CROPQUEST

Camelina : Food and Crop product potential

Gary Gillespie, Liam Brennan, Jim Burke, UCD, Dublin
Dermot Forristal, Teagasc, Oak Park , Carlow

Camelina (Camelina sativa L.)

Camelina is a crop native to Finland, Romania and regions east of the Ural mountains. Camelina, is a summer annual oilseed plant. Leindotter, wild flax and gold of pleasure are the popular common names for the crop. Seeds and capsules of the crop have been found in archaeological excavations from the Bronze Age in Scandinavia (Fan & Eskin, 2013). The crop has been an important oil crop for centuries with references to its cultivation in the Rhine valley region of Germany as far back as 600 BC. The crop was widely grown in Northern and Eastern Europe up to the early 1940's but was replaced with the introduction and widespread use of oilseed rape (Fan & Eskin, 2013). The crop is sometimes referred to as false flax and reaches a height of approximately 90 cm.

Camelina is regaining prominence as a health product due to the high contents of the omega-3 (n–3), alpha-linoleic acid (ALA) content. Reports from the Centre for alternative land use (CALU) found Camelina oil contains 45% ALA compared with 10% ALA in rapeseed oil and virtually none in sunflower oils (CALU, 2007). The oil from camelina is unique, being exceptionally rich in both n–3 fatty acids (typically 38.6g per 100ml and up to 45%) and potent antioxidants (such as vitamin E) (Dubois et al., 2007; Sampath, 2009). The high antioxidant content and an almond–like taste and aroma makes camelina oil a more versatile oil for culinary purposes compared with the most common source of n–3 supplementation: flax oil (Fan & Eskin, 2013).

A study conducted by Teagasc reported average seed yields of 2.5t ha^{-1} over a three year period with oil contents of between 42 – 47% (Crowley & Frohlich, 1998; Dobre et al., 2014). Camelina seeds contain oil levels of 36 – 47% in dry matter, which is twice of that of soybean (18 – 22%) (Li & Sun, 2015).

Camelina has several agronomic advantages compared with some other traditional commodity oilseed crops (e.g., rapeseed, canola, soybean, sunflower), including low water and fertiliser requirements, adaptability to adverse environmental conditions (e.g., cold weather, semiarid climate), capacity to grow in marginal lands, and resistance to common pests and pathogens of cruciferous vegetables (Li & Sun, 2015). CALU (2007) report sowing dates in Wales from April to mid–May and fertiliser inputs of 75 kg ha^{-1} of nitrogen, with higher levels of N leading to problems with lodging of the crop. These values for fertiliser inputs are in line with results obatined by Teagasc during trials of Camelina in 1994 (Crowley & Frohlich, 1998). The crop can be harvested using traditional combine harvesters with the seed pods being more shatter–proof than oilseed rape crops. This results in less losses of the crop during harvesting.

Camelina oil contains high levels of gamma–tocopherol (Vitamin E) and anti–oxidants which confers a reasonable shelf life without the need for special storage conditions. Stems of the Camelina crop can be used as a packaging material (Smith et al., 1997).

Camelina oil as an edible oil

Camelina oil has been part of the European diet for thousands of years. As opposed to flax oil, which cannot be heated as it goes rancid very easily, camelina oil tolerates low to moderate heat well. Camelina oil can be used in specialty oils, n–3–enriched margarines, salad dressings and cream spreads. It can be used in foods intended for baking and shallow frying; however deep–fat frying in this oil tends to develop a strong paint–like flavour which can be carried over to the fried food (Crowley & Frohlich, 1998). Therefore, in addition to uses as dips and salad dressings, camelina oil can be used for baking, sauteing, and other cooking applications not involving very high heat (Fan & Eskin, 2013).

Camelina oil is high in 18:3n–3 (30%), with an n–3 : n–6 ratio of > 1:1 (Hixson & Parrish, 2014). Camelina oil is very high in polyunsaturated fatty acids (PUFA), particularly ALA (27.9% – 40.3%; Table 1), making it an important nutritional source. (Ni Eidhin et al., 2003b) has reported that camelina oil is more stable in terms of the peroxide value than sunflower, sesame and corn oils, and oils with a high content of polyunsaturated fatty acids. However, camelina oil proved to be less stable than commonly used rapeseed and olive oils when stored at 65°C in open containers. The consumption of n–3 fatty acids has been associated with a lower risk of coronary heart disease and a reduction in other inflammatory diseases (Institute of Medicine, 2002). Consequently, it is generally accepted that increasing the dietary intake of n–3 fatty acids has beneficial health effects. However, due to low consumption levels of ALA and the high consumption levels of linoleic acid (C18:2n–6) in modern diets, the conversion of ALA to EPA and DHA is very low (Karvonen et al., 2002).

Table 1: Mean fatty acid composition of various plant oils (% of total fatty acids), adapted from (Dubois et al., 2007).

Fatty acid/ Plant oil	14:0	16:0	16:1	18:0	18:1	18:2	18:3	20:1	20:2	22:1	Ratio of n–6:n–3
Rapeseed	0.1	5.1	0.2	1.7	60.1	21.5	9.9	1.4	0.1	0.4	2.2
Olive	0.0	12.1	0.8	2.6	72.5	9.4	0.6	–	–	–	16
Soy	0.1	10.8	0.2	3.9	23.9	52.1	7.8	–	–	–	6.7
Sunflower	0.1	6.4	0.1	4.5	22.1	65.6	0.5	0.2	–	0.1	131
Coconut	18.5	8.7	–	2.7	6.0	1.8	0.1	0.1	–	–	18
Flaxseed	–	6.1	0.1	3.4	18.4	16.8	55.0	–	–	–	0.4
Hemp	–	6.3	–	2.8	12.1	55.9	19.7	–	0.8	–	2.8
Camelina	–	**5.3**	**0.1**	**3.0**	**18.7**	**16.0**	**38.1**	**11.6**	–	**2.5**	**0.4**

Evidence suggests that human beings evolved on a diet with a ratio of n–6 to n–3 PUFA of about 1:1, whereas typical "Western" diets tend to contain 14 to 25 times more n–6 oils than n–3 oils, indicating that these diets are lacking in n–3 PUFA compared with the diet on which humans evolved and their genetic patterns were established (Simopoulos, 2011). This can be a problem because over-consumption of n–6 oils has been linked to inflammation, cancer and heart disease. It has been reported that inclusion of camelina oil in a diet increased the proportion of ALA, EPA and DHA in the fatty acids of serum lipids and reduced serum low–density lipoprotein (LDL) cholesterol in mildly to moderately hypercholesterolemic human subjects (Karvonen et al., 2002). The nutritional deficiency due to the disproportion of polyunsaturated fatty acids can be alleviated by the addition of n–3 fatty acid rich oils in the diet. In such a situation camelina oil can be an excellent source of polyunsaturated fatty acids and n–3 fatty acid in particular.

Zubr (2009) verified the applicability of camelina seed and press cake as ingredients in bread for human consumption. These ingredients can enrich the bread with n–3 fatty acids. Camelina also possesses high levels of tocopherols and phenolic compounds, which makes it oxidatively more stable than other highly unsaturated oils such as flax. The oil has an unusually high cholesterol content (45 mg per 100 g), as compared to other edible oils containing 10 mg per 100 g (Matthaus, 2004). According to a report by the Institute of Medicine on Dietary Reference Intakes for macronutrients, the n–3 fatty acids being structural membrane lipids can play an important role in nerve tissue and the retina (Institute of Medicine, 2002). The human body cannot naturally synthesize ALA and its deficiency may result in clinical symptoms including neurological abnormalities and poor growth. Therefore, ALA should be included in the diet. ALA can be elongated to EPA (Eicosapentaenoic acid) and DHA (Docosahexaenoic acid), because their metabolic products have beneficial effects which help in preventing coronary heart disease, arrhythmias and thrombosis (Institute of Medicine, 2002).

It's recommended to eat a healthier balance of oils with more n–3s and less n–6s. Camelina oil has twice as much n–3 oils as n–6 oils, which is a much healthier ratio than oils like olive, canola or sunflower seed that have higher amounts of n–6 (Fan & Eskin, 2013).

The oil composition in camelina gives it a high smoke point of 246°C. The smoke point of an oil is the point when it becomes hot enough to start essentially burning, which produces smoke and harmful chemical byproducts. It is recommended to use an oil with a smoke point of at least 204°C for frying purposes. As a comparison, extra–virgin olive oil and coconut oil have smoke points of approximately 176°C, compared to camelina's 246°C. This makes camelina oil a better choice for any high temperature cooking.

Camelina meal as an aquaculture feed

Arguably, of greatest importance for consumers in the developed world, fish and seafood are unique and rich sources n–3 long-chain polyunsaturated fatty acids

(LC-PUFA), particularly eicosapentaenoic (EPA; 20:5n−3) and docosahexaenoic (DHA; 22:6n−3) acids. Similar to other oilseed crops after the oil has been removed from the seeds a resulting press cake remains. Uses for this press cake can make camelina a more profitable crop to cultivate. Camelina oil and meal are potential replacements of fish oil and fish meal in aquaculture feeds. Camelina meal contains a considerable crude protein level (38%), which includes significant amounts of methionine and phenylalanine (Hixson & Parrish, 2014).

The prospects for increasing the production of fish oil are very limited, since most of the fisheries for fish oil production are now tightly monitored to not exceed the established fishing quotas and Total Allowable Catches (TACs). As current supply rates cannot keep up with demand, the fish farming industry, which grows close to 6% annually, in future will have to use less fish oil. This means fish farms have to source alternative feedstocks for the production of aquaculture feeds. Pressure from commercial capture fisheries has left most fish stocks depleted, and as a result, aquaculture now produces nearly half of the world's seafood (Hixson et al., 2013). In fact, 2013 was the first year in which more than half (51%) of the global supply of fish came from aquaculture as opposed to wild caught fish.

With more fish being bred in fish farms demand for oil and meal as feed is set to continue to grow. Camelina is one of the most suitable oilseed crops for aquaculture feed materials due to is its crude protein level (38%), the presence of methionine and phenylalanine and its availability after oil extraction (Hixson & Parrish, 2014).

Camelina meal as animal feed

Dietary recommendations to consume less saturated fat have encouraged recent research into the modification of diets fed to animals to increase the content of beneficial polyunsaturated fatty acids. The resulting press cake after oil extraction from camelina can also be fed to livestock up to approximately 10 – 15% of the ration. Due to the high crude protein content, press cakes are considered economically important and can be used as nutritive supplement in animal feed formulations (Sampath, 2009).

When Camelina seed and meal were used in the diets of dairy cows (Bos primigenius), it reduced milk fat with softer, more spreadable butter mainly due to unsaturated fatty acids in the feed (Hurtaud & Peyraud, 2009). A number of studies reported by Sampath (2009) concluded that camelina meal as an animal feed additive can be beneficial in increasing the n–3 fatty acid content in eggs (Rokka et al., 2002) and the meat quality of laying hens and broiler chickens. The study conducted by Rokka et al. (2002) mixed camelina oil with chicken (Gallus gallus domesticus) feed and increased the n–3 content of the eggs produced without any unpleasant flavor, which is often observed when flaxseed oil is used. Camelina meal contains high amounts of protein and energy suitable for feeding pigs (Sus domesticus) and ruminants (Matthaus & Zubr, 2000). Camelina oil was used to increase the plasma n–3 fatty acid content and reduce the plasma n–6 fatty acid content and serum triglyceride levels in a controlled pig feeding trial

conducted by Ni Eidhin et al. (2003a). Frame et al. (2007) evaluated the use of camelina meal as a potential ingredient for inclusion in the starter diets of young turkeys (Meleagris gallopavo). It was reported that camelina meal should not exceed 5% of the finished feed in a poultry starter diet, as increased percentages result in decreased weight and poor feed conversion. An experiment conducted by Kronberg et al. (2006) feeding cattle 907 g day^{-1} of flaxseed meal protected with lignosulfate for a 71 day period led to a 400% increase in ALA, 140% increase in EPA, and a 140% increase in DPAn−3 in the longissimus dorsi muscles. A number of studies reported by Barcelo-Coblijn and Murphy (2009) and Woods and Fearon (2009) suggest that flax and other *n*−3 fatty acid-enriched sources, such as camelina press cake, can be successfully used in beef and other animal feedlot rations to increase the *n*−3 fatty acids content in the meat produced.

Camelina as a biofuel

The high degree of unsaturation renders camelina oil highly prone to oxidation making it less suitable for certain applications. For example, biodiesel derived from camelina possesses a lower oil stability index (OSI) compared to biodiesel from other feedstocks. While the oil yield is somewhat lower than that of oilseed rape, studies have shown that the cost of production of seed oil from camelina can be less than half that from rapeseed due to comparatively low input requirements (Bansal & Durrett, 2015). Two aviation biofuels processes have already been approved for commercial use, and several more are on track for approval in the coming years. Already, conventional jet fuel blends with up to 50% biofuel derived from sources such as camelina, waste cooking oil, and algae have been used on more than 1,500 commercial flights.

Medicinal value of camelina

The oil extracted from the seeds of camelina sativa can be considered as a good remedy for various medicinal problems. In traditional medicine, it is used internally against stomach and intestine ulcers, gastritis, colic attacks and digestive problems. When applied topically, a healing effect on bruises, skin scratches, squeezing and sprains as well as skin diseases (e.g. acne) and inflammations is described (Rode, 2002). Camelina oil can be helpful for the regeneration of cells, skin elasticity and slenderness recovery (Vollman et al., 2007). The fatty acid profile of camelina makes it a suitable raw material for the production of cosmetic products like skin creams, lotions, balms, lipsticks and bars of soap (Sampath, 2009).

Karvonen et al. (2002) determined the cholesterol reducing effects of camelina oil in a study conducted using mildly and moderately hypercholesterolemic subjects. The total cholesterol in blood serum of the subjects was reduced from 5.9 to 5.6 m mol L^{-1} and LDL (low density lipoprotein) decreased by 12.2% when 33 ml of camelina oil was included in the diet.

The consumption of camelina oil can help to improve the general health of the population to the desired level (Rokka et al., 2002; Waraich et al., 2013; Zubr, 1997).

The most conclusive evidence of the beneficial effects of dietary n−3 long chain polyunsatrated fatty acids in inflammatory disease has been obtained with rheumatoid arthritis (Miles & Calder, 2012). The amounts of n−3 required to gain benefit are much higher than those reported for cardiovascular disease, at around 3 g day^{-1} and thus dietary n−3 is still not reccomended as part of classical treatment plans (Tocher, 2015). There is growing evidence for the beneficial effects of dietary n−3 PUFA in inflammatory bowel diseases including both Crohn's disease and ulcerative colitis (Cabré et al., 2012; Tocher, 2015). There is no official database which gives accurate figures, however, it is estimated that at least 20,000 people are affected by Crohn's disease in Ireland.
Epidemiological studies have indicated that, in general, consumption of oily fish or taking n−3 PUFA supplements may have a protective effect (i.e. decrease the associated risk) in colo−rectal, breast and prostate cancers (Gerber, 2012; Tocher, 2015).

Market outlook

At present camelina is a little known crop in Irish agriculture. Promotional campaigns for both farmers and consumers need to be conducted to highlight the potential as an oil crop. Farmers need to be informed as to the potential of a high value break crop with low inputs while consumers need to be informed of the potential health benefits of the oil with it's favourable oil profile. The established presence of brands such as Newgrange gold in the Irish market place allow for rapid expansion of cultuvation of camelina sativa. The desirable oil profile of camelina with an n−6 : n−3 ratio of < 1 (Table 1), allows for the oil to be marketed as a healthy oil. There is potential to replace large amounts of rapeseed and olive oil that is consumed by consumers who perceive these oils as heart healthy oils.

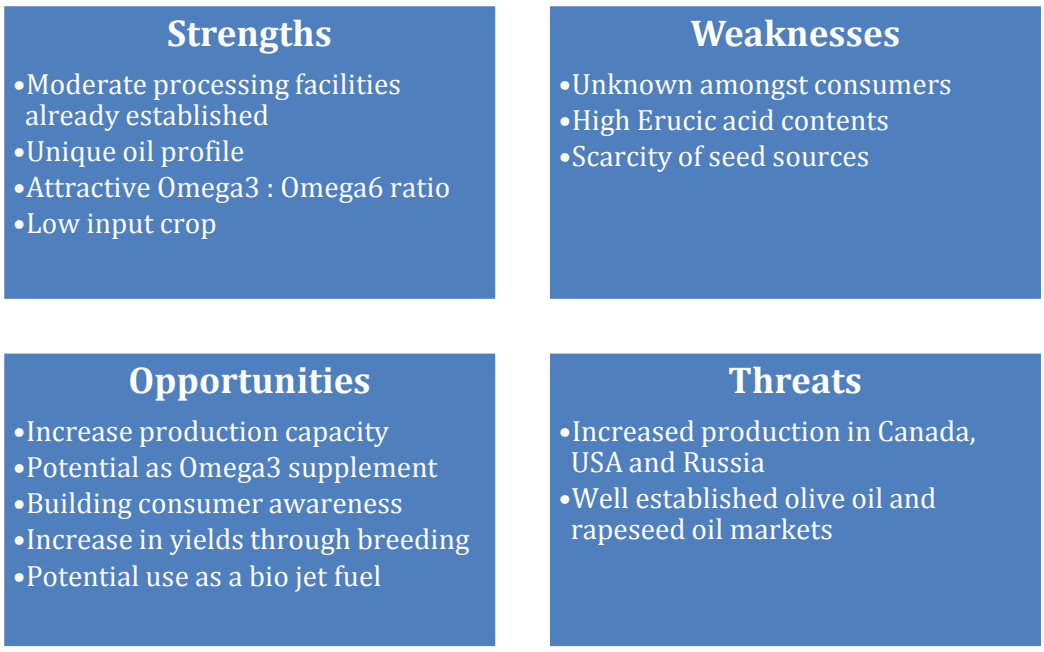

Figure 1: SWOT Analysis for Camelina sativa cultivation in Ireland

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