Experience of truck fleets with BioDiesel made from animal fats as compared to rapeseed oil methyl ester

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Abstract

The limitation of available sources for petroleum exploration is a strong motivation to focus on renewable energy. An alternative to fossil diesel is the production of environmentally-friendly BioDiesel. According to EC-regulations, by 2010 at least 5.75% of the annual fuel consumption will have to be substituted by renewable fuels like BioDiesel. Even though - as compared to mineral fuels - biofuels are currently only available on a niche market, they have a great potential to decrease environmental pollution and improve emission behaviour of engines. In late 2001, SARIA Bio-Industries GmbH have started their own BioDiesel-production in Malchin (Germany) to make use of valuable animal fat that is left as waste material at their nearby carcass disposal plant. The applied production process, which has been developed and built by BDI Anlagenbau GmbH, enables SARIA to produce BioDiesel from animal fats (TME) at highest quality according to EN 14214, which is basically a norm for fatty acid methyl esters. Annual production capacity has been 12.000 tons of BioDiesel right from the start. Differences between rapeseed oil methyl ester (RME) and TME regarding chemical or physical properties and combustion behaviour were investigated. Economics and a LCA will be presented to contrast both fuels. Also technical differences of the plant concepts will be compared for RME production and TME production as implemented at SARIA. Finally impacts on the operation of truck fleets will be discussed. A progress report of the non-stop use of TME at more than 1.000 trucks since 2001 will be given.

Introduction

In Europe, BioDiesel seems to be synonymous for rapeseed oil methyl ester (RME). Only a small, well informed public realises that this alternative fuel can also be produced from different feedstock: oil plants, used cooking oils and animal fats. This aspect will become more and more important when seen in context with the latest developments on food- and feeding stuff safety.

Fact is, that the usage of BioDiesel produced from used cooking oils is well-known to the public and its advantageous emission behaviour compared to fossil diesel or even RME could be pointed out sufficiently [**1**,**2**].

What is less known, is the fact that BioDiesel can also be produced from 100% animal fats (TME, short for: tallow methyl ester) and fulfils the current European standard EN 14214 for fatty acid methyl esters, as long as state-of-the-art process technology is applied.

Properties of Different Feedstock Materials

When chemical properties of various feedstock materials for BioDiesel production are compared, the main difference between vegetable oils like rapeseed oil and animal fats can be found in the diverse fatty acid composition as shown in Table 1.

Table 1: Comparison of Fatty Acid Composition of Rapeseed Oil, Soybean Oil and Tallow [**3**]

		Rapeseed Oil (low erucic)			**Soybean Oil**			**Beef Tallow**		
Saturated Fatty Acids [wt.%]		**Min**	**Aver.**	**Max**	**Min**	**Aver.**	**Max**	**Min**	**Aver.**	**Max**
Lauric Acid	C12:0	0.0	**0.0**	0.0	0.0	**0.0**	0.0	0.0	**0.0**	0.0
Myristic Acid	C14:0	0.0	**0.0**	0.0	0.0	**0.3**	0.5	2.0	**3.0**	4.0
Palmitic Acid	C16:0	3.0	**4.5**	6.0	8.0	**10.0**	12.0	23.0	**26.0**	29.0
Stearic Acid	C18:0	1.0	**1.8**	2.5	3.0	**4.0**	5.0	20.0	**27.5**	35.0
Arachidic Acid	C20:0	0.0	**0.5**	1.0	0.0	**0.3**	0.5	0.0	**0.3**	0.5
Behenic Acid	C22:0	0.0	**0.3**	0.5	0.0	**0.0**	0.0	0.0	**0.0**	0.0
Total		4.0	**7.0**	10.0	11.0	**14.5**	18.0	45.0	**56.8**	68.5
Unsaturated Fatty Acids [wt.%]		**Min**	**Aver.**	**Max**	**Min**	**Aver.**	**Max**	**Min**	**Aver.**	**Max**
Myristoleic Acid	C14:1	0.0	**0.0**	0.0	0.0	**0.0**	0.0	0.5	**0.5**	0.5
Palmitoleic Acid	C16:1	0.1	**0.3**	0.5	0.0	**0.0**	0.0	2.0	**3.0**	4.0
Oleic Acid	C18:1	52.0	**59.0**	66.0	18.0	**21.5**	25.0	26.0	**35.5**	45.0
Linoleic Acid	C18:2	17.0	**21.0**	25.0	49.0	**53.0**	57.0	2.0	**4.0**	6.0
Linolenic Acid	C18:3	8.0	**9.5**	11.0	6.0	**8.5**	11.0	1.0	**1.0**	1.0
Gadoleic Acid	C20:1	1.5	**2.5**	3.5	0.0	**0.3**	0.5	0.0	**0.3**	0.5
Erucic Acid	C22:1	0.0	**1.3**	2.5	0.0	**0.0**	0.0	0.0	**0.0**	0.0
Total		78.6	**93.6**	108.6	73.0	**83.3**	93.5	32	**44.7**	57.5
Iodine Number [-]		96	**115**	134	116	**133**	149	30	**43**	56

While rapeseed oil and soybean oil have a high content of unsaturated fatty acid chains – mainly oleic acid and linoleic acid -, animal fats like tallow or lard have a major content of saturated fatty acid chains – e.g. palmitic and stearic acid.

The increased amount of saturated fatty acid chains shows a reversed trend for two main fuel properties: while the oxidation stability of BioDiesel derived from animal fats increases, the cold temperature performance decreases with a rising content of saturated fatty acid chains. Figure 1 shows the dependence of the content of saturated fatty acid chains in BioDiesel – without additives – on its cold filter plugging point (CFPP).

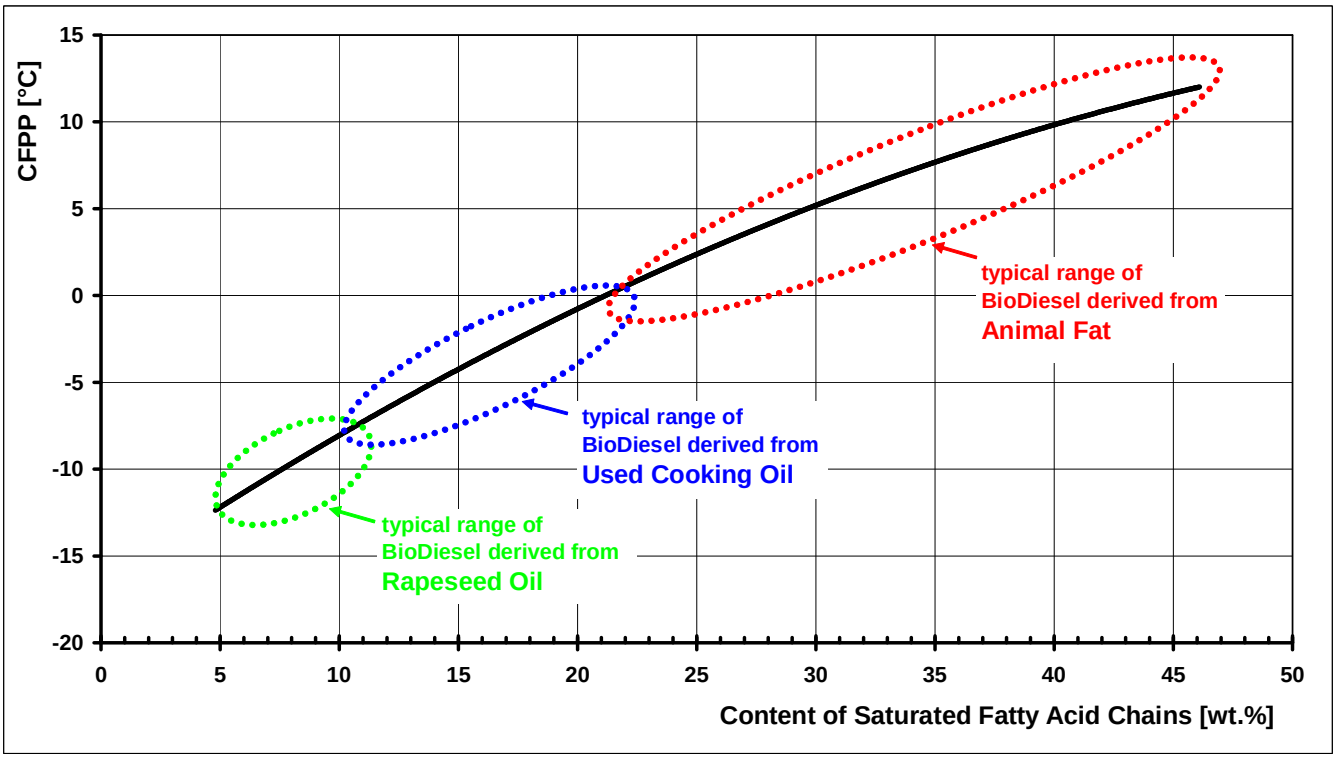

Figure 1: Relation between Content of Saturated Fatty Acid Chains in BioDiesel (without additives) and its CFPP-Value [**3**]

As indicated in Table 2, also the Cetane number of BioDiesel is positively affected by an increased amount of saturated fatty acid chains. Tallow derived BioDiesel (TME) can reach Cetane numbers of up to 75 [-], which leads to a much better performance in diesel engines regarding engine efficiency and subsequently reduced exhaust emissions. Compared to conventional fossil diesel, also the noise level of diesel engines – an often underestimated environmental pollution concern – is reduced when TME is used.

Table 2: Comparison of Iodine Number and Cetane Number of Different Types of BioDiesel [**4**]

	BioDiesel derived from				
	Rapeseed Oil	Soybean Oil	Palm Oil	Lard	Tallow
Iodine Number [-]	110 - 115	125 - 140	44 - 58	60 - 70	50 - 60
Cetane Number [-]	58	53	65	65	75

Also the lubricity behaviour of BioDiesel was investigated [**5,6**]. Compared to soybean oil- and rapeseed oil derived BioDiesel, a superior performance of tallow derived BioDiesel could be found. Table 3 shows the lubricity enhancement of BioDiesel when added to Low-Sulphur diesel (D4). For HFRR 60-C test, the limit for lubricity according to European diesel fuel standard EN 590 is below 460 µm. BioDiesel derived from tallow (TME) showed best performance as lubricity enhancer for Low-Sulphur diesel and fulfils the prescribed limit already at a percentage of 0.5% added to diesel fuel. [**6**]

Table 3: Results of HFRR-Test 60-C: BioDiesel added to Low-Sulphur Diesel at Different Percentage (0.5%; 1%; 2%) [**6**]

Biodiesel derived from	Rate of BioDiesel added to Low-Sulphur Fossil Diesel (D4)		
	0.5%	1.0%	2.0%
Tallow	443 µm	420 µm	321 µm
Rapeseed Oil	509 µm	359 µm	320 µm
Soybean Oil	540 µm	483 µm	487 µm

Certainly, due to the differences in composition and quality of the raw material (e.g. content of free fatty acids, content of impurities etc.), the production of high-quality BioDiesel out of waste animal material needs a more sophisticated production technology and specific know-how concerning the pre-treatment of the feedstock. The appropriate technology was developed by BDI Anlagenbau GmbH in close cooperation with research institutes of Graz Universities. It was already in 1998 that BDI was the world-wide first engineering company in BioDiesel business to build a multi-feedstock BioDiesel production plant in Butler/Kentucky, where also waste animal fat has been used for six years now.

Ecological Study of BioDiesel Production from Animal Fat

In a LCA study ecological effects of the production of BioDiesel (“from well to wheel”) derived from rapeseed oil (RME) or animal fat (TME, with and without synergy effects of a carcass treatment plant for animal by-products) were investigated and compared with the production of fossil diesel fuel. [**7**]

Seven criteria for assessment of fuel production were pointed out:

1. Carcinogenic risk due to fuel components like benzene
2. Particulate matter (PM 10, dust particles < 10 µm) content in exhaust gas
3. Eutrophisation rate of environment (soil, ground water,…)
4. Photosmog - break down rate of ozone layer due to photochemical oxidants
5. Amount of resources consumed for production (fertilizer, catalysts, primary energy,…)
6. Greenhouse effect of relevant off gases (carbon dioxide, laughing gas and methane)
7. Potential of acidification due to caustic gases (e.g. sulphur dioxide)

For TME production it could be shown, that especially primary energy resources can almost completely be substituted. Also carbon dioxide balance is neutral for BioDiesel from animal fat, thus no major contribution to the Greenhouse effect could be stated. Concerning emission behaviour, the amount of particulate matter and concentration of carbon oxide in the off gas is even better for TME than for RME. For all other evaluated criteria, TME is at least comparable with RME. [**7**]

Experience of Fleet Tests at SARIA

In late 2001, SARIA Bio-Industries GmbH – an enterprise of RETHMANN group - have started their own BioDiesel-production in Malchin (Germany) to make use of valuable animal fat that is left as waste material at their nearby carcass disposal plant. The applied production process which has been developed and built by BDI Anlagenbau GmbH, enables SARIA to produce BioDiesel from animal fats (TME) at highest quality according to EN 14214. Annual production capacity of TME has been 12.000 tons of BioDiesel ("ecoMotion^{TM}") right from the start.

Since 2001 TME has been used for more than 1.000 trucks make DAIMLER-CHRYSLER AG of RETHMANN Entsorgungs AG and SARIA Bio-Industries. Due to the cold temperature behaviour of TME, it is blended with fossil diesel or other BioDiesel at a surrounding temperature below 8°C. Ongoing engine tests of DAIMLER-CHRYSLER AG and engine oil checks of WEARCHECK GmbH show that TME is a proper biofuel for engine operation with an environmentally-friendly emission behaviour and without any technical faults. [**7**]

Summary

Summing up it can be stated, that besides its cold temperature performance BioDiesel derived from animal fat – e.g. beef tallow – shows significantly better fuel properties concerning engine performance compared to conventional BioDiesel. Although TME will stay a niche product compared to other biofuels, SARIA Bio-Industries has demonstrated with the applied BioDiesel technology designed by BDI, that animal by-products can be refined to fatty acid methyl esters of highest quality.

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