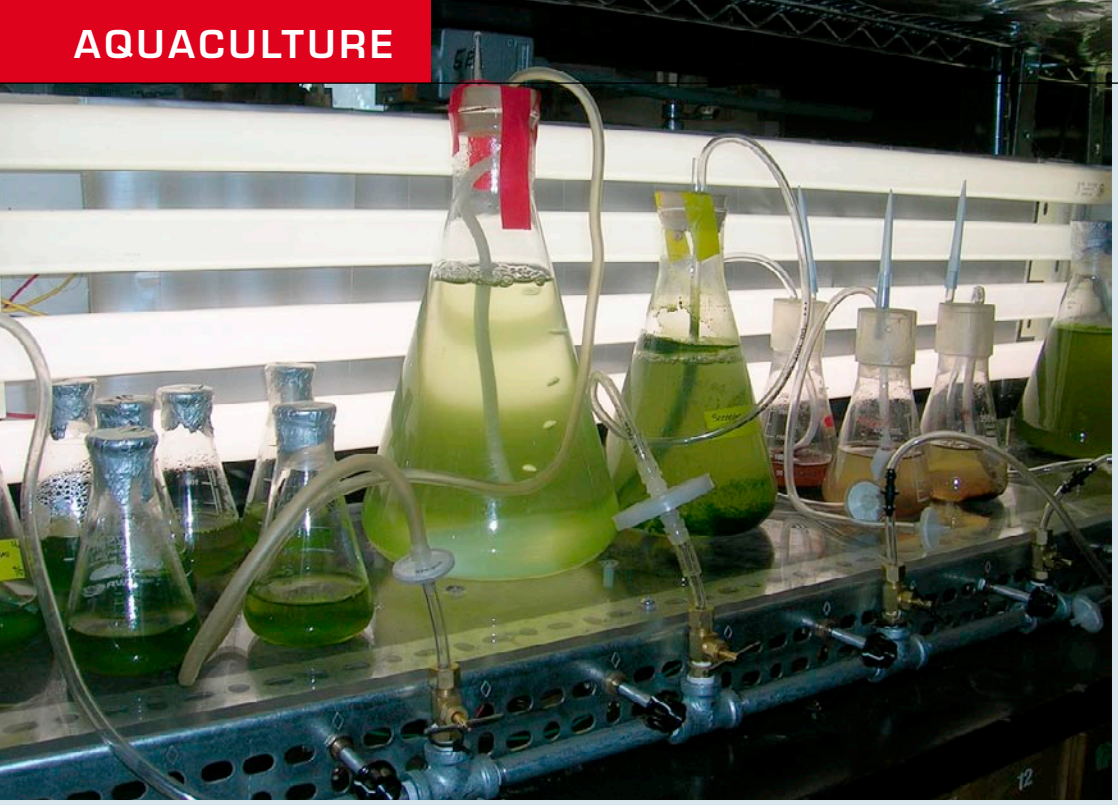


Experiments on algae being carried out at the University of Arizona.

Biofuels from aquatic resources

Diesel from fish waste, biofuel from algae

The rising crude oil price is driving forward the search for alternative energy sources. Fuels from renewable raw materials, biodiesel from rapeseed, and ethanol from corn or sugar cane, would be possible solutions but this usage has led to worldwide scarcity and thus higher prices for a lot of foods. Aquatic resources have so far been given little mention in this tense debate, although microalgae and fish waste could supply high-quality fuels.

No matter what price the market analysts declared to be the "magic" limit – the oil price topped it! At the beginning of 2008 the price for a barrel of crude oil overshot the 100 dollar mark and just a few months later it was dangerously close to 150 dollars. Rarely before had we been so insistently reminded that supplies of mineral oil are not inexhaustible and that we have to start looking for other energy sources. Particularly high hopes were set on biofuels from renewable agricultural raw materials which were seen as one way of closing at least part of the energy gap. Biodiesel from rapeseed and ethanol from corn, soy or sugar cane – for a lot of people that was the solution... particularly since production of biofuels would be a way of solving several problems at the same time. Farmers would be able to use their land more effectively and would have a secure source of income; industrial nations would reduce their dependence on the oil-exporting states. On top of that, biofuels would also contribute towards combating climate change. The EU backs renewable energies, too, and in 2007 stipulated that biofuels should have a share of 10% at fuel stations by 2020. If the CO_2 emissions are to be reduced by 20% by the year 2020, said EU Agricultural Commissioner Mariann Fischer Boel, "there's no getting round biodiesel and ethanol". But this is an ambitious goal, given the fact that currently only 2-3% of the fuels used worldwide come from renewable agricultural resources.

On your plate or in your tank?

At the same time as oil prices rose, however, the prices demanded for a lot of foods also increased drastically. For consumers in western countries this was perhaps a necessary shock because it makes it clear that the foods that are often sold cheaply (or even at a loss) in the shops do have a real value. In poorer countries, however, the price rise threatened the lives of millions of people because rice, soy and wheat were often no longer affordable for them. In a lot of places there were protests and demonstrations, in some countries unrest. The OECD made a rather sober statement that the development of biofuel production was leading to considerable tension on raw material markets without creating any significant advantages for the environment. The German NGO 'Foodwatch' believes that biofuels do not benefit the climate but only the farmers, and Peter Brabeck-Lemanthe, at that time the manager of the food empire Nestlé, thinks that this strategy is ecological madness because rain forests are being burnt down to further the production of ethanol. Every hectare of arable land can only be used for one purpose per season and so a dispute has arisen about how some of the raw materials should be used: as food for the growing world population, as feed for farm animals, or as biofuel for car tanks?

In the meantime the excitement around biofuels has died down noticeably. At German fuel stations biodiesel sometimes even cost more than diesel from mineral oil in summer 2008. And so people suddenly started taking note of sceptical opinions that remind us that biofuels have an overall disappointing environmental balance. A large share of the energy that can be produced from them had to go into the production of the plants. Energy was required for ploughing, sowing

and harvesting, for drying and storing and for distilling the agricultural raw materials to biofuel. Apart from that, the economic potential of this renewable energy was limited: even if the whole of the corn harvest in the USA went into fuel production it would not cover more than 12% of current petrol needs!

Aquatic sector overlooked so far

So is that the end for biofuels? No way! – Particularly because a highly productive raw material segment has so far been largely overlooked. Tony Piccolo pointed this out in a paper that is based on his MBA thesis. Under the heading "Aquatic Biofuels – New Options for Bioenergy" he points to the huge potential of aquatic resources as a raw material for biofuels. In his opinion the use of fish waste or, even better, microalgae could be particularly lucrative.

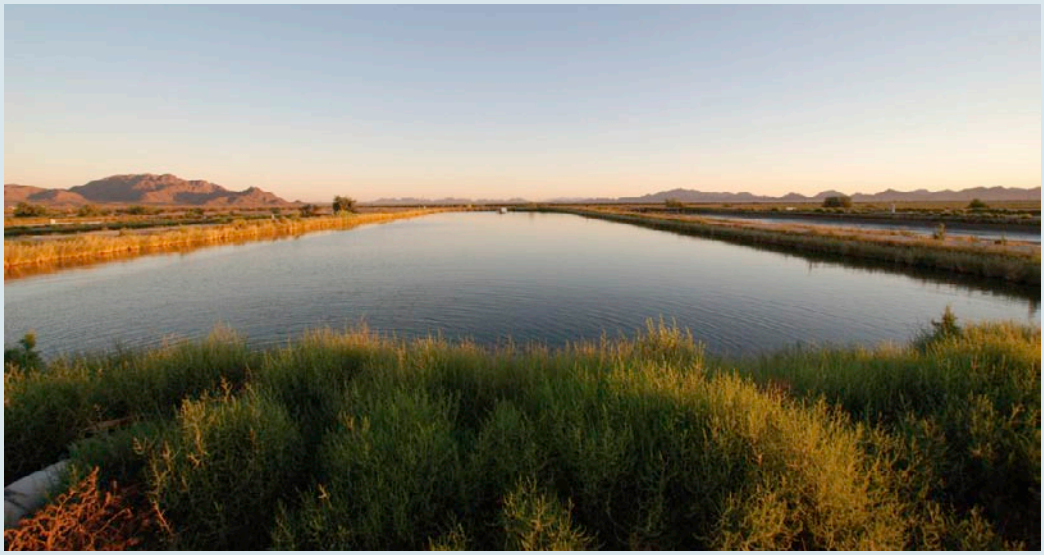
Why planktonic algae in particular? With the help of sunlight, autotrophic algae produce energy-rich compounds from carbon dioxide and water. These are an ideal raw material for biofuel. The green protozoa are extremely productive, they grow and reproduce quickly, contain a large amount of vegetable oils and can be cultivated with relatively little effort. The spectrum of possible production methods for microalgae is extraordinarily broad. It ranges from simple brackish ponds to technically sophisticated bioreactors in which ideal conditions for specific algal species are created and constantly maintained. One of the advantages of some microalgae species over agricultural plants is the fact that they grow in salt water and do not have to be watered with valuable freshwater. For comparison: about 900 litres of water are necessary to produce just one kilogram of feed corn! Apart from that, microalgae can absorb a lot of nutrients from the water and utilise these highly efficiently, thereby making an important contribution to keeping our waters clean. A lot of algal species could even be grown in waste water ponds that would otherwise not come under consideration for any other applications. In contrast to agricultural products algae do not contain sulphur, either, so that when the biofuels are burned later on no sulphur dioxide would be released.

It is possible to produce about one litre of biodiesel from one kilogram of fish slaughter waste.

Microalgae unusually productive

Due to their high productivity microalgae enable an amazingly high yield on a relatively small area. Piccolo calculates that from the algae that are produced on an area the size of two garages the same quantity of biofuel can be produced as from soy beans that grow on an area the size of a football field. The biofuel yield, in relation to hectare of production area was 33 times higher for microalgae than for rapeseed and 88 times higher than for soy. In open waste water ponds it was even possible to produce 100 tonnes algae per year and hectare. A higher yield was only possible in light reactors which are among the most productive systems that there are. Mostly they consist of long, translucent plastic tubes that lie flat on the ground and in which the water with the algae culture circulates. Sensors monitor all parameters within the system that are decisive for the growth of the algae (e.g. temperature, pH value, nutrient content) so that the conditions in the reactor can be maintained at a constant level at all times. Due to the high investment and running costs these bioreactors are only really feasible for financially strong producer countries, however.

Piccolo gives numerous examples of intensive research that is



An open pond used for the cultivation of algae.

already taking place in various regions of the world on the use of microalgae for biofuels. This was particularly true for the USA which wants to reduce its strong dependence on oil imports. For this reason research in this area was specially funded, too. There have already been some remarkable achievements. One team of researchers from the University of Texas has discovered blue-green algae (Cyanobacteria) for example that do not only excrete glucose and saccharose but also a soft almost jelly like cellulose which can easily be broken down. All three substances would be good for the production of biofuel. Because it grows easily in salt water and strong sunshine it could be produced in large quantities in irrigated desert regions. Under laboratory conditions the company US Sustainable Energy in Texas has already produced the first biofuels. For the test they used about 10 kg of an algal species with an oil content of about 5%. In the state of Minnesota, Xcel Energy is supporting an algal biodiesel project which is run by the university and the Metropolitan Council. In North Dakota and California, too, intensive research is being carried out in this area. The scientists in Florida seem to be one step ahead because there the company PetroAlgae hopes to begin commercial production of algae based fuel in 2009. In Arizona, PetroSun BioFuels Refining recently signed a joint venture that is to lead to the construction of an algal biodiesel factory in Coolidge. PetroSun will supply 54 gallons of algal oil to the factory which will then produce biodiesel from it. The first delivery is to be in the third quarter of 2008. Scientists at the Old Dominion University (Virginia) have launched a project that is to use the algal growth from the municipal sewage plant for the production of biodiesel. It is hoped that up to 70,000 gallons of biodiesel will be produced from the algal mass yearly. That is about 265,000 litres.

The topic meets with great interest in New Zealand and the Netherlands, too. The Dutch company AlgaeLink claims to have developed a new technique for extracting algal oil without the need of chemicals, drying or oil presses. The patent is pending and the new technique apparently only needs 26 kilowatts to produce about 12,000 gallons of algal oil per hour. Yield is said to be 50% of the initial algal mash.

One litre diesel from 1 kg fish waste

After algae, the second big raw material source that Piccolo has identified is fish waste which is often produced in large quantities and high quality in aquaculture. Such wastes are mostly used for the production of fishmeal and fish oil but they could also be used for the production of biofuels. For which option one decides depends partly on the market prices for diesel and fishmeal. High-quality fishmeal costs over 1,000 dollars per tonne at the moment on the world market but meal from fish waste is of a considerably lower quality and accordingly cheaper. The diesel price varies from country to country and is sometimes even subsidized for agriculture and fisheries. In spite of this it can be worthwhile to produce biodiesel from fish waste instead of fish oil. It is possible to produce about one litre of biodiesel from one kilogram of fish slaughter waste.

The production of fish biofuel is not all that complicated. First the waste has to be pressed and treated with hot water at a temperature of 90°C to extract the oil it contains. Afterwards the waste is mixed with methanol (c. 9%) and caustic soda to separate the glycerine from the biodiesel. After the fuel has been subsequently cleaned by adding manganese it is utilisable in ships' engines and other combustion engines. The by-product glycerine can be sold to the cosmetics industry which produces soap from it, and the remaining wastes can be further processed to fishmeal which is not, however, as high-quality.

Fish diesel already in use in Honduras

The production of biodiesel from fish waste is also already being carried out in practice, as Piccolo mentions in his thesis. The first company to do this was Agifish, one of the leading pangasius producers in Vietnam. A lot of slaughter waste is produced during the course of processing and Agifish wanted to make profitable use of it. For that reason they founded a joint venture with two local cooling firms and the Raffinerie Saigon Petro which is to produce 30,000 t biodiesel annually from the fish waste. It is estimated that a production of 800,000 t of pangasius in the Mekong region leads to at least 100,000 t slaughter waste per year. The company is to be based in the province An Giang.

Already now the Honduran company Aquafinca St Peter Fish, one of the biggest tilapia exporters in the world, produces 11,000 litres of biodiesel per day from tilapia waste. Aquafinca claims to be the market leader for transforming fish oil to biodiesel. The biodiesel they produce is used to produce

electricity for the company and also for their vehicle fleet which includes ten trucks and eight buses for transporting the 1,500 employees. Aquafinca operates tilapia farms in the El Cajon reservoir and in Lake Yojoa. The company exports about 25,000 t tilapia every year, mainly to the USA.

A plant for the conversion of fish waste into biodiesel.

Fuels based on aquatic resources are not, however, likely to be sufficient to cover the huge – and increasing – energy requirements of mankind. But they could contribute towards solving the problem, particularly because in contrast to fuels from agricultural raw materials they have several advantages. The production of algae fuel and fish diesel does not compete with food production and does not push up the prices for rice, wheat and soy. Aquatic resources have a neutral carbon dioxide balance and thus have only a marginal influence on the environment and climate. That makes them a real alternative for energy supply in many parts of the world. *mk*