Non-Food Applications of Palm-Based Products – Market Opportunities and Environmental Benefits

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INTRODUCTION

Since the energy crisis of the 1970s, the price of crude oil has been escalating and it is forecast to go above USD 100 per barrel in the near future. The fear of an interrupted supply from political uncertainty coupled with the rapid depletion of reserves has sparked widespread interest in alternative energy. Furthermore, the damage caused to the environment from excessive use of fossil fuels has added to the clamour for more sustainable and environmentally friendly alternatives.

In response, vegetable oils such as rapeseed, palm, soyabean and coconut oils are already used for manufacturing of several products, including lubricants, surfactants, surface coatings, polymers, pharmaceuticals and cosmetics (Willing, 1999). In fact, many scientists already see the potential in agricultural crops as drivers of the world's economy in the next few decades. The increasing use of vegetable oils in the manufacture of industrial goods will significantly lessen global dependence on petroleum products.

Vegetable oils have other advantages over petroleum - they are renewable, easily biodegraded, and their processing does not emit a large amount CO_2, which is a greenhouse gas, whereas petroleum products contribute to increase in net CO_2 emissions, are poorly biodegradable and their supply is depleting (Marvey, 2002).

R&D changes in national policies towards environmentalism and the increasing liberalization of global trade are making agricultural crops fast become producers of non-food feedstocks compared to before.

MARKET OPPORTUNITIES

Much of the use of renewable feedstocks and the research on them started in Europe. The use of vegetable oils and animal fats in the non-food sector of the European Union (EU-15) alone is approximately 3 million tonnes per annum. This excludes biodiesel. The key market sectors are lubricants, paints and surface coatings, surfactants and oleochemicals.

- Bio-lubricants. The potential EU market is for approximately 370 000 t per annum but currently less than 10% of that is being produced. There are important environmental benefits in using bio-lubricants where environmental contamination is reduced.
- Bio-printing inks. The EU market is in excess of 120 000 t per annum. Belgium has made considerable progress in using vegetable-based printing inks, but elsewhere, particularly outside of Scandinavia, Netherlands and Germany, is still small. There are no technical reasons for this slack uptake.
- Bio-solvents. The EU solvents market is approximately 4 million tonnes per annum of which 1.9 million tonnes are hydrocarbon-based. Considerable health, environmental and security benefits will accrue by using vegetable derived solvents instead of those from fossil materials. At least 12.5% of the total market can be vegetable derived but to date less than 1.5% has been achieved.

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- Surfactants. Currently, the EU uses is in excess of 2 million tonnes per annum, and is increasing.
- Polymers. The majority of polymers are derived from petroleum but certain products are based on, or incorporate, vegetable oil-based derivatives. There appears to be considerable scope for increases in the use of vegetable oils in polymer production.
- Paints and surface coatings. Increasing use is being made of bio-solvents by the paint industry as well as alkyl resins and varnishes based on vegetable oils.

NON-FOOD APPLICATIONS OF PALM-BASED PRODUCTS

Some of the areas where vegetable oils can be used instead of mineral oil-based products are discussed in the subsequent sections.

Raw Materials in Crop Protection Products

Good crop protection products will improve yield by controlling weeds and pests. Vegetable oils offer biodegradability, new opportunities for products and new functionality. The Malaysian Palm Oil Board (MPOB) has initiated studies to develop insecticides from palm-based materials. Insecticides comprise about 18% of the total pesticides marketed in Malaysia with more than 55% of them solvent-based formulations or emulsifiable concentrates.

For safety and health, consumers now require safer and more convenient formulations such as water-based emulsions (EW). EW formulations offer many advantages over the conventional solvent-based insecticides including lower health risks to the operators due to the aqueous-base, less phytotoxicity to plants, and they are less expensive as water is used instead of oil (Ismail *et al*., 2004). The use of palm-based solvents and surfactants as inert ingredients result in non-flammable insecticides (due to higher flash points) that are environmental friendly.

Table 1 shows the results from bio-efficacy tests on major tropical insect pests in the laboratory at Henkel, Philippines. Two products were tested: Cypermethrin 5% (EW), a palm-based insecticide, and Attact 5R, a commercial insecticide in Philippines. The palm-based insecticide had comparable performance to that of the commercial sample and could kill most of the insects even at 100 ppm.

Biodiesel

Biodiesel is a fuel derived from vegetable oil. According to the US Department of Agriculture (USDA), world production of oilseeds and palm oil is increasing, partly due to increasing use of biodiesel. The current high price of crude oil

TABLE 1. RESULTS FROM AN EFFICACY TEST OF A COMMERCIAL AND PALM-BASED INSECTICIDES

Treatment	Conc. (ppm)	% Mortality of major tropical insect pests					
		Nephni	Nephim	Nilalu	Sogafu	Mites	Anapco
Attact 5R (commercial)	30	50	70	30	20	0	60
	100	100	80	70	40	0	90
	300	100	100	100	100	86	100
	5 000	100	100	100	100	93	100
Cypermetrin 5% (EW)	30	70	100	50	30	0	50
	100	100	100	100	100	0	80
	300	100	100	100	100	60	100
	500	100	100	100	100	96	100

Notes: Nephni = *N. nigropictus*; Nephim = *N. virescens*; Nilalu = *N. lugens*; Sogafu = *S. furcifera*; Mites = *T. kanzawai*; Anapco = *Orchid thrips*

Source: Ismail *et al.* (2004).

makes biodiesel production more attractive.

Biodiesel is the only alternative fuel that has gone through the EPA Tier I and Tier II tests to quantify its emission characteristics and health effects. The study found that B20 (20% biodiesel blended with 80% conventional diesel fuel) reduced total hydrocarbons by up to 30%, carbon monoxide by up to 20%, and total particulate matter by up to 15%. Emissions of nitrogen oxides (NO_x) was very much dependent on the duty cycle of the engine and testing methods employed. Increases in NO_x can be eliminated with the use of normal mechanical remediation techniques (*e.g.* catalysts or timing changes). Research also showed that the ozone forming potential of the hydrocarbon emissions from pure biodiesel is nearly 50% less than that from petroleum emissions. Pure biodiesel does not contain sulphur and therefore has no sulphur dioxide emission from the engines.

Biodiesel and fuel blends containing biodiesel reduces the net amount of CO_2 released to the biosphere. A study by the US Department of Energy found that the production and use of biodiesel produced 78.5% less CO_2 emission compared to petroleum diesel. CO_2 is taken up by crops during photosynthesis and then released when biodiesel is combusted. This makes biodiesel the best technology currently available for heavy-duty diesel applications for reducing atmospheric carbon.

The burning of biodiesel will also results in decreased levels of all the targeted polycyclic aromatic hydrocarbons (PAH) and nitrited PAH (nPAH) compounds compared to petroleum diesel exhaust. PAH and nPAH compounds have been identified as potential carcinogens. Specific PAH compounds were reduced by 75% to 85%, with the exception of benzo(a)anthracene, which was only reduced by roughly 50%. Specific nPAH compounds were also reduced dramatically with biodiesel, *e.g.* 2-nitrofluorene and 1-nitropyrene by 90%, and the rest of the nPAH compounds to only trace levels. These reductions can be attributed to the fact that biodiesel contains no aromatic compounds (National Biodiesel Board, 1998).

Palm oil can be used as a biofuel either directly (as CPO) or as palm oil methyl esters (PME). MPOB, together with Elsbett GmbH, has developed an engine that can run on CPO with only some modifications to the fuel line system (*Figure 1*). The collaboration has resulted in an exhaustive field trial involving 20 Mercedes Benz cars. That the use of palm oil as fuel for the Elsbett engine has great potential is evident from the positive results (Ahmad and Salmah, 1998).

PME has very similar properties to petroleum diesel, and thus can be used directly in conventional unmodified diesel engines. Agreements were made with two bus companies for road tests on three fuels, Malaysian diesel, 50:50 blend of PME and diesel, and pure PME. The results showed that the buses with normal diesel engines could just as well run on PME or the blend (Schäfer, 1998). PME can also be used as feedstock for many oleochemical derivatives.

Further research in MPOB has indicated that a blend of 5% refined, bleached and deodorized (RBD) palm oil in petroleum diesel is suitable as a biofuel (B5 biofuel).

Renewable Raw Materials for Sustainable Surfactants

Natural bases or sustainable surfactants are defined as surface-active compounds produced from natural raw materials including vegetable oils (Coupland, 1992). The future market for renewable-based surfactants forecasted in 2001 by the ECCP Renewable Raw Materials Working Group (*Table 2*) indicated a significantly increased uptake by 2010 (AAFC, 2002) from 460 000 t to 920 000 t, at an impressive annual growth rate of

Figure 1. Crude palm oil used directly to run a car fitted with an Elsbett engines.

TABLE 2. EUROPEAN MARKET FOR RENEWABLE RAW MATERIALS IN VARIOUS END-USES

Product	Current total market ('000 t)	Current renewables volume ('000 t)	Potential renewables volume (2010) ('000 t)	Potential renewables share (2010) (%)
Polymers	33 000	25	500	1.5
Lubricants	4 900	100	1 710	35.0
Solvents	4 000	60	235	12.5
Surfactants	2 300	460	920	40.0
Composites	2 210	26	195	9.0

Source: AAFC (2002).

about 7.2%.

MPOB has developed a technology to produce an anionic surfactant from palm oil, methyl ester sulphonate (MES), which can be used to formulate cleaning products, such as liquid and powder detergents. MES has good cleaning power and is suitable for use in hard water. It also has good biodegradation characteristics and therefore does not pollute the environment.

A preliminary calculation indicates that the cost of producing MES (USD 525.09 t^{-1}, or RM 1995.34 t^{-1}) is lower than that for LAS (USD 928.32 t^{-1} or RM 3527.62 t^{-1}) (Salmiah *et al.*, 2002). Starting from palm oil, MES production involves converting the oil to methyl esters followed by hydrogenation to reduce the unsaturation and then sulphonating the esters to MES. A pilot plant capable of producing 20 kg per hour MES with high activity is already in operation in MPOB.

Oils and Lubricants Based on Oleochemical Esters

Lubricants from oleochemical esters, being from renewable resources, are green alternatives, exhibiting very good or even superior technical performance and possess favourable ecological properties (Willing, 1999).

These vegetable oil-based lubricants offer the following advantages:

- easy approval by original equipment manufacturers (OEMs);
- environmentally benign, especially in total-loss systems; and
- user-friendly.

The current potential European markets for biodegradable lubricants are given in *Table 3*. Of the current consumption, 25 000

TABLE 3. POTENTIAL EUROPEAN MARKETS FOR BIODEGRADABLE LUBRICANTS

Lubricant Type	Total market ('000 t)	Current European ('000 t)	Potential European ('000 t)	Value of potential market (€ million)
Anti-wear hydraulic	610	20	250	825
Grease	90	0.6	35	58
Chain bar	40	10	40	66
Mould release	40	2.5	30	50
Two-cycle	70	1	3	10
Anti-corrosion	25	0.6	7.5	12
Others	0	0.6	3	5
Total	875	35.3	368.5	1 026

Source: IENICA (2000).

million tonnes are used exclusively in Germany. In Germany's Black Forest region, the environmental laws require farm machinery to use only biodegradable fuels and lubricants, thereby almost requiring the use of vegetable oils.

With regard to the German Water Hazard Class (WGK), most of them are classified as WGK 0 (general, non-water polluting). Their favourable ecological properties, together with their well-established technical performance, make oleochemical esters ideal raw materials for ecologically superior high performance lubricants for many industrial and automotive applications, such as hydraulic oils, metal working fluids and gear oils.

Vegetable oil-based lubricants evaporate less quickly and adhere better to the metal surfaces; therefore, less of the products need be used. Other cost benefits associated with vegetable oils include less environmental damage and penalties in case of spill, lower parts wear and maintenance costs and disposal fees.

Palm oil-based greases (lithium grease) have been developed by MPOB with a quality comparable to those of commercial products (*Figure 2*). The properties of this grease are shown in *Table 4* (Yeong *et al.*, 2002).

Figure 2. Palm-based lubricant (left) and grease (right).

MPOB has also developed food-grade grease for palm oil mills, refineries and other food-related industries. This grease does not contain any heavy metals and is not carcinogenic. The consistency of the grease is equivalent to National Grease Lubricating Institute No. 2 and 3, the most common consistency for multipurpose grease. It can also be used at high temperatures and possesses good water resistance and lubricity (Yeong *et al.*, 2004).

Vegetable Oil-Based Printing Inks

It is estimated that the use of vegetable oils in the world market for printing ink is approximately 100 t – 120 000 t (IENICA, 2000). The benefits of vegetable oil-based printing inks, as opposed to mineral-based inks, are:

- considerably improved abrasion resistance and less rub-off;
- excellent machine stability – less spoilage (0.5% - 0.7%);
- more intense colours;
- less ink use (10% - 15%);
- no dry-back;
- no volatile organic components (VOCs);
- vegetable oils are not carcinogenic, but many mineral oils are;
- no unpleasant mineral oil smell - vegetable oils are almost odour-free;
- no polycyclic aromatic hydrocarbons; and
- considerably less pollution of the environment.

MPOB had developed a palm oil-based printing ink in 1992 (*Figure 3*) in collaboration with Coates Brothers (M) Sdn Bhd (Ooi *et al.*, 1992). Comparative

TABLE 4. PROPERTIES OF PALM-BASED GREASES COMPARED TO A COMMERCIAL SAMPLE

Sample	Grease 1	Grease 2	Commercial
Thickener	15% lithium	20% lithium	Lithium
Drop point (°C)	161	172	174
Lubricity at 40 kg, scar diam. (mm)	0.6	0.6	0.3
Weld point (kg)	140	140	180
Cone penetration (mm/10 worked)	361	347	275

Figure 3. Palm-based printing ink.

all religions (*Figure 4*). This is in contrast to tallow or lard-based products, which are not acceptable by Hindus and Muslims, respectively.

Palm-based oleochemicals, for example, glycerine, fatty alcohol, fatty esters and fatty amine, are widely used in CPC formulations for various purposes, such as emulsifiers, humectants, emollients, lubricants and conditioners (Rubaah, 1999). To date, MPOB's Advanced Oleochemical Technology Division (AOTD) has produced several CPC products incorporating palm-based ingredients, mainly for small and medium industries. AOTD offers a complete package for R&D on performance trials of the palm oil-based and conventional petroleum-based inks have shown that the former to be better in tack and print stability (*Table 5*). Palm-based inks have since been put through several continuous commercial runs in a newspaper and the print quality found to be clearer and brighter. Therefore, the quality of palm-based printing inks is comparable, if not better, than that of petroleum-based inks.

TABLE 5. PERFORMANCE COMPARISON: PETROLEUM-BASED *vs.* PALM-BASED PRINTING INKS

Parameter	Petroleum-based	Palm oil-based
Tack	Standard	Standard
Viscosity	Standard	Standard
Shade	Standard	Standard
Gloss	Standard	Standard
Tack: stability	Standard	**Superior**
Rub resistance	Standard	Standard
Print stability	Standard	**Superior**
Storage stability	Standard	Standard
Litho resistance	Standard	Standard

Source: Ooi *et al.* (1992).

Natural-Based Surfactants in Personal Care Products

The use of natural oils as raw materials in cosmetics and personal care products is growing rapidly, driven by the increasing desire of consumers to use naturally-derived raw materials. Over the past few years, natural or naturally derived cosmetics and personal care products (CPC) have been swarming the market, replacing synthetic products. Besides being natural, vegetable oil-based CPC products are acceptable to

Figure 4. Cosmetics formulated from vegetable oils.

palm-based CPC products with letting of the R&D facilities and pilot plants for pre-marketing trial production, and even the efficacy laboratory for safety and efficacy claims substantiation. As a one-stop centre for CPC products, AOTD also provides technical support in commercialisation and halal certification.

CONCLUSION

The environmental benefits of using vegetable oils, especially palm-based products, are many. They are renewable resources with good environmental characteristics, biodegradable, low ecotoxicity and toxicity to humans, and emit no net CO_2 to the atmosphere. When supplies are low, more crops can be planted to make up the shortfall, which would be a boon to agricultural economies. Petroleum, on the other hand, is a finite and depleting resource.

Besides the environmental benefits, there will, in the future, also be other advantages from the wider use of vegetable oils. One of them is the social benefit from rejuvenating rural communities through the establishment of local industries and by providing farmers with additional income, thereby securing their livelihood.

Much interest has been generated in the industrial use of renewable resources, including palm oil. It is for this reason that renewable feedstocks can become one of the major players in the chemical industry in the near future. This might then result in a new economic order, placing agriculture in the economic forefront as one of the largest wealth-generating sectors.

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