COSMOS

ADDING VALUE TO CAMELINA AND CRAMBE OIL

A Summary of Project Achievements and Innovations

The COSMOS project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 635405.

Duration: March 2015 to August 2019

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Camelina and crambe as European sources for medium-chain fatty acids

The EU-funded Horizon 2020 project COSMOS aimed at reducing the dependence of Europe's oleochemical industry on imported plant oils by turning the two oil crops camelina and crambe into profitable, sustainable, multipurpose, European oil crops. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 635405.

It ran from March 2015 to August 2019 and comprised eighteen partners, nine of which are SMEs and large enterprises and the remaining nine are universities and research institutes. The research consortium has been managed by Wageningen Food & Biobased Research.

This brochure informs about the main achievements and innovations generated by the project. For more information, please visit *http://cosmos-h2020.eu*.

Background

"Imagine if the sources for your shampoo are more sustainable and you can see them growing on a field in Europe!"

Dr. Rolf Blaauw
Coordinator of COSMOS

The European oleochemical industry relies predominantly on imported tropical oils. Castor oil, a non-edible seed oil, is imported for the production of polyamides. Palm kernel and coconut oil contain medium-chain length fatty acids (MCFA, C10–C14) which are vital sources for surfactants, detergents, personal care products, lubricants, and other industrial and consumer products. The EU-28 net imports of coconut and palm kernel oil for technical and industrial uses alone amount to about 500,000 t annually.

Currently, there are no European sources for these MCFA. This is problematic, because not only are the prices for MCFA higher than those for the more common long-chain fatty acids such as palmitic, stearic and oleic acid, but their prices are also much more volatile. Furthermore, their production is concentrated in only a few, mainly South-East Asian countries (Malaysia, Indonesia, the Philippines and India).

Alternative plant species that produce medium-chain fatty acids and that are able to grow in European climates do exist, but cultivation trials have so far been problematic. The best described example is from the USA, where efforts toward commercialization of cuphea species rich in MCFA have been ongoing, but issues such as seed shattering and low water use efficiency have impeded progress.

Objectives and approach

The primary aim of COSMOS was to reduce the dependence of Europe's oleochemical industry on imported tropical oils by turning camelina and crambe into profitable and sustainable oilseed crops suited to European climates.

Successful establishment of camelina and crambe and their oils as a European alternative for imported tropical oils will thus contribute positively to employment, income and innovation potential of stakeholders in the crops-to-products value chain.

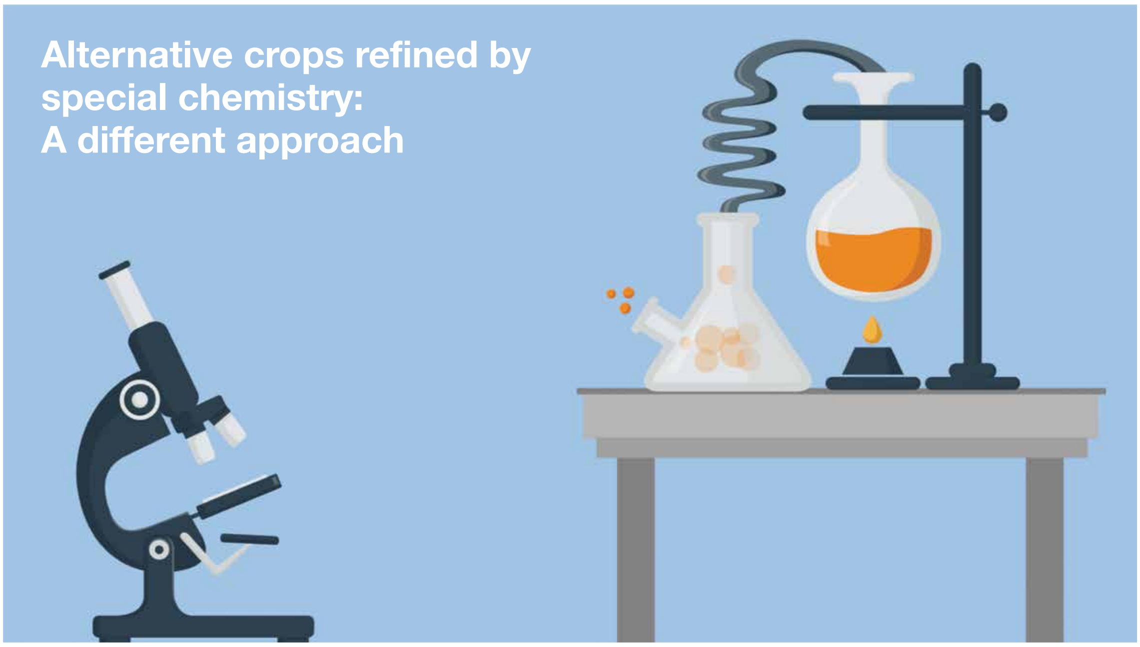
Camelina sativa

Camelina and crambe are low-input crops that can be grown even on marginal land. While crambe was never cultivated on large areas in Europe, camelina had in fact been an important oil crop across the continent, but was later superseded by rapeseed. Recently, interest in both crambe and camelina has been growing, with the latter notably attracting attention in view of its potential as a source of aviation biofuel.

Crambe abyssinica

However, the oils of both crops do not readily contain the desired MCFA by nature. Instead, they consist of longer chain fatty acids. In order to obtain the targeted MCFA, the strategy in COSMOS was to use chemical chain cleavage processes to cut the long chains in two medium-chain halves. Prior to chain scission, fatty acids (FA) less suited to chain cleavage (particularly the so-called polyunsaturated FA) needed to be separated from the desired monounsaturated FA. To this end, technologies using FA-selective enzymes and innovative physical methods have been investigated.

The so obtained oil fractions rich in monounsaturated long-chain FA were subjected to various chemical chain scission methods aimed at converting the long chains into two valuable medium-chain halves. These could then be further processed to give not only MCFA similar to those found in palm kernel and coconut oil, but also other high-value building blocks that can serve as feedstock for the lubricants, surfactants, bio-plastics and flavour & fragrance industries.



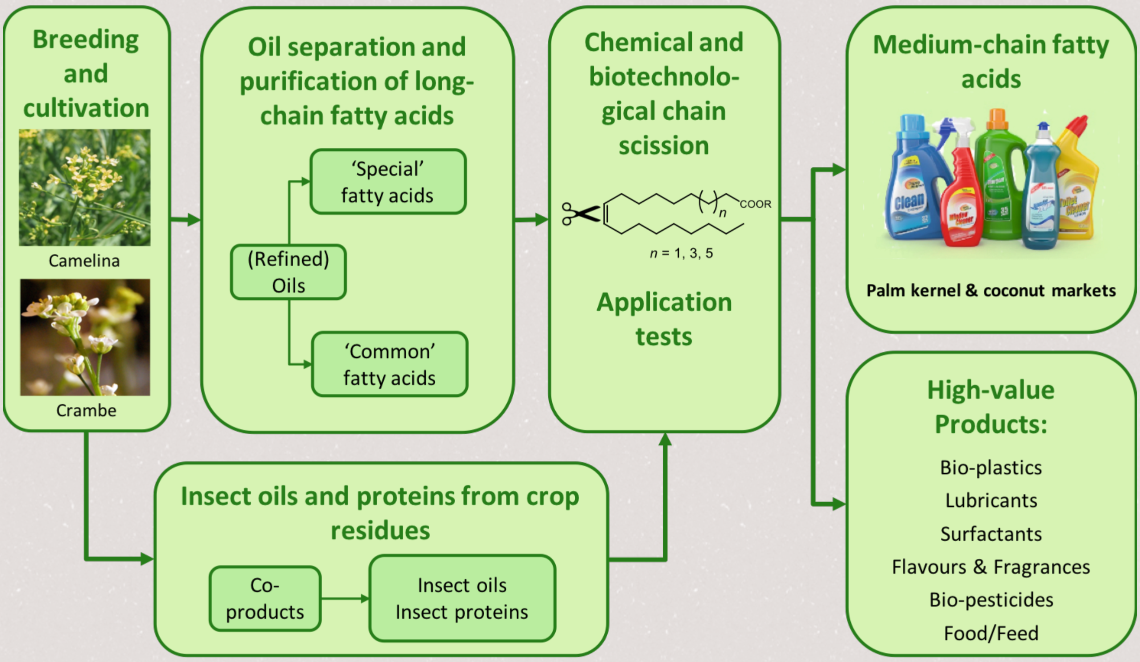
The economic feasibility of the camelina and crambe value chains not only relies on efficient oil separation and conversion, but also on optimal crop yields and oilseed value. Hence, modern crop breeding methods were applied. These were aimed on the one hand at increasing the share of the targeted long-chain monounsaturated FA in the seed oils, and on the other hand at reducing the amounts of bitter tasting compounds that would compromise the nutritional (feed) value of the seed residue remaining after oil extraction. Crop cultivation trials were performed to determine the best conditions for growth, potential crop rotation schemes, and best sowing dates for several regions in Europe.

Insect feeding trials were conducted to evaluate whether insect larvae were capable of further increasing the value of the crops by converting residues to valuable proteins and insect fats.

Finally, the overall economic, social and environmental sustainability based on complete life cycles of the whole value chains was assessed.

The COSMOS project ended in August 2019. More research and development will be needed to bring its innovations to a technology readiness level required for potential commercial exploitation, for example in the form of a pilot plant. In the meantime, this brochure reports on the main findings of the project.

How COSMOS creates European alternatives for palm kernel and coconut fatty acids and at the same time produces high-value co-products:



Main achievements and innovations

Successful large field trials

Field trials with camelina and crambe have been performed in Greece, Italy, Poland and the Netherlands to assess the potential of the crops in terms of cultivation practices, seed yield, oil content, ease of harvesting, and resource inputs under various soil and climate conditions.

These field trials have shown that camelina can be grown both as a spring crop and as a winter crop in Mediterranean climates (Greece, Italy), which opens up additional options for farmers to fit camelina into rotation schemes. Furthermore, innovative double cropping systems have been explored as a means to generate better income for farmers.

New crambe and camelina varieties with increased value for animal feed and oleochemistry

Modern plant breeding techniques have successfully been applied to significantly reduce the amounts of bitter tasting compounds in the seeds. These have a negative effect on animal growth and hence reduce the feed value of the seed residues remaining after seed oil extraction.

Using the same techniques, COSMOS scientists were able to reduce the share of polyunsaturated fatty acids in the oils, while at the same time increasing the levels of monounsaturated fatty acids desired by the chemical industry. Hence, the potential of the oils to serve as a feedstock for the chemical industry, particularly to produce medium-chain oleochemicals, has increased greatly.

A setback for the project was the decision of the European Court of Justice in July 2018 that organisms obtained by the novel genome editing CRISPR/Cas technique (a site-directed mutagenesis method) are to be subject to the European GMO legislation. Since some of the new seed lines developed in COSMOS are produced using the CRISPR/Cas9 technology, this ruling will make it more difficult to further develop these seed lines. Luckily, the project also developed improved crop varieties using an older technique called random chemical mutagenesis. Improved crops derived from these techniques are, due to a history of safe use, exempt from GMO regulations and can be grown in Europe.

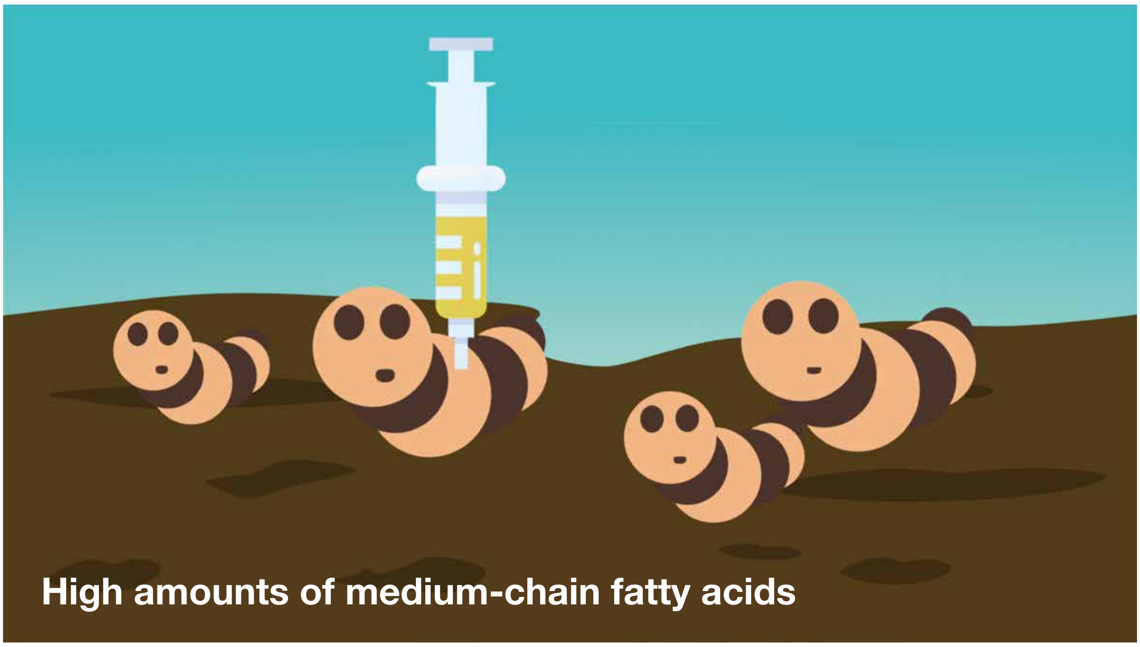
Novel enzymes with improved fatty acid chain length selectivity

Long-chain monounsaturated fatty acids are interesting building blocks in the oleochemical industry. Specifically, gondoic (C20:1 cisΔ11) and erucic acid (C22:1 cisΔ13) are present in large amounts in camelina and crambe oil, respectively, and need to be isolated from the fatty acid mixture of the oils. With conventional techniques such as distillation this is not easy, since their properties are quite similar to those of more common fatty acids present in the oils which are only slightly shorter.

As a better alternative, project partners University of Greifswald and the company Enzymicals developed an enzymatic method to isolate oil fractions with increased shares of gondoic and erucic acid. The method uses selective lipases that were designed to discriminate between very long-chain fatty acids such as gondoic and erucic acid, and slightly shorter ones. Although the levels of both gondoic acid (in camelina oil) and erucic acid (in crambe oil) could be increased, the technology was particularly effective in enriching the levels of erucic acid in crambe oil, probably due to its longer chain length (22 carbons) compared to gondoic acid (20 carbons).

Conversion of crop residues by black soldier fly larvae

An integral part of the project is the valorisation of crop residues by insects. Unfortunately, the larvae of the evaluated insect species were not able to grow well on the straw of the crops. However, black soldier fly larvae were able to turn camelina seed cake (remaining after pressing out the oil) into valuable insect fats and proteins.



The fat extracted from these black soldier fly larvae was found to have a composition very similar to those of coconut and palm kernel oil; it contained large amounts of the medium-chain length lauric acid (C12). Calculations indicate that by growing black soldier fly larvae on diets containing 50% of camelina press cake, oil yields per hectare can be increased indirectly by about 20%.

The insect route provides an additional way to obtain the desired MCFA, apart from chemical cleavage. Finally, since the protein from the larvae has a very high nutritional value in food and feed, the resources are fully valorised. Hence, the COSMOS project has raised the potential of Europe to become less dependent not only on imported oils, but also on imported protein. The challenge for commercialization is in marketing: in many applications of MCFA an animal fat (especially from insects) is not yet a good selling point.

Innovative hydraulic fluids

Project partners Arkema and CPST have used MCFA, self-metathesis products and side products of the fatty acid chain scission chemistry as a feedstock to develop two new classes of lubricating base oils for high-performance hydraulic fluids.

One class of innovative basestocks is represented by derivatized polyol esters, whose manufacture can utilize more than 90% feedstocks from crambe or camelina. Another class of basestocks, novel mono-unsaturated dibasic esters, may contain over 50% of materials, derived from crambe or camelina. They combine excellent fluidity at low temperatures, remarkable resistance to heat-thinning, outstanding additive solvency and thermal conductivity with acceptable oxidation stability and other lubricant properties. Formulations with functional additives were optimized at CPST and showed good performance in standard tests when compared to brand name commercial hydraulic fluids. Many requests for technical data were received from various oleochemical and lubricant companies. Material Transfer Agreement was signed with a large independent lubricant manufacturer and the basestock was shipped for evaluation.

Both project partners have filed a joint application at the European Patent Office (EPO) under EP3483233 and PCT WP19091786. The technology is available for licensing.

Advances in fatty acid chain scission chemistry

Project partner Arkema is currently producing and selling on the world market long-chain monomers for polyamides 10.10 and 11 (both bio-based and made from the tropical oil derived from castor seeds) and polyamide 12.

Arkema is interested to find alternative processes to make monomers for these applications but from other vegetable oils. Camelina has been identified as a potential source of gondoic acid (C20:1, delta-11), while crambe, which is high in monounsaturated fatty acids, could be a source of non-food oleic acid (C18:1, delta-9).

Specific organic reactions (oxidative cleavage, ethenolysis and cross-metathesis with acrylonitrile) are needed to produce the expected molecules from gondoic and oleic acid. Some impurities present in the oils and esters are still strongly affecting the metathesis catalysts which currently makes the route more challenging.

Novel ruthenium catalysts

Project partner Apeiron has developed a new, safe and straightforward process for preparing olefin metathesis catalysts bearing Cyclic Alkyl Amino Carbene (CAAC) ligands.

The novel synthetic pathway allows to obtain a new class of ruthenium catalysts: bis-(CAAC) indenylidene complexes. One member of this family, UltraCat, has been designed for metathesis with ethylene ("ethenolysis") – a process that allows scission of long-chain fatty acid derivatives to shorter molecules of high interest. Moreover, UltraCat exhibits good reactivity profile in other metathesis reactions.

In the same process, benzylidene type catalysts bearing CAAC ligand may be obtained. The most representative member of this family is UltraNitroCat which is very efficient in metathesis reaction with acrylonitrile – one of the most difficult metathesis substrates.

Both UltraCat and UltraNitroCat are now available from Strem and Merck (patents pending WO2017/055945 and WO2018/087678).

Partners of the COSMOS project

Small and Medium Enterprises (SME) and Industry

Apeiron Synthesis S.A, Poland, ***www.apeiron-synthesis.com***
Arkema France SA, France, ***www.arkema.com***
Enzymicals AG, Germany, ***www.enzymicals.com***
ifeu – Institut fuer Energie- und Umweltforschung Heidelberg GmbH, Germany, ***www.ifeu.de***
InCatT B.V., The Netherlands, ***www.incatt.nl***
Linnaeus Plant Sciences B.V., The Netherlands, ***www.linnaeus.net***
nova-Institut GmbH, Germany, ***www.nova-institut.de***
Proti-Farm R&D BV, The Netherlands, ***www.protifarm.com***
SOLUTEX GC, S.L., Spain, ***www.solutex.es***

Research organisations/Universities

Alma Mater Studiorum – Università di Bologna, Italy, ***www.unibo.it***
Centre for Physical Sciences and Technology, Lithuania, ***www.ftmc.lt***
Centre for Renewable Energy Sources and Saving, Greece, ***www.cres.gr***
Imperial College, United Kingdom, ***www.imperial.ac.uk***
Stichting Wageningen Research, The Netherlands, ***www.wageningenur.nl/en.htm***
Universität Greifswald, Germany, ***www.uni-greifswald.de***
Université de Rennes 1, France, ***www.univ-rennes1.fr***
University of Warmia and Mazury in Olsztyn, Poland, ***www.uwm.edu.pl/en***
Wageningen University, The Netherlands, ***www.wageningenur.nl/en.htm***

More information

Project website:
http://cosmos-h2020.eu

Scientific publications:
https://zenodo.org/communities/cosmos-h2020?page=1&size=20

Project Video:
https://youtu.be/H53KW4CYxG4

Public Deliverables:
http://cosmos-h2020.eu/publications/deliverables

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