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Canada's Independent Agri-Food Think Tank

The Economic Impact of Canadian Biodiesel Production on Canadian Grains, Oilseeds and Livestock Producers

Final Report

Prepared for: Canadian Canola Growers Association

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EXECUTIVE SUMMARY

The purpose of this study was to provide the Canadian Canola Growers Association with an understanding of the economic impact of the mandated use of biodiesel blends produced in Canada. The analysis focused specifically on the oilseed sector and the rendered animal fats industry. The objectives were:

- To establish what is currently known with regard to the economic impacts of biodiesel development
- To determine the nature of markets for candidate feedstocks that could be used in manufacturing biodiesel
- To estimate the economic effects of a 2% biodiesel blend requirement in petroleum diesel
- To estimate the economic effects of a 5% biodiesel blend requirement in petroleum diesel
- To determine the ultimate impact on the Canadian canola industry of the mandated biodiesel blend

To meet the above objectives, the following was undertaken. First, a review of previous research in biodiesel was completed. Secondly, an analysis of the major feedstock markets was undertaken. Finally, an empirical analysis of least cost feedstock procurement was completed.

The results showed the following. First, the review of previous research suggested that biodiesel can be made from a range of feedstocks; the two key factors influencing the success of biodiesel manufacturing facilities were feedstock prices and feedstock availability. Previous work suggested that the key competitors facing canola oil in the biodiesel market are rendered oils (yellow grease), rendered animal fats (tallow), palm oil, and soybean oil. Some discussion exists of using minor vegetable oils such as mustard seed oil, but these appear to be preliminary. The literature suggested that canola and soybean oil are apt to be relatively high cost feedstocks for biodiesel production.

The market analysis section provided some detail regarding market dynamics for the various feedstocks. The main observation arising from this analysis is that canola oil and soybean oil tend to be priced as food oils in international markets, while yellow grease, tallow, and palm oil tend to be priced in feed and industrial uses. The main influence in this market has been BSE in Europe. Prior to the late 1990's, palm oil was priced competitively against soybean oil. However, since then, the European response to BSE generated a demand for substitutes for rendered animal fats, and the recognition has grown that palm oil is inherently a less healthy product in foods compared with canola oil. These two factors, combined with rapid and significant increases in production, have driven palm oil prices down to compete against the rendered fats and oils, and put palm oil at a price discount to canola or soybean oil. Thus, a cluster of widely available, low-priced feedstocks for biodiesel production exists (yellow grease, tallow, and palm oil) alongside another cluster of higher-priced potential feedstocks (canola oil and soybean oil).

The empirical analysis employed a simplified Canadian fats and oils market model that served the competing demands for fats and oils at least cost. Two conceptions of market dynamic were considered- one in which feedstock prices remain constant, and another in which feedstock prices fluctuate with volume consumed. Under the assumption that total fat and oil supplies are fixed at historic levels, biodiesel blend requirements of up to just over 2% are feasible; the 5% blend is not feasible based on historic feedstock availability. Under both conceptions of market dynamics, the principal effect of increased feedstock demand from biodiesel is to boost the demand for cheaper feedstocks. The result of this is to drive up the price of the cheaper feedstocks to the point that canola oil obtains penetration into feed and soap/chemical markets that it previously has not had a major role in. To the extent that canola oil develops a greater reputation as a healthy food product that is preferred to other oils, the effect will be to dislodge soybean oil and palm oil from food markets, and capture a greater share of that market.

In addition, to the extent that biodiesel made from rendered fats and greases create difficulties in terms of biodiesel flow or storability that do not result with biodiesel made from or blended with canola oil, more canola oil may be used in biodiesel than what is suggested here. However, it must also be recognized that fuel additives can improve flow and storage characteristics, and that these may be lower cost than canola oil blends. The specific analysis of biodiesel quality as related to feedstock was beyond the scope of this study, but could be critical in determining the ultimate role for canola oil in biodiesel production.

The impact of the above is likely to be a moderate price increase for canola oil and an expansion of canola oil into new markets. Because the oil yield of canola is relatively high, the expectation is that a moderate increase in canola seed prices could result. History suggests a price transmission of about 28% from canola oil to canola seed. Thus results here suggest a price effect on canola oil of about $19/tonne, which translates into an impact on canola seed in the range of $5/tonne. Given recent canola seed production levels of 6.2 million tonnes, the value of the price increase would be in the range of $31 million/year. The extent of the actual price increase in canola oil and canola seed that would result from new biodiesel demand will be positively related to the blend level, and negatively related to the supply response from canola oil and competing fats and oils.

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1.0 Introduction and Background

Discussions are currently underway regarding mandated adoption of alternative bio-based fuels in Canada. Much of the attention has been on ethanol fuels; however, discussions regarding mandated use of biodiesel at varying levels are also in development. Indeed, biodiesel manufacturing facilities are being established in Canada with additional facilities planned in the future, and significant manufacturing capacity already exists in the US.

The expansion of biodiesel will create new demand pressure in the natural fats and oils complex that has not previously existed. The likely impacts of alternative levels of mandated biodiesel use are unknown; in particular:

- Which feedstocks will be preferred in biodiesel manufacturing?
- What will be the origin of preferred feedstocks?
- What will be the effect of biodiesel demand on markets for preferred feedstocks?
- What secondary realignments will occur as alternative fats and oils substitute for feedstocks pulled into biodiesel manufacturing?
- What will be the ultimate impact on the Canadian canola and vegetable oil market, and ultimately on the canola market?

Answers to the above questions will be important as the Canadian canola industry determines how best to position itself relative to biodiesel expansion.

1.1 Purpose and Objectives

The purpose of this project is to provide the Canadian Canola Growers Association with an understanding of the economic impact of the mandated use of biodiesel produced in Canada into blends of 2% and 5%, with petroleum diesel.

This analysis will focus specifically on the oilseed sector and the rendered animal fats industry.

The objectives of this project are:

- To establish what is currently known with regard to the economic impacts of biodiesel development
- To determine the nature of markets for candidate feedstocks that could be used in manufacturing biodiesel
- To estimate the economic effects of a 2% biodiesel blend requirement in petroleum diesel
- To estimate the economic effects of a 5% biodiesel blend requirement in petroleum diesel
- To determine the ultimate impact on the Canadian canola industry of the mandated biodiesel blend

1.2 Methods and Approach

To meet the objectives outlined above, the project was divided into four phases of work:

- Phase I	Background Review
- Phase II	Feedstock Market Analysis
- Phase III	Conceptual Economic Model

- Phase IV Empirical Solution, Testing, Summary and Conclusions

The background review in Phase 1 will help to develop an understanding of the economic approach and analytical methods used in prior economic impact analyses, and provide a profile of the markets for candidate feedstocks in manufacturing biodiesel. The nature of markets for candidate feedstocks will also be assessed in Phase 2. In Phase 3, the literature review will be used to aid in the development of a conceptual model to determine an overall assessment of the economic impact of the adoption of 2% and 5% blend requirements in petroleum diesel in Canada. In Phase 4, the conceptual model will be solved and the results tested, and conclusions will be drawn and recommendations made to the Canadian Canola Growers Association. Each phase is described in detail below.

2.0 Background Review

The purpose of this section is to develop a solid understanding of what has already been observed regarding the economic impacts of adopting biodiesel for renewable fuel use, and the nature of markets for candidate feedstocks.

This section is organized into three parts. Section 2.1 is an introduction providing a background review on the development of biodiesel as a conventional diesel substitute. In section 2.2 selected studies were reviewed to determine the economic impacts that have already been identified, as well as some properties of biodiesel produced from different feedstocks that may influence marketability. Finally, Section 2.3 is a summary based on the observations made from the literature reviewed to help situate the market research that will be conducted in the next phase as well as describing the modeling that has been used in past studies.

2.1 Overview

The idea of using vegetable oil as engine fuel is not new. In fact the first engine designed by Dr. Rudolf Diesel back in 1885 was fueled by peanut oil. However, the idea of crop-based diesel was quickly buried in the 1920s by the expansion of petroleum refining and its cheap byproduct – petroleum diesel. It was not until the last decade that biodiesel started to receive renewed attention as a feasible alternative fuel in North America. The recent market expansion of biodiesel is a result of growing public environmental awareness as well as concerns about energy self-efficiency. Global trends in trade liberalization have also forced governments to find news ways of supporting domestic agricultural production. All of these factors have fueled the interest in biodiesel manufacturing.

Biodiesel is a clean burning alternative diesel fuel produced from vegetable oils and animal fats, which can be used in neat (100%) form or blended with conventional diesel to power any existing diesel engine without modifications. The production process involves a simple one-step chemical reaction between the feedstock and an alcohol in the presence of a catalyst.

The environmental advantage of replacing diesel with its biological counterpart is rather apparent. According to a study conducted by the US Department of Energy (DOE) in 1998, the lifecycle emission of Carbon Monoxide and Particulate Matter, which causes smog and human health problems, from 100% blend biodiesel (B100) is less than 70% of that from regular diesel (2D). The production of hazardous waste can be reduced to 4% of its original amount by switching to biodiesel. The emission of sulfur can be reduced to about 92% in its lifecycle and eliminated from the tailpipe.

Biodiesel is also the most efficient of all fuel types in terms of fossil energy utilization. Published in the same report, the fossil energy efficiency of biodiesel is estimated at 3.22 compared to 0.83 from diesel. In other words, for every unit of fossil energy consumed in the production of biodiesel, 3.22 units of energy can be released through burning, which is more than twice of that from ethanol (1.34), another form of renewable fuel.

Besides the environmental benefits, the fact that biodiesel can be produced from domestically harvested crops helps to provide a secured source of energy and reduce oil imports. Urbanchuk et al., suggests that an increased demand in biodiesel will also lead to higher feedstock prices as well as increased farm incomes. And now, for the first time in history, biodiesel might have a chance of becoming economically competitive in light of the enduring high crude oil price.

2.2 Literature Review

A large number of studies have been conducted in Canada and the US to examine the feasibility and economic impacts of biodiesel production. Some of these studies focus on production costs and market impacts, while others address issues with respect to feedstock availability and fuel properties.

For the purpose of this project, attention was focused on the methods of economic analysis used in the studies and the feasibilities and characteristics of various feedstocks.

2.2.1 Feedstock Feasibility Studies by Region

Canada

Global Change Strategies International Inc completed a preliminary study in 1998 to evaluate the suitability of biodiesel for transportation use in Canada (Prakash, 1998). The report summarized studies completed previously that examined methods of production and the effect of feedstock on fuel qualities. Various properties such as flash point, viscosity, cloud point etc… were compared among diesel, biodiesel manufactured from soy oil, rapeseed oil, tallow, and waste oil. None of the feedstocks were found to lead to superior fuel qualities in all aspects. Fuel derived from rapeseed oil was found to produce safer and faster ignition properties (i.e. higher cetane number[1] and flash point); however it was also the poorest at fuel injection attributes especially at lower temperatures (i.e. higher viscosity). Nevertheless, the degree of variations in these qualities appeared to be minor in comparison, and as the authors suggested, with additional research in additives these differences could likely be eliminated.

In a report prepared by BIOCAP Canada Foundation in 2004 (Holbein et al. 2004), canola oil, tallow and grease were said to likely become the "initial sources" of "biodiesel feedstock domestically". Canada is a net exporter of canola and canola oil, as well as animal fat. In the 2003-2004 crop year, an estimated 50% of the 6 million ton [or tonne?] canola production was expected to be exported, from which 1.3 million tons (approximately 407 million gallons) of canola oil could be extracted. In addition, approximately 5% of the annual canola production in Canada is sub-standard and cannot be sold directly on the food market, making it an excellent source of feedstock (Holbein et al. 2004).

Every year approximately 0.29 million tons (approximately 91 million gallons) of tallow and grease are said to be produced in Canada that could be used to produce biodiesel, "of which 85% is typically exported" (Holbein et al. 2004, p. 7). A preliminary study completed for the same report evaluated the feasibility of biodiesel production equivalent to 5% of the Canadian annual transportation fuel (gasoline and diesel) consumption, using domestic feedstocks. Given the statistics from 2003, it was concluded that in order to produce 0.54 million tons or 167

[1] "Cetane numbers rate the ignition properties of diesel fuels, just as octane numbers determine the quality and value of gasoline (petrol). It's a measure of a fuel's willingness to ignite when it's compressed. The higher the cetane number, the more efficient the fuel. Biodiesel has a higher cetane number than petrodiesel because of its oxygen content." http://journeytoforever.org/biodiesel_yield2.html

million gallons of biodiesel, a substantial increase (10%) in canola production and export diversion (50%) of canola oil and animal fat would be required.

A study was conducted for Natural Resources Canada in 2004 that assessed all biodiesel feedstock potential in Canada and found that although all of the potential feedstocks are currently being marketed, there is some opportunity to divert material from export markets. The authors suggested that it would be probable to produce just over 500 million litres per year of biodiesel from animal fats, yellow grease, canola oil, soya oil and marine oils from across Canada.

In order to assess the financing of biodiesel production in Canada, a financial model of a complete biodiesel operation was developed. The model was developed to project biodiesel production costs and the financial performance of vegetable oil and animal fat plants. The model was designed to cover two years of project development and construction and ten years of operation. It contains key biodiesel production variables and various financing options, balance sheet, statement of earnings, cash flows and finance ratios. Some assumptions and factor costs included in the model include:

- 50 million litres of biodiesel production per year
- The plant will continuously operate
- The biodiesel selling price will provide a 10% after-tax return on shareholder's investment
- Capital cost factors
- Amount of land required
- Building size
- Operating workforce of 8 people plus 6 people in management and sales
- Feedstock costs
- Maintenance costs
- Chemical costs
- Administrative costs

The model was designed so that sensitivity analysis could be conducted on feedstock costs and the selling price of biodiesel.

The authors concluded that biodiesel is high priced due to the high feedstock costs and lower valued co-products (S&T^2 Consultants *et al*, 2004). Feedstock costs are the primary component of the cost of biodiesel. The authors suggest that initial biodiesel production in Canada will be based on lower-cost animal fats that have been rerouted from the export market and not vegetable oils such as canola (S&T^2 Consultants *et al*, 2004).

British Columbia

A study conducted in 2004 on the feasibility of biodiesel production in British Columbia (Boyd et al. 2004) focused its analysis on feedstocks that are cheap and readily available on the market, namely recycled grease, fish oil and rendered animal fat. First, the quantity available of each feedstock was estimated, followed by the identification of existing market demands. Procurement and processing costs were then used to determine the feasibility of each feedstock. The study found that British Columbia produces roughly 125 million liters of aforementioned materials annually from restaurants and meat processing facilities, which could be used to produce roughly 123 million liters of biodiesel per year. Of this 125ML/year, however, only about 9.3ML of brown grease does not yet have competing uses in the manufacturing of oleo-chemical and feed products. The study suggested that direct communication with prospective suppliers is required to determine the actual volume of feedstocks that could be secured at a feasible price.

United States

Duffield et al. (1998) completed a comprehensive study that summarized the volume of production, existing markets and oil yield of various potential feedstocks in the US using publicly available data from the US Department of Agriculture and Department of Commerce. According to the study, oil derived from soybeans represents over 50% of the feedstock available in the US for biodiesel production. Animal fat accounts for about 30% of the total. Rapeseed and canola production in the US are relatively small and do not contribute to the feedstock market at large.

Using data obtained from 1993-1995, it was concluded that yellow greases and lards are the lowest cost feedstock, followed by oils derived from soybeans and corn. Rapeseed and canola oil prices were slightly higher than that of soybeans, but still lower than sunflower. According to the study, yellow grease and lards are used domestically in “animal feed, soaps, and other industrial” products, while “about 97% of the US soybean oil is used for edible purposes” such as cooking oil and margarine (Duffield, 1998, p 8). The conclusions made by Duffield et al. (1998) correspond to an earlier study conducted by Nelson et al. (1994) that investigated the economic feasibility of producing biodiesel from oilseeds, greases and fats. Nelson et al. (1994) conducted cost sensitivity analysis with respect to feedstock cost, by-product value and unit size on a plant model to determine production costs per gallon of biodiesel. Although, soybeans were the most abundant feedstock and were used for the majority of biodiesel production in the United States at the time of writing, Nelson et al. (1994) concluded that waste greases and animal fats were less expensive for biodiesel production and could help to extend the supply of biodiesel.

Through further research Duffield et al. (1998) found that certain properties of biodiesel, such as ignition temperature and oxidation stability, can be improved by genetically modifying the feedstock crops, making certain genotypes of soybean or canola more suitable than the others for biodiesel production.

Canakci and Van Gerpen (2001) also found that animal fats and greases were the lowest cost feedstock in the models that they constructed to economically assess the production of biodiesel from high free fatty acids (FFA) such as rendered animal fats, compared to vegetable oils. In 2001, soybean oil was the only feedstock available in sufficient quantity to produce biodiesel, therefore the feasibility of lower cost animal fats and greases used for biodiesel production were further explored by Canakci and Van Gerpen (2001). Once the pilot plant model was developed and three feedstock case studies were used to populate the model:

1. Soybean oil
2. Yellow greases – 9% FFA
3. Brown greases – 40% FFA

In order to convert high FFA feedstocks to biodiesel an acid-catalyzed pretreatment could be used to reduce the feedstock FFA to less than 1% and then transesterification can take place. When soybean oil is used as the feedstock it has a low enough FFA and therefore does not require the pretreatment.

In the plant model, capital costs, labour and plant construction were not included in the model, however, based on the explanation above, a plant producing biodiesel from animal fats requires an additional production step and therefore more capital. Average minimum and maximum price assumptions were made to establish the sensitivity of feedstock costs on operating costs. Glycerin recovery was not included in the models even though its value could partially offset the capital costs which have also not been included.

Overall, the cost comparisons found that the levels of high FFA in the feedstocks have only a slight impact on the overall cost of production. Both yellow greases and brown greases cost less to acquire but also yield lower amounts of oil due to impurities. Despite the lower yield, overall brown grease cost of production is the lowest of the three cases, followed by yellow grease and then soybean oil.

Southeastern Region of the United States[2]

De la Torre Ugarte et al. (1999) assessed the role that the Southeastern region of the United States could play in supplying feedstocks for biodiesel production. The study assessed both the potential supply of feedstocks from oilseed crops being produced at that time and increased amounts of oilseed crop production that could result. The study also examined potential biodiesel production from animal fats based on the livestock industry in that area. In particular, the study examined biodiesel production's impacts on the national agricultural markets, land use, price, and farm income.

The study was conducted using the POLYSYS model and simulated increases in demand for vegetable oils as well as the potential of higher oil yields from the oilseeds. The most aggressive simulation modeled was to determine the economic impact on the oilseed markets of biodiesel production consisting of 1% of the current use of middle distillate fuels in the US[3].

The analysis was conducted using regional crop budgets and rotations that were then used as inputs into the Policy Analysis System (POLYSYS) simulation model of the whole US agricultural sector. The POLYSYS model simulates changes to the current baseline scenario such as increased vegetable oil demand as well as increased oil yields from oilseed crops. POLYSYS combines national demand, regional supply, national livestock supply, demand and agricultural income modules to develop deviations from a baseline based on changes to demand of vegetable oils and animal fats.

Results of the analysis indicated that a demand in the vegetable oil use for biodiesel would slowly push the price of vegetable oils and soybeans up by about 30%, and due to the additional crushing capacities, the price of soybean meal would decrease. As prices increase and demand for biodiesel increases, soybean acreage at the national level will also increase but not significantly in the Southeast region of the country. The demand would also not be significant enough to warrant the production of canola and sunflower in the area. De la Torre Ugarte et al. (1999) note that the higher the demand for biodiesel, the greater impacts on vegetable oil prices, therefore, significant biodiesel demand could result in vegetable oils being a less attractive feedstock for its production due to its cost.

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[2] This region includes Alabama, Arkansas, Georgia, Kentucky, Louisiana, Missouri, North Carolina, South Carolina, Tennessee and Virginia.
[3] Middle distillate fuels include diesel and home heating oils (De la Torre Ugarte et al. (1999)).

Based on USDA poultry production projections in 1999 and the fact that the Southeast region produces approximately 75% of poultry in the US (De la Torre Ugarte et al. 1999), there would be a significant increase in animal fat production in the area that could sustain increased biodiesel production if poultry fat was more commonly used. Animal fat use in biodiesel production was also expected to increase the price of animal fats since there will be increased competition for them from their other uses (soaps, cosmetics). However, an increased supply of vegetable oils could also reduce the price of animal fats if the supply of oils becomes large enough.

Kansas

David Coltrain from Kansas State University examined whether biodiesel would be worth considering developing more fully in Kansas. At the Risk and Profit Conference in August 2002, Coltrain suggested that based on his analysis of various feedstocks, that no matter which feedstock Kansas would choose to primarily utilize, the state would reap net economic rewards if a subsidy program were put in place to offset the higher cost of production. Cotrain (2002) states that biodiesel would have to priced at $1.00 - $1.50 USD higher than conventional diesel fuel. The primary reason for the higher price is the higher prices of the feedstocks used in biodiesel production and the fact that feedstock costs are 50-70% of total costs.

Feedstock prices will also increase as demand increases and biodiesel production must compete for these feedstocks with other markets that currently exist and are higher priced. Again, subsidies may be required as 'these edible markets that exist are sometimes higher priced than what the market can bear for fats and oils used to produce fuels" (Coltrain, 2002). Coltrain (2002) also notes that biodiesel supporters believe that increased biodiesel use will contribute to savings in the USDA soybean marketing loan program.

Minnesota

Yellow grease is about half the cost of soybean oil and meets all industry specifications for use in biodiesel, therefore Groschen (2002) conducted a study to examine the feasibility of producing biodiesel from waste greases and animal fats in addition to soybean oil which is currently the primary feedstock used in Minnesota.

To attempt to reduce the cost of biodiesel production in Minnesota, Groschen (2002) chose to evaluate a biodiesel product that was produced in an earlier study that consisted of 10% biodiesel from yellow greases, 10% biodiesel from soybean oil and 80% traditional petroleum diesel.

Groschen (2002) examined a number of factors that would have an affect on the biodiesel production including price and availability. The price and availability of vegetable oils will vary depending on the crop year; whereas grease products are essentially a more stable supply and are consistently priced lower than oils. Even as feeding ration restrictions on have been in put in place for livestock and soybean meal demand increases therefore putting more soybean oil on the market, grease prices still remain lower. However, there is a difference in performance with respect to cold flow problems of biodiesel made from grease, however at only 10% of the total product, Groschen did not expect this to have an effect on performance.

At the time of the study yellow grease was being used to produce biodiesel in small amounts, it met product specifications from the American Society of Testing and Materials (ASTM) and it was a low cost feedstock, therefore the economics of yellow grease were competitive with biodiesel produced from soybean oil, yet production was very limited. Groschen (2002) suggested that production may be limited because inedible fats may not enjoy access to the same markets as edible fats.

Groschen (2002) estimated that there was not enough yellow grease in Minnesota to produce biodiesel economically using yellow grease alone. However, the development of a facility that can operate on multiple raw materials might be more feasible from a supply standpoint and help to stabilize biodiesel prices, although it might prevent operational challenges. It was concluded that for the foreseeable future, soybean oil is likely to dominate the biodiesel production industry because of its magnitude and the infrastructure that already exists. Adding grease to biodiesel production however would be competitive, would provide profit for renderers and provide diversity and stability to the market and increase grease prices.

Mississippi

Frazier Barnes and Associates (2003) conducted a comprehensive study to provide information for parties interested in commercializing biodiesel projects, including the development of plant models with an emphasis on the use of soybeans as the feedstock.

The authors note that there are many factors that will affect the growth of biodiesel in the United States, including a renewable energy bill, the use and price of glycerin and primarily, the availability of feedstock. The most abundant feedstock in the United States is soybean oil and more will have to be produced if biodiesel growth continues. Also, the price of biodiesel is strongly correlated to the price of the feedstock. The cost of the feedstock is also crucial because it accounts for 75 – 85% of the total processing cost (Frazier Barnes and Associates, 2003).

Two plant models were developed: a stand-alone biodiesel facility that produces biodiesel, glycerin and other by-products, and a co-operative biodiesel facility that utilizes the owner's soybeans to process into soybean oil and then into biodiesel and its by-products.

Advantages of the stand-alone facility include less capital cost per gallon of biodiesel, less management and operations and easier to site because it does not have to be located in the soybean production region (Frazier Barnes and Associates, 2003). On the other hand, advantages of the integrated facility include lower feedstock costs because there is no transport cost, a security of supply and value added opportunities for its producers (Frazier Barnes and Associates, 2003).

Some assumptions that were made in the development of the facility models include:

- Soybeans procured from Mississippi producers at fair market value
- Soybean prices based on historical market averages
- Depreciation is a straight-line over 13.5 years

Based on financial projections conduced by Frazier Barnes and Associates (2003) both models resulted in a positive net present value, although the integrated facility had a higher rate of return, better cash flow and higher internal rate of return.

New York

A comprehensive analysis of the economic feasibility of creating a biodiesel industry in New York was undertaken for the NY State Energy Research and Development Authority by (Urbanchuk, 2004). The analysis included a review of possible policy options and an assessment of their costs and benefits. The initial policy options include a B2 mandate covering all end uses, on and off road; and a B2 mandate covering on-highway diesel uses.

As a part of the study the authors estimated the current and forecast demand for distillate fuels in New York so that an accurate feedstock analysis of availability could be undertaken. The analysis did not factor in fats and oils imported from foreign sources because these feedstocks would not be subject to the Bioenergy Program payment, nor would they lessen dependence on foreign energy sources.

Since soybeans are the predominant oilseed crop in New York, it is assumed that soybean oil would be the primary vegetable oil utilized to make biodiesel. All three of the existing crushing plants in New York are operating at about half of capacity therefore there is room to grow as demand increases. As demand for soybean oil increases, soybean prices will also increase and this will likely pull land from corn and wheat and provide an incentive to farm idle land. New crops would likely not be grown (sunflower, canola) because it would require new crushing capacity and infrastructure.

Animal fat production from animal slaughtering activities in New York State would be insufficient as a feedstock for biodiesel due to how little is generated in the state. Although exact estimates of the supply of yellow greases (waste cooking oils) is difficult, it will be positively correlated to the number and type of restaurants in the area. Due to the population of New York State it is estimated that yellow greases would be abundant. Brown greases were also examined, but after determining that only a low supply of brown grease would be available, they were no longer considered a viable feedstock.

The overall feedstock analysis showed that even though soybean oil is readily available across the country, the yellow greases and tallow are the most abundant feedstocks in New York. Along with the feedstock analysis the authors discuss by-product production, supply and prices including glycerin and soybean meal. The amount of soybean meal produced by increasing crush of soybeans to produce oil will provide a market incentive for crushers to operate at capacity. The amount of soybean meal produced in New York would be relatively small compared to the whole United States and therefore would have little effect on its price. Based on the feedstock analysis, the authors suggest that the most likely feedstock mix for a plant in New York would be 70% yellow grease and 30% soybean oil at a production of 10-15 million gallons per year (Urbanchuk, 2004).

The authors note that it is likely that increased production of biodiesel across the United States will use more yellow grease as biodiesel users become feedstock neutral and as the USDA's Bioenergy Program is restructured to provide equality between feedstock choices (the program initially excluded yellow greases as an edible feedstock and now incentives are significantly less than for oils). Soybean acreage is estimated to increase by 165,000 acres by 2007 as a result of an increased demand for oil, taking acres from other crops and land that is currently idle. (Urbanchuk, 2004). This is expected reduce farm cash receipts for corn and hay but increase farm cash receipts at a higher level for soybeans, therefore offsetting the losses.

Overall, a B2 mandate for New York State on all highway diesel uses in 2007 and expanding that to all diesel on and off-road uses by 2012 would required approximately 70.6 million gallons of biodiesel per year by 2012. The projected amount of biodiesel that New York could produce from soybean oil and yellow grease is 40 million gallons by 2012, therefore New York wishes to develop a policy to ensure that a maximum amount of biodiesel production takes place in state so that it can reap the economic rewards rather than have it imported from other states and/or Canada, it is likely that an incentive from the state will need to be provided (Urbanchuk, 2004).

North Dakota

North Dakota State University published a report in 2002 (VanWechel et al. 2002) that provided a quantitative evaluation of feedstock options, availability and costs associated with biodiesel production within the region. Soybean oil was determined to be the most suitable feedstock based on its wide availability, while waste grease was considered as a likely low-cost supplement. The study estimated the cost of biodiesel production to be between $2.02 and $2.64 per gallon, given that the price of soybean oil is 17 to 25 cents per pound. Compared to the 2002 diesel price of $0.91 per gallon, biodiesel production in North Dakota was found to be economically uncompetitive at that time.

Oregon

Nuñez (2004) examined the economic competitiveness of producing biodiesel in Oregon from canola oil compared to the mid-western production from soybeans. Eleven previous studies were reviewed in the report and conclusions were drawn suggesting that further studies need to be conducted to determine the "optimal processing plant size, location, and design". Nuñez (2004) also raised the issue of economies of scale in biodiesel production and suggested that in order to support commodity level biodiesel consumption manufacturers must be able to secure "high volume, high quality, and low cost" feedstock in order to produce at a cheaper price.

Plants that use virgin oil must be larger than plants that use waste oil, due to the narrower margin between the feedstock and the finished product price. A simplistic economic model was constructed using cost factors including feedstock cost, crushing cost, glycerin sales credit and transportation cost to simulate the total cost of production using canola seed in Oregon. The result was then compared to the cost estimate from studies conducted in other regions of production using soybeans. It was found that production of biodiesel in Oregon would not be competitive unless the market price for canola seed dropped to below $0.12 per pound.

Tennessee

In 2002, the Agri-Industry Modeling & Analysis Group published their research findings on the feasibility of operating a biodiesel processing facility within Tennessee (English et al. 2002). The authors first examined the current US and world market conditions for biodiesel, soybeans, soy oil, meal and other byproducts to determine the opportunity for additional production capacity. Then, market forecast data from FAPRI (Food and Agricultural Policy Research Institute) and other research findings were collected to construct three scenarios: a baseline, best and worst case.

In the best-case scenario the price of biodiesel is adjusted upwards by its historical coefficient of variation and the price of soybean oil is adjusted downwards. In the worst-case scenario, the reverse was calculated and the existing government subsidies were removed. Analysis was then conducted under each scenario to determine the financial feasibilities and breakeven conditions for both stand-alone factories and integrated facilities with exiting soybean-crushing processor.

Given the production conditions in Tennessee, in order for a plant to remain profitable, soybean prices must not exceed $5.75 per bushel, soy oil price must not exceed 19.34 cents per pound and biodiesel price could not fall below $1.16 per gallon for stand-alone facilities and $1.13 for integrated facilities. English et al. (2002) also found that processing facilities with 10-15 million gallons of annual production capacity are the most efficient, as smaller operations tend to use a "batch" process that costs more than utilizing a "continuous" process. Plant location was also closely examined to minimize transportation and procurement costs. It was estimated that a 13 million gallon facility would require feedstocks of approximately the same quantity in soy oil or 9 million bushels of soybeans.

2.2.2 Economic Impact Studies by Region

United States

A study was conducted by FAPRI in 2001 to estimate the economic "implications of increased usage of corn and soybean oil for the purpose of producing ethanol and biodiesel, respectively" (FAPRI, 2001, p1). The study compared the economic impacts of a baseline projection with a hypothetical high growth scenario over the period between 2001 and 2010, using the economic model also named FAPRI.

In the high-growth scenario, annual demand for corn was assumed to increase from 638 to 1,775 million bushels over the period or more than 1 million bushels higher than the baseline. Demand for soybeans was set to increase from 264 to 2,472 million lbs. over the same period. An economic simulation was run and comparisons were drawn between the scenario and the baseline. Details of the simulation used to produce these data were not discussed in the report.

According to the projection, at the end of 2010, the market price for corn will increase by 28 cents over the baseline as a result of increased demand from ethanol production. Corn acreage will increase by 2.9 million acres over the same period. However, this increase will come at the cost of other crops such as soybeans, which will only increase by 3% while soybean acreage will see a decrease of 1.2 million acres below the baseline.

The price of soy meal and other byproducts will decrease and the price of livestock will be up "as higher corn prices more than offset lower protein prices" (FAPRI, 2001, p3).

A similar study was conducted by Raneses et al. (1998), using the Food and Agricultural Policy Simulator (FAPSIM) to determine the effect of an increase in soy diesel alone on the US agricultural sector. The FAPSIM is a large-scale input-output model maintained by the USDA to produce annual agricultural forecasts. The model consists of more than 700 definitional (fixed), institutional (variable) and behavioral (directional) equations that attempt to capture and simulate the aggregate economic effect of any change in factor input.

The study first identified three specific markets that are most likely to adopt biodiesel, which were federal fleets, mining, and marine and estuary areas. Then three arbitrarily selected penetration levels (20%, 50%and 100%) were assumed to have been achieved in these markets for a 20% biodiesel blend. Simulations were run and the results indicated that the price of soybean oil would increase by more than that of the soybeans, while prices received for soybean meal, livestock and corn would drop proportional to the penetration rate.

Indiana

In 2003, Althoff et al. from Purdue University Department of Agricultural Economics completed a study examining the economic impact of alternative Indiana State legislation on biodiesel. Three possible policy scenarios were introduced in the study to determine their economic impact on consumers, industries and the state government.

The three scenarios were:
1. A mandatory 2% biodiesel blend in all distillated fuels without subsidies.
2. A mandatory 2% biodiesel blend in all distillated fuels with full price subsidies.
3. A mandatory 2% biodiesel blend in all distillated fuels with partial tax credits.

IMPLAN[4] and partial equilibrium analyses were conducted using input data "including consumption, price, elasticity response, and projected biodiesel demand" taken from various US federal agencies (Althoff et al. 2003, p65). A wholesale price (before tax) of $0.815 was used for diesel and $1.649 for B100[5] biodiesel. The analysis assumed that all biodiesel production would take place in Indiana and soybeans would be the only feedstock used. The study did not take into consideration the environmental and performance impact of biodiesel.

Results indicated that the overall economic impact of all three proposed scenarios were negative. While a mandatory biodiesel blend will have positive impacts on soybean production and the processing sector, this advantage will be largely offset by the corresponding decrease in revenue in corn production as a result of the crowding out effect. Depending on the scenario, the extra cost of biodiesel over conventional diesel has to be paid by either the consumers directly at the pumps, through government tax revenue, or a combination of both. The first scenario, which mandates a 2% biodiesel blend without any form of subsidy will experience the biggest loss, while the scenario with a price matching subsidy will experience the least loss. The effect of an increased soybean demand on price was not incorporated into the analysis.

Minnesota

The economic impact of soy diesel production in Minnesota was examined in a report prepared by the Minnesota Department of Agriculture (Ye, 2004). The study was conducted in response to a regulation passed in 2002 requiring all diesel fuels sold within the state of Minnesota to contain at least a 2% blend of biodiesel. The objective of the study was to examine the direct, indirect and induced economic impact of a mandatory two and five percent blend on the soybean production and processing sector.

Estimated annual diesel consumption data were collected and then used to derive the quantity of soybeans required supporting the production of the proposed biodiesel blend. An IMPLAN model was then used to compute the impacts from which the final conclusions were drawn. The results of the study showed that neither a 2% nor a 5% mandatory blend would have any direct

[4] IMPLAN (Impact Analysis for PLANing model) is an economic impact modeling system developed by Minnesota IMPLAN Group Inc. http://www.implan.com/index.html
[5] B100 = 100% pure biodiesel.

impact on the production of soybeans in Minnesota. However, a substantial (12 to 31 percent) increase in in-state soybean processing capacity was predicted. One explanation to this result is possibly the fact that in 2003 only 39% of the soybean production was crushed domestically, while the majority (59%) of it was exported and processed in other states.

Prior to Ye's 2004 study, Doug Tiffany from the University of Minnesota also examined this policy choice for the state (Tiffany, 2001). At the time of writing, the Bioenergy Program administered by the USDA's Commodity Credit Corporation encouraged the use of ethanol and biodiesel in order to increase utilization of domestically produced crops through a payment incentive program. The incentive program was required for two primary reasons: diesel fuel would be much cheaper to continue to make compared to biodiesel (about half the cost), and vegetable oils are high costs feedstocks compared to waste greases and fats. Tiffany's (2004) conclusions agree with Ye (2004), if soybean oil demand increased then less export out of state would occur. Tiffany (2004) quoted a FAPRI model that showed that soybean prices would increase dramatically the first year and remain above current prices due to an increased demand from the proposed mandate. Lastly, Tiffany (2001) also used an IMPLAN model to show the statewide benefits from the development of this industry in Minnesota.

Arkansas

Popp et al. (2005) present an economic and fiscal impact analysis of biodiesel production in Arkansas due to the expected increase in the use of biodiesel in the United States. Arkansas is contemplating a biodiesel blend standard similar to the one that has been adopted in Minnesota (B2 and B5). The authors note that it would likely lead to improved farm sector profits and new jobs the production occurred in state, but would also raise the fuel cost of those industries that use distillate fuels.

Popp et al (2005) estimate the economic and fiscal impact of a 5 million gallon per year biodiesel facility located adjacent to a soybean processing plant on the Arkansas economy by using cost of production figures and a number of assumptions including that only soybean oil will be used, there will be no new net agricultural production and there will be no transport costs due to its location. These figures and assumptions were used with the IMPLAN economic input-output model to determine multiplier effects. The IMPLAN model determined that 51 new jobs, an additional $1.7 million in income and $2.7 million in gross state product would be created; therefore the industry would create net benefits.

Georgia

A study conducted by Shumaker et al. (2003) evaluated the economic feasibility of biodiesel production in Georgia. The study analyzed the cost and availability of various feedstocks in the state. It was found that beef tallow and poultry grease incurred the lowest procurement cost. However, because of the existence of competing uses in feed rations, soap, and other cosmetic products, only an insufficient supply of these feedstocks could be secured to support the proposed 15 million gallons per year biodiesel production. This left a portion of the demand to be filled by soybean oil and other higher cost feedstocks.

The study also evaluated the difference in costs of production between various plant sizes and feedstock prices. It was found that economies of scale would be reached at the production of 15 million gallons of biodiesel per year, as further increase in capacity did not seem to decrease cost markedly.

An analysis was performed using the IMPLAN model to predict the economic impact of an increase in biodiesel production on total output, employment and tax revenue. Results indicated that the operation of "a 15 million gallon biodiesel plant would require about 27% of the vegetable and animal fats currently available within the state of Georgia" (Shumaker, 2003, p 20). It would also in turn generate approximately $34.3m in total output, $2.1m in tax revenue as well as 132 new jobs.

Wisconsin

A recent study was completed in 2005 by University of Wisconsin-Madison on the feasibility of biodiesel production in the state (Fortenbery et al, 2005). Costs of production comparisons were made between various feedstocks and processing capacity levels. Vegetable oils and yellow grease were selected for the study based on their relatively high accessibility in the state. The cost model was constructed to include fixed costs such as machinery, land, storage tanks etc, as well as variable costs including prices paid for feedstock and labour cost.

Results showed that the total production costs of soy diesel and yellow grease diesel in four million gallon per year plants are estimated $2.86 and $1.75 per gallon respectively In a ten million gallon per year plant, the cost of production is lowered for both feedstocks to $2.66 and $1.54 per gallon respectively. This result indicates that feedstock prices as well as plant sizes exert important impact on production price.

The study also used the IMPLAN model to determine the overall economic effect of operating a four million gallon per year biodiesel production using yellow grease as the feedstock. It is estimated that a total of $11.9 million in sales would be generated in the economy as a result of the direct and indirect impact of the increased biodiesel production.

2.3 Observations

2.3.1 Potential Feedstocks, Cost and Availability

Two factors are the most crucial when evaluating the feasibility of feedstocks: price and availability. Depending on the studies cited, cost of feedstock accounts for about 80% of the total operating cost and more than 50% of the total cost (Boyd, 2004; Nuñez, 2004; Frazier Barnes and Associates, 2003). A slight fluctuation in feedstock price could lead to fundamental changes in profit margin. On the other hand, insufficient feedstock supply could place limitations on plant size preventing the achievement of economies of scale, therefore increasing per unit output price. Compared to procurement costs, variations in operating costs derived from using different feedstocks do not affect total cost significantly. While other characteristics of feedstocks pertaining to fuel quality are also important, they can be easily compensated through the use of fuel additives.

In terms of potential feedstocks, biodiesel can be produced from almost any form of vegetable oil and animal fat. In general there are four types of available feedstocks: virgin oil, animal fat, recycled oil, and trap and brown grease. Virgin oils are generally obtained from the crushing of soybeans, canola, sunflower seeds and other oil crops, while animal fats are produced by animal slaughtering and processing plants. Beef tallow, poultry fat, pork grease, and fish oil are some of the common animal fats available for biodiesel production. Recycled oil, also called yellow grease, refers to used-oils recycled from restaurants, manufacturers and industrial operations. Trap and brown grease is usually collected from oil and grease traps inside the sewage systems.

Presently, yellow and brown greases are the cheapest feedstock available for biodiesel production with price roughly half of that for virgin oil. Production processes from these greases are similar to that of other feedstocks plus an additional step to remove the impurities. Supplies of yellow and brown greases are mostly from metropolitan areas due to the nature of their production. The annual production of these greases is very hard to estimate. According to Boyd et al., British Columbia produces roughly 47 million liters of yellow and brown grease annually from restaurants alone. However, other market uses exist for yellow grease including soap, lubricants, paint, plastic, animal feed and other industrial productions, which severely limit its availability leaving it an unlikely source to support large-scale commercial production. In addition, a sudden increase in demand for yellow grease could drive up price considerably due to its relatively stable supply.

Animal fat (tallow and lard) derived from livestock processing is also a good source of feedstock. The price of animal fat is slightly higher than that of yellow grease but much cheaper than vegetable oils. Similarly to animal fats, yellow greases are co-products of another production process, therefore both greases and animal fats have a relatively stable supply. Other market uses also exist for animal fats and will also be difficult to displace, however, Canada currently exports 200,000 – 250,000 tonnes of animal fat per year to the Far East that could be used domestically in biodiesel production (Natural Resources Canada, 2004).

Vegetable oils, on the other hand, are expensive but relatively abundant. Currently 50% of the 6 million ton annual production of canola in Canada is exported un-crushed while excess crushing and processing capacities still exist, which provides the industry with readily available resource to produce biodiesel. In addition, 5% of the canola seeds are frost or heat damaged, making them unsuitable for food use but perfect as a feedstock for biodiesel.

Nevertheless, challenges still exist in producing biodiesel from food-grade canola oil, particularly its price. Currently price for canola oil is higher than other widely used vegetable oils such as soybean oil. Even though canola seeds have a higher oil content and cheaper market price than soybeans, their byproduct value, however, is not competitive with the high protein soybean meals. The higher value byproduct of soybean oil allows it to be sold at about US 50 cents per gallon lower than canola oil, making canola-derived biodiesel relatively more expensive.

Canada is a net importer of soybeans, which means that unless drastic change in production occurs, it is unlikely that it will become a feedstock for biodiesel. Other developing sources of virgin oils, such as flaxseed, algae and *Brassica carinata* (Ethiopian mustard), have also been examined in various feasibility studies. Currently research still needs to be completed to improve the oil content and yield of these crops before they will become economically feasible. As well, flaxseed oil has been deemed too high cost to serve as a biodiesel feedstock (Natural Resources Canada, 2004). Palm oil can also be used and is one of the cheapest vegetable oils available, however, ocean freight costs to transport the oil to North America would largely account for that price gap. If the Far East decided to produce biodiesel, they could have a competitive advantage due to the low cost of the available feedstock (Natural Resources Canada, 2004).

The majority of the feasibility studies that were reviewed, especially in the United States, indicate that biodiesel production would not be feasible without government subsidies, unless diesel prices increase substantially or biodiesel production grows to a level that greatly offsets production costs.

At the surface, the finding that vegetable oil is abundant yet expensive and animal fats are less abundant but cheap, appears to be a paradox. However, the potential for vegetable oils will come as biodiesel plants come on line and the demand for feedstock increases faster than the growth in animal slaughter and waste grease production. As demand from biodiesel production increases, another implication is that the price of animal fats and waste greases will also increase and the cost margin between the two feedstocks should narrow. In order to mitigate supply and demand issues, Groschen (2002) suggests that there is a real risk mitigation benefit in developing plants that can utilize both vegetable oils and greases and fats.

Further examination of potential feedstock markets is found in Section 3.0.

2.3.3 Economic Models Used in Previous Research

One of the most widely used economic models observed from previous studies is the IMPLAN model developed by the US Forest Service in the early 1980s. The model is used to simulate the economic impacts of changes in factor demand in the US economy. There are two components to the IMPLAN model. The first is a large-scale database of multipliers that describes the activities of more than 600 economic sectors and industries at different levels of government. The second component is a multi-equation economic calculator that allows users to introduce changes to the multipliers and perform economic simulations. The biggest advantage of the IMPLAN model is its ability to calculate explicitly the direct and indirect as well as induced effects of any economic change introduced.[6] The model is also capable of analyzing changes that occur on a state or regional level.

While sophisticated models like IMPLAN are useful at estimating the over-all economic and fiscal impacts of key policy changes, they may not, however, be very useful in this study. One of the most crucial drawbacks of the IMPLAN models is its assumption that there is an excess of resource (Althoff, 2003, p 81). The model does not take into consideration the effect of increased biodiesel production on feedstock and byproduct prices. As noted above, both of these factors would affect the feasibility of feedstocks significantly.

The Policy Analysis System (POLYSYS) spatial equilibrium model used by De la Torre Ugarte et al. (1999) simulated changes to the current baseline scenario such as increased vegetable oil demand as well as increased oil yields from oilseed crops. POLYSYS combines national demand, regional supply, national livestock supply, demand and agricultural income modules to develop deviations from a baseline based on changes, in this case to the demand of vegetable oils and animal fats. Similarly, the FAPSIM model used by the USDA also simulates policy changes in the US agricultural sector through examining the aggregate economic effect of any change in factor input.

[6] Direct effects refer to the production changes that are caused by the initial change in demand. Indirect effects refer to the secondary production changes that are results of the direct effects. Induced effects refer to the changes in consumer spending caused by the direct and indirect effects. See: http://www.implan.com/library/documents/implan_io_system_description.pdf.

In the model that will be developed in Section 4.0 of the report, elements of the spatial equilibrium models will be used because elasticity of demand will be included to determine the changes in price and supply of potential feedstocks as demand for biodiesel increases.

However, simpler methods, such as the partial equilibrium analysis used in the Althoff et al. report, could prove to be a superior choice in this case as it can be easily modified to address the uncertain and evolving nature of the industry with more flexibility. In Althoff's study, forecast data for soybean production and price were first obtained from United Soybean Board (USB) to compute the elasticity of soybean oil supply. A demand shock was then introduced to the model equal to that caused by the increase in biodiesel production. The result was then used in a spreadsheet analysis to determine the final impacts on soybean production volume and market price.

The models developed by Canakci and Van Gerpen (2001), Frazier Barnes and Associates (2003) Nunez (2004) and in the Natural Resources Canada (2004) study were all plant-scale models that utilize various inputs and output factors including feedstock costs to simulate total cost of production using canola oil, animal fats and waste greases as feedstocks. Various aspects of these models will also be included in the model developed for this study.

3.0 Biodiesel Feedstock Markets

The previous section highlighted previous studies dealing with a variety of feed stocks used in biodiesel production. The purpose of this section is to provide background and analysis of candidate feedstocks of relevance to Canadian biodiesel production. For each feedstock, the following market analysis framework is applied:

- Profile of the market
  - Production
  - Consumption
  - Prices
- Profile of the suppliers
- Profile of the customers
- Apparent Trends and Synthesis

Section 3.1 provides background and analysis of canola and rapeseed oil as a biodiesel feedstock. Section 3.2 provides a discussion and analysis of soybean oil as a feedstock. Section 3.3 provides a description and analysis of rendered fats as a feedstock for biodiesel production. Section 3.4 describes and provides an analysis of the market for recycled greases and oils.

3.1 Canola and Rapeseed Oils

Biodiesel is readily made from either canola oil or rapeseed oil, typically at a yield of around .9 tonnes biodiesel/tonne feedstock. Canola oil is also used to make a variety of edible products including shortening, margarine, deep frying, baking, salad oils, mayonnaise, sandwich spreads, coffee whiteners, creamers and pharmaceuticals/nutraceuticals. Canola is used in the following inedible uses- cosmetics, dust suppressants, industrial lubricants, fungicides, herbicides, pesticides, oiled fabrics, printing inks, plasticizers, suntan oil, and anti-static for paper. Edible rapeseed oils (which contain less than 2% erucic acid) are used in cooking and vegetable oils, while inedible rapeseed oils are used for many of the above industrial purposes such as lubricants, rubber additives, commercial waxes, nylon, diesel fuels and pesticides.

For the purposes of discussions below, unless indicated otherwise, canola and rapeseed oils are combined and treated synonymously. This is necessary due to limitations in the reporting of data, which mostly fails to differentiate between the two. However, with regard to biodiesel this limitation is not significant, since the two feedstocks would not likely be differentiated.

3.1.1 Canola and Rapeseed Oil Production

The leading producers of canola and rapeseed are the European Union (EU), China, Canada, India, and Australia. These four countries account for about 91% of world production. Canada is a significant producer of canola and rapeseed, but, as can be seen in Table 3.1, it ranks third overall behind the EU-25 and China. Average canola and rapeseed production in Canada between the 1999/2000 and 2003/2004 crop years was 17 percent of total world production. In comparison, the EU comprised 32 percent of world production and China had 29 percent of world production, for the same time period. One reason for the large share of European production of rapeseed is relatively high yields. In the 1999/2000 and 2003/2004 period, EU-25 producers yielded approximately 2.8 (metric) tons per hectare compared to 1.45 in Canada and 1.53 in China.

Table 3.1 World Production and Yield of Rapeseed and Canola

	EU - 25	China	Canada	India	Australia	Other	World
Avg 1999/00 – 2003/04							
Area (million Ha)	4.28	7.17	4.42	5.39	1.4	3.12	24.38
Yields (tons/ha)	2.8	1.53	1.45	0.9	1.21	1.04	1.54
Production (million MT)	11.97	10.96	6.39	4.84	1.7	3.47	37.63
Prelim 2004/05							
Area (million Ha)	4.5	7	4.94	6.9	1.14	2.69	26.03
Yields (tons/ha)	3.4	1.88	1.56	1.01	1.34	1.17	1.79
Production (million MT)	15.29	13.18	7.7	7	1.53	3.35	46.52
Forecast 2005/06							
Area (million Ha)	4.69	7.2	5.2	6.8	0.9	2.62	26.51
Yields (tons/ha)	3.17	1.58	1.58	0.94	1.22	1.13	1.66
Production (million MT)	14.84	11.4	8.2	6.4	1.1	3.04	43.88

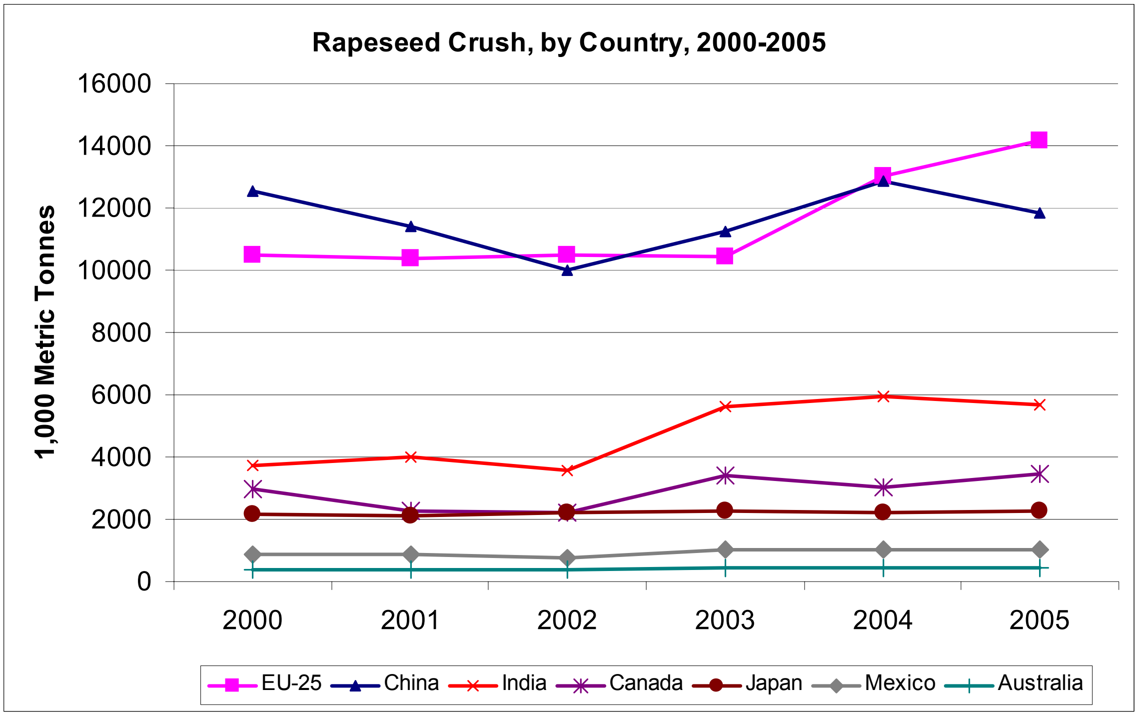
Source: FAS, USDA Oilseeds Outlook Report

Forecasted data for the 2005/2006 crop year shows similar trends as the previous years. EU-25 production is still dominant and rapeseed yields have increased to 3.17 tons per hectare. Chinese production is forecast to decrease compared to previous years, but Canadian production is expected to increase.

Figure 3.1 presents the crush from 2000-2005 for the top canola and rapeseed producing countries (EU-25, China, Canada, India and Japan) and Figure 3.2 shows these countries share of rapeseed crush. Overall, the EU-25 has crushed the most rapeseed for this period, followed closely by China. This is followed by India, and Canada. Japan also registers as a leading crusher, clearly on the basis of imported product. On average, China had 32 percent of the world rapeseed crush between 2000 and 2005, while the EU-25 had 31 percent, despite the fact that overall the EU-25 had the most rapeseed crush during this time period. Canada averaged 8 percent of rapeseed crush.

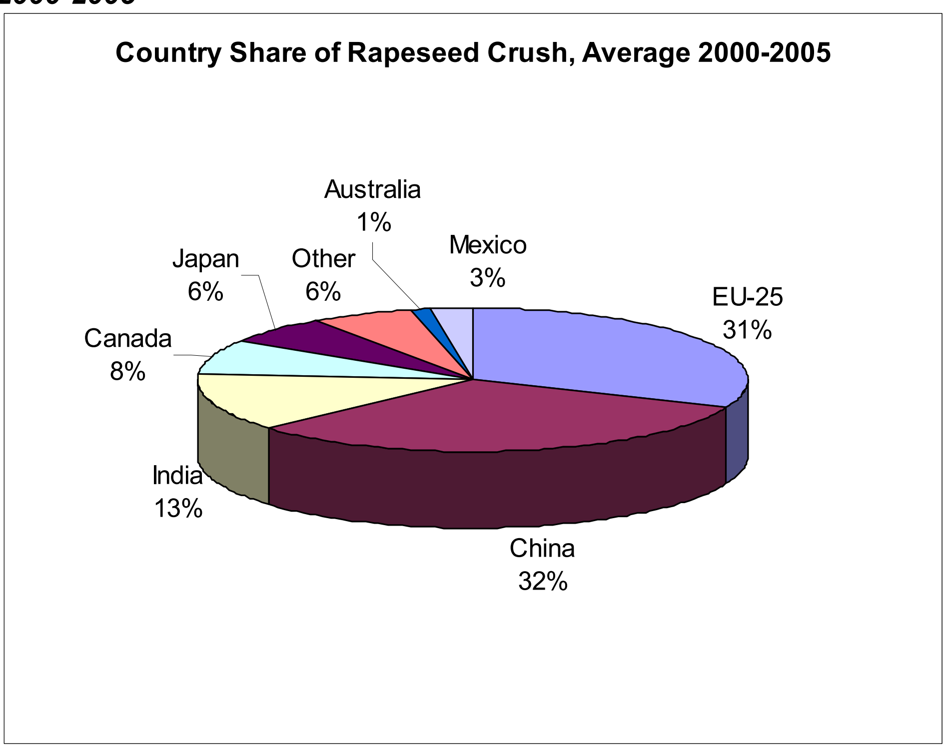
Table 3.2 presents the average growth rate of rapeseed crush. With the exception of China, rapeseed crush is growing overall in the last five years. Much of the growth appears to be occurring in Canada (5%) and Japan (7%).

Figure 3.1: Rapeseed and Canola Crush, Leading Crushers, 2000-2005



Source: FAS, USDA

Figure 3.2: Share of World Rapeseed and Canola Crush, Leading Crushers, Average 2000-2005



Source: FAS,USDA

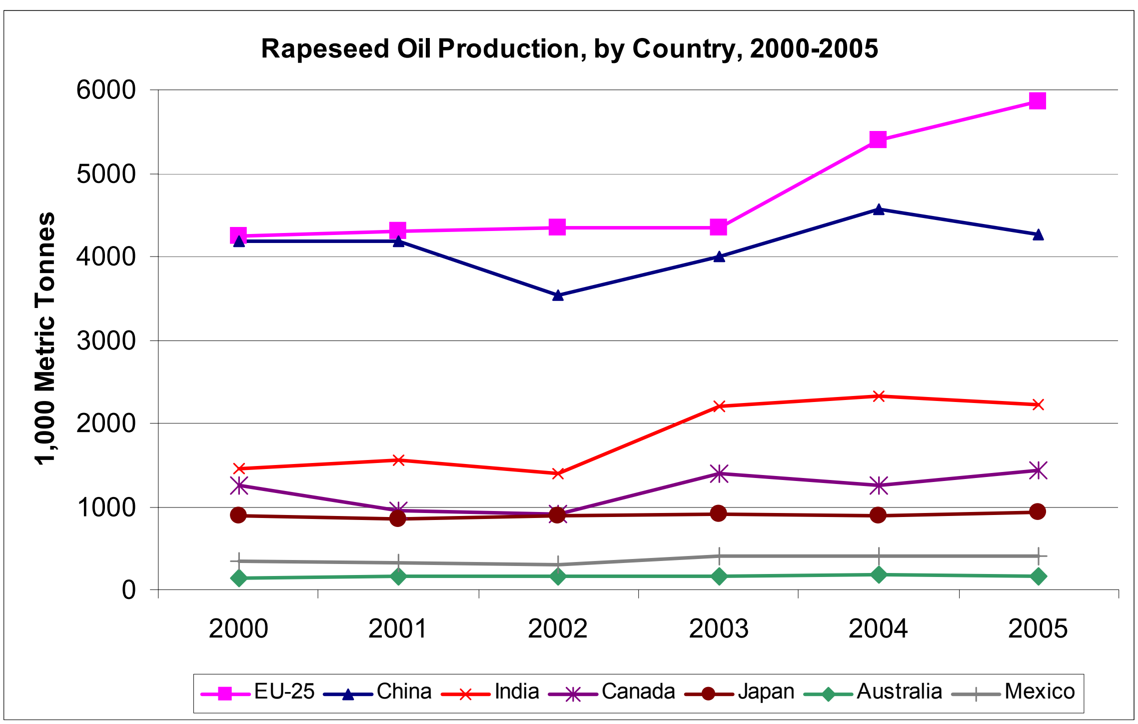
Table 3.2: Growth Rates of Crush and Production

Country	*Average Crush 2000-2005 '000 MT*	*Average Crush Growth Rate, 2000-2005 (%)*	*Average Production 2000-2005 '000 MT*	*Average Oil Production Growth Rate, 2000-2005 (%)*
EU-25	11,498	4.58	4,752	5.04
China	11,645	(0.66)	4,117	0.55
India	4,757	7.04	1,856	7.03
Canada	2,887	5.12	1,198	4.87
Japan	2,210	0.80	891	0.81
Mexico	1035	0.10	364	(1.9)
Australia	419	(1.4)	163	1.41
World	36,575	4.3	14,145	4.27

Source: USDA, FAS

Rapeseed oil and Canola oil production followed similar trends as rapeseed crush. As shown in table 3.2, the EU-25 is the leading producer, followed by China, India, Canada and Japan. Average world production for the 2000-2005 period was 14.1 million metric tonnes and the average rate of growth in production was 4.3 percent. As with rapeseed crush, India has the highest growth rate in rapeseed oil production over the last six years at just over seven percent. Canada and the EU-25 rapeseed oil production is also increasing at a fairly solid rate, but there is just minimal increases in production for China and Japan. Figure 3.3 presents canola/rapeseed oil production in leading producer nations as a time series. Production in the EU and India is up sharply, with slower growth in China, Canada, and Japan.

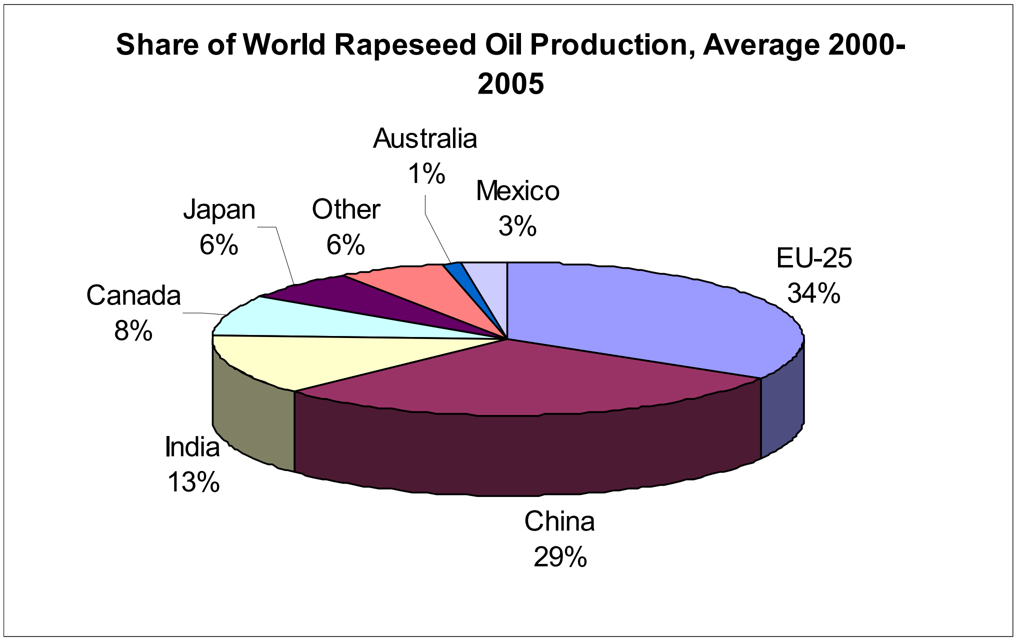
Figure 3.3 Rapeseed and Canola Oil Production, by Selected Country, 2000-2005



Source: USDA, FAS

As shown in Figure 3.4, on average, between 2000-2005, the EU-25 had 35% of total rapeseed oil production, followed by China (29%) and India (13%). These are consistent with rapeseed crush.

Figure 3.4 Percent of World Rapeseed and Canola Oil Production, Leading Producers, 2000-2005



Source: USDA, FAS

3.1.2 Canola and Rapeseed Oil Consumption

The leading consumers of canola and rapeseed oil are the EU, China, India, Canada, Japan, and Mexico. Consumption by leading consumer nations and world consumption are presented in Table 3.3. The table also shows that almost 38 percent of rapeseed oil consumption in the EU-25 is for industrial use. This is not surprising as some 80 percent of the EU biodiesel is made with rapeseed oil, and about one third of the rapeseed crop in 2004 went to production of biodiesel (USDA, FAS GAIN Report No. E35085, “EU-25 Oilseeds and Products: Strong Growth Anticipated for EU Biodiesel Production”, May 5, 2005). Demand for rapeseed oil in the EU surged in 2004 as biofuel capacity increased, due to efforts to reduce the EU’s dependence on fossil fuel imports and to cut greenhouse gas emissions.

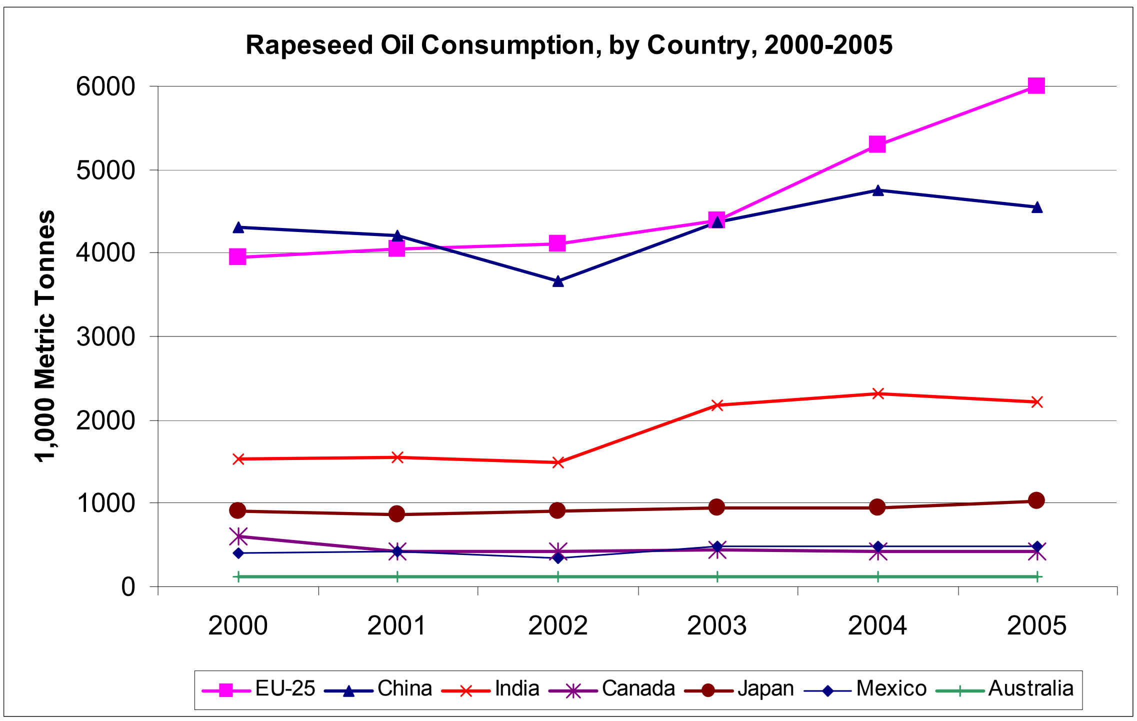
Figure 3.5 shows the trend of rapeseed oil consumption between 2000-2005. The EU-25 are the largest consumers of rapeseed oil, followed closely by China. Consumption in India increased almost 50 percent after 2002, but has remained fairly stable for Canada and Japan. As well, EU-25 consumption has increased fairly dramatically, from just over 4 million metric tonnes in 2001 to 6 million metric tonnes in 2005. Overall world consumption of rapeseed and canola oil is also increasing, and has averaged an increase of over 4 percent between 2000 and 2005.

Table 3.3: Growth in Domestic Production and Industrial Share of Production

Country	***Average Consumption 2000-2005 '000 MT***	***Average Consumption Growth Rate, 2000-2005 (%)***	***Average Industrial Use as a % of Total Domestic Consumption, 2000-20005***
EU-25	4637	8.54	37.90
China	4308	0.50	0
India	1876	5.94	0
Canada	455	-3.45	0
Japan	937	2.19	5.17
Mexico	443	2.52	0
World	14,242	4.3	N/A

Source: FAS, USDA

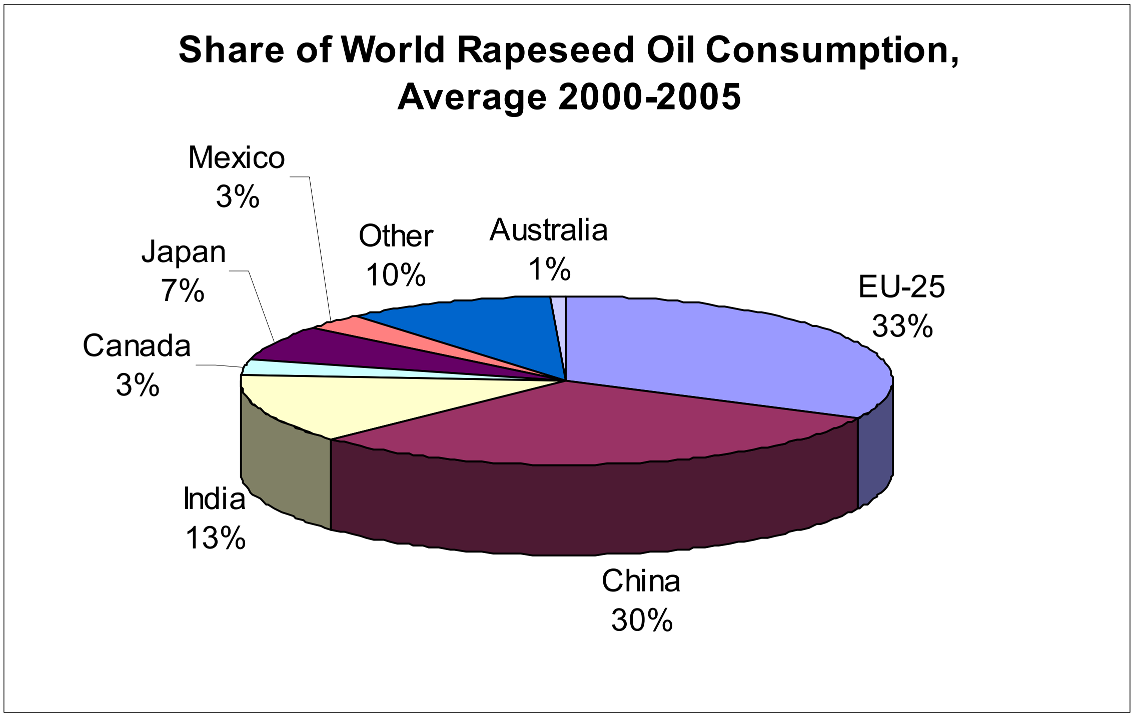
Figure 3.5: Total Domestic Consumption of Rapeseed and Canola Oil, Leading Consumer Nations, 2000-2005



Source: FAS, USDA

Figure 3.6 presents the share of consumption of leading consumer nations. The EU consumed an average 33% of the worlds rapeseed oil between 2000 and 2005. China was also a major consumer (30%), followed by India, Japan, Mexico, Canada and Australia.

Figure 3.6 Percent of World Consumption, by Selected Country, Average 2000-2005



Source: FAS, USDA

3.1.3 Canola and Rapeseed Oil Prices

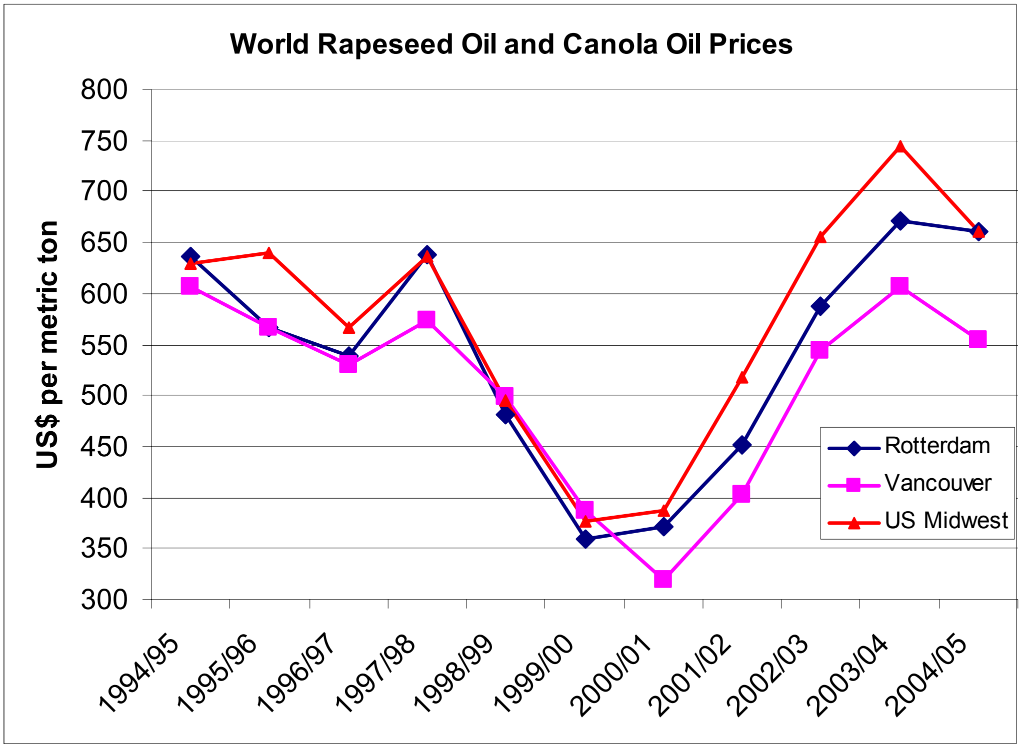
Figure 3.7 presents historic canola and rapeseed oil prices at Vancouver, US Midwest, and Rotterdam. Figure 3.7 shows average Rotterdam prices for rapeseed oil for the 1994/95 to the 2004/05 crop years, along with canola oil prices for Vancouver and the US Midwest. The figure shows that the oil prices track one another quite closely, with canola oil at Vancouver clearly the low price point. Interestingly, while one would expect rapeseed oil prices to be naturally lower than that of canola oil because of rapeseed's more limited uses, Rotterdam prices are actually above Vancouver. The Midwest price for canola oil is at a premium to canola oil in Vancouver, by what would appear to be freight cost. The pattern of prices shows significant volatility

3.1.4 Understanding Canola and Rapeseed Oil Producers

Based on the above sections, it is clear that in the main, major canola and rapeseed oil producers are also the major consumers. The major producing and consuming markets are the EU, China, India, and Canada. In the main, canola and rapeseed serve as substitute crops in regions that cannot grow soybeans (or produce soybean oil). Indeed, pricing of rapeseed and canola oil is highly integrated with soybean oil. This can be confirmed by comparison of Figure 3.7 and Figure 3.5 or Figure 3.3. Changes in production and consumption appear to have relatively little impact on pricing in this market, because it is fully integrated with the soybean oil market.

Implicit in the above is the impact of farm subsidies. In particular, certain EU members have material subsidies for rapeseed, rapeseed oil production, and tax incentives for biodiesel manufacturing using rapeseed oil. The impact is to stabilize the production base and support demand in the EU. Production subsidies in other regions are relatively small or nonexistent. However, canola/rapeseed acreage and production has been on the increase in most production regions, with the exception of Australia.

Figure 3.7 World Price of Canola and Rapeseed Oil



Source: FAS Oilseeds Circular, Canola Council of Canada and USDA Oil Crops Yearbook

3.1.5 Understanding Canola and Rapeseed Oil Consumers

As noted above, the leading canola/rapeseed oil consumers are themselves producers. The notable exceptions are Japan and Mexico, which are significant consumers but have limited domestic canola/rapeseed production. Since 2001, consumption of canola and rapeseed oils has increased, even as prices have increased sharply. The clear implication is that demand is robust, and is likely due to the following:

- Growth in EU rapeseed demand due to biodiesel demand
- Growth in Chinese and Indian demand for rapeseed oil, as part of broader growth in the national economy
- Preference for canola oil's fatty acid profile in foods

3.1.6 Synthesis

Strength in demand appears to have generally lead supply in this market. Canola and rapeseed acreage has been steady to slow-growing, and as a consequence so has the crush and oil production. The price has been volatile, but has recovered to the $US 550-650/tonne range from well under $US 400/tonne in 2000-2001. Throughout the price increase, growth in consumption has been robust, particularly in the EU, China, and India. Put differently, the price has increased significantly since 2001, despite a significant increase in production. This can only occur due to strength in the demand for rapeseed and canola oils, or for strength in the demand for the overall oil complex.

3.2 Soybean Oil

Soybean oil is primarily used in edible vegetable oil products. However, as indicated in the studies reviewed in section 2, soybean oil has also been extensively used as a feedstock in biodiesel production, especially in the US.

3.2.1 Soybean Oil Production

The leading producers of soybeans are the US, Brazil, Argentina, and China. This is shown in Table 3.4 below. World soybean production for the 2005/06 crop year is forecasted at 215.6 million tonnes, which is 19% higher than the average production between 1999/00-2003/04. It is also higher than the 2004/05 preliminary figures. The United States has the largest share of overall soybean production, with an average of 40.7% of production between 1999/00 and 2003/04. Brazil is increasing its share of soybean production, from 44 million tonnes on average between 1999/00 and 2003/04 to a predicted 60 million metric tonnes in 2005/06. Similarly, Argentina has been increasing soybean production and is expected to produce 10 per cent more tonnes of soybeans compared to the average production between 1999/00 and 2003/04.

Table 3.4 World Soybean Production and Yield

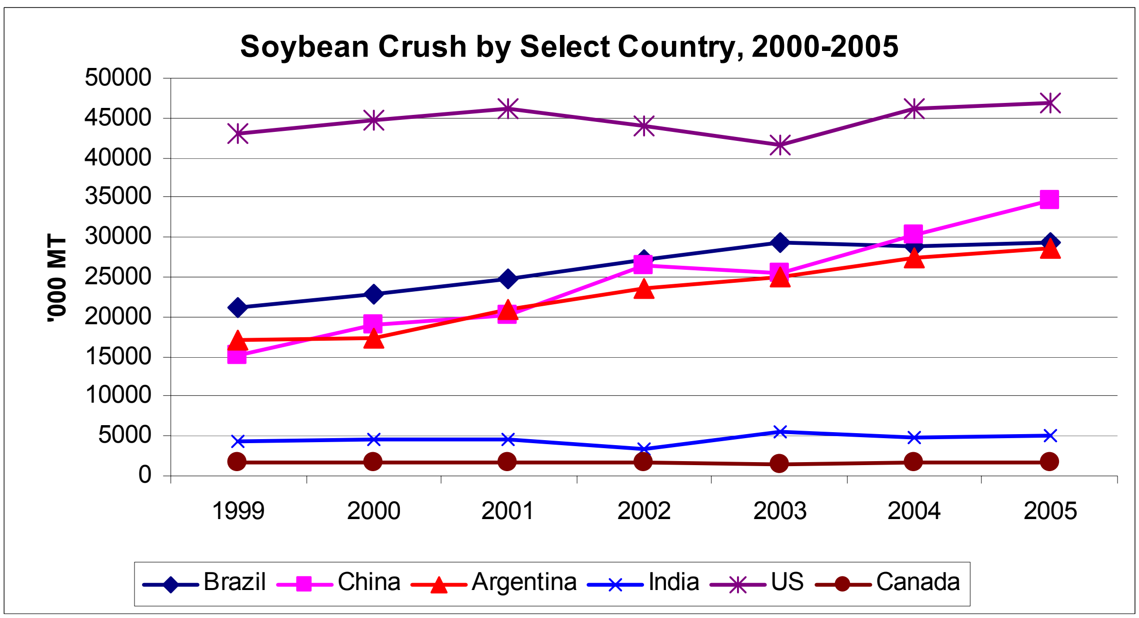
	United States	Brazil	Argentina	China	Other	World
Avg 1999/00 – 2003/04						
Area (million Ha)	29.36	16.77	11.4	8.96	13	79.5
Yields (tonnes/ha)	2.5	2.63	2.59	1.72	1.42	2.28
Production (million MT)	73.55	44.04	29.5	15.4	18.5	180.99
Prelim 2004/05						
Area (million Ha)	29.93	22.84	14.4	9.8	15.74	92.71
Yields (tons/ha)	2.86	2.23	2.71	1.84	1.33	2.31
Production (million MT)	85.48	51	39	18	20.94	214.43
Forecast 2005/06						
Area (million Ha)	29.21	22	14.7	9.7	15.98	91.59
Yields (tonnes/ha)	2.62	2.73	2.65	1.75	1.44	2.35
Production (million MT)	76.64	60	39	17	22.98	215.62

Source: FAS, USDA

Figures 3.8 and 3.9 show soybean crush for the top producing countries and share of the world soybean crush, respectively. The United States has the largest soybean crush and had an average of 27 percent of total soybean crush between 2000 and 2005. The growth of soybean crush, (Table 3.5), however, has progressed at a fairly low rate, averaging just over one percent for the period between 2000 and 2005.

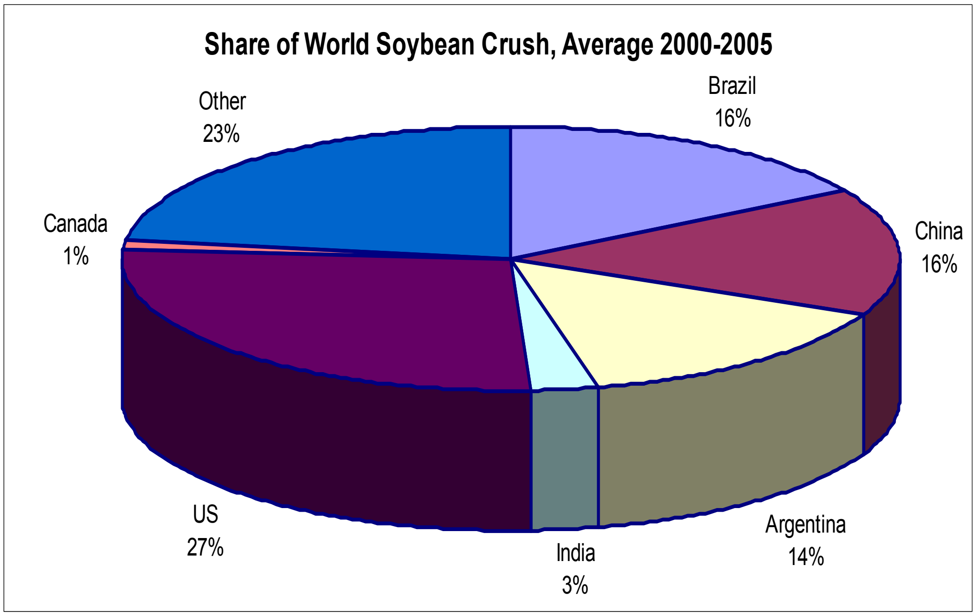
Conversely, growth in soybean crush for China and Argentina have been increasing quite steadily, as crush in China grew over 13 percent between 2000-2005 and over 10 percent for Argentina for the same time period. Brazil, which has an average 16 percent share of world soybean crush, and has been increasing soybean production, has been tapering off in soybean crush. Brazil's average growth rate over the 2000-2005 period was just over five percent, and only 1.6 percent in 2005. Canada and India comprise just four percent of the share of world soybean crush together, and the rest of the crush is made up of 'Other' countries.

Figure 3.8: Soybean Crush, by Select Country, 2000-2005



Source: FAS, USDA

Figure 3.9: Percent of World Soybean Crush, by Select Country, Average 2000-2005



Source: FAS, USDA

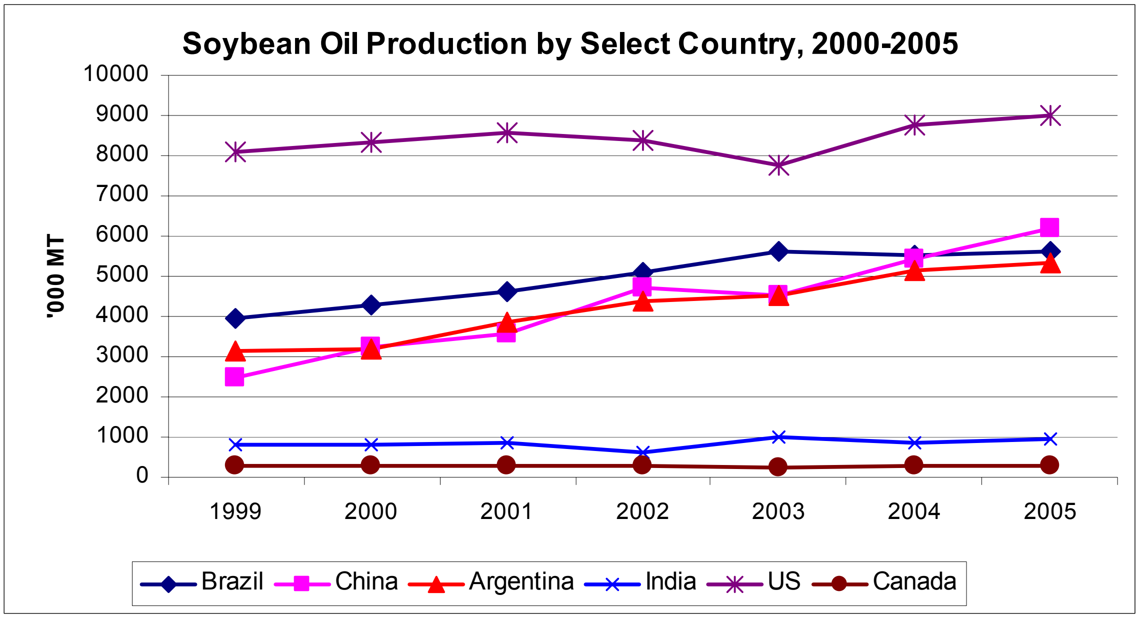
Table 3.5: Soybean Crush and Oil Production Growth Rates

Country	***Average Crush 2000-2005 '000 MT***	***Average Crush Growth Rate, 2000-2005 (%)***	***Average Soybean Oil Production 2000-2005 '000 MT***	***Average Production Growth Rate, 2000-2005 (%)***
Brazil	26,993	5.3	5,133	6.1
China	26,007	13.4	4,618	17.2
Argentina	23,771	10.7	4,405	9.6
India	4,652	6.3	856	6.1
US	44,904	1.1	8,471	2.0
Canada	1,673	1.4	282	1.0
World	165,912	4.8	30,420	5.2

Source: FAS, USDA

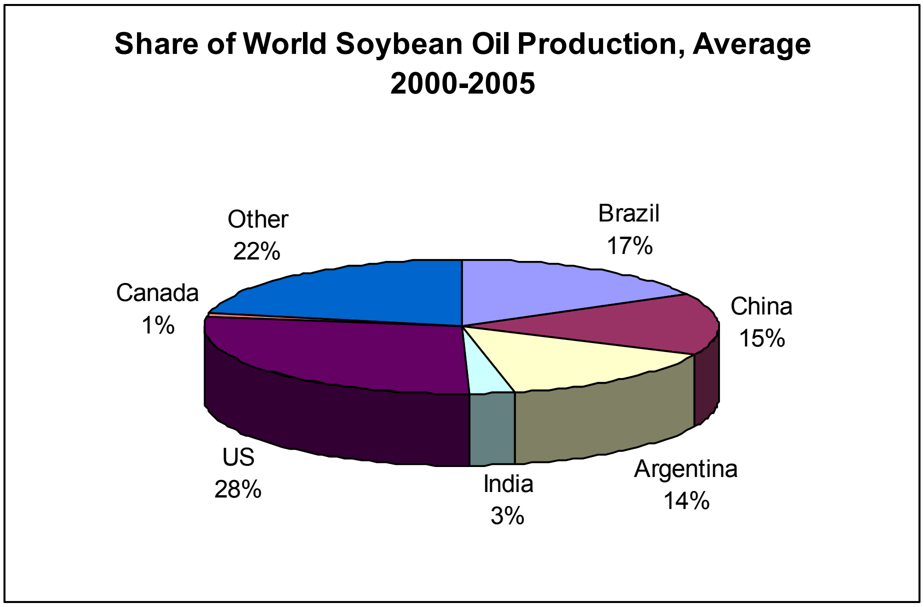
Figures 3.10 and 3.11 show soybean oil production and world share of production by the top producing countries. The trends are very similar to soybean crush and again the United States commands most of the soybean oil production (28%). Production in China and Argentina is, again, growing at an increasing rate (average 17 percent for China and almost ten percent for Argentina). Production in the United States is also growing, but at a slower rate (just over two percent). Apart from a slight dip in production in 2003, world production has been growing overall and the average growth in soybean oil production between 2000 and 2005 was just over five percent.

Figure 3.10 Soybean Oil Production, by Select Country, 2000-2005



Source: FAS, USDA

Figure 3.11 Percent of World Soybean Oil Production, by Select Country, Average 2000-2005



Source: FAS, USDA

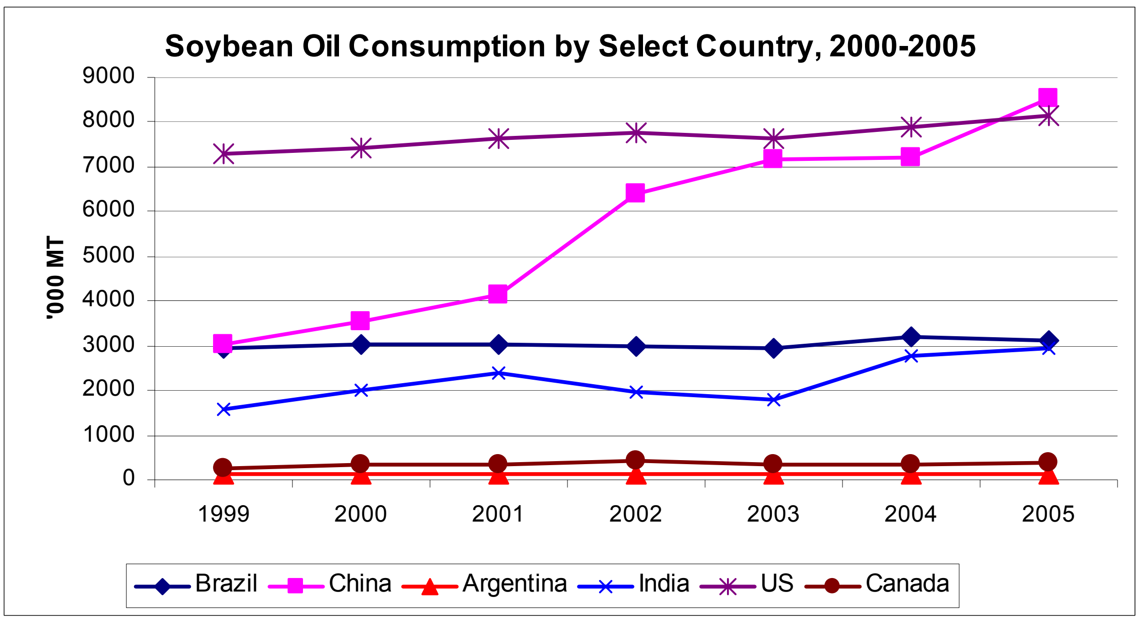
3.2.2 Soybean Oil Consumption

Figures 3.12 and 3.13 show soybean oil consumption and world share of consumption by the top consuming countries. As can be seen, soybean oil consumption in China almost tripled between the 2000 and 2005 period. While China only had an average 20 percent of share of soybean consumption between 2000 and 2005, the rate of consumption grew at an average of almost 20 percent (Table 3.6).

The United States commanded an average 26 percent of the total soybean oil consumption, and while the rates of consumption are still increasing, it is a fairly slow growth rate (just under two percent) when compared to China and even India. Soybean oil consumption in India grew by over 13 percent.

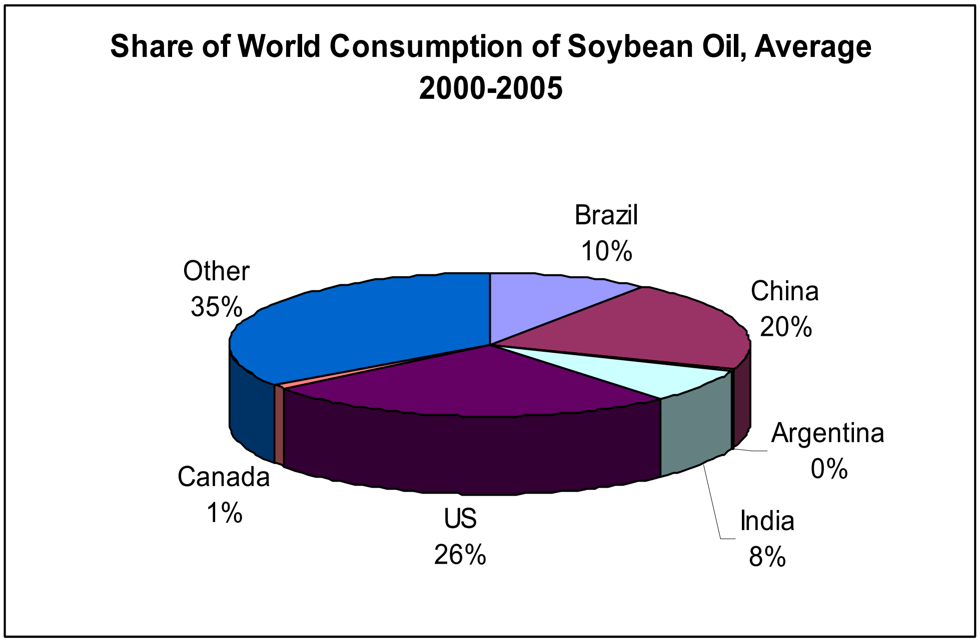
Overall, world consumption of soybean oil has been increasing, despite a slight dip in 2003 (which correlates to a slight decrease in overall soybean oil consumption as well). The average rate of growth of world soybean oil consumption was just over five percent between 2000 and 2005.

Figure 3.12: Soybean Oil Consumption, by Select Country, 2000-2005



Source: FAS, USDA

Figure 3.13 Percent of World Soybean Oil Consumption, by Select Country, Average 2000-2005



Source: FAS, USDA

Table 3.6: Soybean Oil Growth Rates

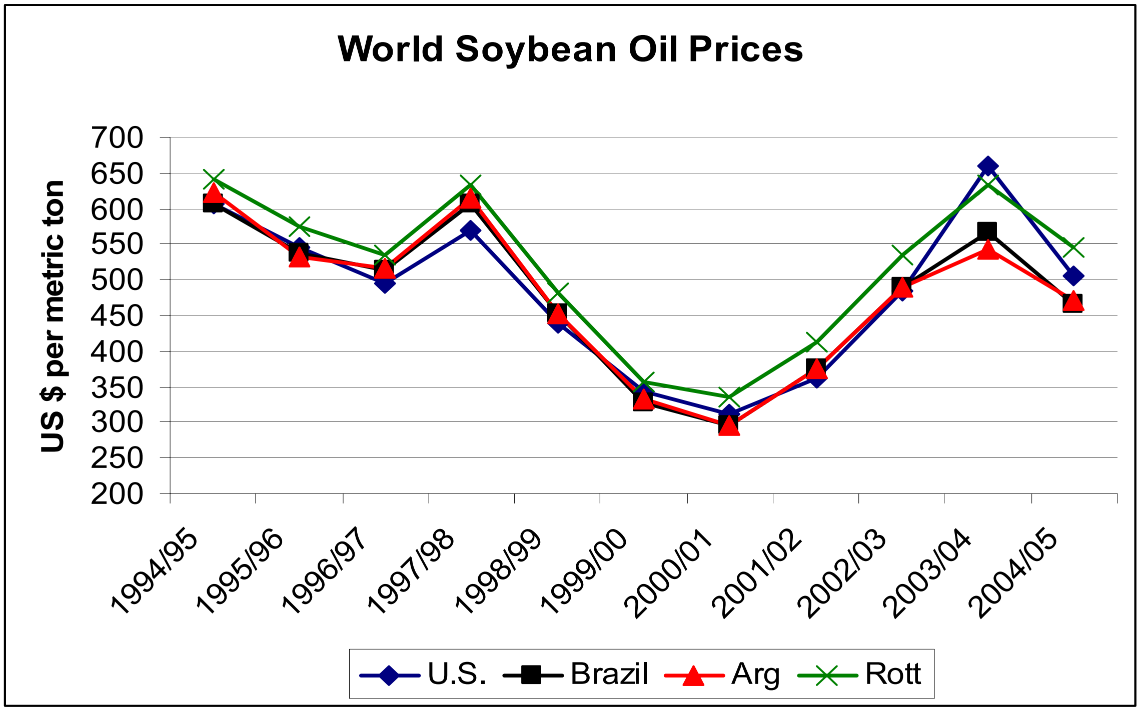
Country	*Average Consumption 2000-2005 '000 MT*	*Average Consumption Growth Rate, 2000-2005 (%)*
Brazil	3,052	1.0
China	6,167	19.9
Argentina	121	4.2
India	2,312	13.6
US	7,748	1.9
Canada	360	6.8
World	30,151	5.2

Source: FAS, USDA

3.2.3 Soybean Oil Prices

Figure 3.14 presents world soybean oil prices, for the United States, Brazil, Argentina and Rotterdam. The figure shows that soybean oil prices converge quite tightly, with the Rotterdam price clearly the high-price market. Historically, the US was the low price soybean oil market. However, in recent years Brazil and Argentina has moved to be the low price market. In addition, it is clear that the market is quite volatile, and shares a similar pattern to that observed in rapeseed and canola oil.

Figure 3.14: World Price Trends in Soybean Oil



Source: FAS, USDA

3.2.4 Understanding Soybean Oil Producers

The four key producers of soybean oil stand out. The US is the leading producer, but its growth is relatively stagnant. Soybean production is subsidized through US Farm Bill programs, and as a consequence soybean production, crush, and soybean oil production is stable. Indeed, past shifts in crop acreage toward and away from soybeans in the US have been due to relative subsidy levels for soybeans relative to other crops, rather than necessarily due to shifts in soybean prices.

Brazil and Argentina have grown significantly in soybean acreage and production, and the crush and oil production has grown concomitantly. Planned soybean acreage in Brazil is forecast to be down slightly this year; however, yields are expected to recover from disappointing levels the last two years back to average levels. This will more than offset acreage decreases, and soybean production will increase. The effect will be to increase product available for crushing, and thus the crush. Stable and growing production in South America is also supportive to the crush in the EU, which is a significant importer of soybeans.

Similarly, Chinese production is forecast to remain stable. This buttresses soybean imports to supply its crush. Agronomic improvements have increased production capability, especially in Northeastern China.

3.2.5 Understanding Soybean Oil Consumers

The major growth customers for soybean oil tend to be developing countries; among the top consumers, this includes China, India, and to a lesser extent Brazil. Consumption is stable in developed countries like the US and Canada. In general, income elasticities for fats and oils are relatively low and decline as household income increases. This is simply because fats and oils are relatively inexpensive sources of energy, and there is a wide range of substitutes. So, there is a tendency for poorer consumers and countries to have a strong demand for them, with demand declining as people become wealthier and energy is no longer the major constraint in their diet.

The implication is that, provided incomes in poorer countries continue to increase broadly, the consumption of soybean oil will continue to remain stable. However, persistent increases in income cause relative shifts toward protein and away from fats in the diet, which could weaken oil consumption. In addition, there are plenty of substitute products, not the least of which is palm oil (discussed briefly below). Also, soybean oil lacks the healthier profile of canola oil in foods, so in developed country markets its consumption may suffer as trans-fat concerns grow. This is important because food is the most important use of soybean oil. In particular, its use in biodiesel is largely in the US where tax incentives are used as a subsidy to biodiesel production.

3.2.6 Understanding Soybean Oil Consumers

As with canola and rapeseed oil, the demand for soybean oil has been aggressive. Significant price increases since 2000/2001 has little effect, as consumption has continued to increase. The drivers of this increased consumption have been China, India, and (primarily) developing countries. This strength in demand has allowed production to increase markedly, most notably in Brazil, Argentina, and China.

The factors that will impact future soybean oil prices are the strength in demand relative to increased production. Economic growth in China and the Far East will tend to fuel demand, as it has in recent years. The caveat is that increased wealth will eventually yield a shift in demand toward proteins and away from fats and oils. At the same time, it is expected that large increases in soybean production potential exist in Argentina and Brazil (which will result in crush in South America or Europe) as well as in Northeastern China. Thus, there are prospects for soybean oil prices to decrease over time.

3.3 Palm Oil

Pam oil is considered in this section briefly as the most significant member of the broader class of tropical oils. It has long been used as a relatively low-grade vegetable oil, and as a feedstock used in industrial chemicals. Palm oil has also recently been imported by the US for the purpose of biodiesel manufacturing, so it is of direct significance.

3.3.1 Palm Oil Production

Table 3.7 presents palm oil production by major producer-nation. The table shows that palm oil production is dominated by two large producers- Malaysia and Indonesia. They account for well over 80% of world production. The next largest producer after Indonesia is Nigeria, which has production that is only about 7% of that in Indonesia. Thus, production is highly geographically concentrated in Southeast Asia. Secondly, production of palm oil has increased sharply. Preliminary data for 2004/05 suggests that world production will be over 33 million tonnes, which represents an increase in production of about 37% since 2000/2001. Production in Malaysia increased 27% over that period, which Indonesian production increased by over 59%.

Table 3.7: Palm Oil Production, by Country, Thousand Metric Tonnes

	2000/01	2001/02	2002/03	2003/04	2004/05 (p)	2005/06 (f)
Malaysia	11,937	11,858	13,180	13,420	15,194	15,500
Indonesia	8,300	9,200	10,300	11,500	13,200	14,200
Nigeria	730	760	770	780	790	800
Thailand	580	780	640	840	760	800
Colombia	560	518	540	614	653	673
Papua New Guinea	330	370	380	380	380	380
Cote d'Ivoire	248	260	234	308	340	360
Ecuador	245	300	320	340	340	340
Costa Rica	137	150	156	190	240	285
Congo	155	167	170	175	175	175
Others	1,073	1,072	1,094	1,154	1,167	1,169
World	**24,295**	**25,435**	**27,784**	**29,701**	**33,239**	**34,682**

3.3.2 Palm Oil Consumption

Table 3.8 presents palm oil consumption according to major consuming nations. China, the EU, Indonesia, and India are the major consumers of palm oil. Besides being the two largest users of palm oil, China and the EU have also increased consumption sharply. China's consumption of palm oil has more than doubled since 2000/2001, and EU consumption is up about 43%. Consumption is in decline among some other major consumers, particularly India. Overall, world consumption is up 34% since 2000-2001.

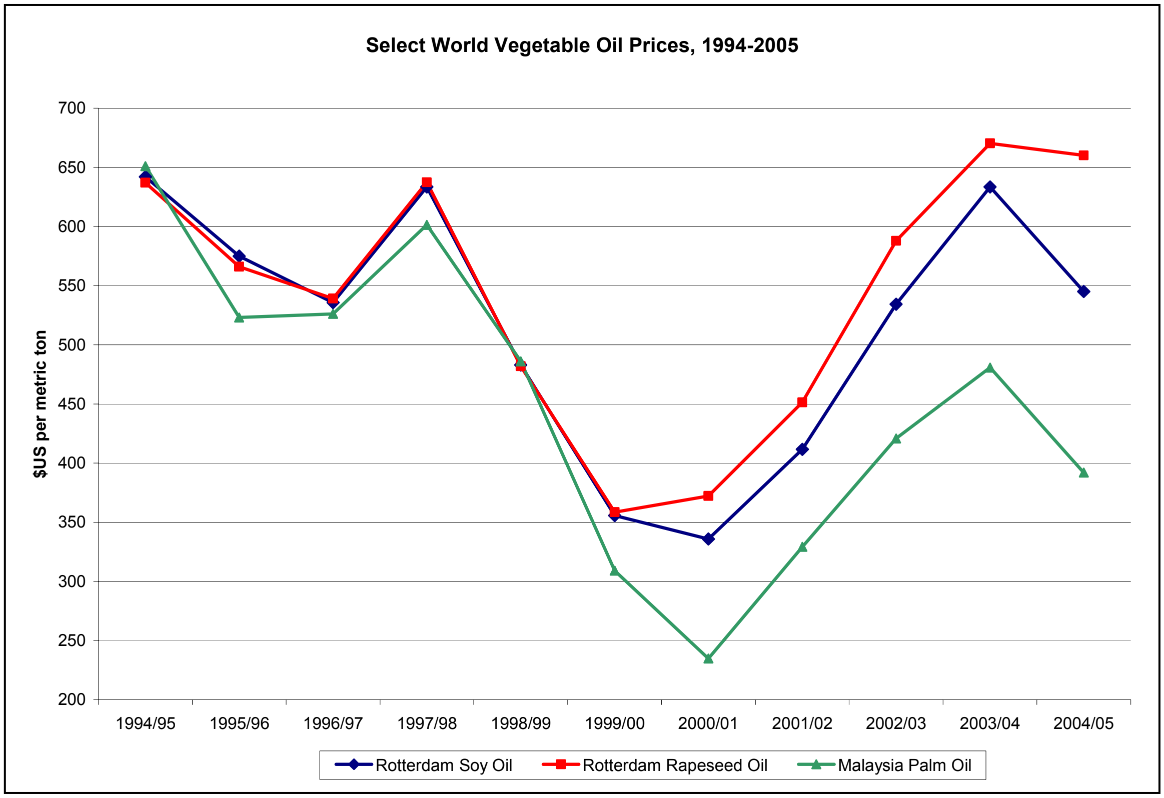
Table 3.8: Palm Oil Consumption, by Country, Thousand Metric Tonnes

	2000/01	2001/02	2002/03	2003/04	2004/05 (p)	2005/06 (f)
China, Peoples Republic of	2,028	2,470	3,525	3,710	4,319	4,750
EU-25	2,738	2,908	2,904	3,235	4,008	4,410
Indonesia	3,277	3,377	3,642	3,790	3,981	4,116
India	4,100	3,500	4,100	3,671	3,353	3,525
Malaysia	1,675	1,742	2,074	1,963	2,326	2,500
Pakistan	1,255	1,236	1,326	1,245	1,490	1,595
Nigeria	879	939	941	961	985	1,005
Bangladesh	306	395	398	540	747	789
Thailand	453	677	549	763	690	737
Others	7312	7741	8213	9375	10189	10613
World	**24,023**	**24,985**	**27,672**	**29,253**	**32,088**	**34,040**

3.3.3 Palm Oil Prices

Figure 3.15 presents palm oil prices in Malaysia plotted against Rotterdam rapeseed oil and soybean oil prices, all in US dollars. The figure shows a curious pattern. First, prior to 1999/2000, palm oil prices moved in close convergence with soybean and rapeseed oil. In fact, accounting for an import basis upon which palm oil would be based at Rotterdam, palm oil would have likely been at a premium to soybean and rapeseed oil.

Figure 3.15: World Price Trends in Palm Oil, Temperate Vegetable Oils



Following 1999/2000, a marked spread developed between palm oil and the other two oils. The correlation between prices remained intact, but the price of palm oil decreased significantly relative to either soybean oil or rapeseed oil. Thus, palm oil is now at a significant discount to soybean and rapeseed oil. The spread between Malaysian palm oil and Rotterdam soybean oil is now about $US 150/tonne (under), compared with a spread of $US 0-50/tonne pre-1999. Anecdotally, about $US 25-40/tonne can be attributed to Rotterdam freight over Malaysia, based on comparisons with Rotterdam in-store palm oil prices obtained from Safras-Mercado.

3.3.4 Synthesis

Palm oil production is up 37% since 2000. The result has been that, since 2000-2001, the palm oil price has essentially become uncoupled from the other major vegetable oils. There are a number of factors influencing this trend:

- Through the mid and late 1990's, EU restrictions on the use of tallow supported increased palm oil consumption. This has decreased as BSE measures in Europe changed
- Palm oil is increasing recognized as a relatively unhealthy cooking oil and ingredient in foods; this makes it less competitive with soybean and canola oil in food use, particularly in developed countries
- Clearly the increased production is ahead of demand. This has pushed by prices below that of competing oils. As will be observed in the next section, palm oil prices have been pushed

down to essentially arbitrage with rendered fats and oils. Some evidence of this is the penetration of imported palm oil into the US market to make biodiesel.

3.4 Rendered Animal Fats

Tallow and recycled fats are derived from the rendering of the animal by-products from slaughterhouses and butcher shops. These can be separated by animal species or mixed into a blended fat.

The rendering process involves heating animal by products and evaporating the water from the material. The raw material as it arrives at the rendering plant from processing plants average 60% water, 20 % fat and 20% protein. This means that of the raw material delivered to a rendering plant 20% by weight is available to the biodiesel process.

These products are traded commercially under several specifications, as shown in Table 3.9.

- Bleachable Fancy Tallow: Primary beef tallow defined by hardness, moisture, insolubles, unsaponifiables, free fatty acids, fatty acid content, and colour ($S\&T^2$ Consultants *et al*, 2004 p. 38).
- Choice White Grease: A specific grade of mostly pork fat defined by hardness, colour, fatty acid content, moisture, insolubles, unsaponifiables, and free fatty acids ($S\&T^2$ Consultants *et al*, 2004 p. 38).

Table 3.9

Name	**Titer (hardness)**	**Free Fatty Acids %**	**Impurities %**
Bleachable Fancy Tallow	41	3	1
Special Tallow	39	3	1
Choice White Grease	36	1.5	1

3.4.1 Production of Rendered Fats

In 2004, $S\&T^2$ Consultants *et al.* estimated the provincial breakdown of animal tallow production in Canada based on fat production coefficients defined by De La Torre Ugarte *et al* (1999) and using Statistics Canada data on animals slaughtered by province. De La Torre Ugarte *et al* (1999) derived the following edible and inedible animal fats produced based on the slaughter weights of animals: cattle, calves and sheep generate 58 pounds per 1000 pounds of live weight, hogs generate 43 pounds of lard per 1000 pounds of live weight and chickens generate 17 pounds of fat per 1000 pounds of chicken. $S\&T^2$ Consultants *et al.* used these estimates to determine total animal fat production by province in 2002. The estimates shown in Table 3.10 include both edible and inedible fat production.

Boyd *et al* (2004) also note that according to the Canadian Food Inspection Agency, Canadian rendering plants produce 270,000 tonnes of animal fat per year.

According to industry sources, presently, about 30% of the rendered fats are exported overseas from the North American market and therefore, could be readily available for biodiesel.

Table 3.10: Animal Fat Production by Province, Tonnes - 2002

Province/ Territory	Beef	Hogs	Sheep	Poultry	Total
British Columbia	1.609.3	1,344.1	296.1	2,789.5	6,039.0
Alberta	69,020.1	15,727.0	621.8	1,631.8	87,000.8
Saskatchewan	8,243.0	10,552.3	226.0	594.5	19,615.8
Manitoba	1,334.0	17,749.1	188.8	864.6	20,136.4
Ontario	19,771.0	27,267.5	1,174.2	6,510.9	54,723.7
Quebec	14,005.5	38,180.3	726.3	5,030.1	57,942.2
New Brunswick	544.5	924.3	22.7	434.3	1,925.8
Nova Scotia	719.9	1.0	69.8	619.0	1,409.8
PEI	738.1	1,094.7	7.6	-	1,840.3
Newfoundland	69.6	20.3	18.0	-	107.8
Yukon	0.0	0.0	0.0	0.0	0.0
NWT	0.0	0.0	0.0	0.0	0.0
Nunavut	0.0	0.0	0.0	0.0	0.0
Total	116,058.0	113,902.7	3,199.1	18,474.9	**251,634.7**

(Source: S&T^2 Consultants *et al. 2004)*

As of 2006, industry sources suggest that animal fat available for use in biodiesel in Canada, if all of it was used for biodiesel, would be 389,150 MT or 442,850,424 litres of biodiesel. In the United States the tallow market would be 3,242,900 MT or 3,690,440,000 litres.

Restrictions for the North American market on imports and exports for these products have been in place since May 2003, with the outbreak of BSE in Canada. Any fats that contain or may contain ruminant material cannot be shipped to the US market but can be exported to most other export markets if they have less than 0.15% impurities. Pork and poultry materials can trade everywhere as long as it is not contaminated with any ruminant material and is produced in a dedicated facility for non-ruminant materials.

The situation in the EU is very different as restrictions that came into force in spring 2003 have made it nearly impossible for North American tallow to be imported into that market for any use and has outlawed the export of EU tallow as well. These same rules also restrict the use of tallow for any other purpose than incineration in government inspected facilities unless it is derived from category 1 raw material (fit for human consumption) and then it is used in pet food and animal feed and not the biodiesel business. Many different companies and the National Renderers Association are working very hard to have these regulations changed but are having very little luck.

3.4.2 Rendered Fats Consumption

Rendered fats are used for a variety of products including biodiesel, feed and lubricant products. Table 3.11 shows the proportion of US consumption of animal fats in 2002. In 2006, the major Canadian buyers of tallow are distributed differently than they are in other areas of the world. Within North America, about 30% of the tallow is used by the chemical splitters such as Cognis and about 60 % in the animal feed business, with 10% used in soap and

Table 3.11: US Animal Fat Uses, 2002

Application	Percentage of Total Use
Fatty Acids	35.9%
Feed	44.0%
Lubricants	1.8%
Paint and varnish	1.8%
Resins and plastics	2.3%
Soap	6.2%
Other inedible products	8.0%
Total consumption in inedible products	100.0%

(Source: S&T^2 Consultants *et al. 2004)*

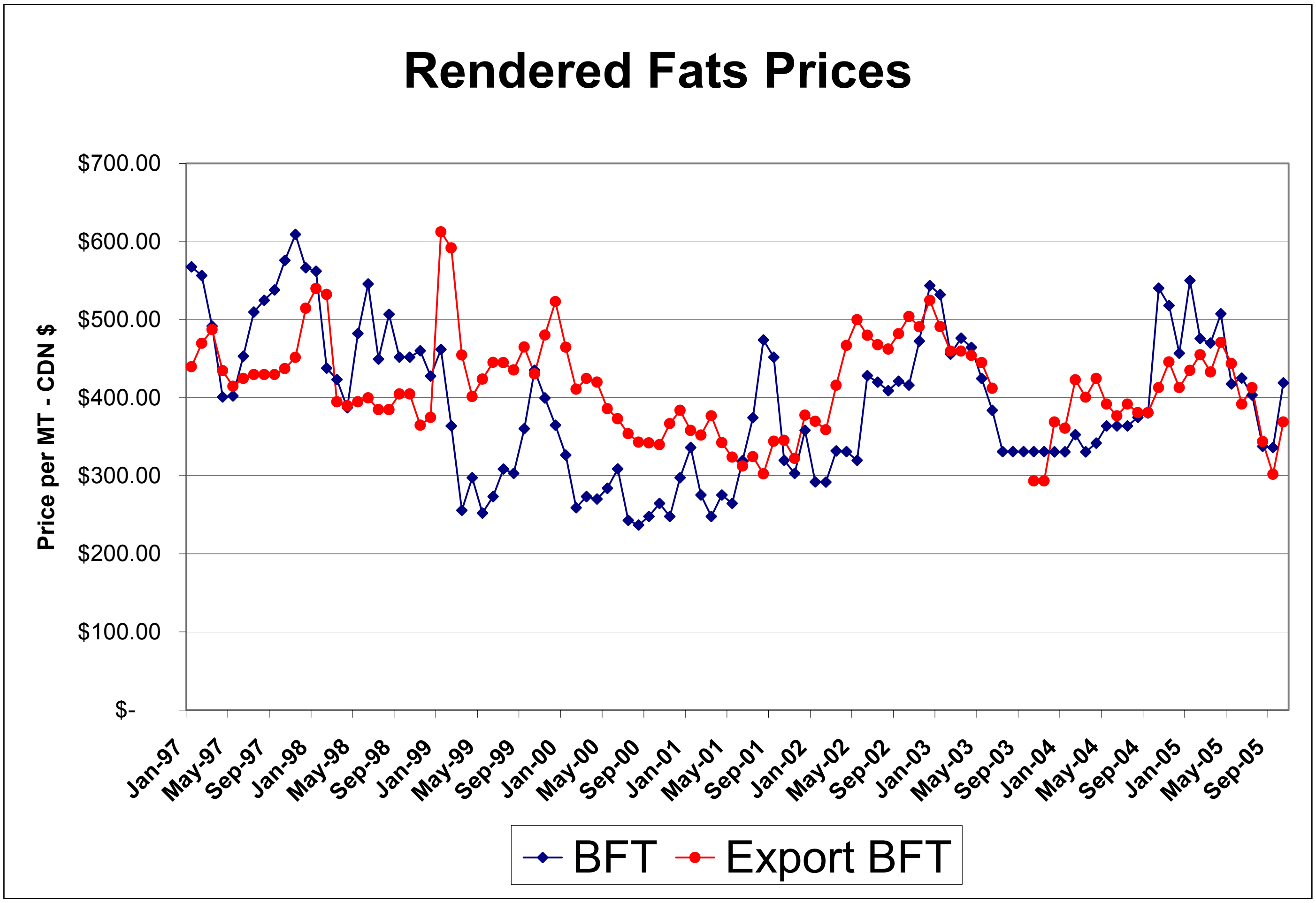
other uses. Internationally the market looks very different, with about 25% used in the soap market, 40% in chemical splitting process and about 35% in the animal feed sector.

3.4.3 Rendered Fats Prices

Figure 3.16 presents prices of bleachable fancy tallow process in Canada. BFT prices have ranged in a band from about $250/tonne to over $500/tonne. Interestingly, prior to the BSE case in May, 2003, export BFT was periodically sold for export at a premium to the domestic market. Trade restrictions since May 2003 have eliminated this premium.

Figure 3.16 presents the commodity markets for BFT and yellow grease. These prices appropriately reflect values in the chemical splitting market (and most likely in the biodiesel market). However, there is some price discrimination related to fragmented markets served by rendered fats and oils. In the rendered fats markets, feed provides a stable demand with a premium of approximately $25 over the chemical markets; this is followed by the premium paid for product in the export market.

Figure 3.16: Canadian Bleachable Fancy Tallow Prices



(Industry sources, 2006)

3.4.4 Understanding Rendered Fats Producers

The rendering industry in Canada is dominated by three companies, Rothsay (a division of Maple Leaf Foods) that has 6 plants in central and eastern Canada, West Coast Reduction with four plants in the prairies and British Columbia and Sanimal with operations in Quebec. Other smaller renderers including Cargil Packers and Tyson, both located in Alberta.

Table 3.12: Major Producers of Rendered Fats

Canada		
Rothsay Recycles	Independent Renderer	Newfoundland, Nova Scotia, Quebec, Ontario, Manitoba
Sanimal	Independent Renderer	Quebec, US
West Coast Reduction	Independent Renderer	Saskatchewan, Alberta, British Columbia
Cargil Packers	Packing plant	Alberta
Tyson	Packing Plant	Alberta
United States		
Darling International Inc.		United States
Baker Commodities		West Coast, United States
Carolina By-Products		Mid-western United States
Griffin Industries		Mid-western United States
Other International Companies		
Prosper Demulder Ltd.		Doncaster, South Yorkshire
Saria Bio-Industries		Germany
Rendac a Sobel Company		Holland

3.4.5 Synthesis

The supply of rendered fats in the Canadian market is a direct function of livestock slaughter, and the extent to which Canadian product can be exported. Slaughter will be far more responsive to meat and livestock prices than prices of rendered products. In the post-BSE environment, in which the domestic slaughter has increased and trade (both exports and imports) is restricted, the net effect has been to increase supplies and dampen prices in the Canadian market. The “anchor” customer of tallow appears to be the industrial chemical market, in which one would expect demand to be relatively steady. Feed is also an important customer, but substitution occurs frequently in this market, notably with yellow grease.

Thus, in the BSE-influenced environment in which trade restrictions on rendered materials persist, and demand is more likely to be steady (in chemical splitting) to soft (in feed), the prospects for prices to decrease are probably greater than to increase. What would reverse this conclusion would be some combination of relaxed trade restrictions, and sudden growth in demand.

3.5 Rendered Greases and Oils

Recycled oils are derived from the collecting of once used cooking oils from restaurants and industrial cooking facilities such as bakeries and removing water and debris. The most common recycled oil is yellow grease. In the US brown grease is also found from the cleaning of restaurant grease traps; however this is not available to buy in Canada. As shown in Table 3.11, brown grease contains higher levels of free fatty acids and other impure contents such as cleaning products, making it a more difficult to process into biodiesel than yellow grease. It is unlikely that brown grease would be used in Canada to produce biodiesel.

The processes that are used to clean and evaporate the water from the incoming waste cooking oil involve heating and filtering the product to remove water and debris as well as to sterilize the product. The waste cooking oil arrives for processing with average 40 % water, and 10 % unwanted material. This means that of the raw material delivered to a processing plant 50% by weight would be available to the biodiesel process.

Table 3.13

Name	Titer (hardness)	Free Fatty Acids %	Impurities %
Yellow Grease	33	15	1.5
Brown Grease	33	20	2.0

3.5.1 Rendered Greases and Oils Production

Yellow grease production data is not tracked; therefore many estimates of production are based on the theory that yellow grease production is highly correlated to population. S&T[2] Consultants *et al* (2004) estimated the production of yellow grease by determining a per capita production rate and applying it to the population. S&T[2] Consultants *et al. (2004)* used a yellow grease production rate of 4.1 kg per person from Wiltsee's study (1998) and multiplied it by the population of each province to get a Canadian total production of yellow grease in tonnes; see Table 3.14 below.

Table 3.14: Yellow Grease Production by Province, Tonnes

Province/ Territory	Population	Yellow Grease (tonnes)
British Columbia	4,141,272	16,903.2
Alberta	3,113,586	12,708.5
Saskatchewan	1,011,808	4,129.8
Manitoba	1,150,848	4,697.3
Ontario	12,068,301	49,258.4
Quebec	7,455,208	30,429.4
New Brunswick	756,652	3,088.4
Nova Scotia	944,765	3,856.2
PEI	139,913	571.1
Newfoundland	531,595	2,169.8
Yukon	29,924	122.1
NWT	41,203	169.0
Nunavut	29,715	121.3
Total	31,142,990	127,114.2

As of early 2006, the product available for use in biodiesel in Canada if all of it was used for biodiesel would be 171,000 MT or 194,598,000 litres. In the US the market there is 1,221,000 MT of product, or enough for 1,389,985,000 litres of biodiesel. Presently about 25 % of this product from the North American market is exported to overseas markets and could be readily available for biodiesel.

3.5.2 Rendered Greases and Oils Consumption

The major buyers of Yellow Grease are split very differently domestically than they are in other areas of the world. Within North America about 20% of the yellow grease is used by the chemical splits such as Unilever and 75 % in the animal feed business and 5 % in soap and other uses. In the international markets this looks very different; with 5 % being used in the soap market 10% in the chemical splitting process and about 85 % in the animal feed sector due to the fact that most countries have no way to heat the product and yellow grease stays in a liquid form and is easier to use in hot countries.

Similar to rendered animal fats, restrictions on imports and exports on these products have been in place since May 2003, with the outbreak of BSE in Canada. Any fats that contain or may contain ruminant material can not be shipped to the US market or imported into Canada. Because there is no proof what was used in the cooking process this product can not exported to the US or imported into Canada. These products can be exported to most other export markets if the have less than 0.15% impurities.

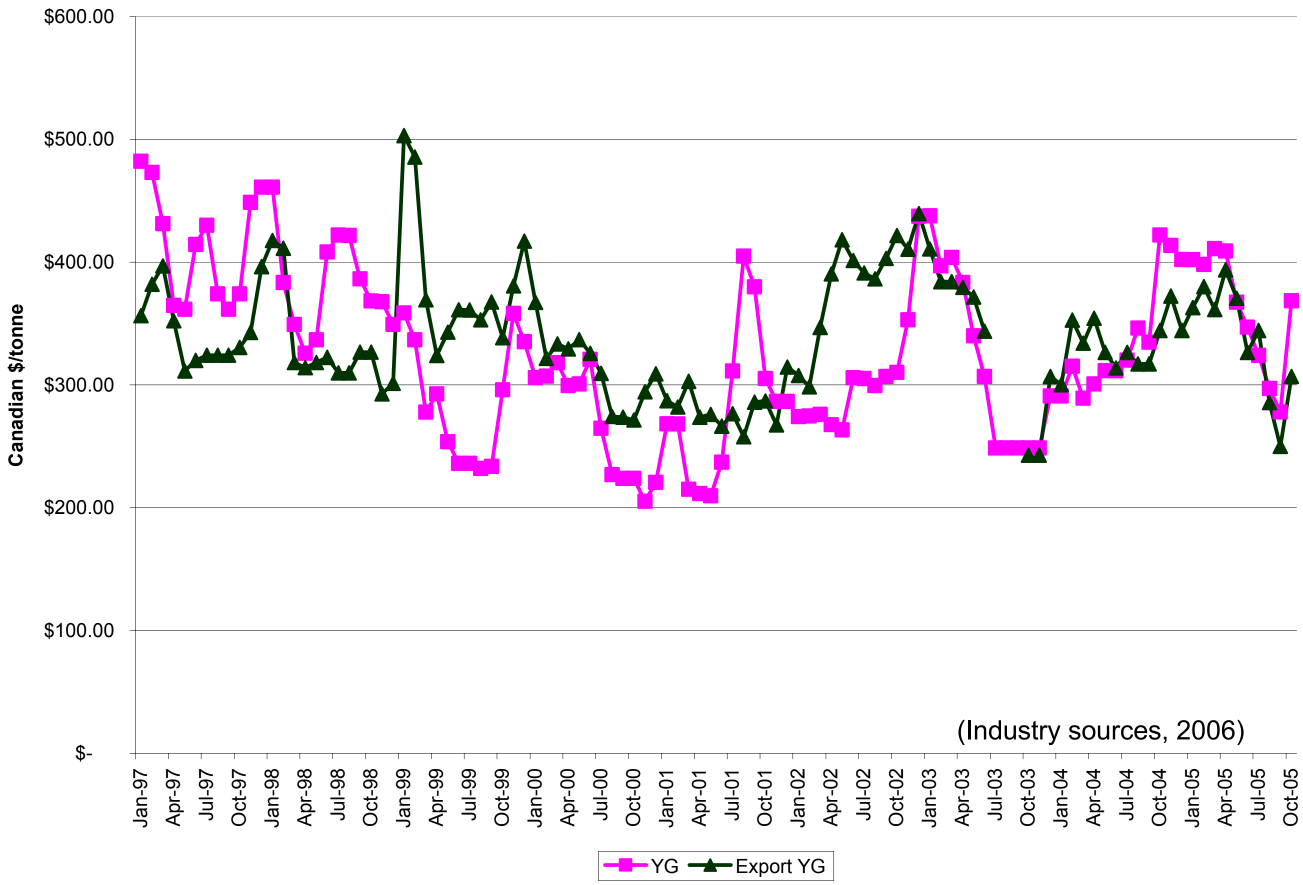
The situation in the EU is very different as restrictions that came into force in spring 2003 have made it basically impossible for North American Yellow Grease to import into their market for any use and has outlawed the export of EU Waste Cooking Oil as well. These same rules also restrict the use of Yellow Grease for any other purpose than incineration in government inspected facilities as it is considered a waste product and requires a waste-handling permit. At this time all the Waste Oiling Oil is being incinerated in government inspected waste to energy facilities. Many different companies and the National Renderers Association are working very hard to have these regulations changed but are having very little luck.

3.5.3 Rendered Greases and Oils Prices

In the rendered fats markets, feed provides a stable demand with a premium of approximately $25 over the chemical markets; this is followed by the export market. The yellow grease prices in Figure 3.17 trend the same as the rendered fats prices shown in Figure 3.16 but at a discount.

S&T^2 Consultants *et al* (2004) note that yellow grease is thought of as a ‘free’ feedstock to biodiesel generators because most generators of the grease must pay to have it disposed of. Therefore, biodiesel producers can essentially take the yellow grease at no charge; however it is expensive to remove the greases with the proper equipment. Therefore, the price of the equipment and collection can increase the price of yellow grease to roughly the same amount as animal fats.

Figure 3.17: Canadian Yellow Grease Prices



3.5.4 Synthesis

Rendered oils experience many of the same dynamics of rendered fats. The supply is likely to be price insensitive, since it is essentially pickups from restaurants which must otherwise pay to dispose of materials. The market is also influenced by trade restrictions stemming from BSE. The customers for rendered oils are largely feed, followed by chemical splitting. As noted above, the feed industry is characterized by least-cost ration balancing, which will have the impact of softening demand and exerting downward price pressure on the market. As with rendered fats, the principal factors required to reverse this dynamic will be a combination of a decrease in supply (which is unlikely, because the alternative is disposal), relaxation of trade restrictions, or a sudden growth in demand.

3.6 Summary and Observations

Two major markets heavily influence all fats and oils markets, they are the Soy Oil market in Chicago and the Malaysian Palm Oil market. The upward and downward trends in the Bleachable Fancy Tallow (BFT) market generally follow the overall trends of the Soya Oil market in Chicago, albeit at a discount, while the Malaysian Palm Oil markets supply a cap to a traded commodity price of tallow. Palm Sterine, for example, is a direct substitute for BFT in chemical and soap markets and customers will stick to it if the price of tallow is only a few dollars higher. Because of these facts a producer of biodiesel could use the Chicago market and Soy Oil to hedge the input cost of the feedstock to the biodiesel production facility. As well, to follow price forecasts for these markets one should be looking to commentary on the Soy Oil markets. Even with the inherent correlation in these markets, it would appear that the prospects of the spread between rendered oils and soy/canola widening is probably better than it tightening. Since Palm Oil will tend arbitrage against the rendered oils, the spread of it against soy/canola also has a better chance of widening than narrowing. In a competitive feedstock market, this serves as a negative in terms of using canola oil as a feedstock.

The implication is that the prospects of using rendered fats and oils as biodiesel feedstocks initially appear better than that of canola oil. However, one of the risks to building a biodiesel plant on the use of rendered fats and oils is the relative thinness of the market. The sudden uptake in oil could move the price relationship closer to the price of fresh oils such as soy and canola oil. This, however, will allow for the fresh oils for biodiesel production and could move toward closing the gap on the price and making fresh oils like canola a better opportunity.

4.0 Conceptual Model

The basic problem faced by biodiesel manufacturers is that of least-cost feedstock procurement, given plant capacity and relative yields of biodiesel from feedstocks. This behavior is fundamental in understanding the role of canola oil in a reshaped fats and oils market due to increased biodiesel production.

However, because the purpose of this study is to consider the strategic position of canola oil given targeted biodiesel production, a slightly different approach is taken. Like the least-cost feedstock problem above, the issue is one of cost minimization across candidate feedstocks subject to constraints. Because biodiesel must compete for feedstocks against fats and oils used in food, fats and oils used in feed, and fats and oils used in soap manufacturing and chemical splitting, the model is set up to minimize the cost of producing each of these based on historical levels. The relevant feedstocks are canola oil, soybean oil, tallow, yellow grease, and imported palm oil. Constraints are imposed on the model that require it to meet biodiesel targets, plus Canadian fat and oil demand in foods, Canadian fat and oil demand in feed, and Canadian fat and oil demand in soap manufacturing/chemical splitting. The structure of the conceptual model is thus the following:

Minimize- Cost of canola oil + cost of soybean oil + cost of tallow + cost of yellow grease + cost of palm oil.

With constraints:

Must satisfy biodiesel demand target
Must satisfy Canadian demand for fats and oils in food
Must satisfy Canadian demand for fats and oils in feed
Must satisfy Canadian demand for fats and oils in soap manufacturing and chemical splitting
Historic levels of feedstock imports are maintained

The above model is conceived as a linear programming model that solves for a least-cost set of feed ingredients given the constraints. Note that exports are not part of the conceptual model; this is intentional to allow flexibility for exports to be drawn back into the domestic market to satisfy biodiesel demand. Historic levels of imports are initially held fixed to prevent imports from swamping demand; this is later relaxed to examine potential price effects. Two versions of the least-cost model are tested. In the first, it is assumed that feedstock prices do not change with respect to feedstock demand. In the second, prices at current levels of feedstock demand (zero biodiesel production) are used as a base, with additional demand related to price based on an elasticity of demand. The complexities require this latter model to be solved as a non-linear programming model.

It must be emphasized that the primary purpose is to consider how candidate feedstocks would be allocated if new demand from biodiesel were to occur, based on data from periods in which no biodiesel demand existed. Thus, the emphasis is on feedstock displacement and substitution across uses given demand constraints, rather than on how much biodiesel could be produced. This is important to recognize because feedstock availability, through increased domestic acreage, increased domestic yields from hybrid technology, and/or increased import, would adjust over time to meet the needs of biodiesel production. By holding feedstock availability constant at historic levels, the least-cost allocation of feed stocks given biodiesel demand and the resulting displacement and substitution can be directly observed.

4.1 Data

In order to operationalize the conceptual model, data must be obtained and formulated into the various components of it.

4.1.1 Biodiesel Yields

The yield of biodiesel from the various feedstocks must be empirically characterized in the model's technical coefficients. This is surprisingly straight forward and general across feedstocks. Based on industry sources, by reacting 1000 kg of feedstock (fat or oil) with 100 kg of methanol and a catalyst, a yield of 1010 kg of biodiesel and 90 kg of glycerin is obtained. Thus, the yield of biodiesel from feedstock by weight is 101%. In converting biodiesel weight to volumes (to meet the production target) the density of biodiesel is .88 g/litre, so each tonne of feedstock yields approximately 1138 litres of biodiesel.

As described above, alternate conceptions exist of blend targets for biodiesel as a proportion of diesel consumption. Based on domestic annual diesel consumption of just over 25 billion litres, a biodiesel blend rate of 2% would represent 503 million litres, and a 5% blend would be 1.257 billion litres, respectively. Given the historic supply level of feedstocks, it is unclear what level of biodiesel blend would initially be feasible. Thus, the blend requirement is increased incrementally by 1 percentage point until the infeasible level of biodiesel blend is determined.

4.1.2 Canadian Fat and Oil Demand in Foods

Annual demand for fats and oils in foods must be supplied by canola oil, soybean oil, butterfat, palm oil, other tropical oils and minor vegetable oils (peanut oil, sunflower oil, etc.). Bleachable Fancy Tallow and yellow grease are treated as inedible products, and cannot be used to satisfy Canadian demand for fats and oils. For simplicity, we focus on the major vegetable oils described above - canola, soybean, and palm. Inquiries with food industry contacts confirmed that while trimmings obtained from livestock slaughter are used in certain food uses (tallow in foodservice French fry cooking oils, shortenings, etc.) the magnitude is quite small and is ignored here.

To estimate the Canadian use of fats and oils in foods, data on per capita consumption (disappearance) of fats and oils collected from Statistics Canada's *Food Statistics* (2004). This data is derived from a supply - disposition approach, and the values published in the retail weight include oils and fat available for purchase by consumers, oils or fat used in food manufacturing, oil used as cooking media, and oil used in food services. The data also include butterfat which is essentially fixed in supply through the dairy marketing system, and which must be removed from the analysis. The most recently available data from the 2004 report show per capita consumption of fats and oils in food of 32.83 kg/capita, with 3.08 kg/capita from butterfat; thus, the net per capita consumption of vegetable oils is 29.75 kg/capita. This value is used in combination with the most recent population estimate of 32,270,507 to obtain an aggregate demand for fats and oils in food of 960,048 tonnes.

4.1.3 Canadian Fat and Oil Demand in Feed

Data on the use of fats and oils in feeds in Canada is generally unavailable. As a result, assumptions must be used to construct demand values. Under one approach the relative shares of total fat and oil production according to end use are solicited by market participants, and based on total supply of product these shares are used to estimate the total feed market across feed stocks. Alternatively, an assumption can be made regarding the inclusion rate of fats and oils in livestock rations, and then aggregated up to total Canadian feed production. Because of the variability across rations and specificity of some feeds with regard to specific types of oils and fats, the former approach was chosen over the latter.

Based on discussions with individuals familiar with the rendering and feed manufacturing industries, it was felt that typically 10% of soybean oil was used in the feed market. Approximately 50% of tallow production is believed to be used in feed, and 75% of yellow grease production is used in feed. It is believed that virtually no palm oil is used in the Canadian feed market.

Based on the above assumptions, the data below on stylized production (domestic production and imports) was used in combination with the above assumptions on product use to generate an estimate of Canadian market consumption. Within that Canadian market consumption, substitution across fats and oils, which may not currently be occurring, is allowed for in order to measure the impact of new biodiesel demand.

4.1.4 Canadian Fat and Oil Demand in Soap Production and Chemical Splitting

As with fat and oil use in feed, statistics on Canadian fat and oil use in soap production and chemical splitting is generally unavailable. As a result, we use the same approach as above. Individuals familiar with fat and oil markets believe that negligible amounts of canola oil are used in soap and chemicals. About 40% of soybean oil is used in soaps and chemicals, about 40% of tallow, and about 25% of yellow grease is used in soaps and chemicals. Imported palm oil is heavily used in soap and chemical production; respondents believed that about 80% of palm oil was used in this market.

As above, the data below on stylized production (domestic production and imports) was used in combination with the above assumptions on product use to generate an estimate of Canadian consumption in soap and chemical production. Within Canadian consumption of fats and oils in soap and chemical splitting, substitution across fats and oils, which may not currently be occurring, is allowed in order to measure the impact of new biodiesel demand.

4.1.5 Feedstock Production

Feedstock production data were obtained from the sources cited in Section 3 above. Canadian canola oil production was taken as the 2000-05 average of just under 1.2 million tonnes. Canadian soybean oil production was also taken as the average over the 2000-05 period published by the USDA FAS at 282,000 tonnes. With regard to production of rendered fats, industry sources were used to determine production because of the relative lack of quality of official statistics in appropriately tracking production from all sources (for example, deadstock). Thus, we assume a total annual production of tallow of 389,150 tonnes and total annual production of yellow grease of 171,000 tonnes.

4.1.6 Feedstock Imports

Imports of certain feedstocks, notably soybean oil and palm oil, are material in determining the available supply of fats and oils in Canada. This is not a material issue with regard to canola oil, tallow and yellow grease, since Canada is a surplus producer. Data from Statistics Canada was averaged over the period 2003-2005, to give average annual imports of 102,033 tonnes and 14,000 tonnes for soybean oil and palm oil, respectively. These data are current rather than longer term averages to reflect the ongoing adjustment occurring since the Canadian cases of BSE.

4.1.7 Feedstock Prices

Market prices for feedstocks were obtained from government and industry sources. Canola oil prices were obtained from the Statistics Canada Grain and Oilseed Review, basis Vancouver. An average was obtained over the crop years 2003/04, 2004/05, and 2005/06 up to December 2005. This gives an average canola oil price of $705/tonne. Soybean oil prices were obtained from AAFC which represent nearby futures prices, quoted in Canadian dollars. The same period of data was selected as with canola oil, with the caveat that the crop year for soybean oil is September to August, rather than August to July. This gives an average soybean oil price of $670/tonne.

Tallow and yellow grease prices were obtained from industry sources, and are the same series as that presented in Figures 3.16 and 3.17 above. The average of these prices was taken over the period May 2003 to October 2005 to reflect the BSE-influenced trade environment. The average tallow price observed was $394/tonne, and the average yellow grease price was $328/tonne.

A thorough search and consultation with rendering industry contacts did not yield historic Canadian-basis palm oil prices. Industry contacts suggested that palm oil is largely a west coast soap production feedstock, and that when ocean freight from Indonesia or Malaysia was added, it tended to be priced competitively with vegetable oils. Referring to Figure 3.15, it is evident that palm oil has varied between $US 250-450/tonne, Malaysia basis, since 2000-2001. Assuming an exchange rate of $Can 1= $US .85, that price range is $Can 294-529/tonne. Further assuming that freight from Malaysia is $40/tonne, Canadian delivered prices for palm oil should lie in the range of $Can 334-569/tonne. The midpoint of this range ($452/tonne) is used as the baseline price for palm oil in Canada.

4.1.8 Feedstock Exports

Canada is or has been a material exporter of some of the feed stocks considered, notably canola oil and rendered fats. Thus, data on historic production naturally exceeds domestic consumption. However, it is clear that if production is held at historic levels, all uses of feedstocks are held at historic levels, and exports are held at historic levels, it would be simply impossible to supply new demands from biodiesel. In fact, the new demand will be met through substitution across feed stocks and through reallocation of uses within a given feedstock. Given this later consideration, historic exports are not specified as a constraint in the model; rather, they are treated as a residual from domestic use. This allows former exports to serve as a possible source of product used in the domestic market in response to biodiesel demand. In addition, in the scenarios in which price fluctuates with volume, it is assumed that the canola oil price is not responsive to export volume, and that it is domestic volume which influences canola oil prices. This is done to focus on the potential impact of domestic biodiesel demand and to abstract from the impact of historic export levels and the resulting price effects.

4.2 Model Tests

In applying the model described above, two broad scenarios were considered. In the first, the prices of feedstocks were assumed not to adjust in response to changes in demand due to biodiesel. Under this scenario, the effect of new demand due to biodiesel can be inferred by considering the shadow values on model constraints. A base run was considered in which the biodiesel blend requirement was zero; the percentage of total Canadian diesel consumption that would be filled by biodiesel was then iteratively increased.

Under the second scenario, it was assumed that feedstock prices could adjust to changes in demand due to biodiesel. This was done by using own-price elasticities of demand in combination with baseline feedstock prices and volumes and actual volumes under alternative biodiesel blend levels. Elasticities for canola oil, soybean oil, and palm oil were obtained from the Food and Agricultural Policy Research Institute (FAPRI) database. These are detailed in Table 4.1 below. Elasticity estimates were unavailable for tallow and yellow grease, and must thus be based on assumption. Given the BSE-influenced trade environment, it is reasonable to assume that demand for tallow and yellow grease would be relatively more responsive to price than for vegetable oils. As a result, an elasticity of -1 is employed.

Table 4.1: Own-price Elasticities of Demand Employed

Product	Elasticity	Basis
Canola Oil	-.35	Canada, food (FAPRI)
Soybean Oil	-.17	Canada, food (FAPRI)
Palm Oil	-.38	World outside of Southeast Asia, food (FAPRI)
Tallow	-1	Assumed value
Yellow Grease	-1	Assumed value

5.0 Empirical Results

The results obtained from the models described above are fragmented into two sections. Section 5.1 presents the results of scenarios with fixed feedstock prices. Section 5.2 presents results assuming feedstock prices fluctuate according to the elasticities in Table 4.1. Section 5.3 summarizes the results of the section.

5.1 Model Results Assuming Constant Feedstock Prices

To solve for minimum feedstock procurement costs, the above parameters were used to build a linear programming model in an Excel spreadsheet, and solved using the “solver” function with the help of an add-in that increases the solver’s capacity. Table 5.1 below presents the base run least-cost analysis, assuming that biodiesel demand is not a component of demand in the fats and oils complex. The results show that canola oil is allocated to domestic food oil demand (which it supplies most of), into soap and chemicals, or is exported. Soybean oil is used in food only, with tallow use split between soap and chemicals and feed. Yellow grease is used exclusively in the soap and chemical market, with palm oil used exclusively in food. The cost of supplying the domestic demands for fats and oils is about $985 million.

Table 5.2 considers the first scenario in which biodiesel demand influences the Canadian fat and oil complex through a mandated 1% biodiesel blend requirement. The table shows that at a 1% blend requirement, feedstocks are required to supply 251 million litres of biodiesel per year. To meet this demand, compared with the base run, the food use of canola oil increases slightly but with previously exported canola oil moving into more soap/chemical use and feed use. Exports are reduced but remain significant. Compared with the base run, soybean oil use is unchanged and remains strictly in food. Tallow is reallocated from soap and chemical use and into biodiesel and feed. Yellow grease is reallocated entirely from soap and chemical use to biodiesel production, as is palm oil which is reallocated from food. The total cost of supplying domestic demands increases about 16% to $1.14 billion.

The factors underpinning the solution in Table 5.2 are interpreted in Table 5.3. The first column in Table 5.3 gives the final optimal value of solved model variables. The second column gives the shadow value of these variables, which indicates the change in total cost that would result from a marginal increase in the level of the constraint. The last two columns indicate the allowable increase and decrease in constraints before the optimal solution would change.

Table 5.1: Base Run, 0% Biodiesel Blend Requirement

	Biodiesel (tonnes)	Food (tonnes)	Feed (tones)	Soap and Chemical (tonnes)	Export (tonnes)	Price ($/tonne)
Canola Oil	-	561,715	-	164,451	471,834	705
Soybean Oil	-	384,333	-	-	-	670
Tallow	-	-	361,258	27,892	-	394
Yellow Grease	-	-	-	171,000	-	328
Palm Oil	-	14,000	-	-	-	452
Total	-	960,048	361,258	363,343	471,834	
Biodiesel produced (litres)				0		
Total cost, all domestic products ($)			985,191,240			

Table 5.2: Least-Cost Feedstock Allocation Assuming a 1% Biodiesel Blend Requirement

	Biodiesel (tonnes)	Food (tonnes)	Feed (tonnes)	Soap and Chemical (tonnes)	Export (tonnes)	Price ($/tonne)
Canola Oil	-	575,715	8,075	363,343	250,867	705
Soybean Oil	-	384,333	-	-	-	670
Tallow	35,967	-	353,183	-	-	394
Yellow Grease	171,000	-	-	-	-	328
Palm Oil	14,000	-	-	-	-	452
Total	220,967	960,048	361,258	363,343	250,867	
Biodiesel produced (litres)			251,534,000			
Total cost, all domestic products ($)			1,140,972,694			

Table 5.3: Factors Constraining Feedstock Markets at a 1% Biodiesel Blend Requirement

Name	Final Value	Shadow Value	Range of Optimal Value Increase	Range of Optimal Value Decrease
Biodiesel Demand	251,534,000	1	285,488,631	9,188,945
Total fats and oils, food use	960,048	705	250,867	575,715
Total fats and oils, feed use	361,258	705	250,867	8,075
Total fats and oils, Soap & Chem use	363,343	705	250,867	363,343
Canola Oil Supply	947,133	-	1E+30	250,867
Soy Oil Supply	384,333	(36)	575,715	250,867
Tallow Supply	389,150	(311)	8,075	250,867
Yellow Grease Supply	171,000	(377)	8,072	171,000
Palm Oil Supply	14,000	(253)	8,072	14,000

Table 5.3 shows that the biodiesel demand could more than double before the optimal solution is changed markedly, but that it would change for a biodiesel demand of 9.2 million litres less than the 1% blend target. The implication of the shadow value on the food, feed, and soap and chemical use of $705 (which corresponds to the canola oil price) is that marginal increases in the demands for these products would be served by canola oil. The negative signs on the soy oil, tallow, yellow grease, and palm oil supply constraints indicate that if additional amounts of these were available, the total cost of supply would decrease. As indicated by its largest negative sign, additional units of yellow grease would decrease costs the most in meeting demands. Indeed, if additional yellow grease were available it would be used in biodiesel production and supplant canola oil as a feedstock, which would be exported. The shadow value of zero on canola oil indicates that its supply constraint does not bind; indeed, some canola oil remains and is available for export.

Table 5.4 presents the results of the analysis assuming a 2% biodiesel blend requirement. This results in production of just over 503 million litres of biodiesel. The demand for biodiesel again results in all available yellow grease and all available palm oil being used in biodiesel production. Canola oil use is split into food (575,715 tonnes), soap and chemical (363,343 tonnes) and feed (229,105 tonnes), with a small amount available for export. Soybean oil is used entirely in food uses. Tallow is reallocated from feed into biodiesel.

Table 5.5 provides interpretation of the factors driving the results in Table 5.4. In many respects, the results reported in Table 5.5 are just an extension of those in Table 5.3. The table shows that additional requirements for fats and oils in food, feed, and soap/chemical would be met by canola oil that can be accessed from supplies that would be otherwise exported. However, canola oil would only satisfy an increase in demand in these uses of up to 29,837 tonnes - precisely the level of canola oil exports under the 2% blend option. As with the 1% blend option, the greatest benefit in reducing feedstock procurement cost is an increase in the availability of yellow grease, which would result in tallow moved back into feed use, and movement of canola oil into export.

Table 5.4: Least Cost Feedstock Allocation Assuming a 2% Biodiesel Blend Requirement

	Biodiesel (tonnes)	Food (tonnes)	Feed (tonnes)	Soap and Chemical (tonnes)	Export (tonnes)	Price ($/tonne)
Canola Oil	-	575,715	229,105	363,343	29,837	705
Soybean Oil	-	384,333	-	-	-	670
Tallow	256,997	-	132,153	-	-	394
Yellow Grease	171,000	-	-	-	-	328
Palm Oil	14,000	-	-	-	-	452
Total	441,997	960,048	361,258	363,343	29,837	
Biodiesel produced (litres)			503,068,000			
Total cost, all domestic products ($)			1,296,799,160			

Table 5.5: Factors Constraining Feedstock Markets at a 2% Biodiesel Blend Requirement

Name	Final Value	Shadow Value	Range of Optimal Value Increase	Range of Optimal Value Decrease
Biodiesel Demand	503,068,000	1	33,954,631	260,722,946
Total fats and oils, food use	960,048	705	29,837	575,715
Total fats and oils, feed use	361,258	705	29,837	229,105
Total fats and oils, Soap & Chem use	363,343	705	29,837	363,343
Canola Oil Supply	947,133	-	575,715	29,837
Soy Oil Supply	384,333	(35)	229,105	29,837
Tallow Supply	389,150	(311)	229,026	29,837
Yellow Grease Supply	171,000	(377)	229,026	29,827
Palm Oil Supply	14,000	(253)	575,715	14,000

At biodiesel blends much in excess of 2%, meeting domestic demands becomes infeasible given assumed supply constraints. In effect, once all canola exports are drawn back into the domestic market, the ability to supply biodiesel production is capped. The shadow values obtained above show that the least-cost means to obtain additional biodiesel production would be to augment yellow grease production, or import it. The next best option is to augment the tallow supply, followed by increased imports of palm oil.

The above suggests that fats and oils could only support a biodiesel blend of just over 2%. However, this is based on historical data in which demand stemming from biodiesel production was not perceived by producers. Had biodiesel demand been in place, there would have been flexibility for response, particularly in terms of increased Canadian acreage of canola and soybeans, and increased imports of soybean oil and palm oil. Because it is relatively fixed in supply, adjustment in tallow and yellow grease is unlikely. Thus, the above should not be interpreted to mean that insufficient feedstock exists to meet the 5% level; rather, the implication is that absent biodiesel demand acreage and crushing capacity did not reorient itself to meet it. This is particularly the case given that a 5% blend requirement would not come into force until 2015.

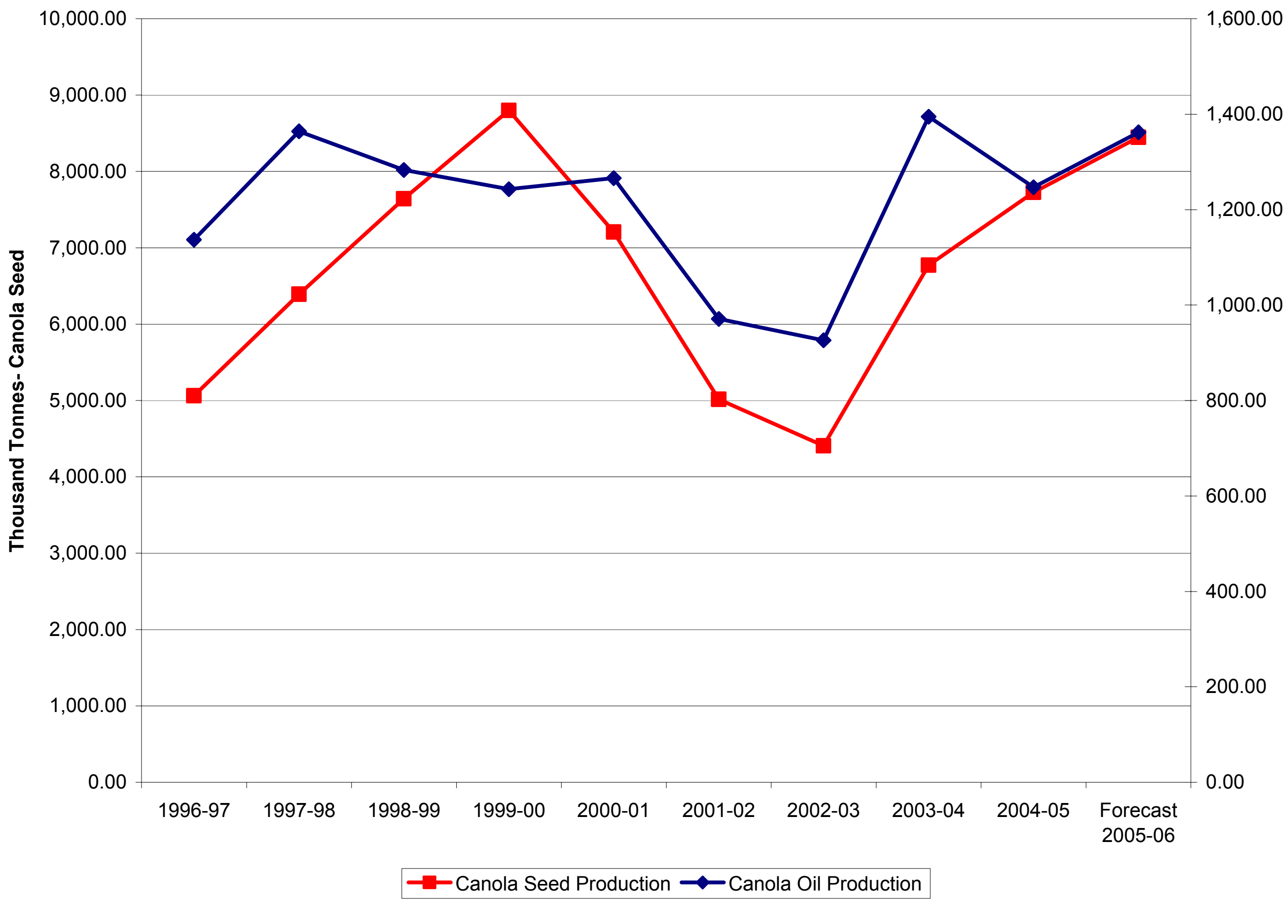
Some evidence that canola oil production could significantly expand to meet new demands for fats and oils due to biodiesel is presented in Figure 5.1 below. The figure plots Canadian canola oil and seed production since 1996-97. It shows that 2005-06 production of canola seed and canola oil have grown to levels around 50% higher than those in 2000-01. One can therefore infer that if market opportunities present themselves, supply has flexibility to respond.

To capture this flexibility, the scenarios above are augmented to assume that growth in supply of up to 50% over historic levels could occur in canola oil, soybean oil, and palm oil feedstocks in response to demand from biodiesel production. It is assumed that tallow and yellow grease would not have material capacity for expansion because the livestock slaughter rendered grease supply is not sensitive to fat and oil values.

The results are presented in Table 5.6. Under this scenario, canola oil would serve the bulk of the Canadian food oils market. All available tallow, yellow grease, and palm oil would be used in biodiesel production, as would most of the soybean oil. Canola oil would be used extensively in feed and soap/chemical use to fill volumes displaced by biodiesel demand.

The sensitivity of results at the 5% blend requirement is presented in Table 5.7. The table shows that all available soybean oil, tallow, yellow grease and palm oil are used in meeting product demands. Additional canola oil is available, which is exported. The shadow values in the table show that the additional availability of yellow grease creates the greatest reduction in cost, followed by tallow and palm oil. Canola oil does not bind the solution, so its shadow value in meeting domestic supply constraints is zero.

Figure 5.1 Canadian Canola Seed and Canola Oil Production



Source: Canadian Canola Council

Table 5.6: Least Cost Feedstock Allocation Assuming a 5% Biodiesel Blend Requirement

	Biodiesel	Food	Feed	Soap and Chemical	Export	Price ($/tonne)
Canola Oil	-	907,484	361,258	363,343	164,915	705
Soybean Oil	523,936	52,564	-	-	-	670
Tallow	389,150	-	-	-	-	394
Yellow Grease	171,000	-	-	-	-	328
Palm Oil	21,000	-	-	-	-	452
Total	1,105,086	960,048	361,258	363,343	164,915	
Biodiesel produced (litres)	1,257,670,000					
Total cost, all domestic products ($)	1,755,780,028	78%				

Table 5.7: Factors Constraining Feedstock Markets at a 5% Biodiesel Blend Requirement

Name	Final Value	Shadow Value	Range of Optimal Value Increase	Range of Optimal Value Decrease
Biodiesel Demand	1,257,670,000	1	59,817,607	596,242,344
Total fats and oils, food use	960,048	705	164,915	907,484
Total fats and oils, feed use	361,258	705	164,915	361,258
Total fats and oils, Soap & Chem use	363,343	705	164,915	363,343
Canola Oil Supply	1,632,085	-	> 1,000,000,000	164,195
Soy Oil Supply	576,500	(35)	907,484	52,564
Tallow Supply	389,150	(311)	523,936	52,564
Yellow Grease Supply	171,000	(377)	523,755	52,545
Palm Oil Supply	21,000	(253)	523,755	21,000

5.1.1 Sensitivity Analysis

The above suggests that canola oil is not a direct source of feedstock for biodiesel production. Rather, as biodiesel demand for feedstocks increases, canola oil fills the void in feed and soap/chemical markets for other feedstocks drawn into biodiesel manufacturing. In the main, canola oil remains a food oil along with soybean oil.

To test the sensitivity of these results, the canola oil price was reduced iteratively by $5/tonne under the 2% blend scenario until a change in the optimal solution was observed. The results showed that at a canola oil price of $665/tonne, which is $5/tonne less than soybean oil, the least cost results changed. This is illustrated in Table 5.8 below. The tables shows that relative to the results in Table 5.4 at base canola oil prices, more canola oil is used in food, supplanting some soybean oil which is exported. Canola oil is used entirely in the domestic market and exports go to zero. No other changes in allocation result and, in particular, no canola oil is used directly in biodiesel production. This adjustment is robust; in fact, the canola oil price can be reduced arbitrarily lower and no further changes result.

Table 5.8: Impact of Reduced Canola Oil Price, Assuming a 2% Biodiesel Blend Requirement

	Biodiesel	Food	Feed	Soap and Chemical	Export	Price ($/tonne)
Canola Oil	-	605,552	229,105	363,343	-	665
Soybean Oil	-	354,496	-	-	29,837	670
Tallow	256,997	-	132,153	-	-	394
Yellow Grease	171,000	-	-	-	-	328
Palm Oil	14,000	-	-	-	-	452
Total	441,997	960,048	361,258	363,343	29,837	
Biodiesel produced (litres)			503,068,000			
Total cost, all domestic products ($)			1,249,923,454			

A second scenario is explored as part of model sensitivity in which the substitutability of vegetable oils in food is considered. Under the above scenarios, it was assumed that canola oil, soybean oil, and palm oil are perfect substitutes. However, in practice canola oil has a preferred fatty acid profile from a health perspective. To a large extent this is accounted for by the price premium for canola oil relative to soybean and palm oils. If canola oil is to become more dominant over substitutes in the future however, it may be argued that the price premium underestimates the true preference for canola oils in food.

To test the sensitivity of results to a distinct preference for canola oil in foods, the “yield” coefficient for canola oil in foods is adjusted to be 5% higher than in soybean and palm. The impact is to require less total vegetable oil to satisfy Canadian demand, but more importantly, it imposes a demand preference for canola oil over substitutes and allows the resulting displacement in biodiesel feedstock supply to be observed. This is tested at the 2% biodiesel blend level.

The results are presented in Table 5.9 below. The 5% preference in favour of canola oil in foods is sufficient to drive all other substitutes out of food use. In particular, soybean oil moves into feed and soap/chemical use, which allows greater export of canola oil. The allocation of feedstocks into biodiesel production is unchanged.

Table 5.9: Impact of Canola Oil Price Preference in Foods, Assuming a 2% Biodiesel Blend Requirement

	Biodiesel	Food	Feed	Soap and Chemical	Export	Price ($/tonne)
Canola Oil	-	914,331	-	208,115	75,554	705
Soybean Oil	-	-	229,105	155,228	-	670
Tallow	256,997	-	132,153	-	-	394
Yellow Grease	171,000	-	-	-	-	328
Palm Oil	14,000	-	-	-	-	452
Total	441,997	914,331	361,258	363,343	75,554	

Biodiesel produced (litres)	503,068,000
Total cost, all domestic products ($)	1,264,568,977

5.2 Model Results Assuming Adjustment in Feedstock Prices

To explore potential direct price impacts on canola oil and substitutes, the above model was expanded to incorporate the demand function for the products. This was done using the elasticities presented in Table 4.1 and assuming the base product consumption under the scenario above in which there is no feedstock demand for biodiesel. Thus, the product consumption levels obtained in Table 5.1 are applied, and the base scenario under variable prices is identical to that assuming fixed prices. Under increased demand from biodiesel, two sets of scenarios are considered. In the first, only the price of canola oil adjusts to changes in feedstock demand. In the second, the prices of all feedstocks respond to the increased demand from biodiesel.

Because both feedstock allocations and prices change simultaneously under this scenario, the cost minimization function is non-linear in the quantities of each feedstock used. Thus, a non-linear solution technique has to be used. The Excel solver used was changed such that it applied a non-linear programming algorithm, and to start each scenario, values were reset to the base run in Table 5.1 to be consistent with the elasticity estimate.

5.2.1 Analysis Assuming Flexibility in Canola Oil Prices Only

Given the constraints described in Section 4 above and in Section 5.1, only canola oil has material exports that can be drawn back into the Canadian market to satisfy biodiesel demand. The other feedstocks are either imported, or Canada faces trade restrictions that result in production being used domestically. The implication of this is that without changing assumptions regarding production and import levels of other feedstocks, only canola oil prices can change. However, to the extent that Canada is a small country relative to the rest of the world in the markets for soybean oil and palm oil, and because of restricted trade in rendered fats due to BSE, this scenario may be relevant.

As described above, if biodiesel feedstock demand is zero, then the results are identical to those presented in Table 5.1 above. Table 5.10 presents the results of a 1% biodiesel blend requirement on feedstock allocation and prices. The results show that canola oil domestic use is mostly in food and soap/chemical, with some use in feed and biodiesel, along with significant exports. Canola oil prices increase from $705/tonne to $780/tonne under this scenario. Soybean oil is used in food, with small amounts in feed and biodiesel. Biodiesel demand is served mostly by yellow grease. Tallow is used in the feed and soap/chemical markets, and biodiesel markets. Palm oil use is dedicated to food.

Table 5.11 presents the results under the 2% biodiesel blend scenario with fluctuating canola oil prices. Not surprisingly, when the biodiesel demand increases and only canola oil prices can adjust, canola oil prices increase. Under this scenario, canola oil prices increase to $855/tonne, and canola oil is used in food and soap/chemical markets, with smaller amounts used in feed and biodiesel. Soybean oil remains is used mainly in food, with some use in biodiesel and feed dedicated to the food market. Tallow is used in feed and biodiesel production. Yellow grease and palm oil are dedicated to biodiesel production.

5.2.2 Analysis Assuming Fluctuation in All Feedstock Prices

To consider the impact of price changes in all feedstocks, an additional assumption was required. In the above analysis, the prices of other feedstocks could not change because their total quantities in the domestic market were essentially fixed. Thus, no additional volume can come into the domestic market and influence prices. At the same time, if it were assumed that an infinite additional volume could either be produced domestically or imported, the solution would be unbounded. To resolve this issue, it is assumed that additional domestic production or imports of all feedstocks of up to 50% of base could be obtained. This provides a clearer picture of potential price movement, given that additional production and/or import substitution could occur. It must be observed, however, that this assumption is primarily used to allow price dynamics to be observed, rather than to model actual adjustment. In particular, it is unlikely that significant supply adjustments would actually occur in tallow and yellow grease; price adjustment would occur however.

Table 5.12 below presents the results of the 1% canola oil blend requirement, assuming that the prices of all feedstocks could fluctuate. Under a 1% blend requirement with a supply response from competing feedstocks, canola oil prices would fall somewhat to $676/tonne; the prices of all other feedstocks increase. This is a function of expanded supplies and of competing feedstocks, and the assumption of an additional 50% supply of all feedstocks. In particular, canola oil is displaced in foods somewhat by increased soybean oil availability, and its use in soap and chemicals is reduced, with exports increasing markedly. Soybean oil is used only in food. Tallow is used in feed, and soap/chemical production, with yellow grease split between biodiesel and soap/chemical. Palm oil is used only in biodiesel.

Interestingly, given the additional availability of product assumed, most of the supply constraints do not bind the solution. This is evident from Table 5.13 below, which presents the shadow values resulting from constraints in the model. The table shows that the shadow values on the canola oil, soybean oil, tallow, and yellow grease supplies are zero, implying that more is

Table 5.10: Least-Cost Feedstock Allocation, Assuming a 1% Biodiesel Blend Requirement and Canola Oil Price Adjustment

	Biodiesel	Food	Feed	Soap and Chemical	Export	Price ($/tonne)
Canola Oil	7,963	595,954	26,318	316,902	250,862	780
Soybean Oil	7,953	350,093	26,287	-		670
Tallow	34,055	-	308,654	46,441		394
Yellow Grease	171,000	-	-	-		328
Palm Oil	-	14,000	-	-		452
Total	220,971	960,048	361,258	363,343	250,862	
Biodiesel produced (litres)			251,534,000			
Total cost, all domestic products ($)			1,212,157,725			

Table 5.11: Least-Cost Feedstock Allocation, Assuming a 2% Biodiesel Blend Requirement and Canola Oil Price Adjustment

	Biodiesel	Food	Feed	Soap and Chemical	Export	Price ($/tonne)
Canola Oil	41,794	706,289	56,742	363,343	29,832	855
Soybean Oil	76,945	253,759	53,629	-		670
Tallow	138,263	-	250,887	-		394
Yellow Grease	171,000	-	-	-		328
Palm Oil	14,000	-	-	-		452
Total	442,002	960,048	361,258	363,343	29,832	
Biodiesel produced (litres)			503,068,000			
Total cost, all doemstic products ($)			1,472,251,363			

Table 5.12: Least-Cost Feedstock Allocation, Assuming a 1% Biodiesel Blend Requirement and Price Adjustment in All Feedstocks

	Biodiesel	Food	Feed	Soap and Chemical	Export	Price ($/tonne)
Canola Oil	-	390,478	-	250,258	557,264	676
Soybean Oil	-	569,569	-	-		725
Tallow	-	-	361,258	80,087		447
Yellow Grease	199,961	-	-	32,998		447
Palm Oil	21,000	0	-	-		538
Total	220,961	960,048	361,258	363,343	557,264	
Biodiesel produced (litres)		251,534,000				
Total cost, all domestic products ($)		1,158,603,829				

Table 5.13: Factors Constraining Feedstock Markets at a 1% Biodiesel Blend Requirement, with Complete Price Flexibility

	Optimal Value	**Shadow Value**
Supply constraint- biodiesel	251,534,000	1
Domestic Canola Oil Supply	641,006	-
Soy Oil Supply	569,678	-
Tallow Supply	441,436	-
Yellow Grease Supply	232,507	-
Palm Oil Supply	21,000	(98)
Total fats and oils, food use	960,048	894
Total fats and oils, feed use	361,258	894
Total fats and oils, Soap & Chem use	363,343	894

available than is actually used at this level of biodiesel blend requirement. The palm oil constraint is binding, and the shadow value indicates that additional unit of palm oil availability would reduce the total cost by $98. Reductions in the demand for fats and oils in food, feed, and soap/chemical imply a reduction in cost of $894, which result from a complex realignment and slight repositioning of ingredient prices.

Table 5.14 presents results assuming a 2% biodiesel blend requirement. Under these conditions, the price of canola oil and all feedstocks increase. Canola oil is used principally in food and soap/chemicals, with some use in biodiesel under this scenario, and significant exports. Soybean oil is used mainly in food, and at low levels in biodiesel. Tallow is used in feed, biodiesel, and soap/chemical production, with yellow grease and palm oil moving only into biodiesel.

Table 5.15 shows that the effective constraints on the model are palm oil, yellow grease, and soybean oil. More canola oil and tallow are actually available than are used. The shadow value of additional demand in food, feed, or soap/chemical production increases to $991.

Given the assumption of additional feedstock availability, the 5% blend requirement was considered. Table 5.16 presents the results with variable prices on all feedstocks and the 5% biodiesel blend standard. The table shows that under this scenario, canola oil exports would be pulled back from export and into the domestic market. Canola oil would be used mostly in food and soap/chemical, but with significant use of canola oil in biodiesel production. Soybean oil would be used in food and feed, with tallow use split between biodiesel and feed. Yellow grease and palm oil would be used almost entirely in biodiesel. Table 5.16 also shows marked increases in feedstock prices, with canola oil prices increasing to $918/tonne.

5.3 Observations on Empirical Feedstock Optimization

The empirical analyses undertaken above serve to illustrate some clear dynamics in the biodiesel feedstock market. First, as indicated from the results of a variety of the scenarios explored above, canola oil is generally not the preferred feedstock for biodiesel production on the basis of least-cost. The fact that the biodiesel yield resulting from each of the feedstocks is essentially the same, but that the canola oil price is relatively high makes this obvious, and the results bear it out. The results show that canola oil moves into biodiesel production when it is available and other feedstock sources are not. The leading feedstocks for biodiesel production are yellow grease, tallow, and palm oil.

Under the scenario in which other feedstocks are unavailable, but canola oil is available and its price is elastic, the results show that canola oil will move into biodiesel production, and that its price will increase. However, under the more likely scenarios in which other feedstock volumes are made available and are price elastic, canola oil use in biodiesel is modest, and the upward price movement in canola oil is also modest. The greater demand “pull” due to biodiesel production occurs on the cheaper feedstocks. In fact, under the 1% biodiesel blend scenario with price flexibility for all feedstocks, the price of canola oil actually decreases somewhat as domestic use falls and its price must decrease for it to compete with other feedstocks. This is clearly unlikely as it assumes a growth in available feedstocks that is not proportional to increased demand from biodiesel; however, it does illustrate that the price effects of increased demand due to biodiesel production fall mainly on the lower-priced feedstocks. As biodiesel production demand comes more into balance with the available feedstock (as in the 2% blend case), with elastic prices canola prices increase modestly. The 5% blend scenario foresees significant price increases in canola oil, but this should be interpreted with caution because the limit on adjustments in the supply of competing feedstocks clearly contribute to this result. The 2% blend result would appear to present the most conservative and likely of outcomes.

Ultimately, the main effect of biodiesel production is to expand canola oil markets from food and export into the feed and soap/chemical production markets, as feedstocks that currently serve those markets are pulled into biodiesel production. The effect is to increase the price of these lower priced feedstocks such that canola oil can be competitive in these markets where it otherwise has not been.

The effect of the above is to create potentially modest effects on canola oil prices, as suggested in Table 5.14. The table suggests that, based on historic production levels without biodiesel demand and with price adjustment in all feedstocks, a blend requirement of 2% could stimulate an increase in canola oil prices from $705/tonne to $724, or about 3%. To interpret this impact at the farm level, Figure 5.2 plots the historic relationship between canola oil and canola seed prices. The figure suggests that, based on history, a marginal change of $1/tonne on canola oil results in a change of around $.28/tonne on canola seed. On this basis, the $19/tonne increase in canola prices could result in a price increase of just over $5/tonne for canola seed. Canola seed production in Canada since 2000-01 has averaged 6.2 million tonnes; at that rate, the annual value of the price increase would be about $31 million per year.

Table 5.14: Least-Cost Feedstock Allocation, Assuming a 2% Biodiesel Blend Requirement and Price Adjustment in All Feedstocks

	Biodiesel	Food	Feed	Soap and Chemical	Export	Price ($/tonne)
Canola Oil	29,985	415,797	-	337,615	414,603	724
Soybean Oil	32,249	544,251	-	-		727
Tallow	102,238	-	361,258	25,728		495
Yellow Grease	256,500	-	-	-		492
Palm Oil	21,000	-	-	-		538
Total	441,972	960,048	361,258	363,343	414,603	
Biodiesel produced (litres)			503,068,000			
Total cost, all domestic products ($)			1,366,433,378			

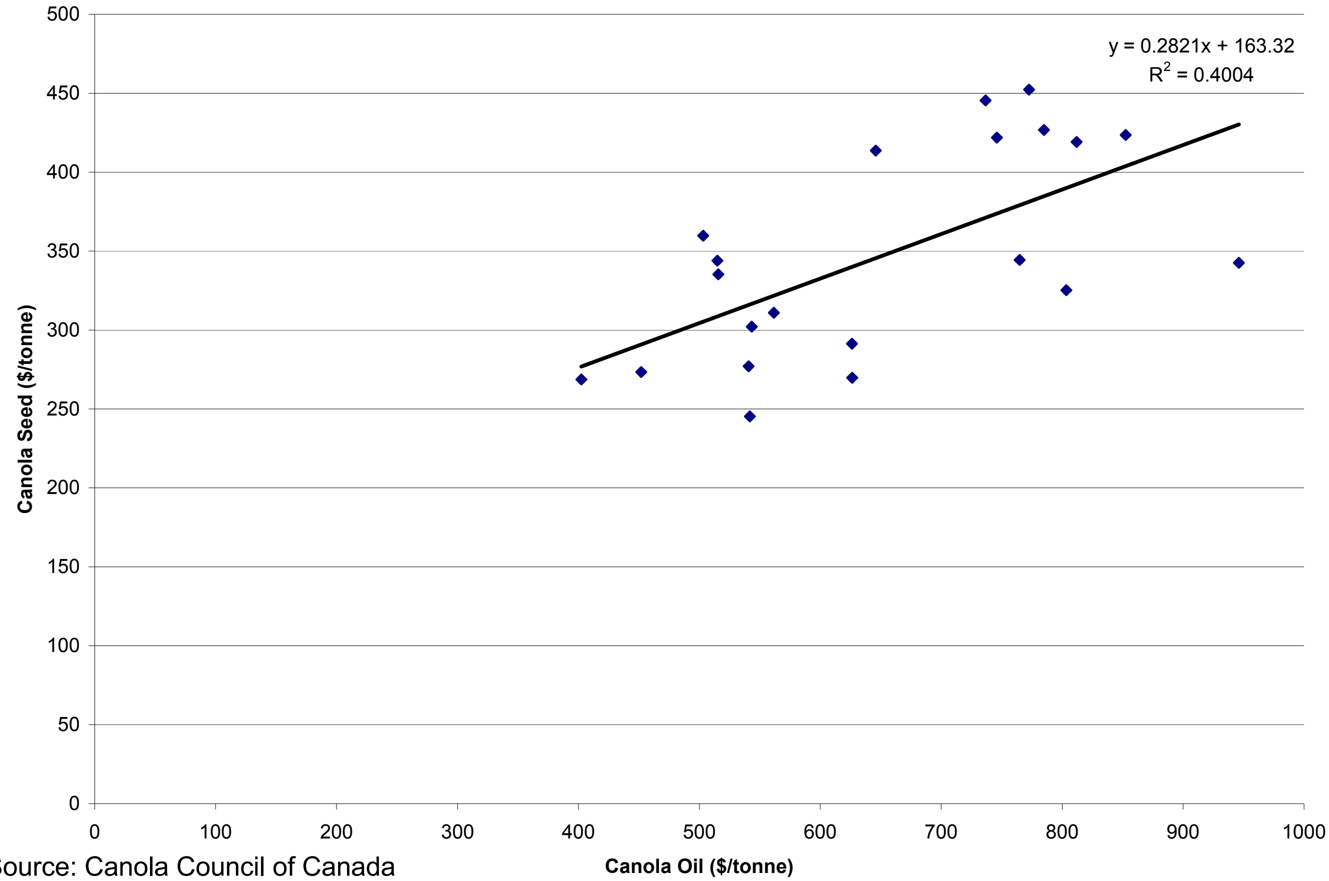
Table 5.15 Factors Constraining Feedstock Markets at a 2% Biodiesel Blend Requirement, with Complete Price Flexibility

Supply constraint- biodiesel	503,068,000	1
Canola Oil Supply	783,397	-
Soy Oil Supply	576,500	(93)
Tallow Supply	489,225	-
Yellow Grease Supply	256,500	(7)
Palm Oil Supply	21,000	(195)
Total fats and oils, food use	960,048	991
Total fats and oils, feed use	361,258	991
Total fats and oils, Soap & Chem use	363,343	991

Table 5.16: Least-Cost Feedstock Allocation, Assuming a 5% Biodiesel Blend Requirement and Price Adjustment in All Feedstocks

	Biodiesel	Food	Feed	Soap and Chemical	Export	Price ($/tonne)
Canola Oil	262,510	686,101	44,138	359,245	-	918
Soybean Oil	262,509	269,852	44,138	-		727
Tallow	323,613	-	256,014	4,098		591
Yellow Grease	239,532	-	16,968	-		492
Palm Oil	16,906	4,094	-	-		538
Total	1,105,070	960,048	361,258	363,343	-	
Biodiesel produced (litres)	1,257,670,000					
Total cost, all domestic products ($)	2,142,225,964					

Figure 5.2 Canola Seed and Canola Oil Prices, Pacific Basis*, 1984-2004



Source: Canola Council of Canada
*Pre-2000 Canola oil price is basis plants

6.0 Summary and Conclusions

The purpose of this study was to determine the economic effects of a mandated biodiesel blend requirement, focusing on canola and canola oil. To meet this purpose, a literature review was conducted to determine what has been found elsewhere with regard to biodiesel, an overview of feedstock markets was conducted, and an empirical analysis was conducted to determine likely feedstock purchasing behaviour under biodiesel blend requirements.

The review of previous research suggested that biodiesel can be made from a range of feedstocks; the two key factors influencing the success of biodiesel manufacturing facilities were feedstock prices and feedstock availability. Previous work suggested that the key competitors facing canola oil in the biodiesel market are rendered oils (yellow grease), rendered animal fats (tallow), palm oil, and soybean oil. Some discussion exists of using minor vegetable oils such as mustard seed oil, but these appear to be preliminary. The literature suggested that canola and soybean oil are apt to be relatively high cost feedstocks for biodiesel production.

The market analysis section provided some detail regarding market dynamics for the various feedstocks. The main observation arising from this analysis is that canola oil and soybean oil tend to be priced as food oils in international markets, while yellow grease, tallow, and palm oil tend to be priced in feed and industrial uses. The main influence in this market has been BSE in Europe. Prior to the late 1990's, palm oil was priced competitively against soybean oil. However, since then, European response to BSE generated a demand for substitutes for rendered animal fats, and the recognition has grown that palm oil is inherently a less healthy product in foods compared with canola oil or palm oil. These two factors, combined with rapid and significant increases in production, have driven palm oil prices down to compete against the rendered fats and oils, and put palm oil at a price discount to canola or soybean oil. Thus, a cluster of widely available, low-priced feedstocks for biodiesel production exists (yellow grease, tallow, and palm oil) alongside another cluster of higher-priced potential feedstocks (canola oil and soybean oil).

The empirical analysis employed a simplified Canadian fat and oils market model that served the competing demands for fats and oils at least cost. Two conceptions of market dynamic were considered- one in which feedstock prices remain constant, and another in which feedstock prices fluctuate with volume consumed. Under the assumption that total fat and oil supplies are fixed at historic levels, biodiesel blend requirements of just over 2% are feasible; these were used given that historic data does not take into account the feed stock consumption due to biodiesel. Based on assumptions regarding potential response of canola oil and alternative feedstock supplies, a scenario was constructed to consider a 5% biodiesel blend requirement.

Under the alternative conceptions of market dynamics, the principal effect of increased feedstock demand from biodiesel is to boost the demand for cheaper feedstocks. The result of this is to drive up the price of the cheaper feedstocks to the point that canola oil obtains penetration into feed and soap/chemical markets that it previously has not had a major role in. To the extent that canola oil develops a greater reputation as a healthy food product that is preferred to other oils, the effect will be to dislodge soybean oil and palm oil from food markets, and capture a greater share of that market.

A caveat related to the above is biodiesel quality. A reviewer to this study commented that biodiesel made on a least-cost basis from rendered fats and greases could have undesirable flow and storability characteristics that would be improved by using canola oil as a feedstock. The specific aspect of the chemistry of biodiesel was beyond the scope of this study, apart from the basic yield relationships. Thus, in reality, there may be advantages from using canola oil in biodiesel to address the quality issues. However, industry contacts pointed out that fuel additives can also be used to address flow ability and bulk storage characteristics, and the use of additives may indeed by cheaper than using canola oil in biodiesel production. The least-cost means of maintaining biodiesel flow and storability characteristics (canola oil vs. fuel additives) may be significant in determining canola oil use in biodiesel.

The impact of the above is a moderate price increase for canola oil and an expansion of canola oil into new markets. Because the oil yield of canola is relatively high, the expectation is that a moderate increase in canola prices could result. History suggests a price transmission of about 28% from canola oil to canola seed. Thus results here suggest a price effect on canola seed in the range of $5/tonne. Given recent canola seed production levels of 6.2 million tonnes, the value of the price increase would be in the range of $31 million/year. The extent of the actual price increase in canola oil and canola seed that would result from new biodiesel demand will be positively related to the blend level, and negatively related to the supply response from canola oil and competing fats and oils.

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