Journal of Agriculture in the Tropics and Subtropics
Volume 102, No. 2, October 2001, pp. 161 - 168

Bio- and alternative fuels for mobility State of the art [1]

Rüdiger Krause [2]

1 Introduction

From the dawn of history various sources of energy served mankind to increase their power: Draught animals since 7000 years for transport, tillage and water lifting, wind mills and hydro power plants for milling - or later for electricity-generation - steam engines in the 18th century as stationary and mobile source of power, followed by electric engine and the internal combustion engine in the late nineteenth century with increasing range of power and efficiency. And we did not yet reach the end !

In the industrialized countries more than 95% of energy consumption now are based on fossile/mineral sources. Only in the so-called developing countries biomass still contributes 33% to energy (mainly food processing). Internal combustion engines, due to different advantages and disadvantages and specific applications, are run by specialized fuels like diesel oil, gas oil (gasoline) or gas, near all of fossile origin. Engine design and fuel are adapted to each other, so that diesel engines normally have to be run by diesel fuel. Multy-fuel or hybrid engines are used only for very limited applications but might come up again, based on the ever improving electronic engine management.

The ever-increasing power demand of industrialized world and especially the hunger for fossile sources like coal, raw oil and gas showed consequences. In the 70ies of last century mankind was shocked to learn to know that

- fossile resources are limited and especially petroleum wells are going to dry out
- scarcity of energy could hit our energy based life substantially and
- sharply increasing energy costs might threaten our beloved comfort in mobility, room climate and use of engine drive.

Energy resources became a strategic weapon.
Above this a series of international conferences like Rio (1992), Kyoto (1997), and this year Bonn (2001) focussed on environment aspects of energy consumption and tried to limit and even to reduce worldwide emissions of climate-relevant gases.

---

[1] This slightly modified paper was presented at the International Biodiesel Workshop in Medan, Indonesia on 2nd Oct. 2001

[2] Prof. Dr.-Ing. R. Krause is Head of Department of Agricultural Engineering, University of Kassel, Witzenhausen

Today world energy strategy aims at

- saving energy by improved efficiency of technologies,
- diversification of energy sources (mainly strategic aspects)
- increasing the ratio of renewable energy (reinvention and modernization of traditional technologies) to reduce the greenhouse effect (clean energy).

Favourite technologies beside petroleum-based ones for the near future are:

available and close to or already competitive	take off next ten years	if ever not before 2050 ready for application
• solar energy • hydro energy • geo thermal energy • biomass energy, f.i. - ethanol - biodiesel - biogas	• hydrogen –fuel cell technology (NN; SCHMIDTCHEN)	• nuclear fusion technology

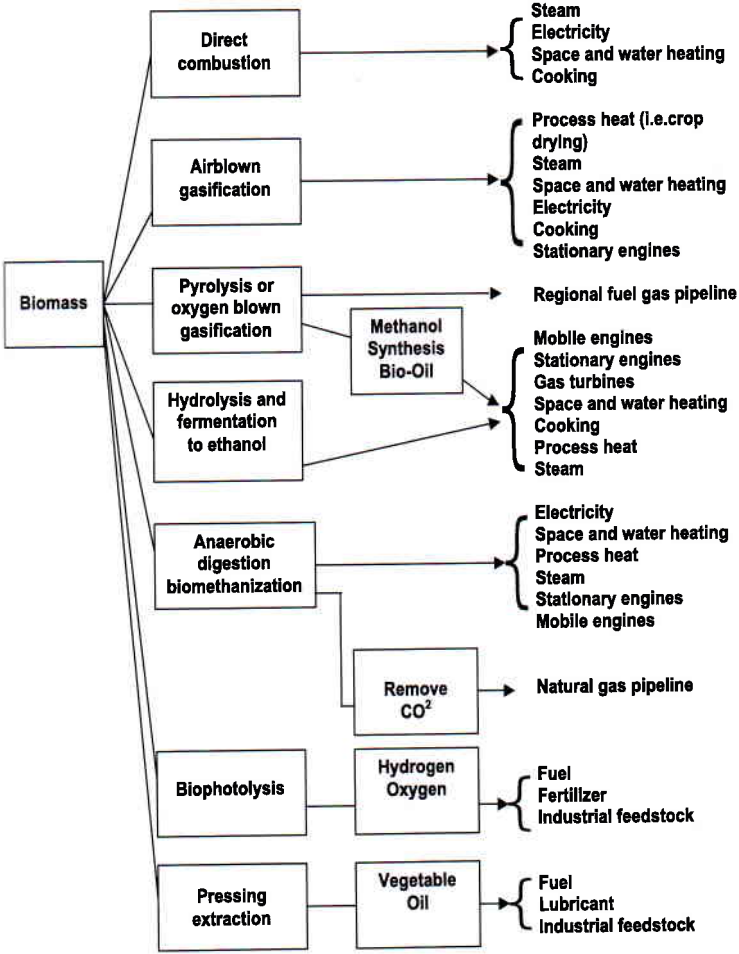
2 Fuel from biomass

The following part of this paper is focusing on fuel from biomass for stationary and mainly for mobile use.

Fig. 1 shows the range of competing technologies. Worldwide ethanol from sugar- and starch-containing plants as a gas oil substitute and biodiesel from oil plants as petroleum based Diesel oil substitute are gaining some regional importance.
Worldwide 25 Mio t of ethanol are produced annually, two thirds of which are blended with gasoline - between 24 % (Brazil) and 10 % (USA) – and in some European countries ethanol is used to substitute lead in gasoline and to prevent O_3 emissions. One third is used pure to run a fleet of 3 Mio gasoline vehicles with special engine modifications in Brazil.

Vegetable oil as a bio-substitute for Diesel oil now is also coming up (MITTELBACH, 1996; SCHÄFER; 1996; LÖHRLEIN, 2001) The first Diesel engine from Rudolf Diesel in 1893 proved already to be vegetarian. It was run by pure peanut oil because Diesel was wise enough to remember that once fossile sources would dry out. But soon fossile Diesel oil took over 100%. Since than engines were improved, more and more sophisticated and today need a well specified, standardized fuel with equal quality, mainly to hold European and North American exhaust gas limits of tolerance (CO, CO_2, HC, NO_x, Particles [NN, 2001]), low specific fuel consumption (< 200 g/kWh) and low level of noise (especially valid for passenger cars). Vegetable oil, which was used by Rudolf Diesel in his early engine, concerning its technologic properties – mainly viscosity – is far from modern Diesel oil. So, if used as fuel (100%, not speaking of blends), we need not only a separate logistic for distribution but also very

Figure 1: Fuel from biomass: range of competing technologies.



Source: OTA 1980, modified

expensive special engines like Elsbett (Fig. 2) - which never reached series production - or old-fashioned prechamber engines (Fig. 3) with 15 to 20 % higher consumption and poor exhaust gas quality.

Figure 2: The Elsbett engine (duothermic combustion).

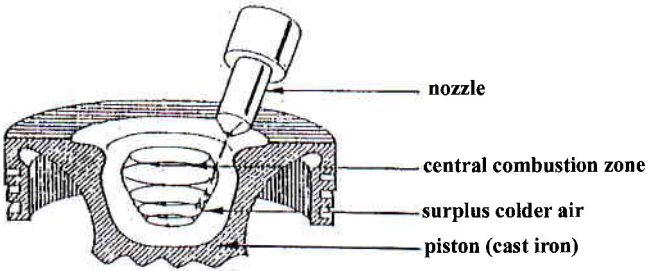
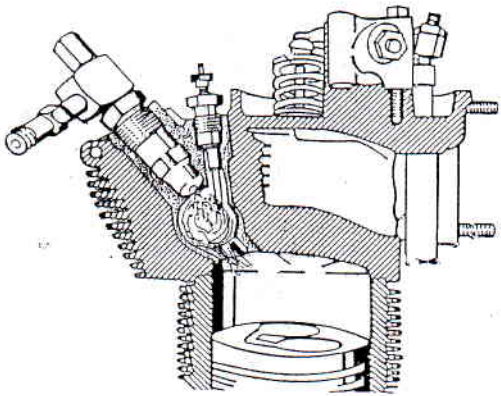


Figure 3: The prechamber / swirlchamber engine.



Above this, uncomplete burning of crude vegetable oil in modern diesel engines could cause residues of unburnt carbon and crusting in the engine and finally can lead to complete engine failure. Engine manufactorers at least in Germany are not at all interested in special engines for pure vegetable oil because there is a very limited demand. Such engines, produced in very low quantities, are not affordably expensive, but there are some small enterprises in Germany who offer engine modification and adaptation.
So except ongoing experimentation with this purified crude vegetable oil and blends in most of the industrialized countries transesterification of vegetable oil to adapt technologic properties to Diesel oil by using a catalytic reaction to substitute triglycerides (glycerine) through alcool (methanol) became processing standard. This bio fuel called "Biodiesel" is allowed to be used pure or blended in only slightly modified, modern standard direct injection Diesel engines. And there is a reduction of particle emissions of at least 50% comparing with diesel oil from fossile sources. Worldwide about 100 processing plants are in operation, based on rapeseed, soybean, palm oil or coconut oil, producing about 700 thousand tonnes annually.

To use transesterified vegetable oil in standard diesel engines we have three alternatives:

- pure, only transesterified
- blended with Diesel oil in varying ratios
- mixed with crude mineral oil before the destillation process in the refinery (hydro cracking)

Technical, economical and mainly political reasons cause different strategies of use in different countries. In Germany there is a tax of about 50 cent of US $ on a litre of Diesel oil and – different from USA – pure Biodiesel is tax-free and so can compete in market price. So we use separate distribution and delivery at gasoline stations. More than 200.000 tons of Biodiesel are sold annually at about 1000 gas stations in Germany. Biodiesel imports from neighbouring countries are increasing.

German Biodiesel is based on rapeseed oil and increasingly on used vegetable oil (ANGGRAINI, 1999). There is a German quality standard (DIN 51606), and most of the diesel engines (passenger cars as well as agricultural tractors and trucks) produced in Germany since 1995 are homologized by the manufacturer to use Biodiesel of this standard. All earlier technical problems with engines and fuel systems have been solved (Biodiesel resistant fueltubes and membrane of the fuelpump, one-way fuel filter).

Due to overproduction of food in Germany farmers are not allowed to grow food crops on about 10% of their agricultural area (set-aside-land) but they receive government subsidies for this area, even if they produce and sell non-food products on these areas. So up to 400.000 ha are planted with rapeseed mainly for fuel production. The harvested 400.000 t of Biodiesel produced from this area can contribute less than one percent to our national Diesel oil consumption and even if we add another 100.000 or

200.000 t of Biodiesel based on used cooking oil and up to 300.000 t animal fat residues from slaughter houses the replacement potential in Germany might be less than 5 % only. And the demand would be greater than what can be offered as long as the unit of energy from Biodiesel is cheaper than that of mineral oil Diesel fuel. Great processing capacities for vegetable oil have been built recently in Germany or are in construction (500.000 t/ha). Use in municipalities and large companies results in a particular surge in demand.

Due to the cold filter plugging point (FPP) the aptness of Biodiesel for winter use (below 0°C) decreases from Biodiesel based on fresh vegetable oil (-20°C) over Biodiesel from used vegetable oil (≈ 0°C) to fuel from animal fat (≈ 7°C). In cold regions mixing with mineral Diesel oil or even complete change to mineral Diesel during the cold season is necessary.

German engine manufacturers are very apprehensive now because the high exhaust gas quality standards can be held only with high quality standardized fuels. In case of Biodiesel imports their quality must be supervised carefully. For vegetable oil imports new quality standards have to be developed for Biodiesel based f.i. on sunflower – or palm oil. But within the next 10 years the scene could change substantially: hydrogen produced by use of renewable energy or methanol made from biomass by gasification to run the fuel cell could come up, pushed by Daimler-Chrysler, Toyota and competitors. The Volkswagen group (VW/Audi) on the other side is experimenting with synthetic fuels (sunfuel) to further improve the internal combustion engine efficiency and cleanliness. They prefer the gasification of any kind of biomass (even biovastes i.e. from food processing) to producer gas and than to change gas to liquid by flash pyrolysis. The "Fischer-Tropsch-Liquification" (developed in Germany during world war II to produce liquid fuel from coal or natural gas) allows producing fuel with any wanted specification – even between Diesel oil and Gasoline, because modern engine concepts are combining both advantages of these different combustion technologies. Bio fuels consortium partners DYNA MOTIVE f.i. invested more than 1,7 Mio. US $ into bio-oil technology in GB last year. In Vancouver, Br.C., Canada fast pyrolysis is applied to produce bio oil from wood residues. Even more money was invested in this booming branch last year in Germany mainly to produce biodiesel from used vegetable oil and animal fat. So diversification in fuels and their basic material goes on.

3 Policy

While Brazil is still focusing on its PROALCOOL-Programme to produce ethanol from sugarcane for passenger cars the USA and most European countries support and promote bio fuels generally, that means, ethanol and Biodiesel as well as biogas.
The approach is different from country to country, but the EC-Administration now tries to harmonize these different ways, paying attention to all aspects like:

- creating new sources of income for farmers (future oil sheiks);
- contributing to the reduction of CO_2 emissions and other climate effective gases;
- improving fuel quality for less exhaust gas emissions (f.i. 50% less particle emissions and up to 40…80% less gas emissions comparing Biodiesel with mineral Diesel oil;
- decreasing the dependency from oil exporting countries by diversification (today the contribution of bio fuel is 0,2% to European fuel consumption).

So Brussels recommends 8% of Biodiesel mixed with mineral diesel and 8% of ethanol mixed with gasoline.

But it should be considered that the high degree of biodegradability makes biodiesel a superb fuel for vehicles run in ecologically sensitive area like fisherboats in lakes and rivers and bulldozers in the tropical rainforest. And these vehicles should even use bio-hydraulic, - gearbox and even – engine oil to minimize pollution in these reservates.

4 Summary

- Biomass-derived bio fuels as a replacement for petroleum-based fuel for mobility are in development or have reached already a high technological standard.
- In case of ethanol a reliable special engine technology is available.
- Standardized Biodiesel, based on rapeseed oil needs no engine modification if the fuel system is Biodiesel resistant and is in Germany under the given situation competitive.
- Biodiesel production capacities in Germany and Europe are sufficient, even in case of crude vegetable oil imports.
- For Biodiesel from other feedstock like soybean –, sunflower – or palm oil as well as from used vegetable oil and animal fat processing has to be adapted and new standards should be elaborated to allow industry to homologize their engines for these fuels.
- Biodiesel can contribute to reduce gaseous emissions and environment pollution.
- Synthetic fuels produced by gasification and liquification of biomass with specific properties and equal quality are coming.
- Competitiveness of bio fuels still depends on government support.
- And we should never forget: food production ranges before energy plant production !

5 Literature

ANGGRAINI A.A., 1999: Wiederverwendung von gebrauchten Speiseölen u. -fetten im energetisch-technischen Bereich. - Ph.D.-thesis Fortschritts-Berichte VDI, Reihe 15 (Umwelttechnik) Nr. 219, 1999

LÖHRLEIN, H.-P., 2001: The Art of Biodiesel Processing. Proc. Biodiesel Workshop „Enhancing Biodiesel Development and Use", Medan, Indonesia, 3rd October 2001

MITTELBACH M., 1996: The high flexibility of small scale biodiesel plant production of methylesters in high quality using various feedstocks - Proc. 2nd European Motor Biofuel Forum, Graz, Austria, Sept. 1996

NN: Fuel Cell Technology - www.smart-gmbh.de

NN, 2001: Ökobilanz von Pflanzenölkraftstoffen - Sonderbeilage AGRA-EUROE 22/01, 28. Mai 2001

SCHÄFER A., 1996: Biodiesel as an alternative fuel for commercial vehicle engines - Proc. 2nd European Motor Biofuel Forum, Graz, Austria, Sept. 1996

SCHMIDTCHEN K.: Hydrogen - the millenium fuel - www.dwv.de