LIFE CYCLE ASSESSMENT OF COTTON SEED OIL

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ABSTRACT

Now a days as we are seeing that our fossil fuels like petroleum, diesel are depleting day by day, In a survey it has been found that these fossil fuels, if we continue to use these fuel with the current rate then these will be exhausted from the earth's surface in coming few years. SoIf we want to use our machinery's, automobiles which are completely dependent on these fuels, then we have to find the alternate source of these fuels. In current scenario we are having an alternate source which can completely replace these fuels and that are Biofuels. Here in this paper there is a life cycle assessment of cotton seed oil which is one of the source of biodiesel production. Various parameters are discussed in this like- the world cotton production its supply and demand, Cotton seed processing, world cotton seed oil production, the product yield is also discussed, and the energy requirements in production.

Keywords: Gossypium hirsutum and Gossypium herbaceum (cottonseed oil), Biodiesel, C.I. Engine,Emission, Performance.

1. INTRODUCTION

The Environmental Protection Agency (EPA) in the United States released their Final Rule for the renewable fuel program in the United States (RFS2) in 2010. This rule includes a lifecycle assessment of various renewable fuels including soybean biodiesel and biodiesel produced from waste products. In order to be eligible under the RFS2 program, renewable fuels had to demonstrate that the lifecycle emissions of the renewable fuel were less than those of petroleum fuels. Biodiesel fuels had to demonstrate a 50% reduction compared to diesel fuel.

Theinclusion of cottonseed biodiesel will require the EPA to undertake a lifecycle assessment of the GHG emissions associated with all stages of the process. Cottonseed oil has been used historically to produce biodiesel in the United States. The report produced by the US Department of Commerce,documented the quantities of individual fats and oils that are used to make methyl esters since 2007. In 2007 there was some cottonseed oil used every month, but in 9 of the 12 months, there were not enough reporting companies to produce a public number. In 2008, there was no cottonseed oil used for methyl esters for 9 months and the other three months had some

used, but insufficient reporting companies to have a number reported. In 2009 and 2010, it was reported that some cottonseed oil was used to produce methyl esters each month but there were insufficient companies reporting to release a value. Methyl esters can be used in non-fuel applications. Due to the proprietary nature of the LCA modelling framework established by the EPA under the RFS2 program, a full LCA analysis of cottonseed biodiesel is not possible outside of the EPA. This work documents the practices of growing cotton, separating the seeds from the fibre, crushing the seeds to extract the oil, and then processing the oil to produce biodiesel.

2. COTTON PRODUCTION, SUPPLY, AND DEMAND

Cotton is produced around the world. The crop is grown primarily for its fibre but significant quantities of oil, high protein meal, and other products and feeds are co-produced. Cotton is a soft, fluffy staple fibre that grows in a boll, or protective capsule, around the seeds of cotton plants of the genus *Gossypium*. The fibre is almost pure cellulose. The botanical purpose of cotton fibre is to aid in seed dispersal. The plant is a shrub native to tropical and subtropical regions around the world, including the Americas, Africa, and India. The greatest diversity of wild cotton species is found in Mexico, followed by Australia and Africa. It is a warm climate crop threatened by heat or freezing temperatures (below 5°C or above 25°C), although its resistance varies from species to species. It can be profitably grown in regions with rainfall of 850-1100 mm, but economic yields cannot be realized in the region with a rainfall less than 500 mm. 50cm of well distributed rainfall or irrigation is necessary for higher yields.

2.1 WORLD COTTON PRODUCTION

The United States is the world's third largest producer of cotton with about 12% of the World's production as shown in the following table. A bale contains 480 pounds, putting world production of cotton fibre at about 24 million tonnes per year. The world and US cotton production is reported in bales and does not include the mass of the seed, this is indicative of the by-product nature of the seed. The total crop mass is therefore about 2.4 times that, or 50 million tonnes of fibre and oilseed per year.

Table-1 World cotton production

	2007/08	2008/09	2009/10	2010/11
	1000 BALES			
China	37000	36700	32000	30500
India	24000	22600	23000	25400
United States	19207	12815	12188	18104
Other	17519	14686	13471	14985
Pakistan	8600	8700	9600	8800
Brazil	7360	5840	5450	8500
Australia	640	1500	1775	4200
Uzbekistan	5350	4600	3900	4100
Total	119676	107081	101384	114589

2.2 World Cottonseed Oil Production

Cottonseed production generally follows cotton production but there can be some small differences due to different lint to seed ratios in the different countries. This can beinfluenced by the varieties grown and the climatic conditions. The cottonseed oil production by country can vary as countries have the option of selling the cottonseed internationally, using the seed directly as feed, or crushing it domestically. The world cottonseed oil production is shown in the following table. The US is the world's fifth largest cottonseed oil producer, compared to being the third largest producer of cotton as less than 50% of the cottonseed produced is crushed in the United States.

Table-2 World Cottonseed Oil Production

	2007/08	2008/09	2009/10	2010/11
	1000 BALES			
China	1625	1600	1466	1389
India	1062	1030	1045	1150
United States	520	497	540	530
Other	380	318	326	460
Pakistan	389	303	280	377

Brazil	313	249	224	221
Australia	166	116	93	110
Uzbekistan	758	666	661	743
Total	5213	4779	4635	4980

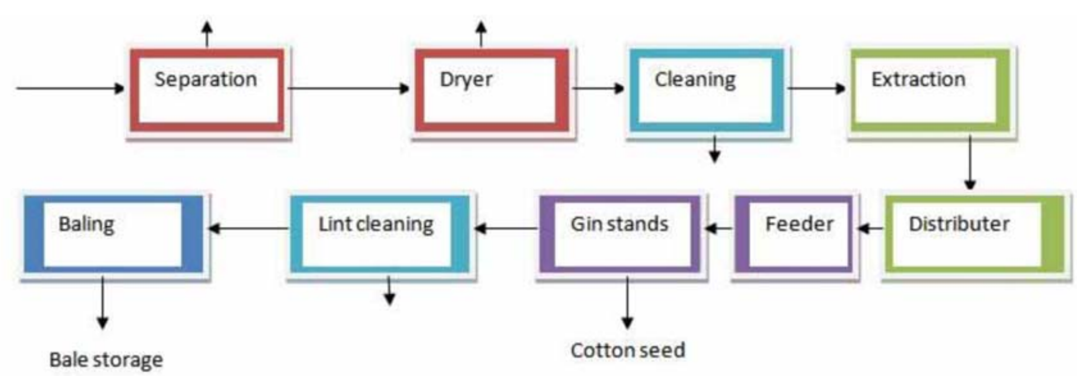
3. COTTON PROCESSING

Freshly picked cotton that has not been ginned is called seed cotton. Cotton bolls are made up of 4 to 5 locks. Each lock contains approximately 7 seeds to which the lint is tightly attached. When fully mature these bolls dry out and fluff open to give the characteristic look of a field of white cotton ready to pick. According to United States Department of Agriculture, it takes about 1,470 pounds of freshly picked seed cotton fromspindle pickers to produce a 480 pound bale of lint, 740 pounds of seed and 210 pounds of gin trash. It takes about 2,350 pounds of seed cotton from stripper harvesters to produce the same amount of lint and seed since strippers gather more stems, leaves, burrs, etc. than spindle pickers. At harvest, most seed cotton is compressed into large free standing modules where it is stored at the side of the field or in the gin yard to await ginning. This system improves the efficiency of harvesters and gins. Harvesters can operate full-time when the weather is suitable without having to wait for trailers to be returned from the gin, and the ginning season can be spread over a longer period. The farmer transports seed cotton to the gin on trailers or module haulers where it is separated from trash and the lint is removed from seed. There are about 700 operating gins in the cotton growing areas of the United States.

4. COTTON GINNING

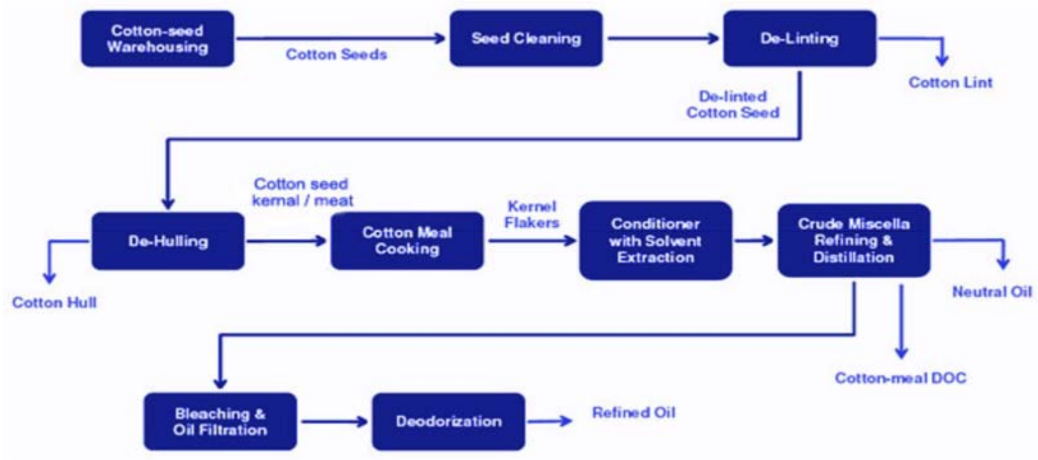
Cotton ginning is the process of separating cottonseed from the lint so that the lint will be baled and taken to textile industries for further processing whereas the cottonseed is milled by oil mills to produce edible oil and other products. Cotton ginning processes the raw cotton through the cotton ginner in order to produce baled cotton and cottonseed. The process is highly automated and consumes electricity and some thermal energy, usually supplied by natural gas. The typical process flow is shown in the following figure.

Figure 4-1 Cotton Ginning Process



5. COTTONSEED CRUSHING

The cottonseed crushing process is described below (National Cottonseed Products Association, 2011). The process is similar to that employed for other oilseeds. It is shown graphically below.



5.1 PRODUCT YIELDS

The cottonseed crushing process produces four products: linters, hulls, meal, and oil. All of the products have economic value.

5.1.1 Oil Yields

The oil content in the seed is important but, ultimately for a biodiesel LCA, it is the oil that is extracted from the seed that is needed for the analysis. The average value for the past nine years has been 15.8%.

Domestically, soybean oil, corn oil, peanut oil, sunflower, and safflower, and some of theanimal fats are competitors of cottonseed oil. Since the United States is a substantialexporter of fats and oils, cottonseed oil must compete with coconut oil from Southeast Asia, palm oil from Malaysia, African peanut oil, olive oil from the Mediterranean basin, European sunflower oil and Canadian Canola oil as well as other commodities of the same type. When made into shortening or margarine, cottonseed oil competes with lard and butter. The prices of all these commodities are closely related and one of them usually does not get far out of line with the price of the others. Buyers of fats and oils usually can shift to a less costly substitute quite easily.

5.1.2 Meal Yields

The typical meal yield is 42% of the cottonseed. Cottonseed meal (CSM) encounters a similar degree of competition from other protein concentrates like peanut meal and sunflower meal but especially soybean meal. Synthetic sources of nitrogen, such as urea and the ammoniated feeds, are also of competitive importance. Cottonseed meal is normally used as a supplement to feed-grains. However, if meal becomes high-priced relative to grains, feeders will increase grain use and reduce meal.

5.1.3 Hull Yields

The hull yield is not included in the USDA production, supply and demand database but the typical yield is 27% of the oilseed. Cottonseed hulls meet competition from various types of hay and from such feeds as corn and sorghum silage. Since hulls are bulky, it is frequently not economical to transport them great distances for feed purposes. Therefore, the market is restricted geographically, and the value of hulls is determined largely by the supply and demand for hay and other roughages produced in the area.

5.1.4 Linter Yields

Similarly, the linter yield is also not included in the USDA database but the typical yield is 8% to 9% of the cottonseed. Like the other cottonseed products, linters meet a great many competitors in their markets. Cotton waste, a by-product of the textile industry, is linters' major competitor in the bedding, automotive, and furniture industries. Foam rubber and polyurethane foam also compete for these markets. Wood pulp is the principal competitor of linters in the chemical products market. While linter pulp is preferred for quality, wood pulp quality has been improving, sells at a lower price, and has been able to increase its share of the chemical market.

5.2 ENERGY REQUIREMENTS

An energy survey of the cottonseed crushing plants was undertaken by National Cottonseed Products Association for this work. A total of 9 plants in the United States participated in the survey. Most of the plants used natural gas as their source of thermal energy, with one plant supplementing the natural gas with wood fuel.

6. BIODIESEL PRODUCTION

Biodiesel production using cottonseed oil is identical to the production of biodiesel produced from soybean oil.

6.1 ENERGY USE

The final documentation for the EPA RFS2 reports an energy use for biodiesel production and the source for the data but there are inconsistencies between the source (Pradhan, et al, 2009) and the EPA documentation. In addition, the NBB conducted a survey of producing members in 2009 and the energy requirements for the industry in 2009 were lower than the EPA has used for the year 2022.

Table-3 Cottonseed Crushing Energy Requirements

	Per ton of cottonseed crushed	Per ton of oil purchased
Electricity purchased, kWh	124	803
Natural gas purchased,mmBTU	0.81	5.27
Wood consumed,mmBTU	0.01	0.08
Total energy,mmBTU	1.25	8.08

Most cottonseed crushers use a solvent extraction process. Hexane is the solvent and while most of the hexane is recovered, some is lost to the system during drying, cooling and storage of the meal. Estimates of hexane losses from other oilseed crushing systems can be found in the literature and are summarized in the following table (European Commission, 2006).

Table-4 Hexane Consumption

Feedstock	Kg hexane/ton seed crushed	Kg hexane/ton oil produced
Soyabeans	0.5-1	2.5-5.0
Rapeseed	0.5-1.2	1.5-2.9
Sunflower seed	0.5-1.2	1.0-2.4
Linseed	2.0	6.0

Table-5 Biodiesel Energy Use

	EPA,RFS2	Pradhan	NBB
	BTU/GAL		
Electricity	361	439	410
Natural Gas	4381	3551	2690
Total	4742	3990	3100

The energy requirements used by the EPA are higher than reported in the original source and those requirements are higher than the industry is actually using. The Pradhan and NBB results are current energy use and they do not reflect possible improvements in technology by 2022. The NBB energy results should be used for cottonseed biodiesel.

6.2 YIELD AND CO-PRODUCTS

The biodiesel yield and the quantity of co-products produced will be the same for cottonseed biodiesel as they are for soybean biodiesel.

7. CONCLUSIONS

The cotton system is more complex than some of the other vegetable oil systems in the United States.

1. The cottonseed is a by-product of cotton production, and there is an additional processing step that is required to separate the cottonseed from the primary product, cottonfibres.
2. Once the cottonseeds are separated from the fibre, the seeds can be fed directly to livestock as well as being crushed or exported.
3. If the cottonseeds are crushed, there are four products, rather than two, that are produced.

These complications lead to increased complexity for the LCA modellers. There are additional allocation processes that must be developed for cottonseed compared to soybeans or canola. In some respects cottonseed oil biodiesel is more like waste oil biodiesel than it is like soybean biodiesel. In the EPA analysis of the GHG emissions for waste oil biodiesel it was determined that waste oil biodiesel production would not create additional waste grease to be produced or animals to be raised and rendered, similarly it is very unlikely that the use of cottonseed oil for biodiesel production will cause an increase in cotton production. An alternative to treating cottonseed as a by-product would be to consider that cottonseed oil and soybean oil are directly interchangeable and that the diversion of cottonseed oil to biodiesel from the food market will result in an equal increase in demand for soybean oil. Since the EPA has already approved soybean biodiesel under RFS2, then cottonseed oil biodiesel should also be approved.

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