



Cuphea Seed Oil as a Potential Alternative Natural Source of Medium-chain Triglycerides used for Healthier Cooking Applications

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Authors' contributions

This work was carried out in collaboration among all authors. Author MAM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors RSF and HAH managed the analyses of the study. Author AN managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Cuphea is a potential new oilseed crop for temperate regions of the USA. It produces and stores in its seeds medium chain length fatty acids, which currently are derived commercially from seeds of tropical palms. Cuphea seeds contain more than 30% of oil rich in medium-chain fatty acids, caprylic, capric, lauric, and myristic fatty acids (C8:0-C14:0). In this paper, we through the light on Cuphea seed oils as the only naturally cultivated seed oils that contain the most prominent Medium-chain triglycerides (MCT). MCTs oils are trended in the last 20 years as the healthier dietary oil which is essentially nontoxic, noncarcinogenic, and nonmutagenic for human consumption. MCTs are readily hydrolyzed by digestive enzymes, and the fatty acid end products are rapidly absorbed into the bloodstream [1].

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The gross energy content of MCTs is 8.3 kcal/g vs 9 kcal/g for fat or Long-chain triglycerides oils (LCTs oils).

The objective of this study was to introduce to the global edible oils industries an innovative potential natural healthier edible oil which contains that majority of its triglyceride compositions is based on medium-chain glycerides (MCT) with avoiding any chemical conversion process to get the MCT rich oils from tropical oils. It will be a basis for a lot of further researches to make its characteristics fulfilling all other nutritional and application needs of healthy cooking applications better than conventional seed or tropical oils.

Keywords: *Cuphea PSR23; Cuphea seed oil; medium-chain triglycerides oil (MCT); low calories oil.*

1. INTRODUCTION

Temperate plant species whose seed oils are rich in medium-chain fatty acids (MCFAs) are relatively rare [2]. One species of particular interest is cuphea, a temperate annual oilseed crop with high levels of MCFAs such as capric and lauric acid [3,4,5]. These fatty acids are highly valued as feed stocks in manufacturing cosmetics, soaps and detergents, pharmaceuticals and industrial lubricants [2,6,7]. This summary primarily covers the advances of cuphea research since the previous reviews of cuphea breeding presented by Knapp [8,9] with the main focus on oilseed production in the cuphea species of *C. lanceolata* and *C. viscosissima* known as (Cuphea PSR23') which are targeted for commercialization in the US.

The desire of agronomists to produce an annual renewable source of medium-chain triglycerides (MCT) that would supplement supplies of coconut and palm kernel oils has driven research to develop domestic sources that are suitable for agricultural production.

Research interests have centered on cuphea primarily for its seeds which have a high content of unique fatty acids [3,10,11]. The predominant fatty acids include caprylic acid (C8), capric acid (C10), lauric acid (C12) and myristic acid (C14). Lauric acid has been the primary fatty acid of interest in US breeding programs. Lauric acid is used in foods, mostly vegetable shortenings and in soaps and detergents as a defoaming agent and booster [12,13]. Traditionally, tropical oil crops such as coconut (*Cocos nucifera* L.) and oil palm (*Elaeis guineensis* Jacq.) commercially supply these acids. Currently, the US soap and detergent industry get half of these fatty acids from the petroleum industry and the other half from imported coconut and palm kernel oils [14].

Coconut oil is 45–50% lauric acid, while some undeveloped lines of cuphea can produce oil that contains nearly 80% lauric acid [15].

To date, there are no temperate oilseed crops that can supply these lipids. Many of the fatty acid-rich species of cuphea are summer annuals and through crop development programs could potentially become domestic sources of fatty acids.

The cuphea breeding line, 'PSR23' (*Cuphea viscosissima* Jacq. *C. lanceolata* W.T. Aiton) is the only domesticated cuphea in the US and is the current the focus of production and breeding programs in Illinois, Iowa, North Dakota and Minnesota. Although rich in capric acid, PSR23 serves well as an agronomically sound plant for agronomic and physiological studies and as a foundation for breeding programs in the US.

Breeding and research efforts on other Cuphea spp. continues throughout the world. Research in India is focused primarily on *C. procumbens* for seed oil production [16,17,18,19,20].

South American researchers are looking at *C. carthagenesis* [21,22] and *C. glutinosa* [23] for medicinal purposes.

Japanese researchers are investigating food uses with *C. lappaceola* [24].

2. Literature Review

In the last 10 years, Cuphea seed oil was explored as a renewable, biodegradable source of oil for lubricants, motor oil, and aircraft fuel [25].

Cuphea PSR23 is a semi-domesticated, high capric-acid hybrid from Cuphea viscosissima, Cuphea lanceolata, is being developed by the U.S. Department of Agriculture (USDA) Research Center in Peoria, Illinois, as a potential commercial alternative source of medium-chain fatty acids [26].

2.1 Cuphea PSR23

Cuphea PSR23 is a potential new crop with an annual growth habit for temperate regions. It produces and stores in its seeds medium chain length fatty acids, which currently are derived commercially from tropical palms and coconut. The growth and yield potential of cuphea 'PSR23' was known for west-central Minnesota – USA but not elsewhere. *Cuphea viscosissima* Jacq. seeds are being developed as a commercial source of caprylic, capric, lauric and myristic acids.

Cuphea plants exhibit several wild plant characteristics that needed to be bred out. These include dormancy, non-uniform germination, indeterminate flowering, seed maturation over a broad period (six weeks), extreme dehiscence (pod-shattering) and the presence of viscid hairs on stem, leaves, flowers, and fruit. Several species are being studied in attempts to make them commercial [27].

Recent large-scale production of several hundred acres in Minnesota and Illinois was not impeded by the stickiness when production combines were used (Fig. 1 and 2).

Cuphea PSR23 produces a seed that is rich in saturated MCT. Efforts to develop this crop have been supported by detergent manufacturers, especially The Procter and Gamble Co., Cincinnati, Ohio, who have played a significant role in recent Cuphea advancements. Approximately 260 species of Cuphea are native to the Americas. Among these species, there is a good diversity for saturated fatty acid classes (caprylic, capric, lauric, myristic and palmitic), where each MCT is represented in high concentration within the seed.

Initial oil characterization of several Cuphea species has been done by the U.S. Department of Agriculture (USDA) Research Center in Peoria, Illinois, which described oil contents that ranged from 16 to 42% and that were rich in lauric and capric acids.

Most of these species are not suitable for cultivation and harvesting for agronomic reasons; however, several species have seen intense breeding efforts toward domestication.

Today Cuphea seeds cultivation has been extended outside the USA to South America, primarily in Brazil.

2.2 Description of Industrial Oil Seed Crop

Cuphea species PSR23 appears to have better potential as an industrial oilseed crop at higher than lower latitudes because of enhanced yields and those from capric acid levels.

Oil content from harvested Cuphea seeds ranged from 20 to 25% rich in medium-chain fatty acids (C8:0 to C14:0) with a crude protein content of 17-18%.

The principal fatty acid was capric acid, which changed from 67 to 73% of total oil and was always highest in the colder, northern-most sites.

In the course of processing and refining cuphea oil, several by-products are generated. Developing commercial uses for these by products would improve the economics of growing cuphea. Oil fractions and byproducts were obtained from processed seeds of cuphea germplasm line PSR 23 [28].

Cuphea extracted oil has been studied to serve as a renewable, biodegradable source of oil for lubricants, motor oil, and aircraft fuel.

Impacts of climate and soil environment on cuphea growth and development have been studied to evaluate the influence of climate and soil on growth, seed yield, and seed oil characteristics of two semi-domesticated cuphea genotypes and three wild species that show potential for domestication.

The three wild species generally performed similarly across the four different environments. Results indicate that domestic species PSR23 and HC-10 are more regionally adapted than the wild species studied, which tended to exhibit a greater range of adaptability to climate and soil conditions [29].

Nevertheless, PSR23 still can be considered only partially domesticated. The remaining obstacles include an indeterminate growth habit, continued seed shattering, and only partial self-fertility.

The oil content of the seeds of Cuphea PSR-23 contains roughly 35 % wt % oil that is composed of 82 % capric (C10:0), 3 % lauric (C12:0), 4 % myristic (C14:0), and 4 % palmitic acid (C16:0) in addition to minor components of unsaturated fatty acids [25].

The fatty acid composition of different *Cuphea* species including PSR-23 is shown in Table 1 [30]. *Cuphea* PSR-23 shown in Table 1, is high in capric acid with an oil content of 30%.

S.J. Knappa et al. [31] was another author who studied and reported in his paper and described the fatty acid and oil percentage diversity of forty-two populations of *C. viscosissima* collected from seven states within the United States. Caprylic (18.0%) and capric acid (69.9%) were the major fatty acids of these populations. The fatty acid percentage ranges were narrow for every fatty acid e.g., 16.4 to 20.4% for caprylic acid and 66.6 to 71.3% for capric acid. The maximum lauric acid percentage was 3.4%. Oil ranged from 27.3 to 33.4%. Although the populations surveyed cover a fairly wide geographic range, they display limited fatty acid diversity. Surveys of germplasm from other parts of the range are needed to further characterize the fatty acid diversity of this species [31].

Joseph A. Laszlo¹ et al. [32] found that the oil from the plant *Cuphea* oil is very useful for modifying olive oil waste molecules, abundantly available phenols from olive oil processing byproduct rich in Tyrosol and hydroxytyrosol to create antioxidants for use in foods. This is done by the non-aqueous enzymatic transesterification of plant phenols with *Cuphea* oil. It was found to be predominately acylated with capric acid derived from the triglyceride fraction of the *Cuphea* germplasm line PSR 23.

The developed process would be suitable for commercial production. This research creates a new commercial use for a specialty oilseed crop, expands the market for *Cuphea* oil, and has developed two novel effective lipophilic antioxidants to help the food industry improve food quality [32].

Seed oil FA composition for 44 species has been also reported by Shirley Graham et al. [33] including first records for 25 species from South America, primarily from Brazil.

Nineteen species are re-analyzed to verify earlier results and expand information on variability in oil composition. An Appendix summarizes the seed oil composition of 108 species classified in two subgenera and in 10 of 13 sections Fifty percent are lauric-acid (C12:0) producers. In South America, the most common FA dominating *Cuphea* oils is lauric acid. In North America, a secondary center of speciation, seed oils are

more diverse; lauric and capric acid (C10:0) are most common, but caprylic (C8:0), myristic (C14:0), linoleic (C18:2), and linolenic acid (18:3) predominate in some species. The dominant FA in the seed oil of each species remains constant throughout its range and in differing habitats and varies within a species in the percentage of total FAs 14–17%. Factors affecting variation are briefly examined.

The greatest diversity of seed oils appears in North America in the most derived clade in the genus, where FAs from caprylic acid (C8:0) to linolenic acid dominate among the species [33].

The growth and yield potential of 'PSR23' (*Cuphea viscosissima lanceolata*) was known initially for west-central Minnesota but not elsewhere. Yields, seed oil contents and fatty acid profiles were determined. The oil content of seeds ranged from 28 to 33% and may have been associated inversely with air temperatures during seed-fill.

The principal fatty acid was capric acid, which ranged from 67 to 73% of total oil and was always highest in the colder, northern-most sites. PSR23 appears to have better potential as an industrial oilseed crop at higher than lower latitudes because of enhanced yields and capric acid levels [34].

Due to the specific fatty acid composition of *Cuphea* seed oils which is rich in (MCFAs) medium-chain fatty acids,(C8:0 to C14:0).

Due to the characteristic fatty acid composition of *Cuphea* seed oil is introduced in this study as a first potential nontropical plant which is rich naturally in MCT fatty acids and hence a potential natural source for MCT oils which play the major role in the also decade as the most the healthy edible oil for dietitian and ideal metabolite edible oil.

2.3 Why MCT OILS are the Ideal Healthy Edible Oil?

MCT oil contains Medium-chain triglycerides (MCT) which are composed of Medium-chain fatty acids (MCFAs) with C6-C12 carbon chain length.

MCFAs are more rapidly metabolized than long-chain fatty acids (LCFAs). Due to its small size and greater solubility compared to long-chain fatty acids (LCFAs), MCFAs are transported

directly to the liver via the portal vein to undergo a beta-oxidation process producing ketones, thus providing a rapid source of energy. MCFAs also cause an increase in diet-induced thermogenesis and satiety. In contrast, LFCA needs to be cycled back into the intestinal lymphatic ducts and transported as chylomicron to the thoracic ducts into the systematic circulation and deposited in the body as fat. As such, medium-chain triglyceride (MCT) has been used for years to treat patients with malabsorption of fat problems and provide instant energy to the athletes.

Currently, MCT oil is synthesized from natural oils like coconut and palm kernel oil and is applied as a healthy oil for dietitians and obesity treatment and has been used for years to treat patients with malabsorption of fat problems and provide instant energy to the athletes [35-36].

However, as MCT oils contain solely of MCFAs, so it lacks essential fatty acid. Besides, MCT is also not suitable to be used for heavy cooking purposes such as frying oil due to foam formation.

So, there was a need to evolve to incorporated LCFAs in the MCT molecule to overcome these weaknesses. This has led to the development of a new type of structured lipid, called medium-and long-chain triacylglycerol abbreviated as (MLCT) oils [38-43].

Table 1. Fatty acid of *Cuphea spicies* with high levels of medium-chain triacylglycerols (MCT)

Species	Fatty acid (%)									
	8:0	10:0	12:0	14:0	16:0	18:0	18:1	18:2	18:3	20:0
<i>C. puberula</i>	94.4	3.3	0.0	0.0	0.6	0.0	0.7	1.0	0.0	0.0
<i>C. hololeuca</i>	0.1	91.6	1.5	0.6	1.3	0.3	1.1	3.1	0.2	0.1
<i>C. viscosissima</i>	16.0	62.3	3.5	0.8	1.5	0.0	1.7	3.5	0.0	0.0
<i>C. lanceolata</i>	0.6	84.0	2.2	2.0	2.8	0.0	5.0	4.0	0.0	0.0
<i>C. wrightii</i>	0.0	29.2	52.7	4.8	2.2	0.4	2.8	3.8	0.0	0.0
<i>C. calophylla</i>	0.1	5.0	85.0	6.8	1.1	0.1	0.5	1.3	0.0	0.0
<i>C. salvadorensis</i>	25.3	0.9	2.8	64.5	5.2	0.0	0.5	0.5	0.3	0.0
<i>C. dentata</i>	0.0	0.0	0.0	0.0	33.0	0.4	9.8	53.2	3.5	0.0
PSR-23 <i>lanceolata</i> × <i>viscosissima</i>	0.6	65.6	3.2	6.5	7.2	0.8	9.1	5.9	0.0	0.0
VS-320	40.2	36.9	4.8	6.8	3.3	0.1	1.4	2.0	0.1	0.0

^aPSR-23 is the cross of *C. lanceolata* × *C. viscosissima*; VS-320 is a genetically altered variety of *C. viscosissima*.



Fig.1. Direct combining of Cuphea PSR23 in ILLINIOS [37]

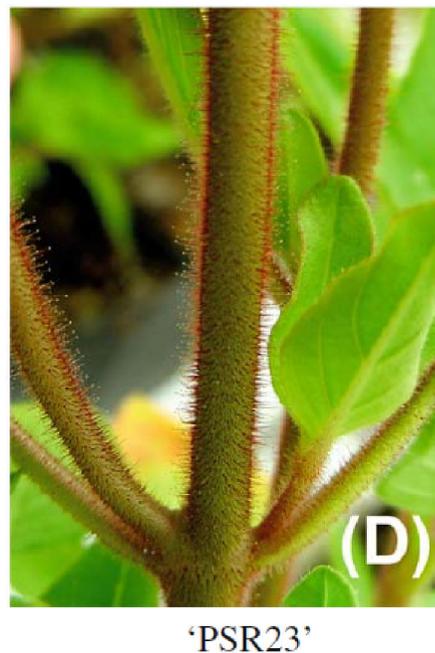


Fig. 2. Cuphea PRS23 plant [37]

Note: This paper may contain brand names that are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable

3. CONCLUSION

Cuphea oil in this study summary is introduced to the global edible industry as a potential alternative natural source of medium-chain triglycerides and a new potential natural healthier edible oil for food applications as an innovative natural MCT oil which contains that

majority of its triglyceride compositions are based on medium-chain glycerides (MCT) with avoiding any chemical conversion process to get the MCT rich oils. It will be a basis for a lot of further researches to make its characteristics fulfilling all other nutritional and application needs of conventional seed or tropical oils.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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