The Canadian Biodiesel Industry: An Analysis of Potential Feedstocks

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Executive Summary

The success of the Canadian biodiesel industry is dependent upon the availability of adequate supplies of reasonably priced feedstocks. This document will analyze the potential availability of biodiesel feedstocks in Canada, with a focus on the suitability of the various oils as precursors for biodiesel production and the potential economic value of the feedstock by-products. The current and future availability of each feedstock will be discussed, as will the proposed growing regions for dedicated biodiesel oilseeds. Finally, a prioritization for the further development of each biodiesel feedstock will be provided.

Biodiesel can be derived from re-used vegetable oils and rendered animal fats, but these resources are limited. At present, it is estimated that the total volume of animal fats produced in Canada on an annual basis are 500,000 tonnes, while annual yellow grease production is less easily quantified. Additionally, there is competition for these resources, as they are also used as a dietary energy source in the animal feed industry and in the manufacture of soaps and detergents. A viable Canadian industry cannot be sustained solely on recycled oils and animal fats. To meet the long-term needs of the industry, a dedicated biodiesel oilseed(s) will need to be identified and developed.

Canola is the most abundant oilseed grown in Canada, and in 2004, 7.7 million tonnes were produced in Canada. The Canola Council of Canada has established a goal of 7.0 million tonnes annual production in Canada, on a sustainable basis. On average, approximately 5% of annual production is heat damaged or “green” canola seed that results from frost damage. At 7.0 million tonnes production, this would total 350,000 tonnes. This off-grade canola seed is usually blended with higher grades of canola seed, and then crushed to produce commercial oil and meal. The biodiesel industry can utilize this seed (as well as off-grade mustards, flax and soybeans) as feedstock for the production of biodiesel. If all the off-grade canola were used to produce biodiesel, total fuel production would be 146,362,000 litres. However, the canola crushing industry will compete for this resource for blending purposes, and the biodiesel industry can expect to obtain only a portion of this total supply.

Brassica rapa canola at one time commanded over 40% of the total canola acreage in Western Canada, but it has now fallen out of favour due to distinct yield disadvantages to *Brassica napus*. However, it could be utilized as a dedicated biodiesel feedstock, as it can be grown in the Palliser Triangle and Peace River Regions of Western Canada, and in the short season growing region of the Maritime Provinces. Its meal by-product can be

sold directly into the livestock industry, and if yield improvements are desired, the glucosinlolate content in the crop can be allowed to rise, and the resultant meal could then be sold into the biopesticide market.

The mustards, *Brassica juncea, Brassica carinata,* and *Sinapis alba,* may provide unique advantages as dedicated biodiesel feedstocks. *B. juncea* is high yielding, and it also has a high oil content. There are *B. juncea* cultivars available that could produce meal by-products with either canola quality or a high-glucosinolate content. The latter could prove quite useful, as the high glucosinolate meal could be marketed as a biopesticide product. Alternatively, low glucosinolate cultivars would produce a meal product that could be sold into the animal feed industry on an equivalent basis with traditional canola meal. The oil from *B. juncea* is of canola quality, which is favourable for biodiesel production. There are, however concerns about the risk involved with genetic crosses among biodiesel-specific *B. juncea* cultivars and canola and mustard quality *B. Juncea* cultivars.

B. carinata and *S. alba* are both large seeded mustards, with high protein contents. The meal by-products, therefore, would contain high levels of protein and rival soybean meal as valuable additions to livestock rations. This is particularly true for *S. alba,* since the glucosinolate content of this species is relatively low. *B. carinata* has a high glucosinolate content, and further work would be needed to reduce these compounds to produce a marketable meal. Alternatively, the high levels of glucosinolates could be exploited in the biopesticide market. Both of these mustards could be grown in the dry regions of the Prairies, and possibly in the Maritime Provinces as well. *B. carinata* may also be adaptable to the hot and humid regions of Southern Ontario, Quebec and British Colombia.

Traditional flax could be difficult to use in biodiesel production, as the high content of linolenic acid (18:3) in the oil (55+%) makes the oil relatively unstable. However, the specialty flax “Solin”, with its elevated level of linoleic acid (18:2), could provide a more viable alternative to traditional flax. “Solin” can produce several high value co-products as well, including whole flax seed for the nutraceutical market, as well as flax meal, cake, flour, straw and fibre.

Soybean oil is the primary feedstock for biodiesel production in the U.S., but Canadian soybeans account for only 1.5% of total world soybean output. Additionally, over 25% of all Canadian soybeans are exported. Soybeans are low in oil content (18%), and Canada is also a net importer of soybean oil (68,000 tonnes in 2003/04). The total contribution of soybean oil that could be obtained for biodiesel production is, therefore, limited, unless an effort is made to breed for higher oil content in soybeans. The soybean meal by-product, however, is of high value to the livestock industry.

Other possible long-term feedstocks for the Canadian biodiesel industry include “chokecherry”, which refers to a group of perennial North American trees, and “false flax”, which is a high-yielding oilseed that has been cultivated in Europe for centuries. Both of these potential feedstocks represent long-term, high-risk research initiatives.

The limited availability of yellow grease, animal fats and off-grade oilseeds necessitates the development of dedicated biodiesel oilseeds for the long-term sustainability of the Canadian biodiesel industry. The oilseeds described in this report each have their own individual advantages and disadvantages, from oil yield and composition, agronomic, and by-product perspectives. Additionally, they are each at different stages of development relative to availability to the industry. Recommendations are made herein for the allocation of research funding in the short-, medium-, and long- term, to advance these developmental efforts.

I. Introduction

Biodiesel fuel, derived from re-used and virgin vegetable oils and animal fats, is used as a substitute for petroleum-based fuels in diesel engines. Biodiesel is widely used in Europe, where it is now the largest single outlet for oil derived from oilseeds, and it is rapidly gaining favour in the North American market as well. Relative to the size of its population, Canada produces more vegetable- and animal-based oils than all other countries except Malaysia, and therefore it has significant potential for the production of renewable fuels, including biodiesel.

To grow and thrive, the industry needs a steady supply of biodiesel feedstock now and in the future. The annual Canadian diesel fuel market is approximately 25 billion litres. Currently, the industry depends upon the availability of off-grade canola seed to meet its needs in Western Canada, and biodiesel production in Eastern Canada has depended upon the availability of yellow grease and tallow from the restaurant and rendering industries there, as well as limited supplies of soybean oil. These combined resources would allow for the production of approximately 2.5 billion litres of biodiesel fuel, or 10% of the total Canadian diesel fuel market. If the Canadian biodiesel industry is to expand, other sources of oil feedstock need to be identified for use in biodiesel production, both in Western and in Eastern Canada.

This document will outline the potential feedstock that is available to the industry, discuss the advantages and disadvantages of each, and provide recommendations and a time frame for their development.

II. Potential Feedstock

The following are the currently utilized and potential sources of biodiesel feedstock that will be discussed in this document:

- Yellow Grease and Tallow
- Off-Grade Canola Seed
- *Brassica rapa (*Polish canola)
- *Brassica juncea* (Oriental mustard)
- *Brassica carinata* (Ethiopian mustard)
- *Sinapis alba* (Yellow mustard)
- Flax (“Solin”)
- Soybeans
- Chokecherry
- False Flax (*Camelina sativa)*

A. Yellow Grease and Tallow

The restaurant and food service industry, and the animal rendering industry, both produce by-products that can be used for the production of biodiesel fuel and fuel additives, particularly in Eastern Canada. Toronto and Montreal, as well as other Ontario and Quebec urban centres, have an abundance of restaurants and food service establishments, which can provide re-cycled vegetable and animal oils and fats as feedstock for biodiesel production. The animal rendering industry produces various types of animal fats, in addition to animal protein meals and other rendered products. These products are primarily utilized in the animal feed industry as a source of dietary energy and essential fatty acids, but this usage is diminishing with concerns raised by the recent occurrence of bovine spongiform encephalopathy (BSE) in Canada and the United States.

Feestocks represent 65-75% of the total cost of biodiesel production, and there is a cost benefit to the use of animal fats and recycled cooking oils relative to the use of virgin oilseeds. In the U.S., it is estimated that beef tallow and yellow grease cost $0.03 U.S ($0.38 Canadian) and $0.05 U.S. ($0.63 Canadian) less per pound, respectively, than soybean oil (estimates vary, since processing costs can be higher for re-cycled products based on lower conversion yields). On a per U.S. gallon basis, this equates to a cost savings of $0.28 U.S. ($0.35 Canadian) per gallon for tallow-based biodiesel, and $0.47 U.S. ($0.59 Canadian) per gallon less for yellow grease-based biodiesel. The equivalent savings on a per litre basis are $0.092 Canadian for tallow, and $0.155 Canadian for yellow grease. The primary concern with the use of yellow grease and rendered animal fats is that despite the low price, they are both limited in availability, and there is competition for their use by the animal feed industry (as a dietary energy source) and the soap and detergent industry.

The estimated volume of animal fat (tallow) produced each year in Canada is 500,000 tonnes. Annual yellow grease production is more difficult to estimate. In British Colombia, the yellow grease produced in restaurants and in the food service industry is 21.4 million litres per year (approximately 19,700 tonnes). This would be sufficient to provide B100 fuel for 636 BC Transit buses, or B20 fuel for 3,180 buses on an annual basis. The combined yellow grease and tallow production in Canada could serve as the basis for a viable biodiesel industry, particularly in Eastern Canada, but the limited supply will necessitate the additional availability of other feedstocks for the long-term sustainability of the industry.

Advantages: There are no real oilseed feedstock alternatives in Eastern Canada, at present, for the development of the biodiesel industry there. Canola production in Ontario is minimal (less than 40,000 tonnes annually), and the soybean industry is not presently focused on the production of high-oil soybeans for the biodiesel industry. With an anticipated production of approximately 2.8 million tonnes of soybeans in Ontario and Quebec in 2004, and an average oil content of 18%, only 504,000 total tonnes of soybean oil will be available from the soybean crop this year, and approximately 25% of that oil will be exported out of the provinces as whole soybeans. The Canadian food processing industry will utilize most of the remaining soybean oil, so there will be little oil available for use by the biodiesel industry. In fact, Canada is a net importer of soybean oil. In 2003/04, Canada imported 119,225 tonnes of soybean oil and exported 36,639 tonnes, for a net gain of 86,586 tonnes.

Re-cycled vegetable oils and rendered animal fats will in all probability form the basis of biodiesel production in Eastern Canada. There are likely adequate supplies of these by-products available, given the current productive capacity of the Canadian biodiesel industry. Projections indicate that 100-200 million litres of biodiesel can be produced annually from yellow grease alone. It is possible that an industry could be built in Eastern Canada based on yellow grease and tallow, and that further growth in the industry could come from either targeted high-oil soybean production or the adaptation of other dedicated biodiesel oilseeds to Eastern Canadian growing conditions to serve as supplementary feedstocks.

Disadvantages: Yellow grease and tallow, although lower cost alternatives to virgin vegetable oils, are limited in availability, and are prone to competition from the animal feed industry, the soap and detergent industry, and export competition. Yellow grease would not have a great deal of relevance to Western Canada, except perhaps in the lower mainland of British Colombia. The population base is not present in the total of Western Canada to produce sufficient volumes of yellow grease, and the oilseed alternatives available there diminish the need for this source of material. Although the animal rendering industry is centered in Western Canada, the animal origin of the tallow is a potential problem. Although there is no evidence linking the development of BSE in cattle and the human equivalent of the disease (Jakob Creutzfeldt Disease) to tallow, there could still be a negative public perception to its use in producing biodiesel.

Recommendation: Yellow grease and tallow are a valuable resource for the biodiesel industry, particularly in Eastern Canada. Therefore, the industries that support the use of these products should be encouraged to proceed with their utilization and further development as resources for the production of biodiesel. Plant breeding funds are not needed in this regard, and should be focused on the development of alternative oilseed crops to supplement the limited supplies of rendered animal fats and re-cycled vegetable oils.

B. Off-Grade Canola Seed

Annual Canadian canola production averaged 6.374 million tonnes from 1999-2003, and it is the Canola Council of Canada's (CCC) goal to increase annual production to 7.0 million tonnes on a sustainable basis. Each year, approximately 5% of total production is off-grade, low-quality canola, which is available for use as a biodiesel feedstock. Extrapolating this to the 5-year average, approximately 319,000 tonnes of off-grade canola seed was available annually for biodiesel production, and if the CCC annual production goal is reached, this will increase to 350,000 tonnes. This is equivalent to the production of approximately 133,398,000 and 146,362,000 litres, respectively, of biodiesel fuel annually, if all the off-grade canola were directed toward the biodiesel industry. This represents less than 1% of the entire Canadian biodiesel market of 25 billion litres.

The Canadian canola crushing industry has traditionally purchased off-grade canola seed for blending with higher-grade canola seed, and it can be expected to continue to do so in the future. The biodiesel industry would be bidding against canola crushers for this off-grade canola seed, and it is likely to source only a portion of this limited supply. Off-grade canola seed should, therefore, be looked at as a readily available, albeit finite supply of biodiesel feedstock. The only projected growth in the supply of this oilseed would come from greatly expanded canola production and/or particularly poor growing conditions in a given year that increased the yield of off-grade seed. Neither of these scenarios is a long-term solution to the needs of the Canadian biodiesel industry.

Recommendation: There is little that can be done to alter the development of this feedstock, nor, from a canola industry perspective, should there be. If anything, one would hope that the canola industry produces higher-grade canola to maximize existing high value canola seed, oil and meal markets.

C. *Brassica rapa*

Brassica rapa, or Polish canola, at one time commanded over 40% of the canola acreage in Western Canada. That proportion has now dropped to 10% or less of the seeded acreage. Still, there is considerable *B. rapa* germplasm available for further development, and it potentially provides an additional feedstock for the biodiesel industry in Canada.

Advantages: Although yield has always been a concern with *B. rapa* cultivars, if one were to ignore the need to lower glucosinolates to obtain canola-quality germplasm, yield could be increased by 20%. Glucosinolates are known for their anti-insecticidal qualities, and they could be targeted toward the biopesticide market, either as a component of the meal or in isolated form. If not, then the by-product that would be available from *B. rapa* would be commercial canola meal. The strongest selling point for this canola species may be its adaptability to cool, moist, short season growing regions, like the Maritime Provinces. It could also be grown in the Palliser Triangle Region of Western Canada, as well as in the Peace River Region of Alberta and British Colombia. Its early maturity also makes it a good rotational crop. Its fatty acid profile and oil content are of canola quality, since registered cultivars had to meet the standards of the Western Canadian Canola and Rapeseed Recommending Committee to attain that status.

Disadvantages: The primary reason why *B. rapa* fell into disfavour among traditional canola growers was its yield relative to *Brassica napus*, particularly as hybrids have become more prevalent.

Recommendation: *B. rapa* provides a readily available, high quality oilseed that can be grown both in the Western Prairie and Maritime Provinces to support the Canadian biodiesel industry. With some of the breeding constraints removed relative to producing canola-quality *B. rapa* cultivars, future research efforts could be directed toward addressing low yield concerns.

D. *Brassica juncea* (Oriental mustard)

Brassica juncea, or oriental mustard, has been a mainstay of the Canadian mustard industry for many years. Certain *B. juncea* varieties, after many years of developmental work, have now gained canola status, adding to the stable of canola-quality cultivars that Canadian farmers can grow in Western Canada. *Brassica juncea* also has several characteristics that make it a strong candidate for selection as a biodiesel-specific oilseed crop.

Advantages: *B. juncea* is a high yielding (approximately 1.5 tonnes/hectare in Western Canada) oilseed, with a high-oil content (50+% in some cultivars). This combination provides for high oil per acre yield potential, which is an important consideration in developing a biodiesel feedstock. Scientists at Agriculture and Agri-Food Canada's Saskatoon Research Centre are now crossing high-yielding *B. juncea* cultivars with cultivars that contain high levels of glucosinolates. *B. juncea* can be brown- or yellow-seeded, and it is stable under a variety of environmental conditions (the oil content remains high), and germplasm is available for a variety of types of uses (human canola production, high glucosinolate production – 140-160 micromoles/gram, biodiesel production).

The availability of cultivars with high levels of glucosinolates is notable from a by-product perspective. For biodiesel production to be economical, it is important that high value by-products be available from the seed in addition to the biodiesel that is produced. This may be in the form of a high-protein meal product that can be fed to animals, or it may be a higher value by-product that can be extracted from the solid fraction of the seed or from the oil. With regard to glucosinolates, it may be possible to utilize their anti-insecticidal properties either as a component of a meal product or in isolated form. If the glucosinolates do not prove marketable, then only the meal may be available as a by-product. It could be sold into the animal feed market, where it would trade on a par with commodity canola meal. The value of this protein ingredient ranges from 55-75% the value of 48% protein soybean meal; depending upon which animal species it is being fed to.

The fatty acid profile of *B. juncea* is available in canola quality (55-60% oleic acid (18:1): 20% linoleic acid (18:2); 10-15% linolenic acid (18:3); 7% saturated fatty acids), which is favourable to biodiesel production. *B. juncea* is also highly blackleg resistant, and it will grow quite well under arid conditions. This makes the dry regions of the prairies, such as the Palliser Triangle Region of Southeast Alberta and Southwest Saskatchewan (2-3 million acres), available for production. *B. juncea* would provide a rotational option to wheat for producers in this region. *B. juncea* could also be grown in the hot, humid areas of Canada, such as Southern Ontario, Quebec and British Colombia.

The available cropping area for *B. juncea* is, therefore, quite large, and given the potential high oil content of the crop, it could contribute significantly to the future supply of biodiesel feedstock.

Disadvantages: In order to segregate high-oil *B. juncea* (biodiesel) from mustard *B. juncea* and canola *B. juncea,* contract production would be required. However, this will likely apply to any oilseed that is bred specifically to produce biodiesel feedstock. There are some concerns that high-oil *B. juncea* will cross with mustard *B. juncea,* as well as with canola *B. juncea* and canola *B. napus* varieties. However, this risk is considered to be low, and post-harvest seed admixture is more likely. Since high-oil *B. juncea* would be yellow-seeded and *B. napus* is brown seeded, the admixture would be easily distinguishable. The difference would not be as obvious were mixing to occur with *B. juncea* mustard, since both would be yellow-seeded. However, Agriculture and Agri-Food Canada scientists are currently developing a simple test that would distinguish high-oil *B. juncea* from mustard *B. juncea*. There is a trend in the canola industry to produce hybrid varieties, which will further minimize out-crossing problems.

If high glucosinolate *B. juncea* is produced for the development of an anti-insecticidal meal or product, the value of the by-products could be substantial. If this market proves unattractive, then other by-products would need to be identified. The meal produced from canola quality *B. juncea* has proven to be equivalent to standard canola meal, and the value of that product is identical to commercial canola meal.

Recommendation: High oil, high glucosinolate cultivars of *B. juncea* are available, and work is progressing to cross these lines to produce optimal cultivars for the biodiesel industry. This work should continue, as *B. juncea* has excellent potential to provide feedstock for biodiesel production that can be grown on land that is currently of marginal agricultural value (arid). *B. juncea* oil is of high quality and quantity, and the seed yield is excellent. Combined with excellent blackleg resistance, and the potential for value-added co-product development, *B. juncea* could make a significant contribution to the biodiesel industry in both the short and the long term.

E. *Brassica carinata* (Ethiopian mustard)

*Brassica carinata,*or Ethiopian mustard, is believed to be a natural hybrid (female *B. nigra* X male *B. oleracea*), which has recently been investigated as a potential producer of biomass and biofuels in Southern and Northern Europe. It is not currently a commercial crop in Canada, however it has several attributes that may be of significance to the biodiesel industry.

Advantages: *Brassica carinata* is large seeded, and it has a high protein content in the meal fraction (47-50%), so the by-product that would be produced after oil extraction is of potentially high value to the animal feed industry. As with *B. juncea*, it contains high levels of glucosinolates (130-135 micromoles/gram, or higher), which may be of value as a biopesticide. It is early maturing, and it can grow in cool, moist climates. This makes it ideally suited for cultivation in the Maritime Provinces, where alternatives to a limited cropping selection are sought. It is also highly blackleg resistant, it has little chance of cross pollination with *B. napus*, and it would grow well in the dry regions of the Prairies (similar to *B. juncea*) as well as in the hot and humid regions of Southern Ontario, Quebec and British Colombia. Its potential acreage base is, therefore, comparable to that of *B. juncea.*

Disadvantages: The oil profile is comparable to mustard, with approximately 35% oleic acid, 35% linoleic acid, and 15-20% linolenic acid. However, the level of erucic acid (22:1) is quite low. Although this profile is not ideal, it is more favourable than some other alternative oilseeds, such as traditional flax, with its high content of linolenic acid. The greatest disadvantage to *B. carinata* is the oil content of the seed. Currently, that stands at 36-38%, with some cultivars as high as 40-42%. Breeding programs would need to focus on increasing the oil content.

Recommendation: Because of the potential large land area that could be seeded to *B. carinata*, and the potential value of the meal and/or glucosinolate by-products, this oilseed merits further development. The focus needs to be on increased oil content and the attainment of a more favourable fatty acid profile (higher oleic acid content, lower linolenic acid content).

F. *Sinapis alba* (Yellow mustard)

Canadian yellow mustard (*Sinapis alba)* is used in a number of different ways, including dry milling as a flour, wet milling as a mustard paste, and whole ground seed for spice mixes, meat and other food products. *Sinapis alba*, as with the previous two mustard species, also has attributes that make it a candidate for further development as a source of biodiesel feedstock.

Advantages: *Sinapis alba* is a large, yellow seeded crop that does not cross very easily with *B. napus*. There is little genetic variation in yellow mustard, and it is easy to select for. Given the large seed size, it is no surprise that the protein content of the meal is quite high (48+%, with some cultivars producing meal with protein content as high as 54%). The crude fibre level in the meal is only 8%, which is significantly less than is the crude fibre level in traditional canola meal (12%). The glucosinolate content is lower than it is in the other mustards (10-50 micromoles/gram), but higher than it is in canola (11-12 micromoles/gram). Therefore, the primary by-product that would be available from *S. alba* is likely to be a high protein meal product that would be competitive with high-protein soybean meal in the animal feed market.

The fatty acid profile of *S. alba* is quite good: oleic acid = 65-70%; linoleic acid = 15%; linolenic acid = 10%; saturated fatty acids = 7%. *S. alba,* as a mustard species, will grow quite well in the same arid regions that *B. juncea* and *B. carinata* will. Additionally, it could be grown on fallow land, in rotation with cereal crops, and possibly in the Maritime

Provinces. In total, the potential landmass available for its cultivation is likely 2.0 million hectares.

Disadvantages: *Sinapis alba* currently has a low oil content (30%), and this would need to be increased substantially to 40+% before it would be competitive with other biodiesel feedstock sources. Yield improvement will also be a challenge, especially when it is grown under non-arid conditions, where it doesn't perform as well as does *B. juncea*. The mustard industry also has concerns about the impact that a canola quality or biodiesel directed *S. alba* would have on the traditional yellow mustard crop. Concern has focused upon the presence of volunteers from the new crop, out crossing into the traditional crop, potential negative impacts on seed quality, and the need for strict identity preservation.

Recommendation*:* *Sinapis alba*, like the other two mustard species under consideration, can be grown across a wide landmass, adding significantly to the total amount of oil available for the biodiesel industry. Additionally, it could produce a high protein meal by-product that could be quite competitive with the high protein soybean meal that is often imported into the Western Canadian provinces from the United States. Development of this oilseed should be encouraged, although the time frame may be longer term than it is for *B. juncea*, given the relatively low oil content found in the germplasm at present.

G. Flax ("Solin")

Flax production has been a staple of Western Canadian agriculture for many decades, with the primary growing areas being in Western Manitoba and Eastern Saskatchewan. The markets for flax have traditionally been industrial, with the United States, Japan, Europe and China taking large quantities of Canadian flax seed in recent years. As industrial markets have turned to alternative products, flax seed and flax products have found new markets in the animal feed industry and the edible food market. Flax is a viable alternative oilseed for use in the biodiesel industry as well, although the inherent instability of the oil due to the high linolenic acid content is problematic.

Advantages: Flax is a high-oil seed, with 50% oil present in some cultivars. "Solin", a high linoleic acid version of flax, also contains up to 48% oil. Although traditional flax has a very high content of linolenic acid (55+%), which is not conducive to optimal biodiesel production, "Solin" has been altered to contain relatively low levels of linolenic acid and high levels of linoleic acid (comparable to sunflower oil). In addition to the traditional growing areas in Manitoba and Saskatchewan (where flax can be rotated with wheat), there is the potential to capture back the 60,000 acres of lost flax production in the Peace River Region of Alberta and British Colombia, and the crop also has potential for cultivation in the Maritimes, Quebec, and the lower mainland of British Colombia.

Probably the strongest selling feature for flax is the by-products that could be produced from the flax seed. Flax has been a part of a 15-year Agriculture and Agri-Food Canada strategy that involves both biodiesel and bio-product development. Some of the potential by-products that may come from the seed include: flax meal for the livestock industry, flax cake, flour and whole seed for the nutraceutical market, flax straw, and flax fibre.

Disadvantages: Yield has been a concern with flax production, as has been a general lack of research on the basic agronomics of production and seed quality issues (stress management, including drought tolerance, crop rotation, zero tillage, disease resistance, oil and meal modification). Traditional flax has an oil profile that is inadequate for biodiesel production. The high level of linolenic acid would not facilitate high-quality biodiesel production, as linolenic acid is inherently unstable. The high linolenic acid content of flax oil (linseed oil) provides it with its characteristic rapid drying capabilities, which makes it a preferred oil for certain industrial applications, but which would give it no advantage in producing biodiesel. The linolenic acid content would need to be lowered considerably, and higher levels of linoleic acid and, preferably, oleic acid, would need to be achieved.

Recommendation: Flax has excellent potential for by-product development, and it has a high level of oil. Modifications to the fatty acid profile and increased yield would make it an ideal candidate for use within the biodiesel industry. The use of "Solin", with its high linoleic acid level and low linolenic acid content would obviate the former concern, and decrease the time needed to further develop the crop for use within the industry.

H. Soybeans

Canada produces only about 1.5% of the world's supply of soybeans, but it is, nonetheless, an important part of the Canadian oilseed industry. Over 25% of all Canadian soybeans are exported, with a significant quantity being targeted toward the edible soy food market, and the remaining soybeans being used either for the production of edible oil and soybean meal or edible soy food products in Canada. Still, the potential exists to target some soybean production at biodiesel feedstock development, both in Eastern and in Western Canada.

Advantages: As a nitrogen fixing plant, soybeans provide a significant cost saving advantage to producers (similar to peas in Western Canada). The traditional soybean growing area in Canada is Ontario and Quebec, where there is already a biodiesel industry based on re-cycled vegetable oils and rendered fat products. Soybean oil would not be needed as the primary source of biodiesel feedstock, but it could be used as an additional source of material in the future. Also, significant growth has been occurring and is expected to continue to occur in Manitoba, potentially providing additional feedstock for the Western Canadian biodiesel industry.

The by-products available from soybeans are particularly valuable. The soybean meal is considered the standard by which all other animal protein products are judged. In the edible protein market, soy is used to make isolates and concentrates that have widespread use as meat extenders and analogs, and soy flours are now used extensively in the baking industry. Soymilk is consumed directly, and it is also used to make tofu and other products for human consumption. In addition to the wide variety of soy food products that are marketed based on the whole bean, the protein, milk and fibre, specific components of the bean, such as the isoflavones, have been marketed for their real and/or perceived health-enhancing benefits.

Disadvantages: Total annual Canadian soybean production has been less than 2.5 million tonnes in recent years (2.26 million tonnes in 2003; 2.8 million tonnes anticipated in 2004), which is substantially less than total annual canola production. Production has been localized in Ontario and Quebec, with Manitoba now becoming a significant producer as well (226,000 tonnes in 2003). The expectation is that Manitoba could eventually reach 900,000 tonnes in annual production, but there is little potential for expansion in Saskatchewan, Alberta and the Maritime Provinces. Additionally, the oil content of the soybean is less than half the oil content of the canola seed (18-20% vs. 40-42%). Therefore, the total amount of oil available is significantly less than is available from canola and, potentially, the mustard species that would be used for biodiesel production. Since 25of Canadian soybeans are exported, only 75% of the available soybean oil remains in Canada. Much of that oil is used in the Ontario and Quebec processed food industry, leaving relatively little oil available for use by the biodiesel sector. Canada is also a net importer of soybean oil to meet the needs of its food processing and animal feed industries. In 2003/04, 86,586 net tonnes of soybean oil were imported into Canada from the United States.

A significant increase in the oil content of soybeans, or an increase in the seeded soybean acreage would be needed before this crop could make a significant contribution to the Canadian biodiesel industry. It is anticipated that, with a dedicated research program, the oil content could eventually be increased from 18-20% to 25+%. Since current research is focused on improving the protein component of the soybean, the time needed to do this could be considerable.

Recommendation: Soybeans are a low-oil seed, but the value of the meal by-product is high. If a research program were dedicated to increasing the quantity of oil to 25-30%, while maintaining protein quality, soybeans could, in the future, become an important contributor to the Canadian biodiesel industry.

I. Chokecherry

“Chokecherry” refers to a group of perennial trees, which can be considered the North American equivalent of Malaysian and Indonesian palm trees. Little research has been directed toward these perennials as a potential feedstock for the biodiesel industry, but they deserve some attention here.

Advantages: These are stable, high-yielding, carbon-fixing perennial trees, which can be considered as replacements for palm oil production. They utilize a marginal land base, and a major resource allocation would not be needed to explore possible uses of these trees as a source of biodiesel feedstock.

Disadvantages: Any research work completed on this potential feedstock would be quite long-term and high-risk. It might best be undertaken in the context of university research, where the focus is not on the immediate.

Recommendation: There is little information available on chokecherry as a potential feedstock for the biodiesel industry, but there may be some merit in allocating some funding to the long-term exploration of the potential for these perennials.

J. False Flax (Camelina *sativa)*

*Camelina sativa,*or false flax, has been cultivated in Europe since the Bronze Age. Recent focus on it is due to interest in the non-food uses of oilseeds, including the development of biodiesel feedstock.

Advantages: False flax is a high-yielding oilseed (1.7-2.0 tonnes/hectare), with excellent disease resistance. It would be well suited to the short season growing area of the Peace River region. It also has relatively low levels of glucosinolates and erucic acid (less than 4%).

Disadvantages*:* It has a unique fatty acid profile that is characterized by a high content of linolenic acid (30-40%), which makes it a good drying oil, and a significant quantity (15%) of eicosenic acid (20:1).

Recommendation: Developmental support for false flax would be a long-term, high-risk investment. A considerable amount of research work would need to be focused on altering the fatty acid profile of the oil and increasing oil yield

III. Overall Recommendations

The different biodiesel feedstocks that have been discussed, with the exception of off-grade canola and yellow grease and tallow, can be categorized as short-term, medium-term and long-term priorities for further developmental work. Off-grade canola is a feedstock that is presently available, and will continue to be available in the future in readily predictable quantities. The production of re-cycled vegetable oils and rendered animal fats is beyond the mandate of the agriculture sector, and development of that industry will not be discussed further in the context of this document.

Short-term development of biodiesel feedstock would be expected to occur over a 5-7 year time period. At that point, the oilseed in question should be making a substantial contribution to the total supply of biodiesel feedstock available to the industry. Medium-term development is defined as 10-12 years, while long-term development would infer a 15+ year time period. For an industry to be viable over the long term, all three time frames must be considered as important. Given the foregoing information, the following categorizations are proposed:

- Short-term priorities : *Brassica juncea*, *Brassica rapa,* flax (“Solin”)
- Medium-term priorities: *Brassica carinata*, *Sinapis alba,* soybeans
- Long-term priorities: Chokecherry, false flax

Support for efforts to develop these crops should be based on the unique requirements of each, including oil and by-product quality, agronomic concerns, and the time-frame required to reach these goals.