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Castor Oil as a Fuel

Prospects and Risks

Castor oil is more than just a raw material in great demand by the pharmaceutical and chemical industries. In several southern countries its use as a fuel is also being discussed in conjunction with social and ecological aspects. A few properties, in particular the extremely high viscosity and high water content, complicate the use of castor oil as a fuel for internal combustion engines. Better perspectives may be possible by transesterification and adding this biodiesel to fossil diesel fuel. This however calls for considerably lower castor oil prices than are now being paid on the world market.

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Keywords

Castor oil, biofuel, characteristics, world market

Literature

Literature references can be called up under LT 06511 via internet http://www.landwirtschaftsverlag.com/landtech/local/literatur.htm.

In the summer of 2004 the government of Brazil passed a vegetable oil programme focussing on the fight against poverty, environmental protection and the provision of energy. The programme is intended to encourage the use of biofuels and also to reduce considerably the tax burden on small producers. The new programme is estimated to create jobs for 250,000 peasant families. In future, particularly the cultivation of oil palms in the north of Brazil and castor in the northeast of the country will be politically encouraged and subsidised. The question is whether castor oil is suitable as a fuel and whether it has a chance on national and international markets for others purposes.

Production

Castor oil, *Ricinus communis L.*, (castor bean, castor, castor oil plant, ricin, higuerilla, mamona, mamoeira, palma christi) is a member of the tropical spurge family (*Euphorbiaceae*) and can nowadays be found naturalised and cultivated in all temperate countries of the world. Seeds of this plant were found in Egyptian graves as early as 4000 B.C. Castor is originally a tree or shrub that can grow above 10 m high, reaching an age of about 4 years. At present the cultivated varieties grow to a height of 60 to 120 cm in one year, and several meters in perennial cultivation (*Fig. 1*). Castor grows in the humid tropics to the sub tropical dry zones

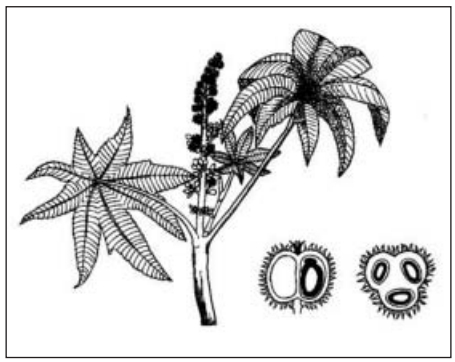

Fig. 1: Castor shoot with blossom stand as well as a longitudinal and a cross section of a capsule [2]

(optimal precipitation 750 to1000 mm, temperature 15 to 38 °C) and can be cultivated in southern Europe [1].

Harvesting castor oil is fairly complex. When harvested by hand the ripe fruit (moisture < 45%) are selectively cut, and later the capsules are removed by hand or by a beaker. Due to the varying stages of ripeness of the seeds up to 5 separated harvests are necessary. In mechanical harvesting modified combine harvesters are normally used, and these partly separate the unripe capsules. In this case the plants must be leafless, which may require the use of defoliants. Since the seeds are very poisonous, caution is needed during harvesting and processing: only 0.18 g per kg of body mass can result in death. Special attention should be given to children due to the pleasant taste of the poisonous seeds.

Castor oil seeds are predominantly cleaned and sorted by machine. Subsequently the oil is obtained by pressing the seeds one to three times and extracting it. During cold pressing, which is preferred for pharmaceu-

Table 1: Fuel specific properties of castor oil and rapeseed oil

Properties, Contents	Units	Rapeseed oil acc. to DIN 51605	Castor oil acc. to var. sources [1]
Density (15 °C)	kg/m³	900 ... 930	950 ... 974
Ignition temp. by P.-M.	°C	> 220	229 ... 260
Kinemat. viscosity (40 °C)	mm²/s	< 36	240 ... 300
Net calorific value	MJ/kg	> 36,0	37,2 ... 39,5
Flammability (Cetane number)	-	> 39	42
Carbon residue	mass-%	< 0,40	0,22
Iodine number	g/100 g	95 ... 125	82 ... 90
Sulphur content	mg/kg	< 10	10
Overall contamination	mg/kg	< 24	~ 10
Neutralisation value	mg KOH/g	< 2,0	1,0 ... 4,0
Oxidative stability (110 °C)	h	> 6,0	95
Phosphor content	mg/kg	< 12	< 4
Total content Mg and Ca	mg/kg	< 20	-
Ash content	mass-%	< 0,01	< 0,01
Water content	mass-%	< 0,075	0,15 ... 0,30

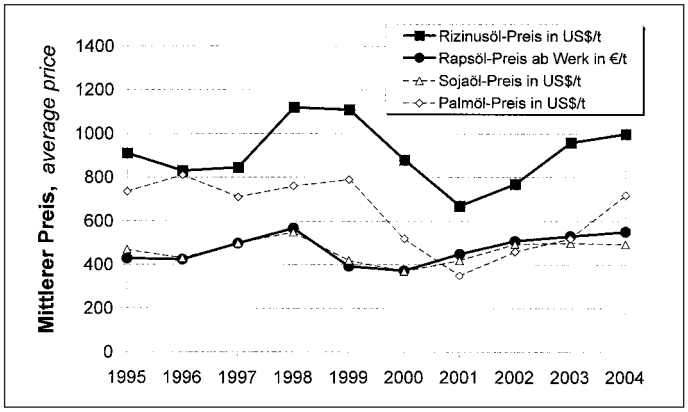

Fig. 2: Price trend of castor oil and other vegetable oils in Germany

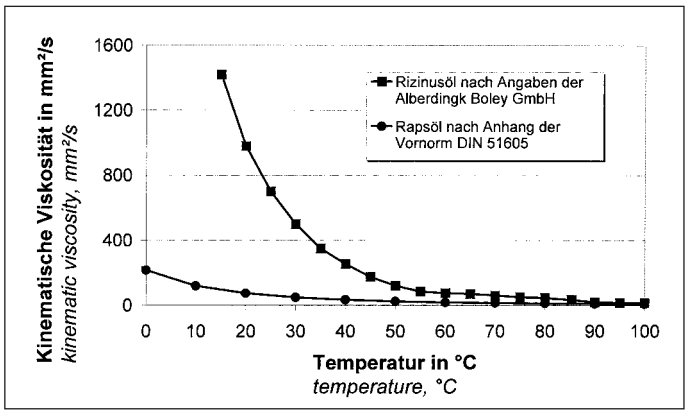

Fig. 3: Kinematical viscosity of castor and rapeseed oil versus temperature

tical and cosmetic use, the yield of oil is 30 to 36% of the mass of seeds. Warm pressing (> 70 °C) produces about 38 to 48%. The remaining oil can to a large extent be extracted by using solvents. When processed according to good professional practice only 1 to 2% of oil remains in the pressed cake.

At present the yield of castor oil seeds in Brazil is about 0.9 t/ha. The average in the world is about 1.1 t/ha. Under very favourable conditions, 4 to 5 t/ha may be obtained. The bean shaped seeds of the castor oil usually contain 40 to 55% oil. With a mean oil content of 47% and mean estimated oil yield of 90%, the world average yield is therefore around 460 kg/ha castor oil. It may be possible to obtain a maximum of 2000 kg/ha oil. Therefore castor is amongst the plants with the highest oil yield potential.

World market

Castor oil merely has less than 0.15% in the international oil seed trade market. For this reason Oil World, a well known vegetable oil statistics, only note the production, trade and consumption data in the margins [1]. At present about 1.3 million tonnes of castor oil seeds are produced in total per year and this corresponds to about 0.55 million tonnes of castor oil. Since the beginning of the 1970's, castor oil seed production has increased continuously but it is, in some cases, subject to yearly fluctuations of 20%, which are above all the result of storm damage in the main regions of cultivation.

About half of all the castor oil produced in the world is exported. India alone exports 80% of this and therefore largely dominates the market. More than 30 internationally operating wholesalers have joined together in the International Castor Oil Association Inc. (ICOA) which was founded in 1957. At the moment they produce over 90% of the entire castor oil world trade.

As a result of fluctuations in production and speculation, the price of castor oil varies considerably. In the past it was between 650 and 1500 US-$/t without tax ex Rotterdam. The average price in the past ten years was about 900 US-$/t and therefore almost twice the price of rapeseed oil in Germany (*Fig. 2*).

Properties

Castor oil provides an odourless, viscous, non drying oil which in its natural state has an initially mild, later unpleasant taste and is yellow-green to yellow-brown in colour. In its processed state it can also be clear. As opposed to other vegetable oils it is characterised by its indigestibility, solubility in alcohol, high hygroscopicity and extraordinarily high viscosity as well as by its high proportion of polyunsaturated fatty acids. A comparatively high proportion of unsaturated fatty acids are contained only in the oil of the HO (High Oleic) sunflower. With an iodine number of less than 90, castor oil is a non drying oil. Long storage times are unproblematic in airtight conditions [1]. The chemical-technical demands of castor oil used as a raw material in the chemical industries are defined by the ICOA standard [3] and by the DIN 55939 [4].

Regarding the fuel related properties, the high calorific value and the high cetane number are of advantage along with the low content of phosphorous and carbon residues. Disadvantageous is that castor oil has a significantly higher viscosity at temperatures under 50 °C, and possibly also a higher compressibility, than other plant oils (*Fig. 3*). This may cause problems at extraction and injection. A further disadvantage is its hygroscopicity, causing a relatively high water content and thereby possibly algae growth, filtration and corrosion problems. Castor oil is also characterised by its extraordinary oxidative and low-temperature stability. In *Table 1*, the most important fuel-related characteristic values of commercial castor oil are compared to the limits of the prestandard DIN 51605 for rapeseed oil fuels. This comparison is only partly admissible, since the norm strictly speaking only applies to rapeseed oil.

So far only a few experiments on the use of castor oil in diesel engines have been carried out. At the beginning of the 1990's castor oil was tested for engines in a laboratory in Thuringia. Due to the cost of the oil or more precisely the lack of cost effectiveness of castor oil cultivation and extraction these experiments were not continued in Germany. A careful assessment on the basis of these experiments shows that castor oil may possibly be appropriate for motor engines suitable for vegetable oil [6]. First experiences with a CHP plant in a Brazilian rain forest village appear to confirm it [7]. It should be, however, taken into account that sometimes even rapeseed oil causes difficulties in engines modified for vegetable oil fuel.

Conclusion

Castor is an undemanding oil plant which grows extremely well in tropical conditions and provides high oil yields, but it does, however, require a large amount of manual labour input. It is therefore a suitable crop for the small scale farming structures in the north east of Brazil. It can help to improve the living conditions of small farmers as well as supplying environmentally friendly energy for multiple purposes.

However, as long as new markets or utilisation strategies are not acquired, the trade and export of castor oil may cause problems as on the one hand the world market is relatively stable and on the other hand the price is so high that it will hardly replace other vegetable oils, such as rapeseed oil, which are also suitable as fuel. Several properties, in particular the extremely high viscosity and the water content also complicate considerably the use of castor oil as fuel in engines. Without the development of special engines, a sustainable turnover is therefore hardly to be expected soon, even in Brazil.

Despite the unfavourable engine-related technical properties of castor oil, it may perhaps be possible to create a methyl or ethyl ester by transesterification, which can be added to fossil diesel fuel in small proportions. In Brazil this is being investigated on a semi technical scale and encouraged, amongst other things, by a new law which stipulates a biodiesel admixture of 2% from 2008, and 5% from 2013.