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Advantages and Challenges of Hemp Biodiesel Production:

A comparison of Hemp vs. Other Crops Commonly used for biodiesel production

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Abstract

Reducing reliance on a fossil fuel is a major challenge to many advanced and developing economies. This is due to the fact that fossil fuel, a finite resource, is depleting at a rapid rate with increasing demand. Additionally, the burning of fossil fuel is responsible for the current climate change, as a result of produced greenhouse gas emissions. Lastly, developing alternative renewable fuels improves energy security and decreases vulnerability of fuel supply. This thesis work explores the advantages and challenges of hemp biodiesel production. The aim of this research is to present a comprehenive evaluation of these advantages and disadvantages in the way of large-scale production of biodiesel produced from hemp oil. The thesis work relies on relavent research paper in the field and reports from the industry. Industrial hemp, a variant of the *Cannabis Sativa* plant (*Cannabis Sativa Linn*), is an important industrial and nutritional crop. Hemp seed oil can be used to produce biodiesel though the process of transesterification. Oil from hemp seeds presents a viable feedstock option for biodiesel production. Hemp provides a competitively high yield compared to similar crops. Biodiesel from hemp seed oil exhibits superior fuel quality with the exception of the kinetic viscosity and oxidation stability parameters, which can be improved with the introduction of chemical additives. Hemp remains a “niche” crop in the food supply chain, which makes it prohibitively expensive a primary feedstock in biodiesel production. Legal and perception challenges remain a major challenge in the way of wide-scale hemp biodiesel production.

Preface

I would like to express my very special thanks and gratitude to my supervisor and program director, Dr. Nawzad Mardan and my thesis examiner, Dr. Taghi Karimipanah for the guidance and support through this thesis work, as well as, throughout the program. This Master Thesis work is submitted in partial fulfillment for the Master in Energy System program granted by Gävle University. I would like to extend my thanks also to the teaching and administrative staff at Gävle University as well as the teaching staff at Uppsala University and the Royal Institute of Technology in Stockholm for their efforts and support throughout the year.

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Abbreviations and Definitions

THC - Tetrahydrocannabinol
PCDDs - Polychlorinated Dibenzodioxins
EEA- European Environmental Agency
IEA- International Energy Agency
SO_x – One of more type of Sulfur Oxide Compounds (SO, SO_2, SO_3, …etc)
GHGs – Greenhouse Gases
BCMAF – British Columbia Ministry of Agriculture and Food
Kg/Ha – Kilograms per Hectare
ASTM – American Society for Testing and Materials

1. Introduction

Industrial hemp, a variant of the *Cannabis Sativa* plant (*Cannabis Sativa Linn*), is an important industrial and nutritional crop. Hemp is cultivated to produce a vast variety of products such as hemp seeds, hemp oil, clothing, rope, paper, insulation, cosmetics, biodegradable plastics, construction material (such as Hempcrete®), resin, pulp, animal bedding and fuel (Wirtshafter 2004). Industrial hemp is one of the fastest growing biomasses and one of the earliest domesticated plants known to humans. It also goes with the green future objectives that societies and governments aim to shift towards in the twenty first century. Hemp requires little to no pesticides or herbicides (EEA 2006). It has deep roots, which helps control the erosion of the topsoil (Amaducci, et al. 2008). Moreover, hemp can be used as a viable environmentally friendly replacement to many potentially harmful products such as tree paper, cotton and synthetic clothing, etc. Hemp paper production does not require the use of chlorine bleaching which produces PCDDs, a carcinogenic waste product common in tree paper production that contributes to deforestation. In comparison, hemp paper can be lightened by the use of non-toxic hydrogen peroxide (Van Roekel 1994). Furthermore, Hemp based biofuels present a viable, low emission replacement for petroleum-based fuels.

In 2002, 18,000 hectares of land were used for hemp cultivation in the EU. However, hemp end products were limited, as 70-80% of the hemp fiber produced was used as pulp and cigarette paper, 15% for automotive parts, 5-6% for insulation mats. As for the seeds, 95% were used as animal feed (Karus 2004).

Figure 1: A Field of Cannabis Sativa L. (Industrial Hemp). Source: Nebraska Hemp Industries Association

Biodiesel is a renewable energy alternative to fossil fuels that is composed of a group of long chain fatty acids called mono-alkyl esters. It is a highly efficient diesel replacement that is produced by a process called transesterification, a chemical reaction between vegetable or animal fat and alcohol in the presence of a catalyst to produce biodiesel (Mannan, et al. 2006). Unlike diesel produced from petroleum, it contains very low level of sulfur, which produces sulfur oxide (SO_x) emissions when burned, a major precursor to acid rain (He, et al. 2009). Additionally, biodiesel requires no modifications to the diesel engine.

Currently, biodiesel is produced commercially mainly from soybean oil in the United States, Palm Oil is Southeast and East Asia and rapeseed oil in Europe (Rosillo-Calle, Pelkmans and Walter 2009).

1.1 Research Question

In this paper, the advantges and challenges (pros and cons) of hemp biodiesel production are identified and discussed. Precisely, the viability and obstacles of hemp biodiesel production are highlighted. Hemp is compared to other energy crops that are used in biodiesel production. Does industrial hemp have an advantage? And does it have the potential to be used as an energy crop for large-scale biodiesel production?

When compared to other crops, does hemp have an advantage to be used in large-scale biodiesel production. What are the advantage and challenges asscociated with hemp biodiesel production?

1.2 Research Objective

The objective of this research is to present a comprehenive evaluation of the advantages and disadvantages of hemp biodiesel production. Preliminary research indicates that industrial hemp has a great potential for biodiesel production with certain challenges.

This research aims at answering the following questions:

1. Does hemp biodiesel present a high quality biodiesel fuel?
2. How does biodiesel from hemp compare to biodiesel produced from other energy crops?
3. What are some of the legal and market obstacles affecting hemp biodiesel production?
4. Does hemp has the potential to be used for large-scale biodiesel production?
5. What are some recommendations to address the challenges affecting hemp biodiesel production

1.3 Methodology

The methodology used in this research relies heavily on literature review of relavent scientific papers and reports from the industry. Considering that hemp has been recently revived as an industry after a wave of legalization across Europe and North America, research in this area is stll very limited generally due to the small size of the industry. Additionally, There is a wide spread stigma regarding hemp cultivation as a result of the confusion regarding its association with the sister species of the Cannabis Sativa L. plant containing high levels of TLC, colloquially referred to as marijuana.

1.4 Limitation of Scope

This scope of this research paper is limited to the study of hemp-based biodiesel fuel. Aside from introducing hemp, its properties, products and history, this report deals strictly with hemp biodiesel and its production. Other hemp products although mentioned are not investigated further as stated in the research question.

1.5 Historical Background

Hemp is one of the earliest cultivated plants known with a history dating back to over 8000 years. Hemp fiber was used extensively in China to make clothes, rope, footwear, paper and food (NAIHC 1997). In later millennia, industrial hemp use became widespread in the Middle East, Europe and Asia. Hemp was also widely used in North America. British colonies were compelled by law to cultivate cannabis sativa, as hemp was the fiber of choice for maritime. It was known for its natural decay resistance and excellent adaptability to cultivation and was used extensively in ship building. Over 120,000 pounds of hemp fiber was used for the rigging of the 44-gun USS Constitution, America's oldest navy vessel (Will 2004). Hemp biodiesel remains an area of little research for a variety of factors discussed in this paper. However, the history of biodiesel fuel goes back to over 150 years.

Chemists E. Duffy and J. Patrick were credited for conducting transesterification of vegetable oil as early as the year 1853. Meanwhile, Rudolf Diesel's prime engine model ran on its own power on August 10, 1893 in Germany. The day has been declared International biodiesel day. The Diesel engine ran on Peanut oil and Diesel was rewarded the "Grand Prix", the highest price at the Paris Exhibition in 1900 (Abdalla and Oshaik 2013). Henry Ford also designed his 1908 Model T automobile to be powered with ethanol, a biofuel made from hemp or corn

(Odec.ca 2015). The first account of biodiesel as we know it today is credited to Belgian scientist G. Chavanne who, in 1937, was granted a patent titled "Procedure for the transformation of vegetable oils for their uses as fuels". The patent is essentially as process of esterification of vegetable oil using ethanol to lower the viscosity of pure vegetable oil and therefore improving the quality of the vegetable oil used as fuel (Xiao and Gao 2005).

Due to the widespread access to inexpensive petroleum based fuels, biofuels gained little interest. After the oil crisis in the 1970s, interest in biofuels was renewed and the first industrial process for the production of fuel was invented in Brazil in 1977. Further efforts in Europe and South Africa further advanced the development of biodiesel in the 1990s (Pacific Biodiesel 2015). With the advent of global warming caused by the emission of GHGs and increased environmental awareness led to renewed enthusiasm in biodiesel fuel as well as other alternative energy fuels.

2. Hemp as an Energy Crop

Many discussions regarding hemp biodiesel and biomass production have focused on the problem of food vs. fuel. In other words, should agricultural land be reserved for producing food crops? Are prices of food affected by using the land to cultivate crops for the purpose of producing fuels? Hemp seems to have a clear advantage over other crops in this regard due to its ability to grow on infertile soil, which leaves the fertile land reserved for food crops. Hemp does not require the use of lots of water or fertilizers to grow and the resilient plant has only a few known diseases that do not usually affect the yield (Buckley 2010).

> *"For sustainable fuels, often it comes down to a question of food versus fuel," says Parnas, a researcher at the University of Connecticut, noting that major current biodiesel plants include food crops such as soybeans, olives, peanuts, and rapeseed. "It's*

> *equally important to make fuel from plants that are not food, but also won't need the high-quality land." (Buckley 2010)*

Nevertheless, there are favourable climatic and soil conditions that provide optimal yield such as sufficient sunlight during the early stages of growth, 300-400mm of rain during the growth season, rich well-drained soil and high fertility (Hemp Technologies Collective 2015) (UoK 2014). Hemp is prone to a range of diseases and insects. However, these diseases are not widespread and are considered insignificant (UoK 2014). In addition to the use of hemp seeds in biodiesel production, the discarded stems can be returned to the soil to provide additional nutrients (UoK 2014). Hemp can grow in a wide range of climatic zones as illustrated in the figure 2 below.

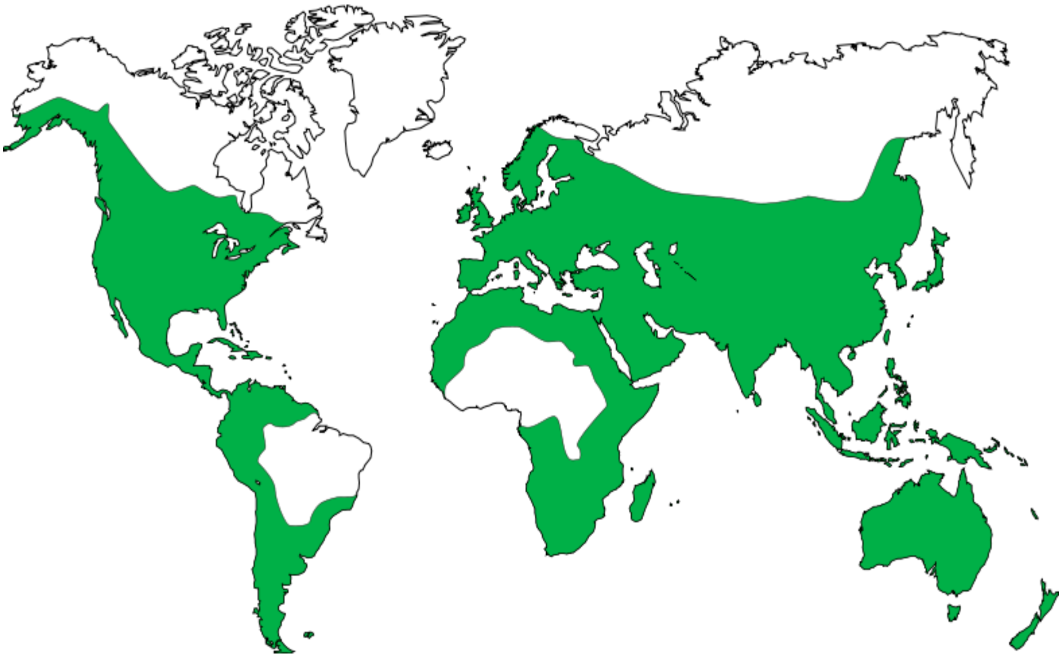

Figure 2: Suitable Climate Zones for Hemp Cultivation. Source: Wikimedia Commons

When discussing fuel crops it is important to compare the crop yield to determine if one crop has an advantage over another.

Table 1 Biodiesel Yield per Acre from Selected Crops

Crop	Fuel Yield (gallons/ha)	Source
Oil Palm	508	(Brown 2006)
Coconut	230	(Brown 2006)
Rapeseed	102	(Brown 2006)
Peanut	90	(Brown 2006)
Sunflower	82	(Brown 2006)
Soybean	56 (Author's estimate)	(Brown 2006)
Hemp	**207 (Calculated)**	**See below**

Statistics on Hemp biodiesel yield are scarce since the production of hemp biodiesel fuel remains an untapped territory. However, biodiesel yield can be estimated using a number of mathematical formulas taking into account hemp seed yield and oil content of the seed, biodiesel conversion rate, etc. The hemp seed yield of the most productive variety of hempseed can exceed 2000 Kg/Ha under good growing conditions (FINOLA 2014) (Callaway 2010). Hemp seeds contain an oil content of roughly 30-35% of the seed weight (FINOLA 2014) (Leizer, et al. 2000). The British Columbian Ministry of Agriculture and Food in Canada reports in its Specialty Crops Factsheet that hemp seed yield of about 1.54 – 2.64 tons/ha, which converts to 226-388 liters per acre at an extraction rate of 35% (BCMAF 1999). For the sake of this report, it is assumed that the average yield of hemp seed is 2000 Kg/Ha. Another important factor in calculating the hemp biodiesel yield is the biodiesel conversion rate, which is the rate of biodiesel output to hemp oil input in the process of transesterification. The conversion of Cannabis Sativa L. seed oil into biodiesel has a high rate of conversion that is greater than 99.5% with a total product yield of over 97%. This means that the product loss due to saponification is very low (Li, Stuart and Parnas 2010).

Finally, hemp seed biodiesel yield can be calculated using the following equation:

$$\text{Hemp Biodiesel Yield} = \text{Hemp Seed Yield} \left(\frac{Kg}{Ha}\right) x\ 35\%\ (\text{Oil Content})\ x\ 1.163 \left(\frac{l}{Kg}\right) x\ 0.264172 \left(\frac{gallons}{l}\right) x\ 97\%$$

Equation 1 Hemp Seed Biodiesel Yield

The above equation gives a total biodiesel yield of 207 gallons/ha, which places well above rapeseed biodiesel on the chart in table 1.

3. Hemp Biodiesel

Biodiesel is produced commercially from a variety of crops, mainly from soybean oil in the United States, Palm Oil is Southeast and East Asia and rapeseed oil in Europe (Rosillo-Calle, Pelkmans and Walter 2009). The quality of fuel depends on a range of characteristics such as heat value, specific gravity, flash point, sulfur content, viscosity, cloud point, pour point, oxidization stability, etc. ASTM standard in the USA and Canada and EN 14214 in the EU defines minimum and maximum limits for these parameters (see table 2).

Figure 3 Hemp Biodiesel is known for its distictive green color

The flash point is the minimum temperature calculated to a barometric pressure of 101.2 kPA at which the fuel will ignite under specific conditions. It is used to classify fuels for transport, storage and distribution according to hazard level. The flash point does not affect the combustion directly; higher values make fuels safer with regards to storage, fuel handling and transporation (Barabas and Todorut 2011). The cloud point is the temperature at which wax crystals begin to form in a petroleum product as it is cooled. The pour point is the lowest temperature at which a petroleum product will begin to flow (Diesel Fuels 1996). Viscosity is defined as the resistance of a fluid to gradual deformation by shear and tensile stress. In other words, it's the fluid resistance to flow or thickness. As biodiesel use has become more widespread, engine manufacturers have expressed concerns with regards to biodiesel's higher viscosity which could result in higher fuel injection pressure at low operating temperatures. However, biodiesel fuels have demonstrated temperature dependent behavior similar to that of common diesel fuels (Tat and Van Gerpen 1999). Sulfur content is an important parameter as burning fuels containing higher sulfur content releases sulfur oxide compounds which are major pollutants and a leading cause of acid rain. Biofuels in general have negligible sulfur content as demonstrated in table 2 below. Oxidation stability is an important indicator of long-term storage capability of the tested fuel (Hartikka, et al. 2013).

Table 2 EN 14214 Biodiesel Quality Specification (CEN 2012)

Property	Unit	Lower Limit	Upper Limit
Ester Content	% (m/m)	96.5	-
Density at 15°C	kg/m³	860	900
Viscosity at 40°C	mm²/s	3.5	5.0
Flash point	°C	> 101	-
Sulfur content	mg/kg	-	10
Cetane number	-	51,0	-
Sulfated ash content	% (m/m)	-	0,02
Water content	mg/kg	-	500
Total contamination	mg/kg	-	24
Copper band corrosion (3 hours at 50 °C)	rating	Class 1	Class 1
Oxidation stability, 110°C	hours	8	-
Acid value	mg KOH/g	-	0,5
Iodine value	-	-	120
Linolenic Acid Methylester	% (m/m)	-	12
Polyunsaturated (>= 4 Double bonds) Methylester	% (m/m)	-	1
Methanol content	% (m/m)	-	0,2
Monoglyceride content	% (m/m)	-	0,7
Diglyceride content	% (m/m)	-	0,2
Triglyceride content	% (m/m)	-	0,2
Free Glycerine	% (m/m)	-	0,02
Total Glycerine	% (m/m)	-	0,25
Group I metals (Na+K)	mg/kg	-	5
Group II metals (Ca+Mg)	mg/kg	-	5
Phosphorus content	mg/kg	-	4

Furthermore, the fuel qualities of different biodiesel products are gathered from different studies and presented in table 3 below.

Table 3 Properties of various biodiesel fuels

Fuel / **Property**	Hemp Biodiesel	Soybean Biodiesel	Rapeseed Biodiesel	**EN 14214 requirements** (CEN 2012)
Flash point (°C)	162	138	96	101
Density (kg/m^3)	864	875	882	860 - 900
Sulfur content (ppm)	0.4	1.1	2.4	10
Kinematic viscosity at 40 °C (mm^2/s)	5.13	3.15	4.37	3.5 - 5
Cloud Point (°C)	-4	0	-4.1	Maximum 0 – 2 for superior quality biodiesel
Pour Point			-12	
Oxidization stability at 110°C (hours)	poor	2.35 (poor)	5.6 (poor)	8
Sources: (Mahajan 2011) (He, Van Gerpen och Thompson 2009) (Li, Stuart and Parnas 2010)				

According to fuel properties listed in table 3 above, hemp is a cleaner fuel than soybean and rapeseed biodiesel fuels. This is demonstrated by a significantly lower sulphur content. It is also a safer fuel for handling, storage and transport due to its higher flash point. However hemp biodiesel performs poorly when it comes to its kinematic viscosity which is slightly higher than the European EN 14214 max of 5 mm^2/s but still lower the American ASTM D6751 maximum of 6mm^2/s (ASTM 2015). Furthermore, Hemp biodiesel as well as other biodiesel exhibit poor oxidation stability compared to common diesel varieties and below the 6 and 8 hours specified by the ASTM D6751 and EN 14214 respectively. It follows that these parameters can easily be improved with the chemical additives to satisfy testing specifications. For example, Antioxidants are often used to inhibit biodiesel oxidative degradation and increase the shelf life of the fuel. (Rizwanul Fattah, et al. 2014). Also, the higher viscosity of biodiesels can be improved by either blending it with petro-diesel or less saturated FAME, as well as the use of some additives (Nwadike, et al. 2013). Therefore, non-blended hemp biodiesel can provide a viable alternative to petro-diesel and a competitive biodiesel when compared to other crops.

4. Hemp biodiesel Blends

Biodiesel can be blended with petroleum diesel at different percentages. The "B" factor is universally used to designate the percentage of biodiesel in the mix (National Biodiesel Board 2015). The most common of these blends are B100, B20, B5 and B2 which contain 20%, 5% and 2% respectively. Fuels are blended for various reasons such as environmental compliance. For example, the Brazilian government has made it mandatory for vehicles to run on blended fuels since 1976 (Biofuels UK 2015). Under the ASTM D975 specification for conventional diesel fuel, low-level blends, such as B5 with 5% biodiesel content or less, can be marketed as 'Diesel' without a separate designated label (US Department of Energy 2015). B20 biodiesel blend is one of the most common blended fuels. It is popular because it represents a good balance of improved performance, lower emissions, materials compatibility, cost and its ability to act as a solvent. In the United States, most biodiesel users can purchase B20 biodiesel blends from the normal fuel distributors (US Department of Energy 2015). Additionally, biodiesel blends of 20% or lower do not require any modification to the diesel engine (NREL 2015). Biodiesel can also be used without blending (B100), however, certain modifications to the engine are required to avoid maintenance and performance issues (NREL 2015). B100 (Pure Biodiesel) contains 8% less energy content than its petroleum counterpart. This represents about 1-2% overall difference. However biodiesel users report negligible difference in fuel economy or performance (US Department of Energy 2015). B100 blend (pure biodiesel) is the least common fuel available at the pump as it requires biodiesel compatible engine parts such as hoses and gaskets. Nevertheless, it can be used on some engines built after 1994 with biodiesel compatibility. On the other hand, Biodiesel fuels exhibit superior engine cleaning effect since they act as solvents and can be used to clean the deposits accumulated in the engine due to petrol diesel use (US Department of Energy 2015).

Hemp performs well in biodiesel blends. In one comparative study, it is found that hemp B20 blend provides better thermal efficiency, lower specific fuel consumption, reduced CO and CO_2 emissions in comparison to pure diesel and Jatropha B20 blends. However, the hemp blend has a higher NOx emission in the study (Gill, Soni and Kundu 2011).

5. Environmental Impact

Hemp biodiesel presents a carbon neutral replacement to diesel fuel. During the three month life cycle of the plant, the cannabis ingests carbon dioxide at a rapid rate much greater compared to that of trees, which makes hemp a very effective scrubber of carbon dioxide. Effectively, hemp could provide the means to by which we are not introducing additional carbon into the environment. Therefore, offering another alternative fuel source to offset our reliance on fossil fuels (Thompson 2013). The carbon dioxide emissions released to the atmosphere when burning biodiesel is reabsorbed through photosynthesis. The short life cycle of hemp allows for crop rotation such as winter cereals which is beneficial to the soil and the yield of both types of crops (Thompson 2013). As a rule of thumb, the emission benefits from using biodiesel fuels corresponds roughly to the blend rating of the fuel. For example, a B20 blend use translates to 20% reduction in greenhouse gas emissions compared to petroleum diesel (US Department of Energy 2015).

Hemp seed oil has a clear advantage over palm seed oil as a source of biodiesel fuel. Palm oil is one of the most commonly produced types of biodiesel, primarily in Southeast Asia. The expanding production of palm oil has a tremendous negative impact on the environment. It is facing increasing scrutiny worldwide for its destruction of the rain forest and wildlife, including the displacement of animal and human populations, and the resulting Carbon dioxide emissions. Therefore, crop selection is very important when combating climate change. According to Stanford research study regarding oil palm plantations published on Oct 7, 2012 in the journal of *Natural Climate Change*:

> *Plantation expansion is projected to contribute more than 558 million metric tons of carbon dioxide to the atmosphere in 2020 – an amount greater than all of Canada's current fossil fuel emissions.*
>
> *In 2010 alone, land-clearing for oil palm plantations in Kalimantan emitted more than 140 million metric tons of carbon dioxide – an amount equivalent to annual emissions from about 28 million vehicles. (Harrison 2012)*

Indonesia, which has the third largest tropical forest within its territories, is one of the largest greenhouse gas emitters in the world. This is due to the effect of deforestation which has cleared over 16 000 square kilometers of Kalimantan's tropical forest, this equates to 60% of its forested areas that has been cleared since 1990 for the cultivation of oil palm trees. (Harrison 2012). Considering hemp's adaptability to various climate regions, it can be used to replace palm oil production as it does not require being cultivated in areas of high precipitation such as the tropics and therefore avoiding further destruction of the rain forest.

Figure 4 Deforestation in West Kalimantan, Indonesia (Source: Rainforest Action Network)

Therefore, it's evidently counterintuitive to consider using palm oil for biodiesel production in order to offset greenhouse gas emissions. For this reason, hemp can also be used as alternative to biodiesel production from palm oil.

6. Technical, Financial and Legal Hurdles

So if hemp is an excellent ecological choice that in parallel to biodiesel production can also offer a great potential for carbon sequestration through the use of its endless product possibilities such as fuel, hempcrete® (Construction blocks made from hemp hurds and lime), textile products, paper, pulp, insulation, etc. all which can be produced from the discarded stems of the plant; Moreover, if biodiesel from hemp is shown to provide a greater yield than many conventional biodiesel crops (i.e. rapeseed, soybean) and exhibit similar fuel quality to that of other types of diesel and biodiesel with the possibility of improved oxidation stability through the addition of antioxidants; Then, what are the obstacles in the way of large scale hemp biodiesel production?

The answer may lay in a series of legal and financial hurdles that crippled the industrial hemp industry and production.

In the early 20th century, hemp production went into decline in Western Europe and the United States as a result of decreased demand of the fiber due to the rising popularity of synthetic fiber at the time. (Will 2004). The Marijuana Tax Act of 1937 in the United States effectively banned industrial hemp production as hemp was erroneously put in the same category as the recreational variety of cannabis containing the psychoactive constituent Tetrahydrocannabinol (TLC). Soon after, many nations followed by enacting similar laws, effectively marginalizing industrial hemp production. However, in more recent years, many nations started revoking their ban on industrial hemp production, recognizing its great potential. While many others still have effective bans in place, hemp production is back on the rise again.

The following table shows the 2013 worldwide hempseed production rates:

Table 4 2013 hempseed production rates

Country	Hempseed Production (Tonnes)
France	48264
China	16000
Chile	1450
Ukraine	1000
Hungary	600
Russian Federation	297
Romania	150
Poland	30
Source: FAO	

The above nations are the only substantial hemp producers in 2013. These low production rates and the rising awareness of the health benefits of hempseeds and oils have made hemp a niche crop in the food and health supply chains where it garners premium prices (Jessen 2007).

> *Today, high demand within the food market, limited production and low yields per acre make industrial hemp unattractive as a viable option for biodiesel production. That could change, however, if states like North Dakota can overcome federal roadblocks to produce industrial hemp in the United States (Jessen 2007)*

At the current rates of production, farmers can make much greater profits selling their seeds in the food market than making biodiesel fuel. Arthur Hanks, executive director of the Canadian Hemp Trade Alliance, in an interview with Biodiesel Magazine, acknowledges these factors as obstacles to using hemp as a feedstock to biodiesel production.

> *Price is the big issue, Hanks says, (...). The human nutritional market pays well for hemp seed. Currently, conventionally grown hemp seed brings in about 45 Canadian cents a pound, he says. Certified organic seed garners 85 Canadian cents a pound, or nearly CAN$40 a bushel. (Jessen 2007)*
>
> *Then there's the hurdle of limited supply. Although healthy demand has increased hemp production numbers in Canada, there's just not enough quantity to go around. In 2005, 24,000 acres of hemp were planted in Canada, more than doubling to 50,000 acres in 2006. "That particularly, is very much an issue of economies of scale," Hanks says. "We are still very much a specialty crop." (Jessen 2007)*

Many still confuse hemp with its more sinister relative marijuana, which contains a significant amount of tetrahydrocannabinol (THC), a hallucinogenic compound that makes smoking and growing marijuana illegal in most countries. Industrial hemp has only a trace amount of THC, and its seeds are currently consumed in a variety of food products. The perception and legal status of hemp need to be challenged to produce a positive influence in hemp related industries.

As hemp production remains illegal in the United States and many other countries. This remains the largest obstacle for a large scale hemp production. However, as the momentum to legalize hemp production is on the rise, the barriers could go up in flames.

Another major hurdle to widespread biodiesel use is the required modification to the diesel engine when – modifications –manufacturers waeeanties – standards – etc. However, this is changing as most recent diesel engines are made to be biodiesel compatible.

There are also some technical and incentive barriers that contribute to hemp biodiesel production and biodiesel in general. One of these technical barrier is that higher blend rating require engine modification to avoid performance and maintenance issues. B100 blends must meet the ASTM D6751 in the United States and EN 14214 in the European Union. Further industry standards and tests are needed for different blend ratings and for different feedstock blends.

7. Conclusion and Recommendations

In a nutshell, hemp oil has a great potential to be used as a primary feedstock, or in combination with other types of oil, in the production of biodiesel fuel. It has not yet been produced on a commercial scale despite numerous studies indicating its advantages.

The cultivation of hemp does not affect agricultural lands reserved for food crops as it has shown tremendous resilience to disease and ability to grow on infertile land with minimum use of pesticides. Hemp can also be incorporated in other crop rotations in which both types of crops would benefit.

Since hemp seeds are used in biodiesel production, the discarded stems of the plant can provide substantial added economic value as it can be used in biomass ethanol production, or the fiber can be utilized in a variety of industrial processes as discussed earlier.

When compared with similar crops that are used in large-scale commercial biodiesel production, hemp provides a substantially greater yield and has a higher oil content than that of rapeseed and soybean. In addition, biodiesel made from hempseed can meet the ATSM D6751 and EN 14214 requirement for fuel quality and surpass that of conventional diesel except in the area of oxidation stability, as is the case with other biodiesel products. However, the oxidation stability can be improved with the addition of antioxidants to the fuel prolonging its shelf life.

Some barriers remain in the way of commercial hempseed biodiesel production. One of the main reasons is the fact the hemp seeds remain a “niche” crop in the food supply chain. Farmers can garner high profits selling hemp seeds in the food supply chain as opposed to feedstock for biofuel. The low hemp production does not match the high demand it garners in the health and food markets. So unless supply surpasses demand for hemp, it will remain prohibitively expensive to be utilized in biodiesel production. Also, the current worldwide production of hemp is very low with only few countries producing it as legal and perception barriers remain a big challenge. Hemp still faces substantial legal hurdles to overcome in many jurisdictions around the globe. It remains illegal in the United States on a federal level as well as in many other countries. There is still room for improvement when it comes to public perception of hemp, as many confused hemp with its close relative variety of the cannabis plant containing THC.

Below is a summary of results and recommendations:

- Hemp seeds present a viable feedstock option for biodiesel production. This is demonstrated by the plant's high yield, ability to grow on infertile soil, resilience to disease and bugs.
- Hemp provides additional economic value, as the discarded stems can be used or sold as raw materials for a wide range of products.
- Hemp biodiesel yield was calculated at 207 gallons/ha. This is higher than the yield of biodiesel from rapeseed and soybeans oils but lower than that of palm oil.
- Hemp biodiesel can meet ASTM D6751 and EN 14214 requirements.
- Hemp biodiesel exhibit poor kinematic viscosity and oxidation stability. However, this can easily be improved with the use of additives.
- Hemp biodiesel performs well in biodiesel blends.
- Hemp biodiesel provides substantial environmental benefits. As a rule of thumb, the amount of emission reduction corresponds roughly to the biodiesel blend rating of the fuel.
- Hemp biodiesel may be used an alternative to the highly controversial biodiesel produced from palm oil.
- Hemp faces many perception and legal challenges that prevent wide-scale production of hemp seed oil
- Hemp remains a niche crop in the food supply chains, rendering it prohibitively expensive as a feedstock in biodiesel production.
- Legalization and increased production of hemp oil may improve the cost of producing hemp oil and subsequently hemp biodiesel.

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