camelina seeds could also favor the accumulation of bioactive compounds such as terpenes, whichare components of essential oils used in food additives, cosmetics, drugs, rubber and lubricants (Degenhardt *et al*., 2009). Camelina oil can be used for biodiesel and renewable jetfuel production (Mupondwa *et al*., 2016). In addition, Camelina oil and mealhave other industrial applications such as making adhesives, coatings,gums, resins and varnishes (Kim *et al*., 2015; Nosal *et al*., 2015).

Camelina oil extraction methods

Camelina oil is extracted from the seeds by many processes such as cold pressing, solvent extraction or super critical CO_2 extraction. The cold pressing technique is applied in two ways: screw press and/or hydraulic press. It is an alternative technique to conventional solvent extraction method because it does not require the use of organic solvent or heat. This technique isaffected by temperature, frequency and press nozzles size (Popa *et al*., 2017). Supercritical CO_2 (SC-CO_2) fluid extraction is an alternative technique to cold pressing. Belayneh *et al*. (2015) compared the composition of oil obtained using 3 different extraction methods: classical extractions by Soxhlet and cold pressing and supercritical- CO_2 extraction. The extraction yields obtained were: 35.9% -Soxhlet extraction with hexane during 6 hours, 29.9% -cold pressing extraction, respectively 31.6% - supercritical-CO_2. The last mentioned method showed a high efficiency regarding oil recovery-88% of the quantity recovered normally with hexane extraction. There were no significant differences between the compositions of the three oils (Belayneh *et al*., 2015).

Camelina seed composition

Camelina sativa oil

Camelina sativa oil is the main product from CS seeds and the average yield of oil from the seeds isabout 40% on Dry Matterbasis (Zubr, 2009). Camelina seeds contain over 38.9% fat, 30 per cent α-linolenicacid (18:3 n-3) (an omega-3 fatty acid) and 25.8 per cent crude protein. Due to the high oil content, omega-3 fatty acid and crude protein, finding alternative use of Camelina meal (a co-product obtained from Camelina seed after oil extraction) in animal diets will increase the market value ofthe crop. The high levels of α-linolenic acid (C18:3, ALA)in camelina oil provide an ideal plant chassis for the synthesis of omega-3 long chain polyunsaturated fatty acids (LC-PUFAs) like eicosapentaenoic acid (C20:5, EPA) or docosahexaenoic acid (C22:6, DHA). Omega-3 LC-PUFAs are central dietary recommendations for fetal development and adult cardiovascular and cognitive health.

Also almost the same percentages of linolenic, linoleic, oleic, eicosenoic and erucic acids were reported following studies conducted by different researchers, as it is shown in Table 1. The oil is also very rich in natural antioxidants, such as tocopherols, making this highly stable oil very resistant to oxidation and rancidity. Camelina oil has a high content of eicosenoic acid, which is rarely found in plants; this makes Camelina a source of medium chain fatty acid (MCFA), which obtained only from palm and coconut oils (Righini *et al*., 2016). MCFA are known for their positive action on metabolic disorders of lipids, by suppressing the fat depositions and oxidation in animals and humans (Nagao and Yanagita, 2010).

Camelina sativa meal

Camelina sativa meal is the product obtained from high-pressure crushing of seed or from a pre-presssolvent extraction process, which removes the oil from the whole seed; it represents an important output with considerable economic value. Camelina meal is used in animal feed (Nain *et al*., 2015); Chicken (Ciurescu *et al*., 2016) and sheep (Cieslak *et al*., 2013) fed Camelina meal had lower blood plasma cholesterol and higher contents of ±-linolenic, eicosapentaenoic acid and docosahexaenoic acid in muscles. Cold-pressed Camelina meal contains 35-40 per cent crude protein, 6-12 per cent fat, 6-7 per cent ash and 41 per cent neutral-detergent fiber. The gross energy is 4600-4800 kcal/kg (Cherian *et al*., 2009). In addition, *Camelina sativa* meal is a good source of vitamins B1 (thiamin), B3 (niacin) and B5 (pantothenic acid).Thiamin play functions as a coenzyme intransketolation and is important in neural transmission. It is directly involved in maintenance of normal appetite and healthy attitude (Berdanier, 2002). Zubr (2010) reports that *Camelina sativa* meal is a marginal source of mineral except the micromineralsiron, manganese and zinc. Analyses of *Camelina sativa* reveal prevalently low content of macro-minerals. The highest content between 1.0-1.6% is calcium, potassium, phosphorus. (Zubr, 2010). Among micro-minerals, *Camelina sativa* presents markedly high content ofiron (329 μg/g), manganese (40 μg/g) and zinc (69 μg/g) (Zubr, 2010).

Applications of *Camelina sativa*

In total, 80% of *Camelina sativa* oil is utilized in health-food products. Approximately, 14% of oil is used in industrial raw materials like cosmetics, detergents, surfactants, emulsifiers, lubricants, fuel, oleo chemicals, plasticizers and adhesives (Carlsson, 2009). In addition, the camelina by-products, such as *Camelina sativa* meal are valorized especially for animal feed (Woyengo *et al*., 2016).

Feed stock and biofuels

Biodiesel defined as a fuel comprised of mono-alkyl esters of long chain fatty acids derived from a renewable lipid feedstock, such as, animal fats or vegetable oils (Litvin, 2009), provide a clean and effective fuel for diesel engines. Thus biodiesel is distinguished than diesel fuel in terms of aromatic content, Sulfur content, flash point and biodegradability. Recently, as feedstock for biofuel production, *Camelina sativa* has attracted renewed interest due to some useful and distinguishable agronomic traits such as: very short growth cycle, resistance to drought andlow temperature, capacity to growth in marginal soils and lower demand of fertilizers, herbicides and pesticides (Vollmann *et al*., 2007). In addition, *Camelina sativa* oil is mainly used for the jet fuel production. The jet fuel obtained from *Camelina sativa* oil tested versus the classical one proved no degradation of the engines and its use resulted in lower soot and carbon monoxide emissions (Berti *et al*., 2016). For biofuel production, it was tested also the use of *Camelina Sativa* meal, which by pyrolysis may lead to high energy liquid fuels with increased stability due to low oxygen content (Goímez-Monedero *et al*., 2015). The *Camelina sativa* base feed is given to different terrestrial animals, aquatic animals andbirds to improve their general health; Hixson and Parrish (2014) have tested the replacement of fish oil and fish meal used inaquaculture Atlantic cod diet with *Camelina Sativa* oiland meal. *Camelina sativa* meal is full of mineral content that makes it suitable for animal feed (Table 2). According to experimental data, the use of fish oil can be replaced with Camelina oil in Atlantic salmon diet, without any impact on weight gain (Hixson *et al*., 2014). Hence, it isclear that *Camelina sativa* products as diet are suitable because has good amount of micronutrient (Bullerwell *et al.* 2016). In addition, *Camelina sativa* meal can be used as additive for animal feed because it has good amount of protein and omega-3-FA (Ryhänen *et al*., 2007). (Table 2). It is also rich in protein and poly unsaturated fatty acids (PUFAs) and can be used in cattle feed (Hurtaud and Peyraud, 2007). *Camelina* sp meal has high amount of protein and energy, which can be a good source for ruminant feeds (Matthäus and Zubr, 2000). In dairy cows, this meal can reduce milk fat, resulting in more spreadable butter (Hurtaud and Peyraud 2007).

Human nutrition

Many studies in human nutrition and health have determined the relationship between the diet and the occurrence of various diseases. The using *Camelina sativa* as animal feed encouraged researchers to use them as human feed. Due to high content of unsaturated fatty acids in *Camelina sativa* oil its oxidative stability should be an important factor, *Camelina sativa* 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 (Abramoviχ and Abram, 2005). In addition, the *Camelina sativa* oil is a rich source of essential Fatty Acids (linoleic and α-linolenic acids) as well as omega-3 (α-linolenic) (Hrastar *et al*., 2009). The low content of erucic acid represents an advantage when using *Camelina sativa* oil in human diet, considering that the ingestion of high quantities of erucic acid are thought to be responsible of cardiac lipidosis (Vollmann and Eynck, 2015). The high levels of omega-3 lipids in *Camelina sativa* oil are perceived as beneficial for human health (Zubr, 1997; Eidhin *et al*., 2003) and the high levels of tocopherols, including vitamin E, make *Camelina sativa* oil more stable to oxidation than other high omega-3 oils such as linseed oil (Hrastar *et al*., 2009).

Camelina is known to have the capacity to reduce serum triglycerides and cholesterol; also, due to its fatty acids profile the camelina oil may be used in human diet as nutraceutical: in salads, for cooking, in margarine with enriched content of omega-3 fatty acids, in salad dressings, mayonnaise, ice cream (Abramovic and Abram, 2005).

Medicinal therapeutic applications

Human body cannot synthesize ±-linolenic acid (omega-3) and its deficiency may result in clinical symptoms including neurological abnormalities and poor growth. Therefore, ±-linolenic acid should be included in the diet. The consumption of *Camelina sativa* oil riched on ±-linolenic acid (32.8-33.0%) can help to improve the general health to the desired level (Lu and Kang, 2008). In addition, the meal (Cake) of Camelina seed contains many phenolic compounds, which showedantioxidant activity like tocopherols, sinapine and sinapic acid (Salminen *et al.*, 2006). Many studies proved the efficiency of using the Camelina oil in treatment of burns, wounds and eye in flammations and it is applied topically; in Slovenia, Camelina oil is used as traditional home remedy (Chaturvedi *et al.*, 2019). Dobrzyńska and Przysławski (2021) 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 and LDL (low density lipoprotein) decreased by 12.2 per cent. 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 (Ortega *et al.*, 2006). In traditional home treatments, *Camelina sativa* oil is useful in the treatment of stomach and duodenal ulcers (Rode, 2002).

Table 1: The major fatty acid composition (%) of camelina seed oil from different published studies.

Compound	Content (%)	Reference
C18:3-linolenic acid	32.8-33.0	Belayneh *et al.*, 2015
	30.5-50.3	Toncea *et al.*, 2013
	28.0-33.4	Katar, 2013
C18:2-linoleic acid	18.3-18.5	Belayneh *et al.*, 2015
	16.6-19.3	Toncea *et al.*, 2013
	19.6	Moser *et al.*, 2010
C18:1-oleic acid	15.7-15.9	Belayneh *et al.*, 2015
	15.1-17.0	Katar, 2013
	18.6	Moser *et al.*, 2010
C20:1-eicosenoic	14.9-15.1	Belayneh *et al.*, 2015
	13.8-14.5	Katar, 2013
	15.2-17.5	Toncea *et al.*, 2013
C22:1-erucic acid	3.3-3.5	Belayneh *et al.*, 2015
	2.9-3.9	Katar, 2013
	2.3	Moser *et al.*, 2010

Camelina oil in cosmetics

A number of other industrial uses for camelina oil have been proposed, including use in paints, inks, soaps, varnishes, lubricants, cosmetics and as a plastic additive (McVay and Lamb, 2007; El Bassam, 2010).The specific dermatological effects of poly-unsaturated fatty acids make *Camelina sativa* oil suitable for cosmetic applications, such as cosmetic oils, skin creams and lotions (Hurtaud and Peyraud, 2007). Camelina oil also has a total tocopherol content of 750 mg/kg oil (Abramovic *et al.*, 2007) and phytosterols (511 mg/100 g oil) (Schwartz *et al.*, 2008) which make it a suitable ingredient in cosmetic preparations that help inpreventing photo-oxidation.

Pesticide and antifungal activities of *Camelina sativa*

Camelina sativa has vast number of neutraceutically important bioactive compounds.Bioactive components like different classes of phenolics, glucosinolates, tocopherols, poly unsaturated fatty acids, mono unsaturated fatty acids, polysaccharides and lignans are reported by researchers in *Camelina sativa* (Abramovic and Abram, 2005; Berhow *et al.*, 2013), it's can be used as potent antifungal, pesticidal, or insecticide in the field crops. The study of Hu *et al.* (2011) proved that the applied of *Camelina sativa* meal at 5% and 1% to soil, it suppresses the *Phymatotrichopsis omnivore*sclerotial germination and hyphal growth of fungi,

Table 2: The *Camelina sativa* meal minerals content and the nutrient profile.

Minerals	Content (ppm)	Reference	Compositions	Content	Reference
Phosphorus	10.21-12.23	Frame *et al.* 2007	Gross energy	4600 kcal/kg	Cherian *et al.* (2009)
Potassium	13.20-14.87		Crude protein	40.0%	Sampath (2009)
Calcium	2.59-2.70		Ash	6.5%	Cherian *et al.* (2009)
Magnesium	4.69		Crude fibre	8.4%	Cherian *et al.* (2009)
Chloride	18.7		**Vitamins**	**μg/g**	**Reference**
Sulfur	9.12		Thiamin (B1)	18.6-19.8	Zubr (2010)
Sodium	15.4-17.6	Cherian *et al.* 2009	Riboflavin (B2)	4.1-4.4	
Iron	151		Niacin (B3)	190.0-212.0	
Manganese	25.1		Pantothenicacid (B5)	11.0-11.4	
Zinc	61.1		Pyridoxine (B6)	1.7-1.9	
Copper	9.18		Folate (B9)	3.1-3.2	
Aluminum	5.37		Glucosinolates	21.2	Aziza *et al.* (2010)

this funguscan infect the roots of over 2000 different species of plants and often results in rapid plantwilting and death; by using *Camelina sativa* meal one can protect fungal attack (Hu *et al*., 2011). In addition, Glucosinolates (GSLs) are secondary metabolites and act as natural pesticides and prevent herbivory (Halkier and Gershenzon, 2006). GSLs in the presence of waterafter an unstable intermediate formation converts into thiocynate, isothiocyanate, ornitrile, these compounds help in defense of plant (Spencer and Daxenbichler, 1980).

Glucosinolates

Glucosinolates (GSLs) are one group of compounds found within and on the surface of cruciferous plants that can act as deterrents or attractants of insect pests and that have been shown to play a part in the recognition of host plants by insects. Glucosinolates are natural, sulfur-rich anionic secondary metabolites, widely distributed in plants of the order Brassicales, GSLs are natural pesticides (Fahey *et al*., 2003; Halkier and Gershenzon, 2006). Camelina seed contains two aliphatic glucosinolates in a significant level; these are glucoarabin (GSL9) and glucocamelinin (GSL10) while the third glucosinolate (GSL11) is in very small amount (Vaughn and Berhow, 2005). The research of Sizmaz *et al*. (2016) proved that the Camelina meal had greater level of glucosinolates than Camelina seed.

Toxicity effects of glucosinolates

GSLs themselves are biologically inactive molecules, but GSL degradation products arebiologically active and known for their diversified biological effects. In addition, the hydrolysis catalyzed by thioglucosidases leads tothe formation of biologically active products. The toxicity of GSLsis generally attributed to the isothiocyanates, thiocyanates, oxazolidinetiones and nitrilesoriginating from enzymatic cleavage of GSLs by myrosinase. Obour *et al*. (2015) showed that the Camelina has two anti-nutritional factors, the presence of high erucic acid and glucosinolates which limits the amount of meal that can be fed makes higher dietary consumptions of Camelina oil unsafe. The concentrationof glucosinolates in dry Camelina seeds ranges from 13 to 36 mol/g. When ingested in sufficient quantity, Glucosinolates cause deleterious effects in animals such as reduced palatability as well as decreased growth and production. Consequently, Camelina meal cannot exceed 10 wt % of the total foodration given to feedlot beef cattle and broiler chickens in the United States. However, even a 10% ceiling represents significant market potential where large numbers of animals are raised for human consumption, thus representing an important revenue stream for Camelina meal (Moser, 2010).

Beneficial effects of glucosinolates

The contact of GSs with the enzyme myrosinase in the presence of watercauses immediately the hydrolysis. The hydrolysis products consist of an aglycone moiety, glucose and sulphate. The aglycone moiety is unstable and rearranges to form isothiocyanates (ITCs), thiocyanates, nitriles, oxazolidinethiones and epithionitriles depending upon the structure of the GSL and the reaction conditions (Fig 4). Natural GSs and their derivatives possess biocidal activity and show toxicity to a range of soil borne as well as plant pathogens and pests (Lord *et al*., 2011). GSs rich plant sources and extracts with the ability to inhibit the growth of pathogens, offer the opportunity to explore them in controlling many plant diseases and as potential bio fumigants (Sotelo *et al*., 2015). GSs and glucosinolate hydrolysis products (GSHPs) volatiles, too, such as ITCs, have at low concentrations been used to control plant pathogens and/or are included as active ingredients among synthetic commercial nematicidal compounds. In addition, GSs and GSHPs have shown great potential as anti-inflammatory agents through their ability to suppress inflammatory mediators independently or with other substances (Rajan *et al*., 2016). GSHPs, mainly volatile ITCs, demonstrate potential in anti-hepatotoxic activity. They include gluconapin, glucoerucin and glucoraphanin that display above 53% acetylcholinesterase (AChE) inhibitory activity in a dose-dependent manner (Blazevic *et al*., 2013). In addition to natural GSs, synthetic GSHPs and their derivatives also show good cholinesteraseinhibitory activity. This has been illustrated

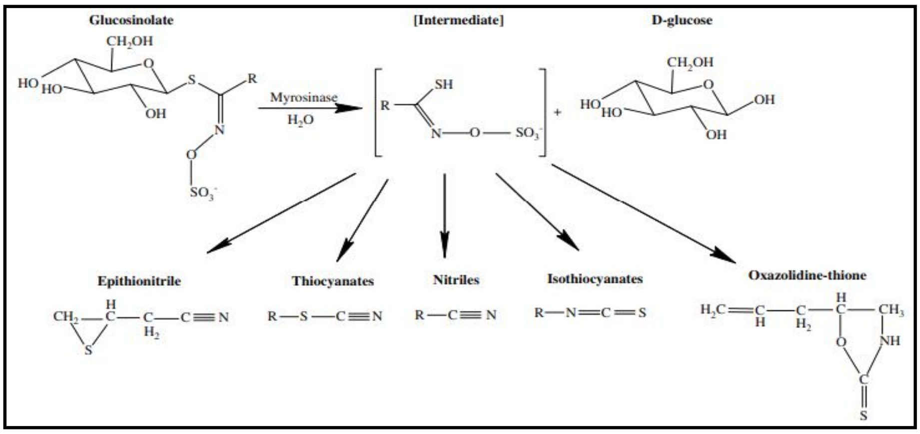

Fig 4: Hydrolysis of glucosinolates by the enzyme myrosinase and their different hydrolysis products. (Rask *et al*., 2000).

in phenyl ITCs and its derivatives that display the mostpromising inhibitory activity with potential applications in treating Alzheimer's disease (Burcul *et al*., 2018).

CONCLUSION

Camelina presents clear favorable characteristics to be implemented in rotation with different cereals. Its tolerance to abiotic stresses, low fertility requirement and its short life cycle make it a good option for obtaining effective coverage reduction over winter weeds. In addition, there are many reasons for this crop to be grown in future as it is exceptionally rich in essential fatty acid, high quality polyunsaturated Fatty acid as compared to other vegetable oil. Other applications of camelina oil are: replacement or supplement of animal feed, biopolymer industry, cosmetic uses and addition in food products. Glucosinolates as secondary metabolites have good potential as natural pesticides and prevent herbivory.

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Conflict of interest

The authors declare that they have no conflict of interest.

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