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Palm oil production through sustainable plantations

The Malaysian oil palm industry is one of the most highly organised sectors of any national agriculture system of the world. Today, though, the focus has shifted to how well agriculture also meets universally accepted standards of sustainability. This paper highlights the development of oil palm cultivation and responsible farming practices in Malaysia, the world's largest producer of palm oil. The oil palm has had a natural head start in fulfilling sustainability indicators due to its plant physiology of high productivity and efficient carbon assimilation. Over the last 50 years, R&D activities and technological advances have helped raise yields and reduce inputs, thereby maximising oil production from a smaller land area than used for other food crops. Palm oil is now a major source of sustainable and renewable raw material for the world's food, oleochemical and biofuel industries. Involvement in cultivation or downstream activities has uplifted the quality of life of people, a key plank of the sustainability platform. In particular, this has helped alleviate poverty among landless farmers in Malaysia. Industry players have recently joined hands with other stakeholders to pursue certification of sustainably produced palm oil with full traceability. Also being explored are measures to conserve forests with high value and the wildlife population.

Keywords: Plantations, sustainable, palm oil.

1 Introduction

Global interest in sustainable agriculture requires a review of how the oil palm plantations have evolved in ensuring that palm oil is produced according to the set standards of responsible production practices. Many inherent advantages are already within the oil palm system of plant physiology of high productivity and efficient carbon assimilation. The oil palm is credited with its high oil yield per unit area. It produces two types of oils from the same fruit – palm oil from the flesh or mesocarp and palm kernel oil from the seed or kernel inside the hard-shell mesocarp. The kernel also yields a residual product known as palm kernel meal, which is mostly used for animal feed.

The two oils are extracted by careful separation at certain stages of the milling process. Palm kernel production is about 10% of the quantity of palm oil produced. The two oils have very different applications and market outlets. Palm oil is used mainly for food, while palm kernel oil goes mainly into the oleochemical industry for making soaps, detergents and toiletry products.

Many other biomass products generated by the oil palm plantations are often under-utilised commercially. Mills regularly generate large quantities of fibre-type products in the form of empty fruit bunches and fruit mesocarp fibres, which have hitherto been mostly sent back to the plantations for mulching, for soil conservation purposes. Some amount of the fruit fibre and the kernel shell are burnt in boilers to generate steam and electricity for the mills. The availability of excess energy sources at the mills helps to minimise the cost of palm oil production in terms of energy needed to extract the oil and kernel. As the oils form about 10% of the total dry biomass produced by the palm, the other 90% of the biomass represents a further huge source of fibre and cellulosic materials which await further commercial exploitation. It is projected that future second-generation biofuel will be based on the conversion of cellulosic fibre or biomass into liquid fuel. This makes the oil palm truly attractive as a future source of renewable energy from the biomass which, if exploited prudently, will enhance the sustainability of oil palm plantations.

2 Developments of oil palm plantations

Malaysia is currently the world's largest producer and exporter of palm oil. The plantation sector dates back to 1896, with the start of the rubber industry. Oil palm cultivation began in 1917, but growth was initially very slow. It was only during the last 50 years that plantation development was accelerated through large-scale investments in the cultivation of the oil palm as one of the approved crops for diversifying the country's agricultural develop-

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Review Article

ment. Malaysia is also known as a major producer of rubber, cocoa and, to some extent, coconuts. Preference for oil palm has led to a rapid expansion of its planted areas (Fig. 1) at the expense of rubber and other crops over the last four decades. Areas under oil palm increased from 54,000 hectares in 1960 to 4.05 million hectares in 2005, reflecting a compound annual growth of 10.06%. Production increased from 94,000 tonnes in 1960 to 15 million tonnes in 2005, or by almost 160 times within 45 years – this represents a compound annual growth of 11.93% per year. These figures speak eloquently not only for the industry's success, but also for the tremendous contribution that Malaysian palm oil has made to the world food sources.

The oil palm thrives under Malaysia's tropical climate which is marked by all-year-round temperatures ranging from 25 to 33 °C and evenly distributed rainfall of 2000 mm per year. Not many countries have similarly ideal temperatures and rainfall patterns. Although countries located within 10 degrees latitude of the equator are said to be suitable for oil palm cultivation, some of them experience several months of drought, which drastically reduces yield. Malaysia and Indonesia have therefore emerged as major producers of palm oil. Other producers from about 20 countries command a production share of less than 3% each.

The commercial variety of oil palm planted in Malaysia is *Elaeis guineensis* which originates from Africa. The oil palm was first introduced into the then Malaya as an ornamental plant way back in 1875 [1]. The first commercial planting was established in 1917 at Tennamaran Estate in Kuala Selangor [2]. Due to a very narrow genetic base of only four mother palms used historically in the propagation of palms in Malaysia, the oil is uniform in its characteristics, with a very narrow range in physical parameters such as iodine values (IV) and melting points. The industry has since added to the genetic collection of African palms to improve the population base for breeding purposes. Some recent introductions from the Nigerian collection by the Malaysian Palm Oil Board (MPOB) have demonstrated new traits that offer certain advantages over existing commercial oil palms. These include improved oil quality, reduced height of the mature palms and higher contents of carotenoids and vitamin E, especially tocotrienols.

From the earliest days, experiments have been carried out to produce hybrid strains of oil palm that give higher yields of oil. The industry's breeding and selection work since the 1960s has contributed to improvements in yield. Commercial materials, which started with the Dura (D) palm variety, had a low oil extraction ratio (OER) in the range of 12–16%. This was replaced by the Tenera (T), a hybrid of the Dura and Pisifera (D × P) varieties, as the planting material of choice, because of higher yield. The much improved OER of over 25% contributed to doubling of the yield. With continuous breeding and selection work, some of the latest planting materials based on the improved Tenera are capable of producing 100% more palm oil compared to the standard Tenera. The progress in breeding to enhance the yield has meant that the viability of oil palm cultivation continues to improve, and such progress has stimulated expansion of cultivation.

In the 1970s, the momentum of high productivity coupled with new ways of exporting palm oil in the processed form enabled larger markets to be developed, especially in countries like India, P.R. of China, and those in the Middle East. The global market for oils and fats grew and it brought along expectations of higher prices. This boosted confidence that palm oil production would be profitable as a long-term investment. Oil palm cultivation was also regarded as a reasonable alternative to planting rubber, the price of which had been affected by competing

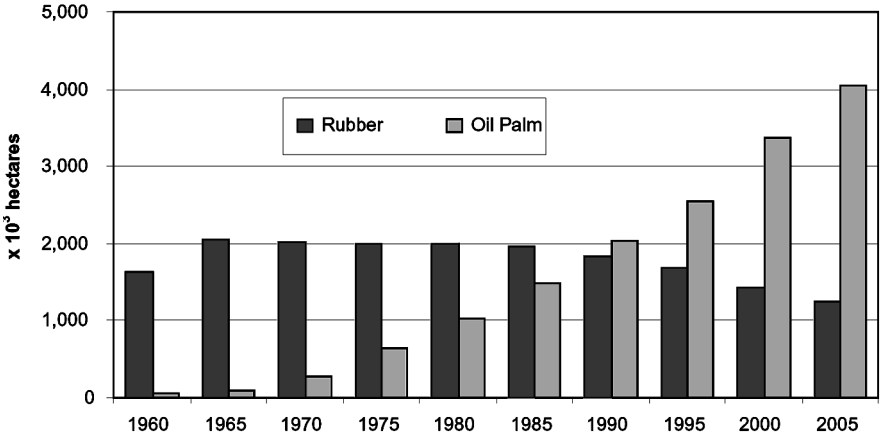

Fig. 1. Planted area for oil palm and rubber in Malaysia. Source: MPOB, Malaysian Rubber Board (MRB).

synthetic rubber. The success in oil palm expansion was consolidated with promotion of downstream industries, including the use of palm oil for oleochemical production. Such strategies provided further impetus for production growth, especially in the 1980s and 1990s.

The lucrative returns attracted neighbouring Indonesia to expand its oil palm cultivation. With more land and labour readily available, the Indonesian industry grew rapidly so that by 2005, its oil production volume was close to that of Malaysia. The need for new market outlets was felt keenly because Indonesian palm oil was beginning to affect the global market share of Malaysian palm oil. Fortunately, the high petroleum prices in 2005 and 2006 led to many countries considering biodiesel production from renewable resources. This new application opened up a potentially large market outlet for palm oil as well as other major oils and fats. The first decade of the 21st century can therefore be regarded as the period of creating additional demand from biofuel, which in turn stimulated supply expansion in all producing countries.

3 How palm oil is produced

In Malaysia, palm oil is produced on estates owned by plantation companies. They also often operate mills where the harvested fruit bunches are processed for oil extraction. Small farmers with varying sizes of oil palm holdings also produce fruits bunches. These are sold through dealers who send the fruit bunches to nearby mills for oil extraction. Over the years, the Malaysian oil palm industry has grown in size and participation, as shown in Tab. 1 which compares the performance of the various sectors.

Investing in oil palm cultivation is a long-term commitment. Estates usually have access to contiguous land area, often in excess of 2000 hectares at each location. This allows economies of scale to prevail and ensures that the management team is employed at an optimum level. It is pertinent to note that growth of the oil palm industry has led to a significant social phenomenon of rural communities relying on plantations as a source of employment and income.

The plantation sector is one of the biggest employers in Malaysia. A typical estate of 2000 hectares would employ a manager (usually a university graduate), three assistant managers, and nine field staff. Manual workers are employed to carry out field duties including weeding, applying fertilisers and harvesting. As a plantation company may have estates at several locations, it falls on the Managing Director to coordinate activities to ensure that palm oil is produced at the lowest cost and maximum yield, to derive strong profits every year.

When operated in a corporate environment, the plantations are deemed to be professionally managed by a Board of Directors, managers, and financial experts, advisors and inspectors. They are backed by research expertise relating to agronomic, soil and water management. Oil palm plantation companies usually aspire to public listing on Bursa Malaysia, as the stock exchange is known. More than 40 are currently listed on the Main Board, while hundreds operate as unlisted companies.

The profitable estate sector has attracted a growing number of smallholders to venture into oil palm cultivation. To overcome the lack of economies of scale, the Malaysian Government created agencies like the Federal Land Development Authority (FELDA) to consolidate or aggregate small areas into an estate of an economic size, and to provide management and infrastructural inputs. FELDA, established in 1956 from a concept supported by the World Bank and the United Nations, is tasked with reducing rural poverty through resettlement of landless farmers in land development schemes where they plant economically viable crops. FELDA's management of smallholders' areas has enabled the resettlement of some 100,000 families who were landless and living below the poverty level. Each family was provided with 4 hectares of land cultivated with crops such as oil palm, rubber or cocoa. In addition, FELDA directly operates some

Tab. 1. Oil palm-planted area in Malaysia.

	1980	1985	1990	1995	2000	2005	2005 Share
	Planted area [ha]						
Private estates	495,412	666,099	749,608	1,230,302	2,024,286	2,412,745	60%
Organised smallholdings	347,856	469,592	650,782	1,230,302	789,558	895,764	22%
State schemes	–	–	–	196,628	242,002	318,292	8%
Independent smallholders	80,761	156,708	261,287	228,621	320,818	424,573	10%
Total	924,029	1,292,399	1,661,677	2,885,853	3,376,664	4,051,374	100%

Source: MPOB

340,000 hectares of oil palm plantations to supplement settlers' income and offset the cost of managing the land development schemes. As a result, FELDA is today the world's largest single plantation company with a combined oil palm area exceeding 600,000 hectares and an annual revenue exceeding US$2 billion. With a proven track record, its work is recognised by other developing nations as a model for poverty eradication. Independent smallholders, too, have switched to planting oil palm, from traditional crops such as rubber, coconut, cocoa or rice. This is due to the high profitability of oil palm compared to other crops.

Similar developments in oil palm cultivation have taken place in Indonesia, the second largest palm oil producer after Malaysia. Countries like Papua New Guinea, Thailand and the Philippines have also expanded their oil palm cultivation, although they started from a smaller base area. Production of palm oil from African and South American tropical areas is increasing as well. Tab. 2 shows the major palm oil producers and their shares of production, while Tab. 3 details world production of oils and fats. Palm oil has, since 2005, overtaken soyabean oil in production terms.

4 Technology of palm oil production

Oil palm planting is preceded by preparation of the land, which may be previously logged-over areas alienated for agricultural use, old oil palm stands, or areas once planted with rubber or cocoa. Standard practices guide the

Tab. 2. World palm oil production from 1980 to 2005.

	1980	1985	1990	1995	2000	2005	2005 Share
	Palm oil output [× 1000 metric tonnes]						
Malaysia	2576	4133	6088	8123	10,842	14,962	44%
Indonesia	691	1243	2413	4220	7050	14,070	42%
Nigeria	433	386	580	660	740	800	2%
Thailand	–	–	232	354	525	685	2%
Colombia	–	–	226	388	524	661	2%
Papua New Guinea	–	–	145	223	336	310	1%
Cote D'Ivoire	–	–	270	285	278	260	1%
Brazil	12	29	66	75	108	160	0%
Others	875	1041	1000	5994	5191	1826	5%
World total	4587	6832	11,020	20,322	25,594	33,733	100%

Source: Oil World

Tab. 3. World oil and fat production.

	1980	1985	1990	1995	2000	2005	2005 Share
	Volume [× 1000 metric tonnes]						
Palm oil	4543	6832	11,020	20,322	25,594	33,733	24%
Soyabean oil	13,382	13,974	16,097	15,119	21,743	33,575	24%
Rapeseed oil	3478	6066	8160	10,936	14,496	16,205	12%
Sunflowerseed oil	5024	6564	7869	7003	9808	9661	7%
Tallow & grease	6283	6518	6813	7013	8071	8211	6%
Lard	4691	4989	5509	5141	6580	7568	5%
Butter fat	5746	6315	6500	4834	5829	6665	5%
Cottonseed oil	2992	3942	3782	3312	3815	4989	4%
Groundnut oil	2864	3575	3897	4325	4382	4523	3%
Palm kernel oil	571	868	1450	1877	2620	3975	3%
Coconut oil	2716	2627	3387	3253	3147	3257	2%
Olive oil	1701	1796	1855	1863	2513	2916	2%
Others	3695	4430	4552	4618	4995	5100	4%
World total	57,686	68,496	80,891	89,615	113,591	140,378	100%

Source: Oil World

planning and implementation stages in establishing an oil palm plantation. The land preparation may include removing past vegetation and piling this into neat rows for natural decomposition, as open burning of the residual vegetation during replanting is disallowed by law. The planting points for the new palms are marked, planting holes are dug and the right dosage of basic fertiliser is put in, after which the oil palm seedlings are ready to be planted. The palms are placed in rows with a distance of 9 m between any two seedlings. The triangular planting pattern created is said to provide for maximum penetration of sunlight, to maximise yield. Planting density works out to 148 palms per hectare.

Seedlings are raised in nurseries for about 12 months before they are ready for transplanting. Ground cover is quickly established by planting cover crops to prevent soil erosion and the growth of weeds. After 30 months, the oil palm may already produce fruit bunches of sufficient size and number to initiate the harvesting process. Harvesting involves removing the ripe bunches, and collecting and sending these to the mill for oil extraction. The harvesting rounds are organised throughout the year so that the same palm is visited every 2 weeks – during which the workers will harvest any ripe bunch using a chisel on a short pole, or a sickle on a longer pole for taller palms.

Advancement in the technology of oil palm cultivation is directed at increasing yield and reducing costs. In most situations, adequate and balanced fertilisation is essential to realise the palm's genetic growth and yield potentials [3]. Many years of fertiliser trial research have provided better knowledge of fertiliser application in terms of type and quantities of fertilisers. Improved knowledge of soil and water management has enabled the palm to sustain a consistent pattern of high yield throughout its economic life of 25–30 years. In Malaysia, extensive areas are now being replanted or are due for replanting into the second or third cycle of palms.

Yield is also being improved through better-quality seeds developed *via* intensive breeding and selection research over the last 50 years. Although the national average yield is 3.7 tonnes per hectare per year, high-yielding individual elite palms can regularly achieve over 10 tonnes per hectare per year.

Annual food crops have undergone many generations of breeding and selection research cycles. However, the oil palm, being a perennial plant, has only undergone a few cycles because it takes at least 6 years to complete a breeding programme. This implies that much more yield improvement could be realised in the future if breeding research continues. It is estimated that the theoretical yield of the oil palm is about 18.5 tonnes of oil per hectare per year [4]. This is superior to the yield of other oilseed crops such as the soybean at 0.4 tonnes per hectare per year.

5 Sustainable plantation practices

The concept of sustainable plantation practices, applied to any agricultural crop, must meet the universally accepted criteria of benefiting the 3 Ps – profit, people and planet. It is also important that the right of developing countries to develop land for agriculture must be respected, as this makes available sources of food and livelihood for people. The right to development was recognised at the Rio Earth Summit in 1992, where the concept of the 3 Ps for sustainable development was founded. Sustainable agricultural production should therefore adhere to the 3 Ps and 1 D concept, to ensure that development is undertaken in a sustainable manner.

Oil palm cultivation in Malaysia has long advocated sustainable farming practices. It has struck a balance between economic needs and preservation of the environment. Laws – including the Protection of Wildlife Act 1972 – were already in place when the industry saw a surge in planted area from the 1980s.

The country's land use pattern reflects a balance between the need for agricultural development and preservation of forest areas for conservation of biodiversity. Of the total land area of almost 33 million hectares, 65% is under forest cover [5]. Agriculture occupies 19%, of which two thirds or 12%, equivalent to 4.05 million hectares, are under oil palm. In contrast, agricultural land accounts for 70% of total land area in developed countries, while forest cover comprises between 10 and 30%.

Plantation agriculture has been the backbone of the Malaysian economy since the turn of the 20th century. Henson [6] reviewed the environment impact of oil palm plantations and provided the enlightening conclusion that such cultivation, in general, poses little direct environmental threat *per se*. Problems arise only during the forest clearing operations.

However, plantation crops such as the oil palm or rubber were originally forest species which have been domesticated to maximise the yield of their respective products. A typical oil palm or rubber plantation in Malaysia could qualify as planted forest, similar to those in the developed countries, but containing more species of fauna and flora as they flourish in a tropical climate. If plantation crops are included as planted forests, total forest cover would rise to 80% in Malaysia.

Planters in Malaysia have even developed oil palm areas on jungle fringes, with suitable techniques to preserve wildlife by maintaining riparian reserves along rivers and oxbow lakes. These reserves contribute towards conserving biodiversity and perform the important function of erosion control. They also serve as wildlife corridors for accessibility to habitats [7].

Plantations routinely implement biological pest control measures today, using the barn owl to reduce rodent populations rather than chemical baits. The oil palm is a hardy plant that is little affected by pests and diseases. This allows for minimal application of approved weedicides and pesticides, compared to other plantation crops [8] or the arable farms in Europe.

Any comparison of sustainability of the oil palm should be made with other agricultural crops. The oil palm has superior qualities in contributing back to the planet. It is estimated that the crop emits eight to ten times more oxygen and absorbs up to ten times more carbon dioxide per hectare per year (K. W. Chan, personal communication) compared to annual crops grown in temperate countries. Similarly, the high photosynthesis rate enables the oil palm to produce between eight and ten times more oil per hectare per year compared to annual oilseeds such as rapeseed or soybean.

In terms of productivity and comparative sustainability, the oil palm needs a smaller land area to produce a target quantity of oil. Oil palm occupies only 9.2 million hectares of agricultural land to produce 31.8% of global oils and fats output. For a similar output, soybean cultivation would require 92.5 million hectares (Tab. 4). If the target is to feed the growing world population and to better utilise the available land for cultivation, it makes good sense to look at palm oil as an effective source of supply since it is also a highly sustainable commodity. Furthermore the future yield is projected to double on individual plantations, as a result of research.

The oil palm contributes to uplifting the quality of life of people, which is a key plank of the sustainability platform. Growing oil palm has helped alleviate poverty among landless farmers in Malaysia, through their participation in the FELDA schemes. The income derived from oil palm, based on 2004 data, is equal to €1687 per hectare per year, compared to an average of €1448 for agricultural crops in the UK – of which about €238 is contributed by the subsidy paid to farmers in the EU [9].

6 Challenges in future sustainable palm oil production

The need to produce palm oil sustainably has led to the establishment of the Round Table on Sustainable Palm Oil (RSPO). A number of Malaysian plantation companies are founding members of the body. The RSPO has progressed towards formulating a set of principles and criteria for sustainable production, but has yet to implement a scheme to enable sustainably produced palm oil to be certified with full traceability. It is not easy to implement such an ambitious scheme, since maintaining the chain of custody for traceability purposes will be difficult and expensive.

The challenge of conserving land for forests with high conservation value remains a major objective. With a growing population and the need to open up more land for agriculture, there will be greater pressure on forested land because income from oil palm is higher than that from productive forests. Conscious of this potential conflict, the Malaysian government implemented a policy in the 1990s to stop the opening up of new forest land for agriculture. Only logged-over land zoned for agricultural development can be planted with oil palm or other crops. Although Malaysia has a large percentage of its land area under forest and only a small percentage under agriculture and oil palm, the policy underscores the acceptance of the need for sustainability.

Tab. 4. Oil productivity of major oil crops.

Oil crop	Oil production [million tonnes]	% of total production	Average oil yield [tonnes/ha/year]	Planted area [million ha]	% of total area
Soyabean	33.58	31.69	0.36	92.10	42.24
Sunflower	9.66	9.12	0.42	22.90	10.50
Rapeseed	16.21	15.30	0.59	27.30	12.52
Oil palm	33.73	31.84	3.68	9.17	4.21
Total[§]	105.94			218.02	

[§] Only for seven major oil crops (soyabean, oil palm, sunflowerseed, rapeseed, cottonseed, groundnuts, and coconut).
Source: Oil World

The oil palm industry is expected to continue to improve its implementation of good agricultural practices and adopt the principles and criteria of the RSPO to produce palm oil in a sustainable manner. In addition, an industry-based wildlife conservation fund has been created to assist in research and other kinds of funding to enhance sustainable practices and conservation efforts. There are allegations linking the oil palm to loss of habitats for biodiversity and wildlife, which include the iconic orang-utans, an endangered species that enjoys full protection in Malaysia. Sanctuaries have long been established by state governments to preserve both their population and habitats. The Sabah state government has designated the Ulu Segama and Malua forest reserves, which form the heartland of the state's orang-utan habitat, as sustainable forest management areas to preserve their biodiversity. Similarly, the Malaysian Palm Oil Council (MPOC) recently launched a US$5.5 million revolving fund to support efforts to enhance biodiversity conservation related to palm oil production worldwide. On the contrary, oil palm use of minimal land area while bringing remunerative income helps to save forests from being destroyed through over-logging, shifting cultivation, or being planted with less productive crops.

To meet future demand for palm oil, Malaysian companies have established oil palm plantations in Indonesia, Papua New Guinea, and other countries with adequate agricultural land, labour and suitable climatic conditions. As investors, they can introduce their experiences in sustainable plantation management and good agricultural practices, thereby increasing the volume of sustainable palm oil.

7 Conclusions

The oil palm plantation industry has emerged in the last 50 years as a major agricultural activity in Malaysia. It has benefited citizens through annual foreign exchange earnings of some RM30 billion or about US$8 billion. By spending some US$80 million a year on R&D, the palm oil industry is able to bring in improvements in a number of operational aspects, leading to higher demand and better prices for palm oil. In turn, this has encouraged sustainable supply because good agricultural practices have become more affordable.

The oil palm, being eco-friendly by its very nature, is a highly productive crop with an output-to-input energy ratio of 9 : 1 compared to 3 : 1 for other oilseed crops such as soybean or rapeseed. This is manifested by the tenfold higher yield of oil. Superior productivity is also reflected in high photosynthetic rates resulting in oxygen emission and carbon dioxide absorption rates that are ten times more effective than those observed for soybean. Oil palm cultivation also uses comparatively less land to supply oils and fats for food and non-food uses, including biofuel, for the world.

Malaysia's long tradition of oil palm cultivation has evolved into a dynamic plantation industry which subscribes to sustainable production practices. Management of plantations is highly developed in both its art and science, with know-how being enhanced through an active R&D system that is funded by the industry itself. Even the small farmers have access to technologies provided *via* an extension service by the MPOB and by experts from estates participating in a nucleus partnership system with smallholders. Details of production technology are documented in production and management manuals, and the industry's major activities are registered and licensed by the MPOB to ensure compliance with standard approved procedures.

The Malaysian oil palm industry has become one of the most highly organised sectors of any national agriculture system of the world. It is able to compete with vegetable oil products produced from developed and developing countries. The competitiveness of palm oil implies that it will remain an important source of sustainable and renewable raw material for food, oleochemical and biofuel industries of the future.

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