Sugar palm (*Arenga pinnata*)

Potential of sugar palm for bio-ethanol production

Prepared by FACT Foundation

Sugar palm harvesting (foto: Maut Star Bussman)

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1 PREFACE

1.1 Foreword

This FACT sheet is based on a Dutch report on biofuels, prepared by Wageningen University in the Netherlands. FACT has translated the document from Dutch into English with the intention of making it available to largest possible audience. The main target groups of this document are parties involved in the development of sustainable biofuels in developing countries (NGO's, small and medium Sized Enterprises, local entrepreneurs, local governments, local farmers and farmers groups). We hope the document helps in making well balanced decisions in new research and projects involving sugar palm. Our main aim is to provide information and assist in the development of projects, either research or (semi-) commercial development, that:

- bring development to the local population,
- do not threaten food security,
- have minimal negative impacts on the environment and biodiversity,
- reduce greenhouse gas emissions and
- have a positive energy balance.

This document will be presented as a living document on the FACT website and will be updated when new information on sugar palm becomes available.

For more information or comments please contact us or visit our website:
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1.2 Acknowledgements

This publication is made available in English by the FACT Foundation. The text is an almost literal translation of the part on sugar palm in the Dutch study "Nieuwe grondstoffen voor biobrandstoffen – alternatieve 1e generatie energiegewassen", prepared by Wageningen University, commissioned by Senternovem (the current AgentschapNL). It was first published in Dutch in August 2009. FACT Foundation thanks Mr. Wolter Elberson (WUR-ASFG) and Mr. Leo Oyen (WUR-PROTA), as well as Mr. John Neeft (AgentschapNL) for their approval and cooperation on this publication.

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2 SUMMARY

Other names: Areng palm, black sugar palm, black-fibre palm (En); Palmier à sucre, palmier areng (Fr); Zuckerpalme (Ge); Aren, enau, kawung (Ind.). Suikerpalm (Nl).
Latin name: *Arenga pinnata* (Wurmb) Merrill
Plant Family: Palmae – Arecaceae

Sugar Palm grows in humid areas around the equator especially in Southeast Asia. It is a large palm with a single trunk, up to 20 m long and a crown consisting of 15 to 20 huge leaves. Main products are (sheet) fiber and sap tapped from the inflorescence, from which palm wine or sugar is made. The trunk of the palm contains starch that can be harvested. The crop is commonly grown on a small scale, from several single trees up to several hectares of trees. After 7 to 10 years when the palm has matured, the first inflorescence develops, and tapping of the palm sap can start. The inflorescence is cut off and the sugar-rich juice flowing from the stem is collected daily. The collected juice quickly ferments into palm wine. If sugar is to be produced the juice needs to be collected in sterilized containers.

palm sugar production (Renee van Slooten)

Reliable estimates of the sugar yield are not yet available. A limited amount of measurements are available which can be used to estimate overall yields by extrapolation. Estimates of the sugar yield under good conditions vary from 8.7 to as high as 25 tonnes/ha/year over the total lifecycle of the palm. This corresponds to 4,610 liters to 13,000 liters of ethanol per hectare per year. Sugar palm is not yet grown on the large commercial scale that is needed for large scale production of bioethanol as fuel. Plans for such production are being developed. In remote off-grid areas, current plantations can be considered for small scale local ethanol production for local energy supply.

The energetic and economic feasibility of bioethanol production from sugar palm is virtually unknown. A positive factor are the potentially very high yields while the long non-productive juvenile phase and the high labor needs can be seen as problematic.

Expansion to large scale sugar palm cultivation comes with risks. Small-scale cultivation of sugar palm perfectly fits into local farming systems. In order to make a proper assessment of the value palm sugar as bio-ethanol crop more information is needed.

3 BIO-ENERGY POTENTIAL OF SUGAR PALM

3.1 Center of origin and climate and soil requirements

Sugar palm occurs naturally in humid regions of Southeast Asia, in an area that extends from India, Indonesia (Java and Sumatra to Iryan Jaya) and Malaysia to the Philippines and Papua New Guinea, from Myanmar and Thailand to Vietnam and in the far north to the Ryukyu archipelago. It occurs in both primary and secondary forest, often near villages. Planted by humans, it appears on a number of places in the tropics including Indonesia. As the natural habitat indicates, the sugar palm grows best in warm tropical (equatorial) climate with plenty of sunshine and abundant rainfall.

Although sugar palm grows best on fertile soils, it grows on various soils from heavy clay to loamy sand and laterite soils, provided they do not regularly flood. The palm can often be found on infertile soils on slopes and as part of secondary forest. The importance of a high temperature shows from the slow growth at higher altitudes. At sea level, flowering begins after 5-7 years and at 900m altitude after 12-15 years. Although sugar palm grows best near the equator, it can also be found at higher latitudes (up to 30 ° latitude), characterized by a more intense dry period.

3.2 Current distribution and status as an energy crop

In its center of origin sugar palm has often been planted, although palm trees growing ‘wild’ are also harvested. Sugar palm mainly has traditional uses and is only recently being considered for development as an energy crop. In 2008, the Eco-Integration project announced to start bioethanol production on 1 million hectares of palm sugar forest (combined production) in Indonesia. The system would make use of existing semi-natural palm plantations and newly established plantations. The palm trees would be harvested in a modern way for conversion into bioethanol. The project aims at export of bioethanol to Europe via the port of Rotterdam. Besides plans for setting up production in Indonesia there are also plans for bioethanol production from sugar palm in Colombia and Tanzania. Market introduction of large-scale bioethanol production for the global market is thus already foreseen, even before reliable data is available on the value of sugar palm as a bioethanol crop.

3.3 Description of the crop

Sugar Palm is a large palm with a single unbranched stem. The roots grow up to 10m deep. The trunk can grow up to 20 m high and 65 cm in diameter and it is covered with the bases of broken leaves and long black fibers. The crown has 12-20 leaves that are up to 10 m long and are made up of up to 150 smaller leaflets. The flowers are arranged in a large bunch, up to 2 m long, with male or female flowers.

The fruit is 5-8 cm long and contains 1 hard black seed. The germination of the seed is unpredictable and takes from one month to more than one year, which hinders the establishment of larger plantings. During 3-5 years after germination the palm forms a rosette of leaves but no stem yet. In the following 5-10 years the palm develops a trunk with a total of approximately 50 leaves. The last two leaves appear simultaneously, after which the palm enters its generative phase and stops producing new leaves. In the axils of the upper leaves 4-8 female flower bunches are formed from top to bottom. At the end 7-15 mostly male flower bunches are formed. The trunk serves as a storage organ for starch, which at the beginning of flowering is converted into sugars for the production of seeds - or palm juice that is harvested. Pollination of flowers is done by bees. The female flower bunches bear thousands of flowers that in 12 months develop into ripe fruits. A palm that is not tapped can form up to 250,000 fruits and seeds. About two years after the formation of the first inflorescence, when the fruits in the inflorescence near the top of the palm have matured, the palm dies. By a carefully developed tapping scheme, the productive life of the palm can be extended with a number of years. In order to keep the palm alive, a number of female flowers needs to remain present and should not be cut off for tapping. The art of tapping is to keep this number of flowers as small as possible and in the meanwhile making the tapping period as long as possible.

Inflorescence of sugar palm (E. Keijsers)

3.4 Growth Propagation and planting

In small-scale production usually a few seeds are sown at the place where a new palm is needed. Sometimes seedlings are also being collected and transplanted. In a nursery more care for the seeds is needed, because it is important to get a simultaneous germination. Intact ripe fruits or seeds are collected from the most productive palms. To facilitate the uptake of water by the seed and promote uniform seed germination, the skin of the seed is scratched open. Then the seeds are soaked in water for a day and placed in a humid germination bed. If the humidity is high, in about 3 weeks time 75% of the seeds has germinated. The sprouted seeds are planted in polybags. The seedlings develop best in full sunlight. When the plants have two leaves, they are ready to be planted out in the field. In a plantation, the trees are planted at a density of about 250 palms per hectare. Under intensive management a ground cover crop and sometimes also a number of shade trees and wind-breaking hedges are planted.

3.5 Plantation management

Plantation management is generally limited to occasional weeding. Fertilizer application is rare although the amounts of nutrients removed with the juice are significant. A 1933 study found that with the juice each year about 30 kg/ha of nitrogen, 1 kg/ha of phosphorus and 87 kg/ha potassium are removed.

3.6 Pests and diseases

Serious pests and diseases have not been reported in sugar palm and in the current small scale practice, chemical control is not necessary. Occasionally sugar palm is attacked by locusts and caterpillars, but this has never developed into a regular and returning pest. Only rhinoceros beetles may affect the growing point of the palm, as they do in coconut and oil palm. The attack can lead to the death of the palm, but the scale of damage remains limited. Control is virtually impossible and would also disrupt the local ecology in a way that the net result would be negative. It is anticipated that in large scale plantations (as in oil palm) pests and diseases will become more prominent.

3.7 Harvesting

In order to tap the sugar-rich sap from the flower bunches (inflorescences), the stem of the inflorescence is cleared from bracts and fibers, then knocked upon with a mallet and swayed around in various directions. Both male and female inflorescences can be tapped, but with male inflorescences are more often unsuccessful. Although the principle of the treatment is the same everywhere, there are clear regional differences in approach and frequency of tapping. The right time to start tapping is determined by cutting a few sprigs of the inflorescence. If they continue to bleed for more than one day, tapping can start. This moment is just before the flowers would normally open. With a machete, the stem of the inflorescence is sliced off in one stroke to get a smooth surface. In order to collect 'toddy' (fermented juice) a bamboo vessel is attached under the stem. This vessel is inoculated with old 'toddy' or with yeast which results in the production of bioethanol. In case of tapping for sugar production the vessel is emptied daily to limit fermentation. In order to keep the sap flowing a small next part of the stem is regularly sliced off. The length of the stalk therefore also determines the length of the period that an inflorescence can be tapped. If a thick slice is removed, 60 liters of juice per day can be produced, but this leads to fast weakening and premature death of the palm. Not all plants produce a good sap flow. In current plantations this is about half the trees. These non-productive palms can be harvested for starch. Harvesting for starch follows the same procedures as in sago palm. The tree is cut down just before the first bloom and the trunk is cut lengthwise in half. This is a difficult operation, because the outer wooden cylinder is very hard. The soft core is cut out, crushed and washed. At the end a bright white powder is obtained.

3.8 Yields and conversion into biofuel

Very high yields of sugar palm have been claimed, "to as much as 6 times that of sugarcane". It is difficult to make good estimates of yield and yield potential of sugar palm since good yield data on the full lifecycle of a plantation are lacking. Usually the yield of individual palms is reported and these cannot simply be extrapolated to yields per hectare. Extrapolation of yield per day to yield per year is also difficult. Reliable data of larger uniform plantations are still missing.

Based on available data, estimates of the potential production per hectare can be made. Assuming a modern plantation with 200 trees per hectare that are not harvested for the first 9 years and then produce for 3 years. A productive palm produces about 4 months per year, with a yield of 12 liters per day containing about 12% sucrose. This means each palm produces 1.44 kg of sugar per day. If the palm produces 4 months per year for 3 years total production amounts to 520 kg of sugar. With 200 trees per hectare the total yield of the plantation is 104 tons of palm sugar. This represents a peak production during the generative phase of the plantation of 34 tonnes of sugar per hectare per year. After 3 years of tapping the palm dies, so average annual production over 12 years is 8.66 tons of sugar which equals a production of 4,610 liter of bioethanol per year. This is similar to good yields of bioethanol from sugar cane. When the non-productive vegetative phase can be shortened (by breeding), productivity may be somewhat increased.

Fermentation of sugar palm – Sulawesi (E. Keijsers)

Actual measurements show that in North Sulawesi in village plantations under good conditions around 70 kg of sugar per hectare per day is harvested in plantations of palms of different ages. Over the year this would amount to 25 tonnes of sugar per hectare which is equal to 13,300 liters of bioethanol. These are very high yields that may not be physiologically possible. In reality, several generations of palm trees are grown in the same plantation and in the same cluster. In a cluster, palms of 3, 6 and 9 years old are growing together. New young palm trees are allowed to grow next to the oldest trees, and as such sunlight interception by the crop is increased. On every 3 palms, 2 palms are in the vegetative phase and 1 palm is in its generative and productive phase and can be tapped for 4 months per year. In this way over a long period a constant one third of the palms will be productive and for many years provides a constant quantity of 11 tons of sugar per hectare per year. This corresponds to about 6000 liters of bioethanol per hectare per year. By plant breeding, e.g. aiming at reducing the length of the vegetative period, it would be possible to further increase yields. The above projection shows that under optimal conditions, sugar palm can be very productive with yields higher than sugar cane. As is the case for sugar cane, fuel for the distillation plant is available from the crop residue, in the form of palm trunks and leaves. It is necessary to assess the productivity in practice. As indicated above, tapping requires a lot of expert knowledge and experience, which are necessary to get an optimal production.

Thickening the palm sugar (Renee van Slooten)

Molding the palm sugar (Renee van Slooten)

It is also important to realize that between palms there are large differences in yield, regardless of the way of tapping. This indicates significant genetic variation, but this has not been systematically inventorized. There are no collections of sugar palm present in gene banks. In North Sulawesi in several plantations and from wild stocks the best individual trees are selected for propagation. It seems possible that this could increase the rate of trees that can be successfully tapped from 50% to 85%.

3.9 Traditional uses

Besides the production of bioethanol sugar palm has many traditional uses.

3.9.1 Sugars

In order to produce sugar the collected juice is cooked in open pans. Oil is added to prevent boiling over. When the liquid is dark red and starts to become solid the solution is poured into molds to crystallize. Shelf life is limited because of impurities. Sometimes lime or sodium bisulphate is added to improve shelf life. The juice is also drunk fresh ('nira') or after fermentation ('toddy'). It is also made into vinegar. The main product is the raw dark red palm sugar which is used in many dishes like sweets, soft drinks and canned products. Bioethanol can be distilled from the 'toddy'.

3.9.2 Fibers

After palm juice, fibers are the most important product, particularly the fibers at the base of the leaves that surround the stem. These are rough and hard, but extremely durable (even in contact with seawater) and are used to make shipping ropes. In addition, fibers are used to make sieves, mattresses, brushes, brooms and mats to protect poles against damage in the soil or by seawater.

Sugar palm leaves are used for plaiting and roofing which is common for the leaves of most feather palms. The 'leaves' are dried and used as a substitute for paper. If the palm is not tapped, it provides a number of extra products. Starch is extracted from the soft core of the trunk, as from sago palm. The starch is used to create special dishes. Alongside the soft core and the outer fibers, the trunk also consists of a wooden cylinder. The wood is decorative and is used for floors, furniture and machine parts.

3.9.3 Other uses

The larvae of beetles living in the trunk are collected and are a protein-rich food. Palm heart, the young and still unopened white leaves, is eaten as a vegetable. The seeds mixed with sugar are processed to candy and the flowers are an important source of honey.

3.10 Economy

Little is known about the economics of sugar and bioethanol production from sugar palm. The important factors that determine the economics are known. First there is the long juvenile phase of the sugar palm that can be as long as 10 years before harvesting starts. This increases the payback time of a new plantation. When capital is scarce and interest rates are high this is a problem. Integrating existing bioethanol production in existing plantations and reducing the juvenile phase could be possible solutions. At a few places natural sugar palm stands are probably uniform enough to enable commercial bioethanol production. The full potential is difficult to estimate.

The labor requirements for juice collection are quite high. It is estimated that one worker can tap 20 palms per day. This means that 3 or 4 workers per hectare are needed on the plantation. As a reference in an efficient oil palm plantation only 1 worker per 10 hectare is needed for harvesting. Methods to reduce the labor needs for tapping are being developed. Positive aspects are the high productivity and the low costs of inputs like pesticides and fertilizer. Byproducts such as fiber, wood and other products can also generate extra income.

3.11 Sustainability

A good analysis of sustainability (such as a LCA, greenhouse gas emissions and energy balances) of bioethanol production from sugar palm has not yet been made and there is little experience with production in large-scale estates. Nevertheless, some things can be said about the potential sustainability of bioethanol production from sugar palm.

1. A favorable aspect is the very high productivity of sugar palm. A production of 4,000 to 5,000 liters of bioethanol per hectare certainly seems feasible based on the available data. An increase of sugar palm production seems possible and would lead to a more efficient land use than sugar cane. When sugar palm is planted in large scale plantations for bioethanol production, it will (like palm oil) occupy land in the wet tropics where the natural vegetation is rainforest. Although there are many possibilities for such plantations on marginal land, this still may lead to direct or indirect loss of rainforests. It is thus essential to set clear sustainability criteria that also include indirect land use change. The current

initiatives that start from existing plantations or are set up on degraded land seem to have fewer objections.

2. Sugar palm is also a food crop. Bioethanol production can therefore be seen as competition for food (sugar market) or land use for food crops. The ability to supply other products such as starch, string, leaves and fruits can reduce the footprint of bioethanol. Furthermore, wood from the plantation can be used as fuel for a bioethanol plant. This is beneficial for the energy balance and greenhouse gas emissions. Sugar palm only grows in the wet tropics, where rainfall is seldom a limiting factor. Little is known about the need for nutrients and fertilization. If only the juice is removed, the need is relatively low. Growing sugar palm under marginal conditions seems possible especially on steep land and degraded land.

3. Sugar palm has an important role in the economy of the local population. The cultivation of sugar palm is labor intensive, but provides a good and stable income throughout the year. By-products (fruits, roofing materials, materials for braiding, wood and starch) may significantly contribute to income. In contrast, the long non-productive juvenile phase makes recovery of investment difficult.

4. Sugar palm seems productive and this is one of the key success factors for an energy crop. A limited local demand for palm sugar production is the main reason why large scale production systems have not yet been developed. A good feasibility study, conducted in an existing plantation, is needed.