EXTENSION

FAPC-257

Properties of oils produced from uncommon oilseed crops part 2: Carinata, Pennycress and Lesquerella

March 2025

Background

Properties of oils obtained from Camelina, Crambe and Meadowfoam were discussed in part 1 of this fact sheet series (FAPC-256). Part 2 of this series covers oilseed crops Carinata, Pennycress and Lesquerella.

1. Carinata

Brassica Carinata A. Braun, also known as "Ethiopian mustard," "Ethiopian rape," "Abyssinian mustard" or "Carinata", is being examined as an annual non-food oilseed crop for producing renewable fuels, protein-rich meal and bio-products. It is believed that Carinata was first cultivated in northeastern Africa in 4th to 5th millennia and was introduced to North America as a leafy vegetable from Ethiopia in 1957 (Seepaul, Kumar, Iboyi, et al., 2021). Today, it is being investigated as a heat and drought tolerant, and cold and disease resistant winter oilseed crop that can be adapted as a rotation and/or cover crop in the southeastern U.S. (Seepaul, Kumar, Boote, et al., 2021). Commercial production of Carinata started in Canada, the southeastern and northern plains of the U.S. and Uruguay in 2010s (Seepaul et al., 2019). The Carinata plant can grow as tall as 1 1/2 to 2 meters (5 to 6 feet) and seed yield may be up to 3 tons per hectare.

1.1 Seed and Oil Properties

Carinata seeds are spherical in shape with a diameter of 1 to 1 1/2 millimeters and yellow to brown in color. The weight of 1,000 seeds varies with nitrogen application rate between 3.8 to 4.2 grams (Seepaul et al., 2020).

Carinata seeds contain 19% to 28% protein and 42% to 52% oil which is rich in erucic acid (41% to 43% of total fatty acids present in the oil) (Seepaul, Kumar, Iboyi, et al., 2021). Linoleic, linolenic and oleic acids are the other major fatty acids found in Carinata (Table 1). Defatted seeds, meal, contain about 44% protein, 24% neutral detergent fiber and 13% acid detergent fiber (Schulmeister et al., 2019).

1.2 Potential applications

Just like many other seed oils, Carinata oil can be used to produce biodiesel via transesterification (see Fact sheet FAPC-150), hydrotreated to produce jet fuel and converted to naphtha, jet and diesel fuels (see fact sheet FAPC-177) through catalytic hydrothermolysis processes (Gesch et al., 2015). Considering that the molecular weight of Carinata oil is higher than that of soybean, canola or jatropha oils, conversion of Carinata oil yields higher amounts of hydrocarbon fuels and chemicals. Oils rich in very long-chain fatty acids (VLCFA) containing 20 or more carbons are good candidates for producing a wide variety of industrial products. Carinata oil, which is an excellent source of VLCFA, such as erucic acid, can be used in production of surfactants, lubricants, various industrial polymers, composite materials, coatings, adhesives, epoxy resins and glues (Marillia et al., 2014). High glucosinolate content in Carinata seeds make the oil and seed cake difficult to use in food or feed applications. However, studies on the development of low glucosinolate Carinata types are ongoing (Marillia et al., 2014).

2. Pennycress

Thlaspi arvense L., also known as stinkweed, fanweed, field pennycress or pennycress belongs to the *Brassicaceae*, mustard, family which includes other oilseed crops such as rapeseed, canola (rapeseed variety double-low in erucic acid and glucosinolate), and Camelina (*Camelina sativa*). Pennycress was classified as a common weed in 1818 by English botanist Thomas Nutall, yet it is not an invasive plant species (Best & McIntyre, 1975). It grows in soil around livestock operations and construction sites, on borders of production fields, and as a weed in rapeseed and canola fields. Although Pennycress is not on the U.S. or Canadian federal lists of noxious weeds, it is categorized as a noxious weed in several U.S. states, including Michigan and the Canadian province of Manitoba (Basnet & Ellison, 2024).

Pennycress is getting attention as a potential oilseed crop for use in nonedible industrial product manufacturing. It is being evaluated as an annual winter oilseed and cover crop for potentially integrating into corn-soybean production systems in the U.S. (Cubins et al., 2022). Pennycress is touted for its ecological benefits as a winter cover crop because it inhibits emergence of early spring weeds and maintains water quality by reducing nutrient runoffs. Pennycress is a cold tolerant plant; hence, it can be grown in temperate regions in the fall through spring. Pennycress has a short growth cycle, which makes it suitable for crop rotation and multiple crop production in the same year. Poor seed dormancy, pod shattering and stand establishment issues are drawbacks for wide adaptation and commercial production of this crop. Considering the availability of a genetically diverse Pennycress germplasm and its demonstrated transformability, the latter issues are expected to be resolved rapidly (Sedbrook et al., 2014).

2.1 Seed and Oil Properties

Mature Pennycress plants reach 20 to 30 inches (51 to 76 centimeters) tall. The plant produces very small light to dark brown or purple colored, 0.06-inch (0.15 centimeter) long oval seeds in pods. Each plant may produce up to 15,000 seeds. The very small size of the seeds, weighing about 1 milligram per seed, makes the mechanized harvesting of the crop quite difficult. Pennycress seed yield is reported to vary between 750 and 2,400 kilograms per hectare, depending on the climate (Mitich, 1996). There are also reports indicating that improved Pennycress biotypes can yield 1,513 to 2,241 kilograms per hectare, and the reduced shattering variety, IO217, averages 2,271 kilograms per hectare (Basnet & Ellison, 2024; Cubins et al., 2019).

Pennycress seed oil content varies from 19% to 38%. Regular Pennycress seed oil is rich in erucic acid (Table 1). Similar to the other Brassica species, Pennycress seeds contain high levels of glucosinolates. Sinigrin is the main glucosinolate compound found in Pennycress. Myrosinase enzyme naturally present in the seeds converts glucosinolates to toxic compounds such as isothiocyanates (a potent biocide), nitriles and epithionitriles, which are harmful to both humans and animals (Williams, 2020). Higher oleic acid, low erucic acid and glucosinolate content, early flowering and maturity, and high protein content Pennycress biotypes are being developed (Winfield et al., 2024).

2.2 Potential applications

Pennycress is primarily grown for its seed oil and meal. Laboratory scale tests have shown that biodiesel produced from Pennycress seed oil meets ASTM D6751 biodiesel standards and has high cetane numbers and excellent low temperature properties (Moser et al., 2009). It was also demonstrated that defatted seed meal can be converted to high-carbon, low-oxygen and high energy content liquid fuel intermediates via a fast pyrolysis process. Liquid pyrolysis products can potentially be used in jet fuel formulation (Boateng et al., 2010).

The presence of glucosinolate in seed meal limits its utilization as animal feed. However, there are ongoing studies indicating the potential of Pennycress meal as a soil amendment for inhibiting germination and growth of weeds, as a biofumigant to deter pests and as nitrogen rich organic fertilizer (Hartnell et al., 2022; Vaughn et al., 2005; Williams, 2020).

3. Lesquerella

Lesquerella (*Physaria fendleri*) is a member of the *Brassicaceae* or *Crucifer* family. It is also referred to as bladderpod, yellowtop, desert mustard and cloth of gold. *Lesquerella fendleri,* which is mostly found in the western U.S., is a short-lived perennial plant that can be grown as an annual crop (Dierig & Ray, 2010). It is being evaluated as an alternative oilseed crop for arid regions in the U.S. The interest in *Lesquerella* species started in the late 1950s while USDA-ARS scientists were screening large numbers of oilseed plants from the wild and trying to find new or unusual oils that would not compete with edible vegetable oils.

Lesquerella production and management practices are reported to be similar to that of winter wheat. Seed yield varies with growth location and agronomic practices used, i.e., 496 kilograms per hectare in Southern Oregon when planted in March (Roseberg, 1993) and 1,100 kilograms per hectare in Northern Mexico when sown in December (García et al., 2007). In Arizona, the optimum seed yield is reported to be about 1,500 pounds per acre (1,681 kilograms per hectare) (Wang et al., 2010). Improved biotypes can yield over 2,000 kilograms of seeds per hectare..

3.1 Seed and oil properties

A single Lesquerella flower produces seeds enclosed in a pod, which may contain up to 30 seeds inside. The seed size is small, 1,000 seeds weighing only 0.25 to 1.1 grams, average being 0.6 grams per 1,000 seeds. Oil content in individual seeds varies from 15% to 44% of seed weight. The average oil content increases from 27% to 33% with bulk density increasing from 684 to 745 grams per liter (Isbell et al., 2008). Lesquerella seed oil has a unique fatty acid profile that is rich in hydroxy fatty acids (HFA) (Cruz, V.M.V., 2015). Lesquerolic (14-hydroxy- eicosa-11-enoic, 14-OH-20:1), oleic and linolenic acids are the major fatty acids found in the seed oil. Lesquerella seed oil contains 55% to 60% lesquerolic acid (Isbell, 2009). Protein content of the seeds is about 20% and defatting Lesquerella seeds increases the protein content in the meal to 30%.

3.2 Potential applications

The unique fatty acid profile of Lesquerella seed oil provides opportunities for its utilization in many bioproducts. Hydroxy fatty acids are vital raw materials for formulating numerous industrial products, such as lithium greases, gelling agents, industrial lubricants, paints, coatings, polymers, plasticizers, cosmetics, drying agents, pharmaceuticals and surfactants. The current commercial source of HFA is Castor (*Ricinus communis*) oil, which is rich in ricinoleic acid (scientific name is 12-hydroxy-octadeca-9-enoate, 12-OH-18:1 and it consists of 90% of all the fatty acids present in the oil). Castor beans contain a toxin known as ricin that makes the castor oil production extremely challenging. Lesquerella is a potential oilseed crop that is a safe source of hydroxy fatty acids. Although high concentration of linolenic acid in Lesquerella seed oil (12% of the total fatty acids present in the oil) reduces oxidative stability of many Lesquerella derived products, in some cases it provides good cold temperature properties, i.e., lubricants, and biodiesel made with Lesquerella seed oils is shown to have excellent cold flow properties (Isbell et al., 2006; Moser et al., 2008).

Estolide triglycerides are used as viscosity improvers in vegetable-based lubricants and base stock for lubricants. Estolides synthesized from Lesquerella oil are reported to be the best performing estolides to date at cold temperatures (Isbell et al., 2006).

Lesquerella seed coat, which has a glutinous polysaccharide layer, contains a natural gum that can be used as a thickening or gelling agent in edible and nonedible formulations (Holser et al., 2000). The mucilage from seeds is reported to be effective as a biological control agent against mosquito larvae (Barber et al., 1974).

Table 1. Fatty acid composition of Carinata, Pennycress and cuphea seed oils (adapted from the references shown at the end of the text). It is important to note that the reported broad range of individual fatty acids for a crop may be due to the agronomic practices used for crop production, climate at the growth location, plant biotypes, oil extraction method and analytical techniques used for fatty acid analyses).

Seed type/fatty acid	Carinata	Pennycress		Lesquerella
		Regular	HO	
Octanoic/caprylic (8:0)	-	-	-	-
Decanoic/capric (10:0)	-	-	-	-
Lauric (12:0)	-	-	-	-
Myristic (14:0)	0-0.08	0-0.4	-	-
Palmitic (16:0)	3-3.9	2.3-5.0	3.3	0.9-1.4
Palmitoleic (16:1)	0.04-3.0	0-0.5		0.2-1.1
Stearic (18:0)	0.8-1.6	0.2-0.8	0.9	1.4-2.1
Oleic (18:1)	7-61.3	12.2-17.1	62.6	13.9-15.7
18:1-OH	-	-	-	0.1-1.2
Linoleic (18:2)	16-18.3	15.4-22.4	15.4	6.9-8.5
Linolenic (18:3)	13-13.6	8.9-15.3	17.0	12.9-19.8
Arachidic (20:0)	0.8-0.9	0.2-2.2	-	-
Eicosenoic/Gadoleic/Gondoic (20:1)	6-8.8	8.6-11.5	-	0.4-1.0
20:1-OH	-	-	-	54.3-63.3
Eicosadienoic (20:2)	0-1.4	1.6-3.3		
20:2-OH	-	-	-	2.6-3.5
Eicosatrienoic 20:3	-	0-1.1		-
Behenic (22:0)	0.5-0.8	0-0.6		-
Docosenoic/Erucic (22:1)	36.4-43	27.5-39.0	0.8	-
Docosadienoic (22:2)	0-0.5	0-0.7	-	-
Lignoceric (24:0)	0.3-1	0-0.3	-	-
Nervonic (24:1)	1.4	0.1-3.7	0.1	-

References

Barber, J., Page, C. I., & Felsot, A. (1974). Interactions between mosquito larvae and mucilaginous plant seeds. I. Carbohydrate composition of mucilage in relation to entrapment of larvae.

Basnet, P., & Ellison, S. (2024). Pennycress domestication and improvement efforts. Crop Science, 64(2), 535–559. https://doi.org/10.1002/csc2.21183

Best, K., & McIntyre, G. (1975). The biology of Canadian weeds: 9. Thlaspi arvense L. Canadian Journal of Plant Science, 55(1), 279–292.

Boateng, A., Mullen, C., & Goldberg, N. (2010). Producing stable pyrolysis liquids from the oil-seed presscakes of mustard family plants: Pennycress (Thlaspi arvense L.) and Camelina (Camelina sativa). Energy & Fuels, 24(12), 6624–6632.

Cruz, V.M.V., D., D. A. (2015). Germplasm Improvement to Develop Commercially Viable Lines of the New Oilseed Crop Lesquerella. In Industrial Crops. Handbook of Plant Breeding (Vol. 9). Springer. https://doi.org/10.1007/978-1-4939-1447-0_14

Cubins, J. A., Wells, M. S., Frels, K., Ott, M. A., Forcella, F., Johnson, G. A., Walia, M. K., Becker, R. L., & Gesch, R. W. (2019). Management of pennycress as a winter annual cash cover crop. A review. Agronomy for Sustainable Development, 39(5), 46. https://doi.org/10.1007/s13593-019-0592-0

Cubins, J. A., Wells, S. S., Walia, M. K., Wyse, D. L., Becker, R., Forcella, F., Gardner, R. D., Johnson, G. A., & Gesch, R. W. (2022). Harvest attributes and seed quality predict physiological maturity of pennycress. Industrial Crops and Products, 176, 114355. https://doi.org/10.1016/j.indcrop.2021.114355

Dierig, D., & Ray, D. T. (2010). New crops breeding: Lesquerella. Oil Crops, 507–516.

García, R. R., de Rodríguez, D. J., Angulo-Sánchez, J., Dierig, D., Solís, H. D., & De la Rosa-Loera, A. (2007). Lesquerella fendleri response to different sowing dates in northern Mexico. Industrial Crops and Products, 25(2), 117–122.

Gesch, R. W., Isbell, T. A., Oblath, E. A., Allen, B. L., Archer, D. W., Brown, J., Hatfield, J. L., Jabro, J. D., Kiniry, J. R., Long, D. S., & Vigil, M. F. (2015). Comparison of several Brassica species in the north central U.S. for potential jet fuel feedstock. Advances in Industrial Crops and Products Worldwide: AAIC 2014 International Conference, 75, 2–7. https://doi.org/10.1016/j.indcrop.2015.05.084

Hartnell, G., Lemke, S., & Aulbach, C. (2022). Composition of a low erucic acid, low fiber field pennycress (Thlaspi arvense L) grain referred to as CoverCressTM developed through breeding and gene editing. bioRxiv, 2022–06.

Holser, R. A., Carriere, C. J., & Abbott, T. P. (2000). Rheological properties of lesquerella gum fractions recovered by aqueous extraction. Industrial Crops and Products, 12(1), 63–69. https://doi.org/10.1016/S0926-6690(00)00038-8

Isbell, T. A. (2009). US effort in the development of new crops (Lesquerella, Pennycress Coriander and Cuphea). OCL, 16(4-5–6), 205–210. https://doi.org/10.1051/ocl.2009.0269

Isbell, T. A., Lowery, B. A., DeKeyser, S. S., Winchell, M. L., & Cermak, S. C. (2006). Physical properties of triglyceride estolides from lesquerella and castor oils. Industrial Crops and Products, 23(3), 256–263.

Isbell, T. A., Mund, M. S., Evangelista, R. L., & Dierig, D. A. (2008). Method for analysis of fatty acid distribution and oil content on a single Lesquerella fendleri seed. Industrial Crops and Products, 28(2), 231–236. https://doi.org/10.1016/j.indcrop.2008.02.010

Marillia, E.-F., Francis, T., Falk, K. C., Smith, M., & Taylor, D. C. (2014). Palliser's promise: Brassica carinata, An emerging western Canadian crop for delivery of new bio-industrial oil feedstocks. Trait Introduction Methods and Innovation Platforms in Plant Biotechnology, 3(1), 65–74. https://doi.org/10.1016/j.bcab.2013.09.012

Mitich, L. W. (1996). Field Pennycress (Thlaspi arvense L.)—The Stinkweed. Weed Technology, 10(3), 675–678. Cambridge Core. https://doi.org/10.1017/S0890037X00040604

Moser, B. R., Cermak, S. C., & Isbell, T. A. (2008). Evaluation of castor and lesquerella oil derivatives as additives in biodiesel and ultralow sulfur diesel fuels. Energy & Fuels, 22(2), 1349–1352.

Moser, B. R., Knothe, G., Vaughn, S. F., & Isbell, T. A. (2009). Production and evaluation of biodiesel from field pennycress (Thlaspi arvense L.) oil. Energy & Fuels, 23(8), 4149–4155.

Roseberg, R. J. (1993). Cultural practices for Lesquerella production. Journal of the American Oil Chemists' Society, 70(12), 1241–1244.

Schulmeister, T. M., Ruiz-Moreno, M., Silva, G. M., Garcia-Ascolani, M., Ciriaco, F. M., Henry, D. D., Lamb, G. C., Dubeux, J. C. B., Jr., & Dilorenzo, N. (2019). Evaluation of Brassica carinata meal as a protein supplement for growing beef heifers1,2. Journal of Animal Science, 97(10), 4334–4340. https://doi.org/10.1093/jas/skz280

Sedbrook, J. C., Phippen, W. B., & Marks, M. D. (2014). New approaches to facilitate rapid domestication of a wild plant to an oilseed crop: Example pennycress (Thlaspi arvense L.). Plant Science, 227, 122–132. https://doi.org/10.1016/j.plantsci.2014.07.008

Seepaul, R., Kumar, S., Boote, K. J., Small, I. M., George, S., & Wright, D. L. (2021). Physiological analysis of growth and development of winter carinata (Brassica carinata A. Braun). GCB Bioenergy, 13(7), 1112–1133.

Seepaul, R., Kumar, S., Iboyi, J. E., Bashyal, M., Stansly, T. L., Bennett, R., Boote, K. J., Mulvaney, M. J., Small, I. M., George, S., & Wright, D. L. (2021). Brassica carinata: Biology and agronomy as a biofuel crop. GCB Bioenergy, 13(4), 582–599. https://doi.org/10.1111/gcbb.12804

Seepaul, R., Mulvaney, M. J., Small, I. M., George, S., & Wright, D. L. (2020). Carinata growth, yield, and chemical composition responses to nitrogen fertilizer management. Agronomy Journal, 112(6), 5249–5263. https://doi.org/10.1002/agj2.20416

Seepaul, R., Small, I., Mulvaney, M., George, S., Leon, R., Paula-Moraes, S., Geller, D., Marois, J., & Wright, D. (2019). Carinata, the sustainable crop for a bio-based economy: 2018–2019 production recommendations for the southeastern United States. University of Florida Institute of Food and Agricultural Sciences: Gainesville, FL, USA, 1–12.

Vaughn, S. F., Isbell, T. A., Weisleder, D., & Berhow, M. A. (2005). Biofumigant compounds released by field pennycress (Thlaspi arvense) seedmeal. Journal of Chemical Ecology, 31(1), 167–177. https://doi.org/10.1007/s10886-005-0982-4

Wang, G. S., McCloskey, W., Foster, M., & Dierig, D. (2010). Lesquerella: A winter oilseed crop for the Southwest. https://repository.arizona.edu/handle/10150/147025

Williams, D. (2020). Elucidating the role of the high aliphatic glucosinolate (Hag) genes in pennycress (Thlaspi Arvense L.) glucosinolate production.

Winfield, D. D., Dunn, R. O., Winkler-Moser, J. K., Cermak, S. C., & Marks, D. M. (2024). Characterization, physical properties, and potential industrial applications of high oleic pennycress oil. Industrial Crops and Products, 210, 118095. https://doi.org/10.1016/j.indcrop.2024.118095

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