Australian Nuffield Farming Scholars Association

2003 SCHOLARSHIP REPORT

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Topic: De-centralised energy production

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Executive Summary

The idea of growing our fuel is not new. In fact my Grandfather grew fuel as a part of his crop rotation…oaten hay for his team of horses!

I guess he did that, because that's just what you do when you have a team of hungry horses. But if we think more deeply about the concept, perhaps it is possible to regard fuel production as a normal, integrated part of any farm or crop rotation. Farmers are used to growing food, so why not fuel?

The sun is a massive source of energy. Every hour of every day, enough energy reaches the earth from the sun, to provide the energy demands of the whole world for a year! It is important to realise what a wonderful free resource we have, and tap into that energy.

Plants are amazing things. The more I cultivate them and think about them, I realise how little we understand them. Plants have the unique ability of being able to convert solar energy and carbon dioxide (CO2) into stored energy. In essence, they are really organic, photosynthesis laboratories. Plants are abundant and come in many varieties, and have the ability to store this energy in different forms such as cellulose, carbohydrate, protein, oil, etc.

Over time we have learnt how to cross-pollinate and select plants with desirable traits for specific purposes (crops). All of a sudden a plant is not just a plant or a weed, it has become a useful way of capturing and storing energy, just like a car battery.

It is important to understand the types of stored energy we have, and how to release this energy. The form of stored energy that interests me the most is vegetable oil, as plant oil can be used in a variety of ways, as a renewable, alternative fuel for diesel engines.

Acknowledgments

I would like to thank the Australian Nuffield Farming Association for the opportunity to travel the world and study what has become a great personal interest. I know it is an experience that would not have happened without their assistance, and for that I am very grateful. There have been circumstances, which have complicated my ability to travel, and I would like to thank the Association and Mr Bryan Clark for their understanding.

The inclusion of a six-week core study program is a fundamental strength of the program. I travelled with a great bunch of fellow scholars and shared experiences that I will always remember.

Thank you to:

My sponsors, Rural Industries Research and Development Corporation and Mr. Murray Hansen. Thankyou for your continued support of the Australian Nuffield Farming scholarship.

Dr Sue Knights for your interest, support and encouragement. I would never have applied for a Nuffield Farming Scholarship without it.

Barry and Elsa Williams, for your friendship, support and belief in me.

Mr. Ulrich Keller, EGON Keller GMBH & Co. Thankyou for your organisation, help, time and hospitality. You made my time in Germany enjoyable and memorable, and I would not have been able to do it without your enormous assistance. Your English is far better than my German! Most of all, thankyou for your friendship.

Thankyou also to Mr Klaus Thuneke, TFZ and Elsbett Technologie GmbH. I am inspired by the work that is being done in Germany. Thankyou to Mr Werner, Mr Enkelking and Mr Dugenheim for giving me the opportunity to visit your oil mills.

Mr. John Nicholson. I thoroughly enjoyed our time together and found you quite an inspiration. Thanks to you and the members of Bio-power for your hospitality. Most of all I enjoyed the stimulating conversations. Long live the Wormingford Pub.

Mr. Vaino Laiho. Thankyou to you and your family for the warmth and hospitality I enjoyed while in Finland. Thankyou for all the time and effort you put into my schedule. The brass music was second to none, and I shall never forget the traditional smoke sauna. Nothing can beat motoring in a Mercedes Benz, running on mustard oil!

Thankyou to Dr Seppo Niemi. I hope one day we can do co-operative research on mustard seed oil fuel. Thanks also to Mr Riestmaki Jorma and Brothers Jarmo and Jorma Makela. I appreciated visiting your farms.

To the fellow Nuffield scholars I spent time with while away, thankyou. Our door is always open.

Last but not least, a big thankyou to my family, Helen, Louise, Mum and Dad. Thanks for keeping the home fires burning, and giving me this wonderful opportunity. I appreciate your love, support and understanding. Thanks Bevan and Allan for giving dad a hand while I was away.

To those who I have failed to mention, thankyou. You are no less important.

Objectives

My main objective was to travel to Europe, where vegetable oil has been used during the last two decades as an alternative fuel for diesel engines. The Europeans have spent considerable time developing a large biodiesel (chemically modified vegetable oil) industry, and currently produce in excess of two million tonnes of biodiesel annually (2,000,000,000 litres). This fuel is produced in large centralised manufacturing facilities.

My real interest is in the area of de-centralised energy production, which has experienced huge growth in Germany over the last twenty years. De-centralised energy production gives anyone the opportunity to produce fuel, and the German Government has encouraged its growth. While in Germany, I saw oil mills in purpose built facilities, on farms in converted barns and animal sheds, and even in car garages! In Finland, oil production for fuel is not as common as in Germany, but still there are small scale oil mills that had been established on farms, and produce vegetable oil for both domestic consumption and for fuel.

The growth of de-centralised energy production has in turn generated genuine interest in using pure vegetable oil as a diesel fuel alternative. In the 1960's an engine was developed and manufactured to specifically run on vegetable oil by a company known as Elsbett. This engine attracted a lot of interest, especially during the crude oil shortages of the 1970's. However, new crude oil reserves were discovered, the barrel price dropped and the interest in vegetable oil fuelled engines disappeared.

But once again, as energy prices have risen, so has the interest in pure vegetable oil. Research has shown that the production of de-centralised energy (vegetable oil) in conjunction with the conversion of suitable vehicles to Pure Plant Oil (PPO) has significant advantages and savings over centralised energy production.

The goal of my trip was to look at de-centralised energy production facilities first hand, and to look at the infrastructure and technology necessary to establish similar systems in Australia.

Introduction

In 1900 at the World Exhibition in Paris, Dr Rudolph Diesel showed his diesel engine, an engine that was capable of running on a variety of fuels including peanut oil (vegetable oil). Later on, Dr Diesel went on to say, "The diesel engine can be fed with vegetable oils and would help considerably in the development of agriculture of the countries that use it." Rudolph also believed that one day it would be possible that vegetable oil as a fuel would be as important as petroleum and coal tar products.

Interestingly enough, two of the most revolutionary inventions of last century both used plant fuels. The high compression diesel engine could run on vegetable oil, while the internal combustion engine on grain alcohol (ethanol). Since their invention, both these engines have now been optimised to run on fossil fuels.

As a farmer, I have realised that what I grow is not 'food' as such, but an 'internationally tradable commodity'. Unfortunately all the charts show the long term price is down, while the costs of production continue to rise. Either I need to get bigger or get out, right? WRONG. What I need to do, is to start producing a product that the market wants, and that market is energy. Remember my Grandfather? Instead of growing oaten hay for "organic tractors" (horses), why not grow food for "iron horses" (tractors) instead?

The idea of using vegetable oil as an alternative fuel is not a new one and has been used successfully in Europe since the 1970's. In Germany, it has become commonplace for individuals and farmers to establish small-scale oil mills and produce rapsole (canola oil).

Twenty years ago, there were approximately eight large oil-processing mills in Germany. This figure has now grown to over 200 mills, which includes both small and medium sized oil mills. Farmers have seen the production of rapsole creating a whole new host of opportunities. There are markets for the supply of automotive and industrial fuels, biogas production, electricity generation, central heating, and animal feed markets.

There is also increased demand for the needs of the domestic consumer. Cooking and culinary oils, health and beauty products (makeup, lotions, moisturisers, vegetable oil soaps, etc), laundry detergents and cleaning products, to name a few. All are widely available in supermarkets, organic stores and retail shops, with some farmers also having a retail outlet on farm.

Vegetable based engine oils and hydraulic oils are making their way into the market place, while scientists are learning how to make biodegradable plastics and polymers from plant oil. Car manufacturers are even experimenting with making cars and car components from plant fibres!

How did I become interested in renewable fuels?

It was in October, during the mid 1990's that a very significant event occurred. Early one morning we experienced a severe frost event, and as time went by, the degree of crop damaged became apparent… our crop yields were reduced by 70%. It was called a "one in one hundred year" frost event. The following two seasons we were also effected by 'unseasonal' late frosts.

In 1999, I gained employment in a neighbouring town, working for a small seed processing company. While working here, I began to realise the "futility" of farming. I was like a rat running in a cage of the multi national companies…everyone else made money out of my hard work, except me! It became obvious to me I needed to break the cycle. Was there a crop that I could 'value add' on farm? Could I create an alternative income? Could I reduce my energy demands (fuel, fertiliser), but still generate an income from the farm? What crop could I grow that was frost tolerant?

One day quite by accident, I saw a short trailer after the news, about a chef in Sydney making fuel out of used cooking oil from the restaurant where he worked. I couldn't believe what I was seeing. Fuel from used cooking oil! What an amazing concept. It has proved to be a concept that has turned my life upside down. I had been exposed to the idea of producing fuel from vegetable oil. This fuel is known as 'Biodiesel'.

Not in my wildest dreams did I ever imagine that four years later, after receiving a Nuffield Farming Scholarship, I would get the chance to travel the world studying renewable fuels, let alone to be sitting in Finland, typing this introduction. I am visiting Vaino Laiho, a Finish farmer who grows and produces mustard seed oil on his farm. He grows his own fuel, and produces his own organic fertiliser. He is able to generate an income and he is having a positive impact on his environment.

Here endeth the first lesson.

Change is in the air.

I suspect people are now starting to notice change. We are starting to realise things are not the same in our environment. As a farmer, I notice it. Late seasonal 'breaks' and drier winters. Poor spring rainfall and late frosts. There seem to be more extremes in the weather. We are now starting to observe the effects of the industrial revolution. We have contaminated our water, changed the landscape, and polluted the air.

We have all contributed to a change in the environment. Our pollution is acting like a blanket, making our planet warmer, a phenomenon known as global warming. Data worldwide has shown a huge increase in weather related natural disasters. Even insurance companies are concerned about global warming as it affects their profitability.

Over the last decade, we have learnt how to separate and recycle our daily rubbish. Why not do the same with our pollution. Instead of digging up crude oil to burn and release carbon stores into the atmosphere, why not leave the carbon stores in the ground and recycle our carbon. After all, plants need carbon dioxide to grow. By using biodiesel or vegetable oil as fuel, we release the same amount of carbon at combustion as what the plant absorbs while it is growing.

Crude oil is not an infinite resource. In the 1950's a theory was put forward by Hubert that is known as 'peak oil'. Peak oil is a reference to the point at which we have consumed half of the world's crude oil reserves. It is expected that the next half of the crude reserves would be used far more rapidly as world energy demand increased.

By 1930, 17 billion barrels of crude oil had been extracted worldwide. We now consume 24 billion barrels per year! It is expected that crude oil supplies will dry up somewhere around 2040.

Vegetable oil is also a resource that can be replenished quickly. It can grow from seed and be processed into oil in as little as 120 days! How long did it take to make crude oil?

By using renewable fuels, we can also reduce the pollution in our cities. International studies have all shown, those particulate emissions, carcinogenic compounds and smog could be reduced by as much as 60%. Imagine reductions in asthma, bronchitis, heart and lung disease. Not only would we have a better lifestyle and lower incidence of disease, we would also have significant savings in health care costs.

Renewable fuels would also have a positive effect for agriculture too. It would create new markets, alternative income streams and employment. Renewable fuels are paramount to creating a society that values sustainable economic and environmental stewardship. Hopefully, by reading this report, you might be challenged to think about new ideas or even old ideas in new ways.

Oil Processing.

In Europe, rapeseed is the feedstock of choice for biodiesel manufacture. Farmers are familiar with the cultivation and harvesting of 'raps', the crushing infrastructure is already in place (traditionally associated with the production of vegetable oil for human consumption), and because of the consistent, high quality of the oil, it is easy to manufacture a consistently high quality biodiesel.

In America there has been a concerted effort on breeding Mustards as an alternative to Rapeseed. High yields have been achieved, creating the opportunity for a low cost, non-edible oil, for biodiesel production. At the same time, the press cake is valuable to agriculture as a natural pesticide, and also has the ability to reduce weed seed germination. There is also a Mustard breeding program in Australia, but it's main focus is to breed an oilseed alternative to Canola for the drier agriculture regions of Australia.

Once we have decided what oilseed crop will be grown for our vegetable oil, the next step is to extract the oil from the seed, and to do that we need an oil mill. There are numerous manufacturers offering all sorts of oil processing machines and components, and to be honest it can all be a little bit overwhelming. After reading this chapter, you should have a better understanding of oilseed processes and processing.

Oil Extraction.

The processing of vegetable oil is usually done in large centralised oil mills, which have a daily capacity of up to 4000 tonnes. There are 12 such oil mills located around Germany, mainly sited near seaports.

However, in the last few years, decentralised oil production has become an important source of income for a wide variety of individuals and organisations, and there are now more than 180 small scale units operating in Germany.

The growth of the decentralised oilseed market has seen a rise in the demand for small scale processing equipment, and there are a number of companies which manufacturer oil seed processing machinery. There are slight variations on the theme, but essentially they all use the same principle.

There are two methods of extraction for vegetable oil:

- Conventional hot pressing combined with solvent extraction (large centralised processing mills); or
- Cold pressing (small scale decentralised production)

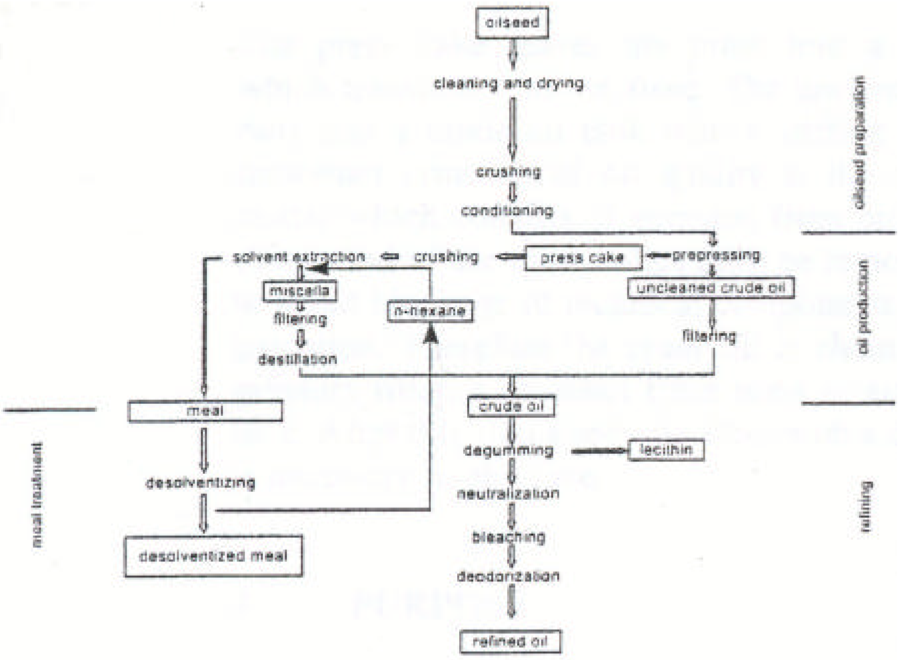
Large Scale Oil Extraction

Large centralised oil mills typically use a process known as 'hot pressing' to extract vegetable oil. This method of extraction is the most suitable for producing high volumes of vegetable oil with the lowest possible oil residues. Most large mills also employ a process to recover residual oil from the press cake or meal using a solvent. This is known as 'solvent extraction'.

Typically, processing of oilseed in a large plant begins with the cleaning and drying of the seed, to remove any possible contaminants. The seed is then passed through crushing barrels to crack the seed. The seed is then heated with steam at a temperature of 80-90°C for 15-30 minutes. This process is known as 'conditioning', and improves oil separation from the seed, and neutralises some enzymes. The pre-heated seed is then pre-pressed, and the press cake is then pressed again. Approximately 50% of the oil is extracted during these two pressings.
The press cake then moves through to solvent extraction (usually hexane), where the remaining oil residues are recovered. The press cake is then desolventised, and the meal is suitable for use as a high protein product.

The mixture of vegetable oil and hexane (know as miscella) is then filtered and distilled to recover the solvent from the oil. The solvent is then recycled into the process. The crude rape-seed oil is then degummed, to remove phosphates and neutralise free fatty acids. The oil is then bleached to remove pigments such as carotinoides and chlorophyll and is finally de-odourised by steam distillation under vacuum to remove odour and taste compounds.

This process is capable of extracting 98%+ of all the available oil from the seed, and according to German research, consumes approximately 1.7 Gj of energy per tonne of seed. Because of the large capital cost to build such a facility, it is not practical to build such a plant to process small volumes of oil.



Simplified diagram of large scale oil extraction

Small Scale, Cold press

The process for small scale, de-centralised oil extraction is known as ‘cold pressing. This describes a technique for extracting oil from nuts and seeds using pressure and low heat (room temperature). By extracting the oil at a low temperature, the ‘goodness’ and flavour of the oil is retained. Pressing at high temperatures will extract more oil, but the heat will destroy much of the natural nutrition in the oil and contribute to oxidisation and a bitter taste. You will often notice the term ‘cold pressed’ used to describe the method used to extract olive oil for example. Historically, cold pressing oil involved nothing more than a wooden barrel filled with seed or fruit that had a plunger on top with a heavy weight or a wooden screw. The plunger would press down, squeezing out the oil, and the oil would then drain through holes in the bottom of the barrel. Filtration would either be done by settling or pouring the oil through cloth or paper. Although this is a very simple and easy method of extraction, it is very slow and the oil yield is not high, with the skins containing high oil residuals.

Cold pressing equipment still employs the same principle, but capacity and oil yield has been increased considerably with an improvement in press design. The two most common press designs are:

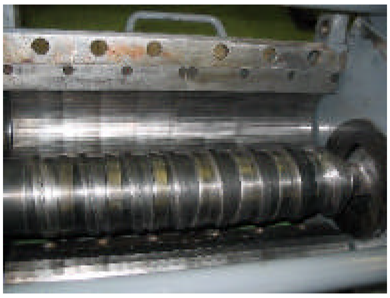
- Hydraulic
- Continuous screw

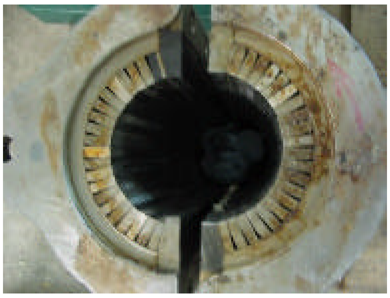
Hydraulic press

A hydraulic press, similar to the wooden barrel, employs a cylinder that is fed with fruit, nuts or seed. High pressure is exerted by a hydraulic ram. Once the ram has reached the end of its stroke, the ram is retracted, residues removed, and the cylinder loaded for the next extraction.

Hydraulic pressing is most often the preferred method of extraction for 'delicate' oils, such as almond or evening primrose oil. Less heat is generated and multiple pressings of the meal or skins can be made without great detriment to the oil quality.

Continuous screw press





A continuous screw press uses a 'screw' or 'worm' within a press cage. A press cage can be made from a steel barrel with rows of holes drilled through it, or from a series of 'bars' with shims or spacers to allow the oil to flow from the cage. At the end of the press cage is a cone or plug that creates a restriction, which allows pressure to build up within the cage, 'squeezing' the oil from the seed. Once the pressure inside the press cage has exceeded the resistance determined by the setting of the press cone, the meal or press cake leaves the screw press and is replaced by fresh seed, being fed into the machine by the screw.

A combination of the revolution speed of the screw and the setting of the press cone determine the capacity of the machine. Closing the cone and slowing the screw, will create more pressure and extract more oil, but will generate a higher percentage of suspended fine organic material known as 'fines' in the oil. This will also generate more heat during extraction, which is detrimental to the quality of the oil. Ideally, to retain the nutritional value and quality of oil, the oil needs to be extracted at a temperature no greater than 40°C, and the setting of the screw press varies according to the quality of the seed.

Crushing capacities vary according to the physical size of the press, and can range from a few kilograms per hour up to larger quantities of around 800 kg per hour. In the end, the capacity of the cold press is determined by a compromise in the variables of speed, heat and residual oil, which varies according to the quality of the seed.

Oil yields from this simple process are obviously lower than those obtained through large-scale commercial plants. Recent research into de-centralised oil production in Germany (survey of 20 different oil mills), revealed an average oil extraction rate of 77.6% of all available oil in the seed, with an average energy consumption of 0.38Gj of energy per tonne of seed.

Small scale oil mill

The design of a small scale oil mill should be as simple as possible to reduce capital investment and operating costs, and can be simplified to the following points;

- Cleaning (and drying) of seed
- Extraction of oil by continuous screw press
- Filtration

Cleaning and drying of oil seed

The cleaning of seed can be done in a number of ways. The seed may be cleaned before storage, or prior to crushing with a small rotary screen, or sieve. A sieve can be as simple as a wooden box with a screen nailed to the bottom. Whatever the choice, the purpose is to have the seed as clean as possible, which will result in trouble free pressing. With regards to moisture, it is important to note most screw presses have an ideal operational moisture range. Keeping within this range will result in increased oil yield and quality.

Extraction

As previously mentioned, the most suitable press for a small-scale oil mill, is a screw press. The choice of oil press should be determined by a number of factors:

- Volume of oil required, which will determine press size.
- The feedstock to be crushed.
- Typical hourly capacity, residual oil content, and the percentage of ‘fines’ generated by the pressing operation.
- Power consumption and availability of power supply, e.g. 3 phase, single phase.
- Serviceability, spare parts, customer service and support.
- Price. Consider both the purchase cost and running costs.

Filtration

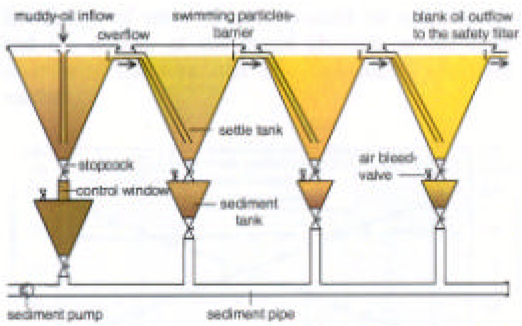
Perhaps one of the most significant steps in production, it is very important to remove all the suspended organic matter and fines for two very good reasons;

- To prevent the blockage of valves, pipes and components; and
- To reduce oxidisation and extend oil life and quality

A wide variety of methods are used to filter vegetable oil, but regardless of the method used, vegetable oil should be filtered to a final filtration of 5 microns. Filtration methods include:

- Settling tanks
- Plate filter press
- Disposable safety filters e.g., cartridge, bag, candle

Settling tanks



Settling tanks, as the name implies, refers to a series of tanks or containers in which the oil is allowed to stand, and over time (1-2 weeks) the fines in the oil sink to the bottom of the vessel.

Some settling tanks use a 'cascade' arrangement, where the clearer oil constantly flows over into the next container, until the oil is visually clear of any organic matter or fines. Where there is not a large demand for oil to be rapidly filtered, oil can be stored in 205 litre drums, and decanted at a later stage.

Mr Klaus Thuneke explaining the operation of settling tanks.

However, research has shown that even though the oil may have a very clear appearance, it still has a large contamination of particles of varying size, and it is necessary to filter the oil through a safety filter such as a bag or cartridge filter before use. Settling tanks are not a fast method, but are a low cost option for filtration.

Plate filter presses

A plate filter press allows the rapid, continuous filtration of freshly pressed vegetable oil. As the name implies, a plate filter press consists of a number of plates clamped together, with sheets of filtering medium between them. The oil is pumped through the plates under pressure, and the organic material is trapped by the filtering medium between the plates. Usually, a pressure gauge indicates when it is time to change the filter cloths. The filters can be reusable or disposable, and can be cloths made of natural or synthetic fibres. Paper is also used, depending on the required filtration size.

Plate filter presses are more expensive than settling tanks, but take up less area and are considerably quicker. As with settling tanks, it is still advisable to pass filtered oil through a 5 micron safety filter.

Safety filters

Safety filters come in a wide variety of filtering mediums, shapes, sizes and prices. They should not be used as the primary method of filtration, as their filtering life will be determined by how well the oil is filtered previously. Poorly filtered oil will shorten their life considerably. It is advisable to install safety filters wherever filtered oil is to be transferred between tanks.

Putting a small scale-mill together

Taking these points into consideration, the following chart is a representation of a small-scale oil mill. This diagram of a simple oil mill gives examples of different seeds and nuts that contain oil, and could be processed through this mill. The chart also includes a roller mill to allow de-dulling of nuts before being pressed.

Small Scale Oil Mill

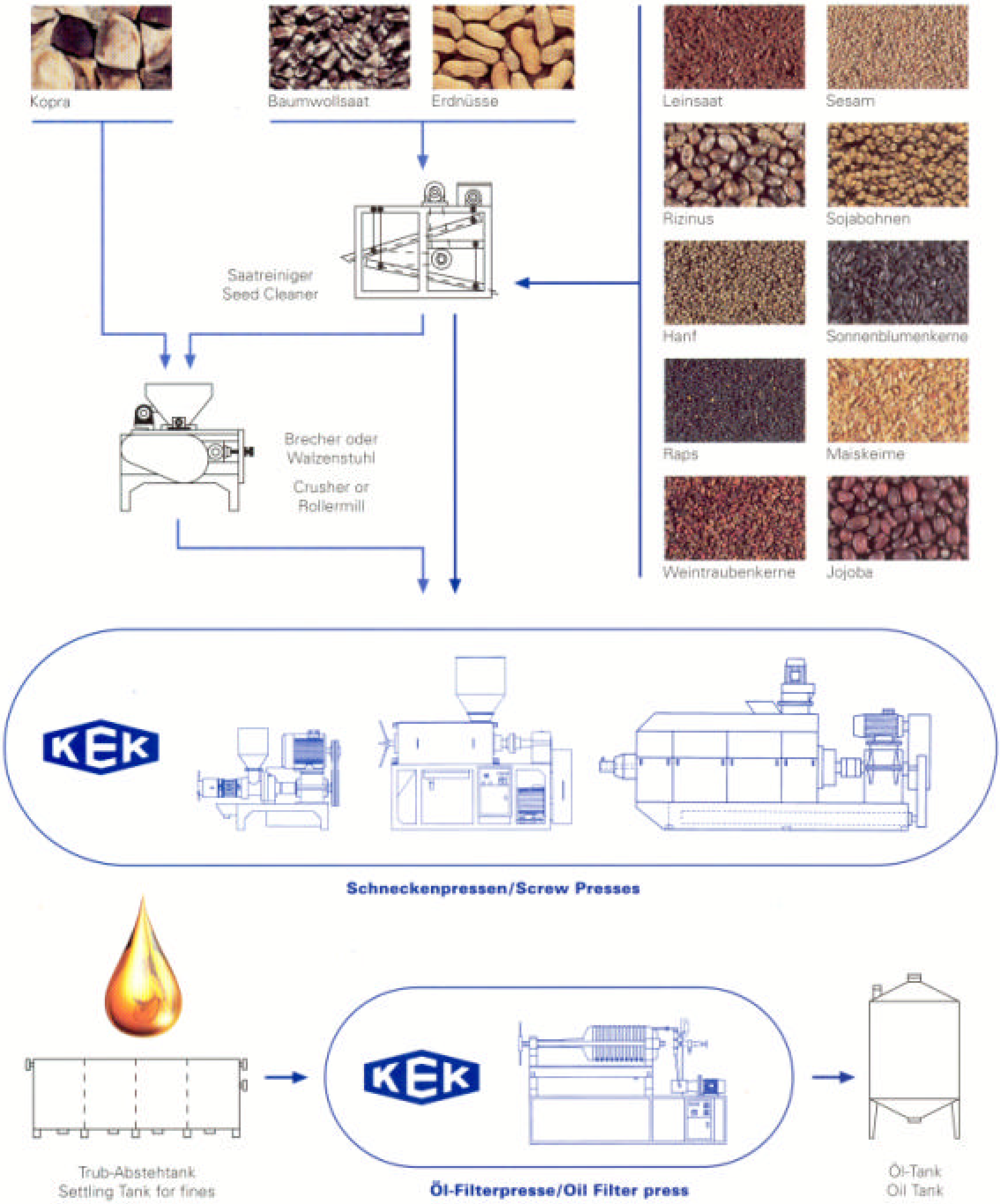


Diagram kindly provided by EGON KELLER GMBH & CO

Advantages of de-centralised oil production

- It is a safe, simple extraction process to produce vegetable oil. Vegetable oil is 100% biodegradable and non toxic, there is no harsh toxic chemicals involved, therefore it significantly reduces the risk of potential impact on the environment.
- Small scale, processing mills are quiet and compact, and as I observed in Europe, they can even be set up in the car garage behind the house. In fact you probably wouldn't even realise there was an oil mill there.
- Localised mills have the capacity to offer alternative processing and marketing options for farmers.
- Contributes both a financial and social benefit to rural and regional communities, through the creation of jobs and service industries
- Provides energy 'independence'. Producing a product that can also be used as a fuel, the local market becomes less vulnerable to supply shortages.
- Substantial energy savings. German research has shown de-centralised oil mills on average consume 75% less energy per tonne
- Cost effective. Reduces the need for large capital investment.
- Utilisation of local infrastructure. Takes advantage of local existing infrastructure to reduce storage and transportation costs.

Regardless of location and capacity, it is important that de-centralised oil mills consider the following:

- The capacity of the oil mill is matched to the area of supply.
- There is appropriate infrastructure for storage and handling of the oilseed.
- There are suitable markets for both the vegetable oil and press cake.
- Simple plant design to reduce operating costs and
- The quality of the oil must be suitable for its intended use.

European examples of small scale de-centralised oil mills

Mr. Werner, Forcheim-Sud, Germany

Mr. Werner has a small farm and predominately conducts business as a grain merchant. Recently, he established a fully automated 'cold press' facility on his farm. His processing mill has approximately three computer workstations where he can observe 'real time' processing, and can continuously monitor extraction and production. Mr. Werner calculates that he is achieving an 86.6% extraction rate of available oil in the seed, leaving only 6% residual oil in the press cake.

Mr. Werner purchases both raps seed (Canola) and Sunflower seed. He takes grain deliveries at his facility, and pays farmers on an adjusted basis according to test results. He has two large diesel 'co-gen' units which he uses for all his electricity needs, hot air and hot water requirements. Ironically, Mr. Werner uses fossil diesel to power his 'co-gen' units, as he is able to purchase 'agricultural rebated' diesel for less than what he sells the vegetable oil he produces. This will come to an end next year with the introduction of German fuel excise reform.

Mr. Werner sells crude, filtered vegetable oils into the market. He also has a fuel bowser on farm, and operates a retail 'fuel' business, open to the general public. 'Raps oil' retails at approximately 63 Euro cents per litre, while fossil diesel retails at approximately 109 Euro cents per litre.

He has also built a small shop adjoining the house and sells bottled and labelled cold pressed 'raps oil' for cooking and domestic purposes.

Mr. Werner also recently purchased a 'continuous flow' containerised biodiesel production unit. This facility will be installed in the very near future. Mr. Werner commented on the high level of mandatory obligations that are associated with a biodiesel plant, and include EPA and HSO requirements.

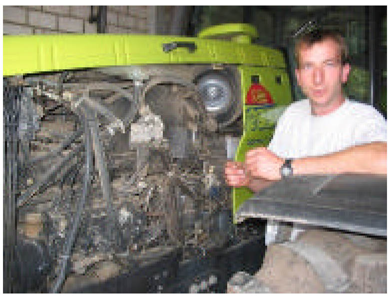
Mr. Werner has established a local feed market for the press cake, and has custom built a 'feed mix plant' with six bins, for blending mixes to customers' feed specifications. The blending facility holds raps press cake, sunflower press cake, linseed, soya and coarse grain. It has the capacity to dispense calcium carbonate and other minerals into the mix. At the moment, excess meal is being sold to produce "biogas". Mr. Werner is also exploring the option of producing fertiliser.

Mr. Enkelking, Glissen, Germany

Mr. Enkelking owns and operates a 200-hectare farm. He plants both rapeseed (canola) and wheat, approximately 50 hectares of each. He has a 1500 head piggery, and buys and sells pigs, fattening them on a mixture of raps press cake, wheat and other nutrients. Mr. Enkelking also has his own feed mixing bin.

Mr. Enkelking has four screw presses, and produces 50,000 litres of rapsole per week. Unlike Mr. Werner's fully computerised facility, this facility regulates itself on a mechanical basis.

Oil is bottled, labelled and sold for human domestic consumption and as an energy source for animal rations. The rest is then sold into the fuel market, which is his biggest market. He provides fuel quality 'rapsole' to a growing number of local transport companies, and expects increased demand for rapsole next year, with EU 'agricultural diesel' reforms being implemented.



He supplies mostly all of his own fuel needs. He has a car, 'Valmet' tractor and a Scania truck, running 'two tank' PPO systems. He uses a rapsole/diesel blend in both his Mercedes tray truck and Class header, with his header being converted to a 'two tank' system next year.

As well as growing his own raps seed, Mr. Enkelking also buys seed. He takes grain deliveries at his farm, and pays farmers on an adjusted basis according to test results. He has the capacity to store 2000 tonnes of raps seed, and has just installed another 4 bins this year, giving an additional 1000 tonnes of storage.

Mr. Dugenheim, Mayern, Germany

Mr. Dugenheim's story is an interesting one. He is an automotive mechanic by trade, but left to establish his own repair workshop / machining business from home. He had been looking for an opportunity to expand his business and after considering several options, established a de-centralised oil mill. He produces rapsole purely for the fuel market, and has a retail 'fuel' outlet in his backyard.

Mr. Dugenheim recently became a sponsor of a diesel engine racing car, and provides pure vegetable oil for fuel as a part of his sponsorship. Raps press cake is also sold into the domestic market as a feed mix component.

In order to secure storage for his oil mill, Mr. Dugenheim recently purchased a small grain delivery centre, with the capacity to clean seed. He has approximately 130 tonnes of 'raps' storage at the moment, with the trading of coarse grains utilising the remaining storage. The oil mill is a low cost, low tech facility and has been installed in the car garage and hay shed.

He has two presses, a settling tank and a dual filtering arrangement.

Mr. Dugenheim constructed a simple belt elevator that he has made from water guttering. The belt elevator transfers the press cake from the screw presses to an adjoining storage area. To supply grain to his screw presses, he has simply cut a hole through the cement floor above the presses in the garage, and augers rap-seed onto the cement floor from above. To fit the supply auger in, he knocked a hole through the wall.

This is a great example of a low cost, innovative, decentralised oil mill.

Mr Riestmaki Jorma, Finland

Riestmaki is a farmer who has an oil processing facility, crushing linseed, which consists of three presses. He has purchased one press from Vaino, and the other two presses from another manufacturer. The top press gives a pre-press, with both the meal and press cake feeding into the bottom press. It is here that linseed oil goes one way, while a more finely crushed linseed meal goes into an auger, and then into a 500kg bulk bag, to be packed by a distributor.

Unlike in Germany, the seed is not pressed for its oil, but rather the press cake. The linseed meal contains in the vicinity of 25% residual oil, and is packed in 500g boxes and sold in health shops and supermarkets. The linseed oil that is extracted is left to stand, bottled and sold. There is no filtration.

Riestmaki crushes 100 tonnes of linseed annually, of which 10 tonnes is organic. This seed is purchased from a number of farmers on a clean seed basis. The linseed is machine cleaned at a nearby cleaning facility.

Left Vaino Laiho, Riestmaki Jorma, Right

Mr Jarmo & Mr Jorma Makela, Finland

Crops, winery and oil processing

In 1988, the Makela brothers turned to organic farming. They attended a wine maker's school, and set up a winery making alcohol from blackberries and strawberries. They have planted 650 'bushes' of each crop, and harvest yields approximately 650kg of each.

The fruit is frozen and crushed. The resulting pulp is filtered through a filter plate press, has sugar added and is fermented in stainless steel tanks. The brothers also produce a sparkling wine, which is one of a few sparkling wines produced in Finland. They bottle and label the wine on farm and do cellar door sales. They also have a café and dance hall, which is a converted farm barn.

The brothers have an oil press and crush approximately 100,000kg of rape-seed annually. They have supply contracts with local farmers, which totals to an area of about 120ha. They have a grain dryer and dry the rapeseed down to 9% moisture before crushing.

They bottle approximately 1% of the expelled oil for human consumption, and sell the rest of the oil for animal feed. They also sell the press cake for animal rations.

They have 6 storage bins on farm, and have a simple QA scheme, which can identify the grower of both the oil and press cake. The oil is stored in individual, numbered containers. After 2 weeks the container is opened and the clean oil decanted. The fines are fed to their 70 pigs. The press cake is stored in numbered bulk bags. Jarmo estimates they extract approximately 25% of the available oil.

As well as supplying the bottled oil and feed market, the brothers also run a farm tractor on a mix of 50% rape seed oil and 50% diesel. They are very satisfied with the tractor performance.

Renewable Fuel Alternatives

Once we have processed or obtained clean, filtered vegetable oil, there are four main renewable fuel alternatives to diesel.

- Chemically modify triglyceride oil molecules through a process known as transesterification, to become alcohol esters; **Biodiesel (BD)**
- Modify the fuel delivery system to utilise vegetable oil as the primary source of fuel, while still having the capacity to use fossil diesel; **Straight Vegetable Oil (SVO) or Pure Plant Oil (PPO)**;
- Physically modify and optimise the engine to use vegetable oil as fuel
- Modify the combustion and viscosity characteristics of vegetable oil, (through emulsions or by mixing with other renewable products) to make a fuel that has the characteristics of biodiesel or diesel; **Emulsified Vegetable Oil (EVO)**

Biodiesel

Today, the term biodiesel is used to describe the many forms of alcohol esters that are produced from various triglyceride oil molecules. The term triglyceride is used to describe an oil molecule that consists of a glycerol molecule and three ester molecules. It can best be described as a tennis ball with three ping pong balls stuck on it. The tennis ball represents a glycerol molecule, while the ping pong balls represent ester molecules.

The Transesterification process (which is the process used to make biodiesel), chemically breaks the bond that sticks the ping pong balls to the tennis ball and attaches a golf ball to each of the ping pong balls instead. The golf balls represent an alcohol molecule, so now we have broken our original molecule into three alcohol/ester chains. These new molecules are known as fatty acid methyl esters (FAME) or biodiesel.

During transesterification some of the fatty acids in the oil are turned into soap, and when these soaps are combusted, they form soot. To prevent this from happening, it is necessary to remove the soaps. The easiest way to remove these soaps from the biodiesel is to use a gentle water wash, and turn the soaps into soapy water. Since oil floats on top of water because it has a lower specific gravity, the biodiesel will float on top of the soapy water. Generally the biodiesel is washed until it has a neutral pH.

The biodiesel can then be dried in a variety of ways, either by using a centrifuge, vacuum drying, or by heating and leaving to stand in a tank. Once clear, the biodiesel is filtered and then is ready for use.

The oils the FAME is produced from influence the characteristics of the biodiesel. For example, methyl esters derived from oils such as coconut, palm and animal tallows have a higher cloud point. That means in cold weather the fuel becomes thick and blocks the fuel filter and prevents the engine from starting. When the fuel is warmed up, it becomes thin again. Biodiesel made from these oils may begin to cloud at around 12 - 15°C, and are more suitable for use either in more temperate climates or blended with biodiesel (RME) made from Canola oil/ rapsole which has a cloud point similar to fossil diesel.

Initially, processing of triglycerides into biodiesel was performed on a ‘batch’ basis. The capacity of batch processing was limited to the physical size of processing tanks, agitation pumps, residence time, storage tanks and factory size. Now there are many ‘continuous flow’ processors, which incorporate technology such as centrifuges, pressurised and heated reaction chambers, vacuum drying, etc, and although physically small, have the capacity to produce large volumes of fuel (50 million litres annually or more!)

More recently, new processes such as ‘thermal decomposition’ and ‘microbial digestion’ have been used to produce biodiesel from triglyceride oils without the use of alcohols or alkyl/acids. This technology offers the possibility to produce fuel in a more environmentally friendly manner, although at this stage is not cost effective. However, as fossil reserves diminish, and there is a corresponding increase in the price of crude oil, this processing technology will become more cost effective and commonplace.

For the ‘personal use’ or ‘small scale’ producer, it is quite possible to purchase or build your own batch processor from salvage components and manufacture a high quality fuel derived from waste oil or virgin oil. However, if you intend to manufacture biodiesel in Australia, you will need to be registered with the ATO as a fuel manufacturer. There is no exemption for personal use or non-commercial production. To obtain the necessary application forms, you will need to call the Australian Taxation Office, Petroleum Industry Group Licensing Officer, phone 1300 137 292. You will be required to register your production premises and storage facilities, and it will be necessary to maintain and keep well documented records for 5 years. The period for excise settlement will be determined by the ATO.

Legal obligations and registration

In April 2004, the Energy Grants (Cleaner Fuels) Scheme Bill 2003 and Energy Grants (Cleaner Fuels) Scheme Bill 2003 were passed, which saw the taxation of the biofuels industry in Australia. This legislation saw the introduction of a mandatory registration scheme for all producers of biodiesel, with the collection of excise backdated to 18 September 2003. All producers of biodiesel are required to register for the scheme. There is no exemption for 'personal use' or 'non commercial production'. It is now illegal to produce home made biodiesel or unlicensed biodiesel. Registration is on an annual basis, and is reviewed in December.

This scheme is coupled to a manufacturers' rebate equivalent to the excise rate, and will be eventually phased out. The rebate is paid on the provision that the manufactured fuel meets the Australian standard for biodiesel. The cost to test biodiesel to the current standard, is approximately $3000.00. Presently, there is no single laboratory in Australia, which is capable of testing all the parameters of biodiesel required for the Australian standard. However, I have since been informed that the Department of the Environment and Heritage has delayed the testing of the cetane parameter until September 2005, when testing facilities will become available.

Under the new Energy Credits & Grants scheme, biodiesel is listed as an eligible fuel for on road use, but not for off road use. This will act as a deterrent for Australian farmers wishing to use biodiesel rich fuels.

Presently, Straight Vegetable oil attracts no excise as it falls outside of the fuel excise scheme. Essentially, vegetable oil is a food, not a fuel. However, if co-solvents such as biodiesel, ethanol or fossil diesel are added to vegetable oil, to improve its combustion characteristics, the entire volume is deemed to be a manufactured fuel, and is liable to taxation.

Straight Vegetable Oil (SVO) or Pure Plant Oil (PPO)

In Europe, but in particular Germany, the use of crude rape seed oil as a fuel in properly modified diesel engines has become important for a number of reasons;

- Vegetable oil helps to conserve natural resources, (e.g. fossil diesel and fuels for electricity production to power oil processing mills)
- Vegetable oil has major environmental benefits and can be used as a biodegradable fuel in sensitive areas such as farm land, alpine regions, aquatic and marine areas.
- Vegetable oil is also extremely safe to transport, handle and store. Pure vegetable oil has a minimum flash point of 220° C and is not listed in any hazardous materials class.
- Vegetable oil has a better energy balance than biodiesel, because there is no need for transesterification. There are also reduced transportation costs when used as a fuel locally where it is grown and processed.
- There is a financial incentive to use vegetable oil as an alternative fuel. Under energy reforms, the diesel fuel subsidy is reducing, while at the same time fossil diesel prices are climbing. A number of companies are now converting diesel vehicles to run on vegetable oil to take advantage of lower fuel prices. Currently there are savings of 25-45 Euro cents per litre. In Germany there are a number of trucks running on vegetable oil, and there is also a joint project which has seen the conversion of two trains to rape seed plant oil.
- Vegetable oil is also being used to generate electricity and produce 'heat' energy in co-generation units.

Suitability of diesel engines for conversion

It is also important to realise that not all diesel engines and fuel injection pumps are as equally well suited to use vegetable oil as an alternative fuel. But as a general rule, the following points apply:

- Older, indirect injection and pre-combustion chamber engines are very well suited, as they allow a longer swirl and atomisation time, which leads to a more complete combustion. These engines when combined with an 'in line' injector pump are very tolerant of pure vegetable oil.

- Rotary fuel injection pumps have been shown to be less tolerant of pure vegetable oil, in particular the Lucas rotary fuel injection pumps. Even when vegetable oil is heated, rotary injector pumps can still experience difficulties with the higher viscosity of vegetable oil. In some cases, can even lead to premature fuel pump failure.

- It is important to change engine oil at regular intervals. It is recommended to reduce oil change intervals to 125-150 hrs. Research has shown that the contamination of fossil oil with vegetable oil will lead to polymerisation, and eventual engine failure.

- If converting a diesel engine to SVO / PPO, choose a kit or conversion from a reputable manufacturer.

- Use only SVO or PPO that meets the RK Quality standard 05/2000.

In 1996, engine manufacturers introduced the Direct Injection (DI) engine. Initially, there were technical issues to deal with the conversion of these engines, but now there are many vehicles of this 'generation' that have travelled in excess of 250,000km on pure vegetable oil. After market conversions and DIY kits are now available for the majority of these vehicles on the market.

In the last few years, a new 'generation' of diesel engine has appeared on the market, namely the CDI-direct injection engine or Common Rail Injection engine. Mercedes and Volkswagen vehicles utilising these engines have been successfully converted to pure vegetable oil, and have travelled in excess of 100,000kms.

After market conversions are now offered for common rail injection engines built by these two vehicle manufacturers. In the near future, I suspect conversions will be offered for other makes of vehicles using common rail engines.

Just recently, a three year research program known as 'The Tractor 100 program' concluded. The aim of the research program was to convert a wide range of Agricultural tractors to use PPO as their primary source of fuel, and to assess if any technical or operational problems would arise as a result. The results were extremely varied. Some tractors preformed very well with little or no problems, while other tractors experienced great difficulty with PPO as a fuel. Analysis of the test results documented that the quality of the vegetable oil became a major contributing factor to the success or failure of the individual tractors. Other factors included the type of engine, the type and make of the fuel pumps and engine service intervals.

In summary, European experience has shown that by converting suitable engines (vehicles), using quality components, observing regular engine maintenance and using fuel that meets the RK Quality standard, any properly converted vehicle will not experience abnormal performance when using pure vegetable oil as a fuel.

Setting a standard

Reliable operation of engines running vegetable oil can only be achieved by using vegetable oil that is of a consistent, high quality. The properties of the vegetable oil have to meet certain values, otherwise the result can be poor engine performance and a failure to meet emission limits.

To determine the criteria for vegetable oil as a fuel, a joint research project was conducted, and a large consultative process began. This project involved 'Bayerische Landesanstalt fur Landtechnik' (Bavarian Research Centre of Agricultural Engineering) supported by the Bavarian Government, analytical services company 'Gesellschaft', and numerous manufacturers, plant oil conversion companies, mill operators and other interested groups.

The result of this process saw the creation of a 'Quality Standard for Rap-seed Oil as a Fuel' (RK Qualitatsstandard 05/2000). This standard defined nine characteristic properties of rape seed oil, and identified six variable properties of rape seed oil, which can be influenced by poor pressing procedures.

These variable properties are:

- Contamination
- Acid value
- Oxidation stability
- Phosphorus content
- Ash content and
- Water content

Contamination

Fine particles in the vegetable oil can block both fuel filters and fuel injection nozzles. Fine particles can also cause carbon deposits and wear in the combustion chamber, and have an influence on particulate emissions. The standard value has been set at 25mg/kg, which are achievable with good filtration.

Acid value

Acid value is an indication of the percentage of free fatty acids present in the oil. Free fatty acids form under certain conditions such as poor storage, oil exposure to high temperatures, water and reaction with certain metals, e.g. copper. Free fatty acids can cause corrosion, and also result in polymerisation of engine oil, which can lead to more frequent oil change intervals and in extreme cases, engine failure. The standard value is set at 2.0mg KOH/g.

Oxidation stability

This is very similar to the acid value, as oxidation stability is influenced by a high percentage of unsaturated fatty acids in the oil. Again, poor storage conditions, high temperatures, water and reactions with certain metals, e.g. copper can influence oxidation stability. The standard value has been set at 5.0 hours at 110° C test temperature.

Phosphorus content

High phosphorus levels in the oil can contribute to excessive carbon deposits building up in the combustion chamber. This can specifically cause a problem in direct injection engines, and those that operate under light engine load conditions. Phosphorus content is influenced by poor pressing procedure, and is attributed to excessive heat during the cold pressing operation. Typically, the temperature of the oil leaving the screw press should be approximately 40°C during operation. By pressing at lower temperatures, the phosphorus content of the seed is contained in the press cake, where it is a valuable nutrient. The standard value is set at 15mg/kg.

Ash

Ash is an indication of abrasive material in the fuel. The standard value has been set at 0.01%.

LTV-Work-Session on Decentral Vegetable Oil Production, Weihenstephan				in Cooperation with:
Quality Standard for Rapeseed Oil as a Fuel (RK-Qualitätsstandard) 05/2000				
Properties / Contents	**Unit**	**Limiting Value min.**	**max.**	**Testing Method**
charcteristic properties for Rapeseed Oil				
Density (15 °C)	kg/m³	900	930	DIN EN ISO 3675 DIN EN ISO 12185
Flash Point by P.-M.	°C	220		DIN EN 22719
Calorific Value	kJ/kg	35000		DIN 51900-3
Kinematic Viscosity (40 °C)	mm²/s		38	DIN EN ISO 3104
Low Temperature Behaviour				Rotational Viscometer (testing conditions will be developed)
Cetane Number				Testing method will be reviewed
Carbon Residue	Mass-%		0.40	DIN EN ISO 10370
Iodine Number	g/100 g	100	120	DIN 53241-1
Sulphur Content	mg/kg		20	ASTM D5453-93
variable properties				
Contamination	mg/kg		25	DIN EN 12662
Acid Value	mg KOH/g		2.0	DIN EN ISO 660
Oxidation Stability (110 °C)	h	5.0		ISO 6886
Phosphorus Content	mg/kg		15	ASTM D3231-99
Ash Content	Mass-%		0.01	DIN EN ISO 6245
Water Content	Mass-%		0.075	pr EN ISO 12937

00 1ER 100e

Water content

Low levels of water can actually be an advantage during combustion, as there is an increased energy output from the combustion of water. Low levels of water can also reduce combustion temperatures, which in turn reduce nitrous oxide (NOX) emissions. However, water can cause cavities and corrosion in the fuel injection system. Water content is less critical in vegetable oil than in conventional diesel, but water layers can act as a 'culture medium' for bacteria and algae during storage. The standard for maximum water content has been set at 0.075%.

Conversion kits

In Germany alone, there are over 5000 cars operating on pure vegetable oil, with over 1500 service stations retailing pure vegetable oil at the fuel bowser. This figure does not include stationery diesel engines, transport or agricultural engines. At the time I was in Germany, the comparative prices at the fuel pump were; raps (SVO) 72.9, biodiesel 82.9, diesel 94.9, ULP 110.9, premium 112.9. All prices are in euro cents.

The use of pure vegetable oil as a fuel has generated considerable interest especially in the transport industry, and in total there are a great deal more vehicles using vegetable oil as fuel.
Research and experience has shown that the combustion characteristics of pure vegetable oil are greatly enhanced by pre-heating the oil. A research project entitled, 'Advanced

Combustion Research for Energy from Vegetable Oils' (ACREVO) was conducted by the combined research of eight European research Institutes and Universities. The objective was to look at the burning characteristics of vegetable oil droplets under high pressure and high temperature conditions, and to try and address problems such as poor atomisation and coking, and to understand the mechanics of deposit formation associated with vegetable oil combustion.

The project found that the optimum temperature for the combustion of vegetable oil is 150° C. At this temperature, vegetable oil has the same atomisation, swirl patterns and combustion characteristics as conventional diesel.

The project also studied the emissions of stable gasses CO, CO_2, NOx, O_2 and hydro-carbons, i.e. temperature, soot formation and 'burnout' of rape seed oil. The resulting data was compared with that obtained from a conventional fossil diesel fuel under the same combustion characteristics. They found the overall combustion performance of rape seed oil performed very well in comparison with the diesel fuel, and determined that pure rape seed oil produced almost 40% less soot than diesel fuel.

Worldwide, there are a number of kits available that can either be professionally installed, or fitted by the motoring enthusiast. There are slight variations on the theme, but the conversion kits are based on two configurations:

- A dual tank system or
- A single tank system

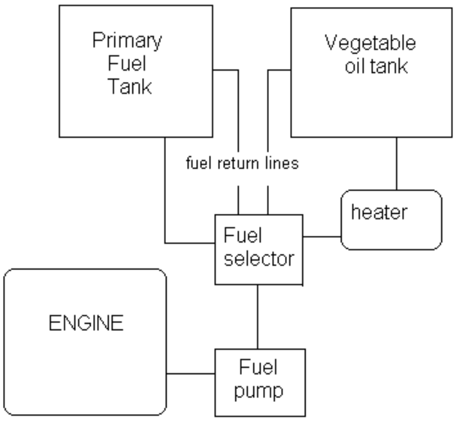
Dual tank system

A two-tank system, as the name implies, uses two separate fuel tanks. A fuel tank for diesel or biodiesel and a fuel tank for pure vegetable oil. The operation of a two-tank system involves a 'start up' and a 'shut down' procedure.

The engine is started on conventional diesel or biodiesel, and once the engine has reached operating temperature and the heat exchangers have pre-heated the oil, a fuel selector valve changes the fuel source to heated vegetable oil. Once the vehicle is nearing its destination, the fuel selector valve reverts to conventional diesel or biodiesel to 'flush' any carbon deposits that may have formed, and to allow easy starting of the vehicle. Two tank systems, because of the need for 'start up' and 'shut down' procedures, are only practical for long distances, or long travel times.

Typical components of a two tank system include:

- A primary and secondary fuel tank
- Heat exchangers to pre heat the vegetable oil; can either be coolant operated, electric or a combination of both
- On board filtration
- Selection valve
- Miscellaneous components; fuel hose, hose clamps, electrical wire, switches, etc



Simplified diagram of a two tank system

Elsbett two tank kit

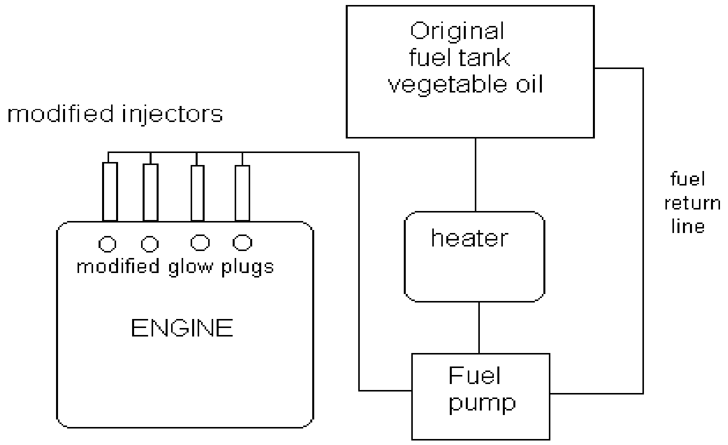
Single tank system

Single tanks systems are the more technically advanced conversions of the two options. A single tank system allows the use of vegetable oil as the only source of fuel and will allow the engine to cold start on vegetable oil, just like conventional diesel fuel.

Elsbett single tank system

Typical components of a single tank include:

- Modified fuel injectors
- Modified 'hotter' glow plugs
- Heat exchangers
- On board filtration
- Miscellaneous components; fuel hose, hose clamps, electrical wire, switches, etc



Simplified diagram of a single tank system

Mustard Seed Oil (MSO)

Vaino Laiho, Finland

Vaino Laiho lives with his wife and children on a farm in Finland, and grows Mustard. Large areas of Mustard seed are grown in Finland on fallow fields, of which a considerable portion is only suitable for non food use. Over the last decade, Vaino has been investigating the possibility of producing all his fuel from this mustard seed and has pioneered the use of mustard seed oil as a diesel fuel alternative.

Vaino has also been evaluating the suitability of mustard seed varieties for fuel. There are three types of mustard grown in Finland, although 'black mustard' is very rarely grown now.

The two main types are:

- White Mustard, mainly as a fodder crop or green manure, low oil yield, poor cold flow properties for fuel.
- Brassica Mustard, higher oil yield, high glucosinolate variety, good cold flow properties for fuel.

As well as providing a significant portion of his own fuel, Vaino has been successfully using the mustard meal as an organic fertiliser on his fields. Results from on farm trials have shown that mustard is an extremely good bio-fumigant. It also has the capacity to reduce weed germination.

Vaino has been experimenting with the use of mustard seed oil as fuel, which he affectionately calls 'Mustard diesel'. Because of extremely low winter temperatures, Vaino blends small amounts of diesel with the mustard oil to reduce its viscosity. Like Bio-power fuel, the mixture has performed well without the need for additional heating.

Similar to biodiesel, both Mustard seed oil and Mustard diesel tend to dissolve carbon deposits and contribute to fuel filter blockages until the deposits are removed.

In 1993, Vaino began working closely with Dr Seppo Nieme of Turku Polytechnic, to document and test the durability of Mustard seed oil. Since then, a number of papers have been presented to the American Society of Engineers (ASE) reporting on the success of mustard seed oil as a fuel.

The laboratory facilities at Turku Polytechnic include diesel test engines fitted with dynamometers and emissions analysis equipment. With this equipment, it is possible to simulate field conditions and accurately determine engine performance and emissions.

Left Vaino Laiho,

Dr Seppo Niemi, Right

Dr Nieme in conjunction with his associates, conducted a three stage test program including engine performance, exhaust emissions, engine optimisation (injector timing, fuel injector modification) and an engine durability test of 150 hours. Dr Nieme pointed out that unlike biodiesel, neat mustard seed oil actually had a reduction of NOX emissions, not an increase. He also observed reductions in smoke values. Testing of straight mustard oil at different temperatures to evaluate engine performance has been limited, although the few tests that have been conducted do not seem to suggest any noticeable changes in engine performance, except where the viscosity of the oil exceeds 10 –15 centi-strokes. Viscosity greater than this, can create air locks in the diesel fuel pump, and cause the engine to starve for fuel.

Engine modification

The physical modification of engines or the manufacturing of engines designed specifically for pure vegetable oil is almost now non-existent, mainly due to high costs of production or modification.

In 1965, the company Elsbett was founded as an Institute for Research and Development of the Internal Combustion engine. Elsbett developed their own engine, designed specifically to run on pure vegetable oil, and were the pioneers of mechanical direct injection technology.

The Elsbett engine featured pistons with 'combustion chambers' cast into the pistons. These chambers allow a longer period of time for more complete vaporisation of vegetable oil, as well as providing a central 'hot air combustion area'. By combusting the vegetable oil in this area of the piston, the vaporised oil blends perfectly with the air inside the cylinder. This means there is no vegetable oil coming in contact with the cylinder walls, and unwanted carbon deposits are avoided. This also eliminates the risk of polymerisation of engine oil with vegetable oil leading to possible engine failure.

Through good design, the Elsbett engine achieved an energy efficiency of 40–43%. This meant less energy was lost as heat, and as a result there was no need for engine cooling with a water radiator. The engine is sufficiently cooled by its own sump oil and its own heat exchanger (to cool the oil).

As already mentioned, Elsbett pioneered mechanical direct injection, which had the capacity to adjust to the performance demands of the engine, making the need for an additional injector pump unnecessary. Elsbett also carried out engine conversions based (mainly) around the Mercedes diesel. This involved installing the Elsbett pistons, injectors and any additional necessary modifications. Due to high servicing and manufacturing costs, Elsbett is now focusing its design expertise and experience with vegetable oil, into the area of after market car conversions and DIY kits.

Emulsified Vegetable Oil (EVO)

Recently, there has been considerable interest expressed in improving the viscosity and combustion characteristic of pure vegetable oil by manufacturing emulsions.

Like SVO or PPO, this fuel is regarded as having a better 'energy balance' than biodiesel, because of the reduced energy demands to produce this fuel. There are no by-products such as crude Glycerol or Free Fatty Acid 'soaps' created as a part of the manufacturing process. These components remain a part of the fuel and are combusted. Although glycerol has a high flash point, it contains a lot of energy. If it can be combusted without carbonisation, the glycerol will significantly increase the energy value of the fuel.

In the 'Advanced Combustion Research for Energy from Vegetable Oils' (ACREVO) research project, the following observations were made when emulsifying pure vegetable oil with ethanol;

- The addition of 9% ethyl alcohol (ethanol 95%) to the pure vegetable oil, allowed a reduction in the optimum pre-heating oil temperature from 150° C to 80° C and
- The combustion of the emulsion also significantly produced less soot, at the exhaust.

Recent research conducted by 'Bayerische Landesanstalt fur Landtechnik' (Bavarian Research Centre of Agricultural Engineering), found that the flash point of pure vegetable oil can be easily modified using petrol or diesel mixtures. Blending 1% petrol with pure vegetable oil will decrease the flash-point of the fuel to less than 100°C. Having a low flash point is advantageous because the fuel can then be used without the need for heating, as with SVO. Unfortunately, because of the low flash point, the fuel mixture may then fall into the classification of an A class hazard, as defined under the Flammable Liquids Act. The safe handling and transportation characteristics of pure vegetable oil are lost. Of the individuals and companies producing this type of fuel, the majority tends to use waste vegetable oil, as it is generally a low cost, under utilised resource. However, this may have regulatory implications.

The process of making co-solvent blends or emulsified vegetable oils, typically involves the use of settling tanks, filters, stirrers, mixers and various co-solvents. The end result is to formulate a fuel (without transesterification) that has all the characteristics of fossil diesel with the extra added advantages of;

- Environmental, social and health benefits, through greatly reduced emissions. (e.g., particulates, carbon dioxide and carcinogenic Poly Aromatic Hydrocarbons)
- Better energy balance, and reduced 'by-product' chain.
- Transforms a wasted resource into a renewable fuel, and takes it out of the 'waste management' stream.
- Uses 'low tech' and can be produced on a small or large scale, at minimal cost.
- Creates new industry, employment and business opportunities.
- May be used in any diesel engine vehicle, without the need for modification.
- Produces a fuel that is competitively priced with fossil diesel.

Bio-power (UK)

Established by Mr John Nicholson, Bio-power (UK) is an English company that produces blended vegetable oil based fuel.

The Bio-power network is an organisation that strongly advocates the capacity to modify used products such as used frying oils, to generate an alternative and renewable source of energy. Because it is such a unique concept in the UK, policy makers, legislators and the tax office, are having difficulty trying to categorise this organisation, and define how it fits into the 'traditional' framework.

Refining, filtration and separation of the 'red-skins' and 'white-skins' (clearer portion of the used cooking oil and white semi solid portion) is achieved by using a 'cascade' arrangement (very similar to 'fines' settling tanks) and residence time. Once this had been achieved, the Bio-power formula (co-solvents, peroxides and alcohol) is mixed with the oil to enhance the performance characteristics of the oil. The oil at all times remains oil. There is no chemical process such as transesterification taking place.

The Bio-power method revolves around a unique combination of solvents, cetane and viscosity improvers, to enhance the combustion and performance characteristics of used cooking oil. This achieves an improved burn characteristic, which exceeds that of mineral diesel. Bio-power fuels can also be designed for specific applications.

At this stage the Bio-power process is only two years old, and there are continuous improvements being made to the process. Where possible, Bio-power uses plant based and derived fuel improvers in their formulation. Like PPO/SVO systems, there is an improvement to be gained by using heat exchangers to warm the fuel, but this is not necessary.

Regulatory implications of using Waste Vegetable Oil (WVO) or Used Cooking Oil (UCO) in the UK

Used cooking oils and fats are classified by the EPA as an environmental pollutant, and are collected by members of the highly regulated Waste Management Collection Industry, on a 'fee for service' basis. However, when a fee is paid for the removal of used cooking oil and fats, it then falls within the legislative framework and becomes 'waste', and is subject to regulatory requirements. This regulation has occurred because of the problems associated with poor waste management practices and the illegal dumping of used fats and oils into the environment as well as into waste water and sewage drains.

To get around very specific and tight legislative powers, Bio-power UK for the purpose of the act does not charge collection fees, which means they do not operate a waste management collection service. Bio-power members will collect (and even purchase) used oil and fats to modify for use as a fuel. This point of difference, although small, enables this not for profit company to utilise a wasted resource as a valuable renewable fuel, without falling into the Waste Management Act. As a result, there is a lot of resentment towards Bio-power UK from the recycled oils and fats industries. There are legal challenges and court cases pending and occurring.

Traditionally, once the fats and oils had been collected, heated, mixed, filtered and centrifuged, the blended product was then sold into the animal feed industry. Post mad cow disease, UK and EU policy has seen the use of recycled oils and fats (which contain animal content) become an illegal practice. This will be strictly enforced in the UK this year, which will result in a significant waste management problem.

Used fats and oils are now being fed into the biodiesel industry, but the cost of the feedstock is too high to make centralised production of BD profitable. Recyclers have been selling used oil into the feed market at 28 pence a litre (and claim they cannot sell this feedstock cheaper), while for centralised biodiesel production, the feedstock needs to be 7 – 10 pence litre.

The UK Government is offering a fuel tax rebate of 20 pence per litre from the current price of ULSD, but for bio-fuels to meet the rebate criteria, they must be manufactured from used or waste vegetable oil. Fuels (biodiesel) that are manufactured from virgin oils are not eligible for this rebate. However, the EPA has determined that once a product has been classified as a waste, all people who handle that product until its eventual disposal (including motorists who fill their fuel tanks) need to be registered with the EPA as Waste Management Collection Services. This has created the ironic situation that if any bio-fuel is manufactured from a feedstock that has been provided by a Waste Management Collection facility, then that fuel is subject to waste regulations, through the entire chain, until that fuel is finally disposed of, namely by combustion in a diesel engine. The UK Government is encouraging producers to manufacture biofuels from recycled fats and oils, only to be made unviable by the EPA!

Biodiesel production in the UK like Australia, is tightly controlled by Government legislation, and restricted to large centralised production. To date, Bio-power has been successful in representing their position and continues to lobby for legislative reform.

Recommendations

I feel more strongly convicted than ever before, that the renewable fuels industry has significant potential for Australian agriculture, and a part of that industry is de-centralised energy production. For this potential to be reached in Australia, it has to be a concerted effort between farmers, researchers, farmer representative bodies and Government.

Like the USA, we need to conduct research to identify and select oil producing crops suitable for the Australian environment and farming systems. Ideally, we need crops that are capable of producing high yields of non-food grade oil (like the mustard program), or to make available a wide selection of oil bearing crops that have a specific role to play in a crop rotation. These could include a bio-fumigant (mustard), an oil bearing legume (lupin equivalent to soya bean), oil bearing salt tolerant grasses / shrubs and oil bearing trees (Jatropha for example).

Australian agriculture has an opportunity to utilise renewable fuels in its production, given 'fair and reasonable' legislative treatment. Ideally, the Australian Government needs to remove excise tax from renewable fuels in order to stimulate and encourage growth in the renewable energies sector.

In this respect, the EU and in particular the German government is very active in their promotion of biodiesel and biofuels, and have introduced legislation that has seen enormous growth in the biodiesel and biofuels industry. In November 2003, the EU council of Ministers overwhelmingly adopted a new Directive on Energy Taxation to remove excise on biodiesel and biofuels. This followed the earlier adoption in May 2003 for the promotion of biofuels, which directs EU member states to increase the use of biofuels to a minimum of 2% in petrol and diesel sold for transport in 2005, and increasing to a minimum of 5.75% by 2010.

A revision of the standard for diesel has also seen biodiesel blends of up to 5% with fossil diesel to be considered conventional diesel and exempt from taxation. This legislation has opened up the possibilities of mineral oil industries forming partnerships with the biodiesel sector to market blends of up to 5%.

The mid term review of the CAP in June 2003, maintained set-aside arrangements for agriculture and saw the creation of a new support scheme for non-food crops, and a ‘carbon credit’ payment of $45euro/ha for EU farmers growing energy crops.

The overall result of this legislation has seen huge growth in the EU biodiesel industry. Total biodiesel production has grown from 1.05 million tonnes in 2002, to over 1.4 million tonnes in 2003 and projected to reach 2.24 million tonnes in 2004. Germany, the EU’s largest producer of biodiesel, is projected to produce 1.088 million tonnes, almost half the total biodiesel production in Europe.

In the UK a partial de-taxation of biodiesel of 20 pence per litre is being applied, although the price of biodiesel is still not competitive with fossil diesel. In April 2004 the British Government conducted a 12-week consultation with the industry to examine new tools to support biofuels, including the introduction of mandatory blending of biofuels with fossil fuels, and the de-taxation of biofuels.

Australia has the potential to become one of the world’s largest producers of renewable energy. Australia has a natural geographical advantage for the production of biofuels. As a country, Australia receives one of the highest levels of sunlight hours per year. We should be looking to capitalise on this natural advantage. Regardless of Government policy in Australia, there is still a large export market of vegetable oil in Europe to satisfy.

In Finland of all places, they have a research program evaluating mustard oil as a renewable fuel! This is surprising considering Finland’s close geographical location to the artic circle. By comparison in Australia we have vast area of land not being utilised as it is regarded as being unsuitable for traditional agriculture. This, for example, may be an opportunity to use saline water ponds to grow algae, from which we can extract oil and manufacture biodiesel.

Australian farmers through the NFF and state representative bodies, need to formulate environmental policy and renewable fuel policy to demonstrate that we are ‘fair dinkum’ about our ‘clean and green’ reputation. Australia is a part of the global village, and as such we have an obligation to the world to be responsible with our ‘greenhouse’ emissions. A move towards the production and use of renewable fuel should be a part of our commitment for global social responsibility.

Rather than relying on Government legislation, the free market through the establishment of a ‘carbon trading exchange’, may be the mechanism to see businesses move to emission reduction strategies in Australia. The financial markets could then create commercially viable opportunities through alternative income streams.

I believe the renewable energies sector is going to be one of the most exciting industries to emerge this century, and will provide new opportunities for agriculture. As in Europe, I believe there is no reason why de-centralised fuel production cannot be integrated into any farming operation, adding to the overall economic stability of Australian agriculture.

References

Small scale processing machinery specification brochure,
Egon Keller GMBH & Co,

Elsbett Technologie GmbH, 2002 company profile

"Production of Vegetable oils in de-centralised plants and aspects of quality Management – Investigations on plants in practice to optimise the process", Bernhard Widmann, University of Munich, Centre of Agricultural Engineering, Freising, Germany

"Purification of Cold pressed rapeseed oil to use as a fuel for adapted diesel engines", E Remmele & B Widmann, Bavarian Research Centre of Agricultural Engineering, Freising, Germany

"Minimum requirements of rapeseed oil as a fuel in vegetable oil suited engines", E Remmele, BA Widmann, K Thuneke, Bavarian Research Centre of Agricultural Engineering, Freising, Germany

"Interaction between rapeseed oil fuel and motor oil", K Thuneke, A Rockaschel, TFZ, Straubing, Germany

"Standardisation of rapeseed oil as a fuel", K Thuneke, E Remmele, B Widmann & Th. Wilharm, Proceedings 1st World conference on Biomass for energy and industry, 5-9 June 2000 in Sevilla, Spain

"Quality of rapeseed oil as a fuel for adapted diesel engines – field survey", E Remmele, K Stotz, TFZ, Straubing, Germany

'Bio-power introductory seminar information pack' September 2004, J Nicholson, Bangor, Wales

"Results from a durability test of a mustard seed oil driven tractor engine", Seppo A. Niemi & Timo T. Hatonen

"From the fryer to the fuel tank", Joshua Tickell

Peak oil website, www.hubbertpeak.com/hubbert

"University of Rostock: Fuel from Rapeseed in tractors". PowerPoint presentation.