Scientific Bulletin. Series F. Biotechnologies, Vol. XXI, 2017
ISSN 2285-1364, CD-ROM ISSN 2285-5521, ISSN Online 2285-1372, ISSN-L 2285-1364

CAMELINA SATIVA OIL-A REVIEW

Alina-Loredana POPA[1], Ștefana JURCOANE[1], Brândușa DUMITRIU[2]

[1]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania
[2]S.C. BIOTEHNOS S.A., 3-5 Gorunului Street, Otopeni, Romania
Corresponding author email: alina_popa1990@yahoo.com

Abstract

Camelina sativa is an oil seeded plant belonging to the Brassicaceae family. It can be cultivated both in winter and spring season, having a remarkable capacity to adapt and resist to difficult climate conditions. Moreover, Camelina crop has shown resistance to pests and diseases which affect other crops from the same family. The synthesis of phytoalexins seems to be responsible for the unusual camelina defense system. Camelina oil is the main product resulted by extraction from seeds. The most common extraction methods are: mechanical extraction, solvent extraction and enzymatic extraction. Recently it has been considered also the supercritical-CO_2 extraction. The oil obtained contains an unsaponifiable fraction represented by tocopherols, sterols and a saponifiable fraction consisting in fatty acids. The fatty acids profile is mainly represented by unsaturated fatty acids- mono and mostly polyunsaturated (>55%) and saturated fatty acids (9.1-10.8%). The most frequent fatty acids from camelina oil are linolenic, linoleic, oleic and eicosenoic. In comparison with other Brassicaceae plants, camelina oil has a low content of erucic acid. Camelina oil, due to its composition, has multiple uses in various industries: feed technology for substitution or supplementation of other oils (fish, broilers) in animal diets, biodiesel production, jet fuel production, biopolymer industry (peel adhesion properties, paints, varnishes), 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: *Camelina oil, extraction, fatty acids*

INTRODUCTION

Camelina, scientifically named *Camelina sativa* is a dicotyledonous oil seeded plant belonging to *Brassicaceae* family. It is originated from Southern Europe and South-West of Asia (Dobre et al., 2014; Vollmann et al., 2015; Berti et al., 2016).

Morphologically, camelina has a smooth or hairy steam, whose height may be between 65 and 110 cm. The steam is ramified and as it reaches maturity, it becomes woody. The arrow-shaped leaves, with smooth to wavy edges, are 5-8 cm long. Most of the flowers, with 5-7 mm diameter, are autogamous. The very small seeds are kept in silicules (Berti et al., 2016).

Archeological evidences proving camelina existence in Europe show that its cultivation was performed since 4000 (BCE). In Romania, the camelina use is associated with the period of transition from Eneolithic to Bronze Age (Berti et al., 2016).

Camelina is an annual crop which can be cultivated both in spring and in winter seasons (Gesch and Archer, 2013, Dobre et al., 2014 Berti et al., 2016), winter varieties showing a high resistance to harsh climate conditions (Berti et al., 2016).

Camelina cultivation requires low water and fertilizers compared with other crops from the same family and the crop is more resistant to common pests and pathogens which usually affect similar crops (Kim et al., 2015). Its resistance may result due to synthetizing of phytoalexins (Vollmann et al., 2001). 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).

In Romania, both the climate and the soil are favorable for camelina cultivation (Imbrea et al., 2011).

CAMELINA OIL EXTRACTION

The principal camelina oil seed extraction methods are: mechanical extraction, solvent extraction and enzymatic extraction (Atabani, 2013).

The oldest method used for oil extraction from seeds is hydraulic pressing. It was first used in Europe, in 1795. This method was replaced, in time, by the extraction using screw presses (Rosenthal et al., 1996). Nowadays, manual ram press or engine driven screw are the most frequently used (Atabani et al., 2013).

The mechanical extraction doesn't require special resources, but the oil obtained must be subjected to additional processing like filtration and degumming (Atabani et al., 2013).

Another important aspect to be taken into consideration when choosing mechanical extraction is the fact that the equipment is adapted to certain types of seeds, which has an impact over the extraction yield. The seeds pre-treatment have also an impact on the extraction (Atabani et al., 2013).

The solvent extraction was first used in 1870, in Europe. In its beginnings the method was rarely used, but with time it has become a large scale process. The method can be used to complete the mechanical extraction (Rosenthal, 1996).

Using solvent extraction, a high yield may be obtained, making it a favorable option for oil production at large scale. Several factors, such as particle size, extraction solvent, temperature, stirring may influence the yields obtained with this method (Atabani et al., 2013). Moser et al. (2010) obtained a yield of 30.5 wt% oil from dried seeds with hexane extraction by Soxhlet method for 24 h.

The enzymatic extraction does not produce neither pollutant solvents, harmful for the environment, nor chemical substances dangerous for human health, which is considered a big advantage. On the other hand, one of the disadvantages of this method is the fact that it is time consuming (Atabani et al., 2013).

Several techniques can be used for the extraction of camelina oil such as: warm or cold mechanical pressing extraction, organic solvent extraction, supercritical CO_2 extraction (Berti et al., 2016).

Berti et al. (2016) have reported a higher yield when extracting camelina oil through Soxhlet method compared with supercritical-CO_2 extraction, respectively cold mechanical 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.

The supercritical-CO_2 extraction advantages are: supercritical-CO_2 is a cheap and easy to find (Moslavac et al., 2014) green solvent (Belayneh et al., 2015), it is easy to remove from products, it allows solvent recovery consecutive to other extraction methods. The main disadvantage of this method is the high price of the required equipment (Moslavac et al., 2014).

The main advantage of cold pressing is that it doesn't require organic solvents. The oil obtained retains the valuable bioactive compounds such as: fatty acids, phenols, flavonoids, tocopherols, minerals, fibers and many others (Moslavac et al., 2014). One of this method disadvantages is the low extraction efficiency compared to the classical solvent extraction.

The high quantity of antioxidants (tocopherols) in the raw oil is a major advantage regarding its time stability. Raw oil has a life span of 12-24 months compared with the one highly processed through refining, bleaching, deodorization, which has a life span of 6-9 months (Berti et al., 2016).

Cold pressing is affected by temperature, frequency and press nozzles size. Researchers have tried to optimize the camelina oil extraction by cold pressing. The best results were obtained when using a temperature of 52°C, a frequency of 20 Hz and nozzle size of 9 mm. In this optimal conditions, 289.5 ml of camelina oil with a temperature of 32.6 °C were obtained (Moslavac et al., 2014).

Mechanical extraction with a yield over 60% can be done with manual or engine mechanical presses (Atabani et al., 2013).

The unrefined camelina oil has a clear-yellow color and a broccoli like flavor, while refined oil has no smell and has a pale-yellow color (Atabani et al., 2013).

CAMELINA OIL COMPOSITION

In the camelina oil composition can be distinguished two fractions: one unsaponifiable (tocopherols, sterols) and another saponifiable (fatty acids).

Most of the camelina oil applications are possible due to its fatty acids content.

The fatty acids profile is mainly represented by unsaturated fatty acids- mono and principally polyunsaturated (>55%) and saturated fatty acids (9.1-10.8%). (Toncea et al., 2013)

Many researchers have found that the major component in the camelina oil composition is the omega-3 fatty acid- linolenic acid. 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 (Shukla et al., 2002; Abramovič and Abram, 2005; Moser et al., 2010; Jurcoane et al. 2011; Toncea et al., 2013; Katar, 2013; Belayneh et al., 2015).

Table 1. Camelina oil fatty acids profile reported by different researchers

Compound	Content	Reference
C18:3-linolenic acid	30.5-50.3 %	Toncea et al., 2013
	32.6 %	Moser et al., 2010
	35.6%	Jurcoane et al., 2011
	28.0-33.4%	Katar, 2013
	32.8-33.0%	Belayneh et al., 2015
	38.1%	Shukla et al., 2002
	35.2%	Abramovič and Abram, 2005
C18:2-linoleic acid	16.6%-19.3%	Toncea et al., 2013
	19.6 %	Moser et al., 2010
	20.9%	Jurcoane et al., 2011
	18.5-22.4%	Katar, 2013
	18.3-18.5%	Belayneh et al., 2015
	16.0%	Shukla et al., 2002
	16.9%	Abramovič and Abram, 2005
C18:1-oleic acid	14.9-15.5%	Toncea et al., 2013
	18.6 %	Moser et al., 2010
	16.3%	Jurcoane et al., 2011
	15.1-17.0%	Katar, 2013
	15.7-15.9%	Belayneh et al., 2015
	18.7%	Shukla et al., 2002
	17.4%	Abramovič and Abram, 2005
C20:1-eicosenoic	15.2-17.5%	Toncea et al., 2013
	12.4 %	Moser et al., 2010
	No report	Jurcoane et al., 2011
	13.8-14.5%	Katar,2013
	14.9-15.1%	Belayneh et al., 2015
	11.6%	Shukla et al., 2002
	14.9%	Abramovič and Abram, 2005
C22:1-erucic acid	1.6-4.2%	Toncea et al., 2013
	2.3 %	Moser et al., 2010
	1.6 %	Jurcoane et al., 2011
	2.9-3.9%	Katar, 2013
	3.3-3.5%	Belayneh et al., 2015
	2.5%	Shukla et al., 2002
	1.6%	Abramovič and Abram, 2005

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 in Europe, are now 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).

On the other hand, camelina oil has a low content of erucic acid, which may be an advantage considering that this acid is known to produce cardiac damage by its capacity to increase the triglycerides and free fatty acids (Pasini et al., 1992).

Tocopherols (vitamin E) and sterols are minor lipid components in camelina oil (Belayneh et al., 2015).

Regarding the sterol profile, the following compounds have been identified in the camelina oil: cholesterol, brassicasterol, campesterol, sitosterol, Δ^5-avenasterol. Camelina oil has a high content of cholesterol compared with other commercial oils. The presence of brassicasterol is another particularity of camelina oil, since it can be found in few other sources (Shukla et al., 2002).

The sterols content reported by different authors was between 3600 mg/kg and 5900 mg/kg (Belayneh et al., 2015).

The total tocopherol content reported by different researchers was between 634 and 780 mg/kg. (Belayneh et al., 2015)

CAMELINA OIL USES

Camelina oil has many applications in different fields. The most explored application of camelina oil is the biofuel production (Berti et al., 2016, Goímez-Monedero et al., 2016). Nonetheless, the camelina by-products, such as camelina meal or cake are valorized especially for animal feed (Hixson și Parrish 2014, Hixson et al., 2014, Jaśkiewicz et al., 2014, Woyengo et al., 2016). The possibility of using camelina in its entirety makes it advantageous from an economical point of view (Righini et al., 2016).

The main areas of research for camelina uses are: biofuel production, animal feed, biopolymer industry.

Biofuel production

Camelina oil is mainly used for biodiesel production. Also it is a viable choice for the jet fuel production. The jet fuel obtained from camelina 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 meal, which by pyrolysis may lead to high energy liquid fuels with increased stability due to low oxygen content. (Goímez-Monedero et al., 2016)

Animal feed

Hixson and Parrish (2014) have tested the replacement of fish oil and fish meal used in aquaculture Atlantic cod diet with camelina oil and meal. The high content of omega-3 and omega-6 fatty acids, with a higher percentage of omega-3 acids, especially α-linolenic acid (30%) (Hixson și Parrish 2014, Hixson et al., 2014) from the camelina oil and the high level of raw protein from the meal make them appropriate to be used as replacements of fish oil and meal. The results of the research have shown, a decrease of weight of the cod fed with camelina oil, compared with the one fed with fish oil and even more the lowest weight was registered for those individuals for which together with the replacement of fish oil it was replaced a part of the fish meal used in their diet. Moreover, it was observed a change in the lipids profile (Hixson și Parrish 2014). Another study performed on Atlantic salmon showed an increase of total lipid content for the fishes fed with camelina oil as a replacement of the fish oil (Hixson et al., 2014).

A different reasearch whose aim was to compare the effects of supplementing the broilers' diet with three types of oils: camelina, soy and rape, showed also that camelina oil as a supplement in the diet leads to the increase of α-linolenic acid in the muscles and in the abdominal fat. Both, the content of fatty acids and the one of α-linolenic acid from the muscles were higher when the diet was supplemented with camelina oil compared to rape oil (Jaśkiewicz et al., 2014).

Camelina meal, a by-product of the seed pressing has a high content of oil rich in α-linolenic acid, which makes it appropriate for feed products. It may be a choice for poultry diet. (Woyengo et al., 2016) Due to its composition, camelina meal is a source of aminoacids and esential fatty acids oils. (Berti et al., 2016; Woyengo et al., 2016)

Use in biopolymer industry

Nowadays, there is a growing tendency for the use of vegetable oils in the petrochemical-based polymer industry, due to the fact that they are renewable environmentally friendly compounds. The epoxidized camelina oil showed peel adhesion proprieties, which makes it appropriate, after further formulation, for preparation of pressure sensitive adhesives. The adhesion properties of camelina oil may be increased when it is combined with other epoxidized oils such as soybean oil. In addition epoxidized camelina oil has the potential to be used as coating or resin (Kim et al., 2015).

Camelina oil may be used in combination with glycerol and epoxidized vegetable oil for the synthetizing of alkyd resins for manufacture of paints and varnishes (Nosal et al., 2016).

Camelina oil in cosmetics

The CIR (Cosmetic Ingredient Review) assessed the *Camelina sativa* seed oil and the hydrogenated *Camelina sativa* seed oil as safe to be used in cosmetics and personal care products, after conducting tests for skin irritation, allergenicity, phototoxicity, photoallergenicity and mutagenicity. These compounds, according with the EU Regulation, are allowed to be used in products marketed in Europe. In cosmetics, the above mentioned oils act as skin-conditioning agents-emollient or skin-conditioning agents-occlusive (Burnett and Fiume, 2011).

Human nutrition

In human nutrition camelina oil is valuable due to its omega-3 high content (Vollmann et al., 2001). The low content of erucic acid represents an advantage when using camelina oil in human diet, considering that the ingestion of high quantities of erucic acid are thought to be responsible of cardiac lipidosis (Vollmann et al., 2015).

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 (Abramovič and Abram, 2005).

Recently Faustino et al. (2016) have used camelina oil to obtain human milk fat replacement for babies. Due to its high polyunsaturated fatty acids content, with omega-3 fatty acid as the major compound, camelina oil can be used in food products.

CONCLUSIONS

Considering its high adaptability and its low requirements, camelina is a low input crop with multiple benefits.

Due to its fatty acids profile, camelina oil has an immense potential for various applications.

Until now, the main area of research for camelina oil applications is the biofuel production. The results obtained are promising.

Other applications of camelina oil are: replacement or supplement of animal feed, applications in biopolymer industry, cosmetic uses, human milk fat replacement, and addition in food products.

The research was conducted as part of the project PTE21 / 2016.

REFERENCES

Abramovič H., Abram V., 2005, Properties of Camelina sativa Oil, Food Technol. Biotechnol. 43 (1) 63–70

Atabani A.E., Silitonga A.S., Ong H.C., MahliaT.M.I., Masjuki H.H., Badruddin I. A., Fayaz H., 2013, Non-edible vegetable oils: A critical evaluation of oil extraction, fatty acid compositions,biodiesel production, characteristics, engine performance and emissions production, Renewable and Sustainable Energy Reviews 18: 211–245

Belayneh H. D., Wehling R. L., Cahoonb E., Ciftci O. N., 2015, Extraction of omega-3-rich oil from Camelina sativa seed using supercritical carbon dioxide, The Journal of Supercritical Fluids 104:153-159

Berti M., Gesch R. , Eynck C., Anderson J., Cermak S., 2016, Camelina uses, genetics, genomics, production, and management,Industrial Crops and Products 94:690-710

Burnett C., Fiume M., March 4, 2011, Final Report - Plant-Derived Fatty Acid Oils as Used in Cosmetics, Cosmetic Ingredient Review (CIR)

Dobre P., Jurcoane Ş., Matei F.*, Cristea S., .Farcas N., Moraru A.C. , 2014, Camelina sativa as a double crop using the minimal tillage system, Romanian Biotechnological Letters, Vol.19, No.2, pg. 9190-9195

Faustino A. R., Osorio N.M. , Tecelão C.,. Canet A, Valero F.,Ferreira-Dias S., 2016, Camelina oil as a source of polyunsaturated fatty acids for the production of human milk fat substitutes catalyzed by a heterologous Rhizopus oryzae lipase, Eur. J. Lipid Sci. Technol. 2016, 118, 532–544

Goímez-Monedero B., Bimbela F., Arauzo, J.S. Faria, J., Ruiz M.P., 2015, Pyrolysisof red eucalyptus, camelina straw, and wheat straw in an ablative reactor, Energy Fuels 29, 1766–1775.

Gesch R.W., Archer D.W., 2013, Double-cropping with winter camelina in the northern Corn Belt to produce fuel and food, Industrial Crops and Products 44 , 718– 725

Hixson S.M., Parrish C.C., Anderson D.M., 2014. Full substitution of fish oil with camelina (Camelina sativa) oil, with partial substitution of fish meal with camelina meal, in diets for farmed Atlantic salmon (Salmo salar) and its effecton tissue lipids and sensory quality, Food Chem. 157, 51–61

Hixson SM, Parrish CC, 2014, Substitution of fish oil with camelina oil and inclusion of camelina meal in diets fed to Atlantic cod (Gadus morhua) and their effects on growth, tissue lipid classes, and fatty acids, J Anim Sci. 2014 Mar, 92(3):1055-67.

Imbrea F. , Jurcoane S., Hălmăjan H. V., Duda M. , Botoș L., 2011, Camelina sativa: A new source of vegetal oils, Romanian Biotechnological Letters vol. 16, nr. 3: 6263-6270

Jaśkiewicz T., Sagan A., Puzio I., 2014, Effect of the Camelina sativa oil on the performance, essential fatty acid level in tissues and fat-soluble vitamins content in the livers of broiler chickens, Livest. Sci. 165, 74–79.

Jurcoane S., Dobre P., Florea C., Petre S. M., Ropota M., Camelina sativa-a useful plant source for renewable jet fuels, human nutrition and animal feed, Proceeding Simpozion National editia Xia Plante medicinale –prezent si perspective, pag 33-34, Piatra Neamt, Romania, 9-10 iunie 2011

Katar D., 2013, Determination of fatty acid composition on different false flax (Camelina sativa (L.) Crantz) genotypes under ankara ecological conditions, Turkish Journal of Field Crops, 18(1), 66-72

Kim N., Li Y., Sun X. S., 2015, Epoxidation of Camelina sativa oil and peel adhesion properties, Industrial Crops and Products 64, 1–8

Moslavac T., Jokić S., D. Šubarić, K. Aladić, J. Vukoja, Prce N., 2014, Pressing and supercritical CO_2 extraction of Camelina sativa oil, Industrial Crops and Products 54:122–129

Moser B. R., Vaughn S. F., Evaluation of alkyl esters from Camelina sativa oil as biodiesel and as blend components in ultra low-sulfur diesel fuel, 2010, Bioresource Technology 101: 646-653

Nagao K., Yanagita T., 2010, Medium-chain fatty acids: Functional lipids for the prevention and treatment of the metabolic syndrome, Pharmacological Research 61, 208–212

Nosal H., Nowicki J.,Warzała M. , Semeniuk I. , Sabura E. , 2016, Synthesis and characterization of alkyd resins based on Camelina sativa oil, glycerol and selected epoxidized vegetable oils as functional modifiers, Progress in Organic Coatings 101, 553–568

Pasini E., Cargnoni A., Condorelli E., Marzo A., Lisciani R., Ferrari R., 1992, Effect of prolonged treatment with propionyl-L-carnitine on erucic acid-induced myocardial dysfunction in rats, Mol Cell Biochem. Jun 26; 112(2):117-23

Petre S.M., . Moraru A, Dobre P., Jurcoane S., 2015, Life Cycle Assessment of Camelina sativa – environmental friendly source for biofuels and livestock protein available in Romania? , Romanian Biotechnological Letters, Vol. 20, No. 4, pg. 10561-10571

Righini D., Zanetti F., Monti A., 2016, The bio-based economy can serve as the springboard for camelina and crambe to quit the limbo, OCL 23(5) D504

Rosenthal A., Pyle D. L., Niranjan K. ,1996, Aqueous and enzymatic processes edible oil extraction, Enzyme and Microbial Technology 19:402-420

Shukla V.K.S, Dutta P.C., Artz W.E., 2002, Camelina Oil and Its Unusual Cholesterol Content, JAOCS, Vol. 79, no. 10, 965-969

Toncea I., Necseriu D., Prisecaru T., Balint L.N., Ghilvacs M.I., Popa M., The seed’s and oil composition of Camelia – first romanian cultivar of camelina (Camelina sativa, L. Crantz), 2013, Romanian Biotechnological Letters, Vol. 18, No. 5, 8594-8602

Vollmann J., Steinkellner S., Glauninger J., 2001, Variation in Resistance of Camelina (Camelina sativa [L.] Crtz.) to Downy Mildew (Peronospora camelinae Gäum.), J. Phytopathology 149, 129-133

Vollmann J., Eynck C., 2015, Camelina as a sustainable oilseed crop:Contributions of plant breeding and genetic engineering, Biotechnology Journal, 10, 525-535

Woyengo T. A, Patterson R.,Slominski B. A. ,Beltranena E., Zijlstra R. T. , 2016, Nutritive value of cold-pressed camelina cake with or without supplementation of multi-enzyme in broiler chicken, Poultry Science 95:2314–2321