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Camelina sativa, A Montana Omega-3 and Fuel Crop*

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Camelina sativa (L.) Crantz, (Brassicaceae), commonly known as false flax, leindotter and gold of pleasure, is a fall or spring planted annual oilcrop species (Putman et al. 1993). This versatile crop has been cultivated in Europe since the Bronze Age. Camelina seed was found in the stomach of Tollund man, a 4th century BCE mummy recovered from a peat bog in Denmark (Glob 1969). Anthropologists postulate that the man's last meal had been a soup made from vegetables and seeds including barley, linseed, camelina, knotweed, bristle grass, and chamomile. The Romans used camelina oil as massage oil, lamp fuel, and cooking oil, as well as the meal for food or feed. Camelina, like many *Brassicaceae*, germinates and emerges in the early spring, well before most cereal grains. Early emergence has several advantages for dryland production including efficient utilization of spring moisture and competitiveness with common weeds.

In response to the resurgent interest in oil crops for sustainable biofuel production, the Montana State University (MSU) Agricultural Research Centers have conducted a multi-year, multi-specie oilseed trial. This trial included nine different oilseed crops (sunflower, safflower, soybean, rapeseed, mustard, flax, crambe, canola, and camelina). *Camelina sativa* emerged from this trial as a promising oilseed crop for production across Montana and the Northern Great Plains. Evaluation parameters included input costs, production costs, harvest costs, and yield. *Camelina sativa* was not always the highest yielding oilseed crop but it was the most economical crop to produce due to minimal input requirements.

GREAT NORTHERN GROWER COOPERATIVE

MSU worked with Montana Producers to establish a grower cooperative to produce, process, and distribute camelina. As a result of this collaboration camelina production in Montana rapidly escalated from 0 commercial hectares in 2004 to approximately 4,050 ha in 2006. Production in 2007 is estimated at 20,250 ha.

VALUE-ADDED CAMELINA PRODUCTS

Camelina oil can be used for production of biodiesel. However the omega-3 fatty acid (α-linolenic acid) and gamma-tocopherol content of the oil may preclude its use as biofuel feedstock because of its high value in food and feed. Camelina seed contains 30%–40% oil. The linolenic acid or omega-3 fatty acid (C18:3) makes up about 35%–39% of the total oil content, with the remaining fatty acids being oleic (15%–20%), linoleic (20%–25%), gondoic (5%–10%) and erucic (4%–5%). The cold pressed meal still contains 10%–14% oil by weight, with a protein content of about 40%, allowing it to compete with soybean meal as an animal feed. The glucosinolate levels in the meal are lower than in other brassicaceous species, making it more desirable as an animal feed.

A previous review by Vollmann et al. (1996) suggested that camelina oil had considerable agronomic potential as an industrial oilseed crop. In Montana, camelina is emerging as a high-value, multi-use crop with applications in food, feed, and industry (Fig. 1).

A diversity of start-up industries and government entities are in the process of sorting out the different uses for this crop. The multiple possible uses suggest to these authors that there may be a stable market demand for farm gate seed.

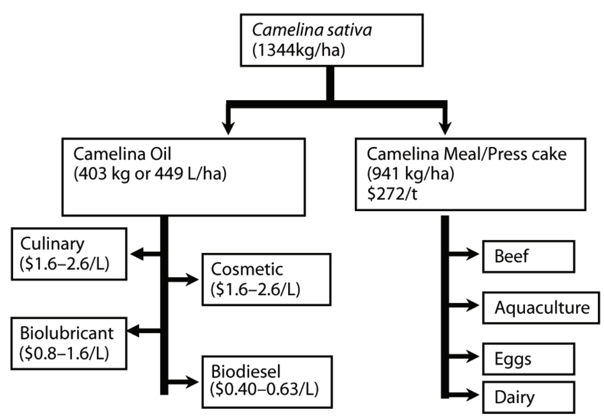

Fig. 1. Potential markets for camelina oil and meal.

* Research Funding from USDA CSREES (MSU Biobased Institute), USDA SBIR, Montana Board of Research and Commercialization, and US Egg and Poultry Association has enabled expansion of this unique Montana crop and development of value-added applications.

AGRONOMICS

Camelina is well-suited for production in Montana. A distinct advantage with this crop over almost any other is the very low seeding rate (2.5 kg/ha). A new cultivar can be increased at a rate of 500–1000 fold in a single cropping year. This low seeding rate is a key factor of the low input cost. A second factor is the true competitiveness of camelina in terms of weed control. The crop seems to be well suited to planting early, even fall planting. It is suited for dryland cropping systems when early planted to maximize the soil moisture and rainfall in the cool months of April, May and the first weeks of June. Harvest is by direct cutting, or swathing and field drying to avoid shattering. Some use of duct tape on certain key locations of a combine is necessary to prevent seed loss. Several herbicides appear promising in station trials although none are registered for use at this time. The palatability of the crop when green is not lost on grazing animals including antelope in Montana.

Selection of Montana Cultivars of *Camelina sativa*

Selection criteria for breeding programs are always more convoluted for crops of a multiuse nature. In this crop, selection can be made for oil properties to favor biofuel use (diesel and fuel cell uses), lubricant use (hydroxyl acids), nutrition (high omega-3 content), antioxidants to avoid oil oxidation and rancidity (gamma-tocopherol content), and lower erucic acid and gondoic acid content. These features are most assuredly at cross purposes, and one might need to breed and select for certain of these with the concomitant exclusion of others. Additional selection parameters include low glucosinolate content, high value protein in the meal, and gum content. Agronomic characters for selection include shattering, seed size, herbicide resistance, and resistance to downy mildew. As with other oil crops the ratios of the different unsaturated fatty acids can be influenced by day and night time temperatures, with the plant compensating for differences in geographic location.

Like many crops of ancient times, camelina has small seeds. Breeding programs in several European countries have not changed this aspect to a very noticeable extent, possibly because there is an inverse correlation of seed size with oil content. Genetically, camelina is probably the closest crop plant to that famous and completely sequenced cousin *Arabidopsis thaliana* (Flannery et al. 2006). This genetic proximity is of great value in marker assisted breeding, in identification of specific enzymes and their coded regions, the use of RNA inhibition techniques, and in the ease of genetic transformation using the *Agrobacterium tumefaciens* plasmid transformation systems (Lu, pers. commun.).

Duane Johnson has established a camelina breeding program at the MSU Northwestern Agricultural Research Center (Creston, Montana). The goal of the program is to develop camelina cultivars that are adapted to Montana and the Northern Great Plains. Selection parameters include yield, oil content, oil composition, and disease resistance. Over 50 accessions from the USDA and world collections of camelina have been evaluated. Three lines (MT-1, MT-3 and MT-5) have been selected for future development as Montana cultivars (Fig. 2, 3).

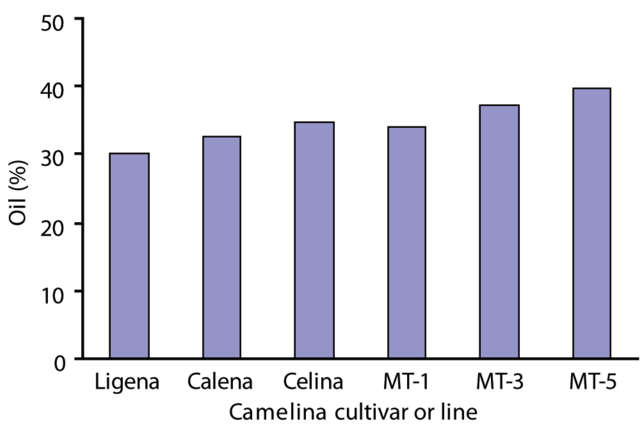

Fig. 2. Oil Composition of European camelina cultivars [‘Celine’ (France), ‘Calena’ (Austria), and ‘Ligena’ (Germany)] and 3 Montana breeding lines (MT-1, MT-3, and MT-5).

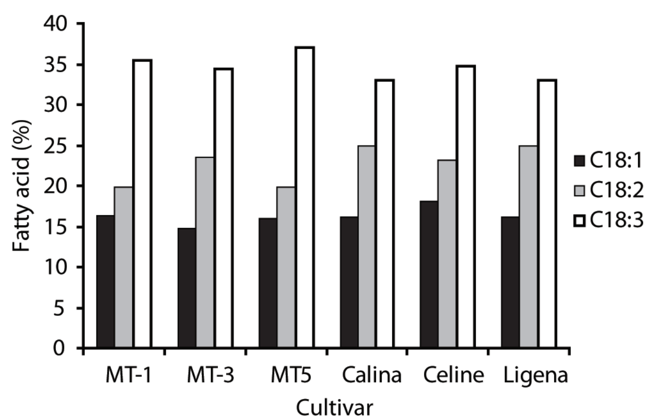

Fig. 3. Fatty acid profile of 3 European camelina cultivars [‘Celine’ (France), ‘Calena’ (Austria), and ‘Ligena’ (Germany)] and 3 Montana selections (MT-1, MT-3, and MT-5). Fatty acid profile was determined using GC-MS.

CAMELINA MEAL

Camelina meal, the extruded product remaining after cold extraction of the oil generally contains 10%–12% oil (approximately 5% omega-3 fatty acid) and 40% protein. Camelina meal and oil are also being evaluated as a source of omega-3 in feeds for fish, beef, poultry, and dairy production.

Poultry

Camelina meal was analyzed as an ingredient for production of omega-3 rich eggs. This study was done in collaboration with Nick Dale at the University of Georgia. Poultry readily consumed feeds containing up to 15% camelina meal. There were not adverse effects on chicken health or egg production. The fatty acid profile of yolks from eggs from chickens fed different levels of camelina (0%, 5%, 10%, 15%) were analyzed for omega-3 (C18:3) content. The content of omega-3 in the egg increased with increasing camelina content in the feed (Fig. 4). Currently, camelina meal is being fed to nearly 40,000 laying hens in Montana. The camelina eggs contain enriched levels of linolenic acid (Fig. 4). The increase in the omega-3 content is relative to the percentage of camelina meal in the feed.

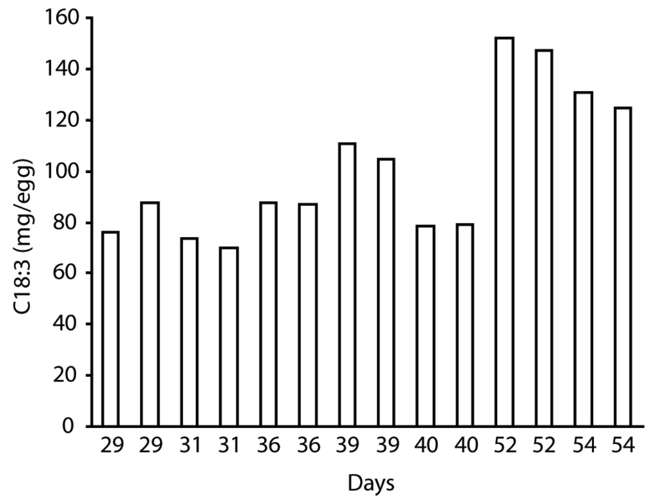

Fig. 4. Linolenic acid (omega-3) content of yolks from chickens fed 12% camelina meal.

Dairy

Camelina meal has been evaluated for production of omega-3 enriched goat milk. Similar to poultry, milk from camelina-fed goats contained increased concentrations of linolenic acid. Researchers at the University of Idaho and Idaho Ag Experiment Station will evaluate camelina meal as a feed ingredient in dairy cattle in 2007.

Beef

Darrin Boss conducted a study to evaluate camelina meal in beef finishing feeds. Cattle were fed formulations containing soy meal or camelina meal. There were no statistical differences in the feed efficiency or average daily gain of beef fed soy-based or camelina-based feeds. No detrimental effects on health were reported throughout the feed study or at harvest. The fatty acid profiles of the muscle and fat tissue are currently being evaluated.

SUMMARY

Camelina sativa is a new crop with a variety of uses. It is relatively easy to breed, and easy to grow with low input costs. Its meal is valuable as animal feed, and its oil has an important nutritional components (alpha linolenic acid and gamma-tocopherol). The industrial potential of this crop, given the current fuel crisis, is rather large.

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