OLEOCHEMICALS :

PROCESS ENGINEERING & INNOVATION –

PAST, PRESENT AND FUTURE

QUA KIAT SENG, ASEAN Oleochemical Manufacturers Group, Wisma FMM, No. 3, Persiaran Dagang, PJU 9, Bandar Sri Damansara, 52200 Kuala Lumpur

ABSTRACT

Malaysia leads a highly successful agricultural industry that has nutured equally successful downstream processing sectors. The first commercial planting of oil palm was in 1917 in Tennamaran Estate in Selangor. In the 1960s the pace of cultivation of oil palms was accelerated. The Malaysian government encouraged technological improvements to further add value to its exports and palm oil has remained a top tier export (4th in 2016).

The beginning of oleochemicals is said to be in 1825. ASEAN oleochemical manufacturing started in Malaysia in 1980 but the changes in the region in the last 37 years has been dramatic for the industry globally. The paper will review process engineering and innovation in this short time ranging from technology and capacity to raw materials, process safety and sustainability. Going forward it will look at bio-products and bio-processes, what the next generation oleochemical complex could look like and new technology that blurs the demarcation between oleochemicals and petrochemicals.

HISTORY OF OLEOCHEMICALS

Oleochemicals can be traced back more than 2000 years. The Phoenicians made crude soap by heating goat fat with cooking fire ashes. In 1779 the Swedish chemist Carl Wilhelm Scheele discovered glycerol. In 1813 the French chemist Michel Eugene Chevreul described fatty acids and in 1825 together with Joseph Louis Gay-Lussac received a French patent for the separation of fatty acids and their use in candle fabrication. Gay-Lussac also obtained a patent covering the distillation of fatty acids. 1825 is considered to be the beginning of oleochemicals.

In Malaysia the first milestone for oleochemical processing began in 1979 when the government put science and technology behind the palm oil industry by setting up PORIM (Palm Oil Research Institute of Malaysia) which in 2000 became MPOB (Malaysian Palm Oil Board) which was a merger of PORIM and PORLA (Palm Oil Registration and Licensing Authority).

The Malaysian government offered tax holidays such as pioneer status. Oleochemical manufacturers were, due to low margins, soon driving technology providers for larger and more efficient plants. The demand for new plants enabled the technology suppliers to invest in R&D to this end.

From 2011 till 2020 the national driver is the 10th and 11th Malaysia Plan known as the National Transformation Programme. Under the programme Palm Oil & Rubber are identified as an NKEA (National Key Economic Area) and for Palm Oil there are 8 EPP (Entry Point Projects). For oleochemicals the most relevant is EPP 6 : Developing High-Value Oleo Derivatives and Bio-Based Oleochemicals. This EPP will steer manufacturing from basic oleo-chemicals to higher-value oleo derivatives and to take advantage of the global shift to environmental friendly green oleo-chemicals. The Champions for EPP 6 is the private sector players.

The first significant oleochemical plant in ASEAN was Acidchem in Penang in Malaysia followed quickly in by European, US and Japanese producers. The Malaysian Oleochemical Manufacturers Group was set up in 1984. In 1986 the Philippines Oleochemical Manufacturers Association was set up in 1986 which made it possible for the ASEAN Oleochemical Manufacturers Group to be formed that comprised MOMG, POMA members and one player from Thailand. Indonesia was a late entrant and Asosiasi Produsen Oleochemical Indonesia was set up in 1996 adding one more country to AOMG. From the late 1990s prominent western producers of sold or limited their oleochemicals activities to focus on more profitable consumer goods business. Henkel, Unilever, Petrofina and Akzo sold whilst Procter & Gamble closed or sold their fatty acid plants. After the mad cow disease or BSE (bovine spongiform encephalopathy) 2000 many uses of tallow were replaced by vegetable oils including palm oil.

PROCESS ENGINEERING & INNOVATION

There are a number of oleochemical routes possible and some routes to the end consumer are shorter eg soap and MES (methyl ester sulphonates).

1.Capacity/Technology

Oleochemical plants that started in Malaysia in the 1980s were around 30,000 t/a, smaller than plants in Europe or USA. Later due to low margins and the drive for larger volumes, producers pressed engineering companies towards larger and modern plants with increasingly superior technology. Due to increase competition amongst suppliers of plants particulary in the area of methyl ester, glycerine and fatty alcohols investment costs were falling. Today large plants are in the region of 150,000 to 250,000 t/a.

Today a single splitter can do 600t/d (150)* operating at 260 degrees Celcius (250) and high pressure of 63 bar (52) achieving splitting degrees about 99%. Less high pressure steam is consumed with lower exit temperatures of split fatty acid and sweetwater. The new internals foul less quickly.

In distillation and fractionation purities of cuts above 99% is now achievable and able to handle different feedstocks. Reboilers now use falling film to minimize thermal cracking whilst top product condensers generate steam and reduce cooling water requirement. High performance structured packing now result in smaller columns.

*old conditions in brackets

2. Fatty Alcohols

Technology available today is superior to the technology practiced by the traditional industry leaders. In the past there was generally only one supplier of technology for a specific process but not today. An example is in the development of fatty alcohol technology as seen in Table 1.

Period	Raw Material	Catalyst	Conditions	Company
1960s	Fatty acids	Slurry	300 bar, liquid	Lurgi
1980s	Methyl ester	Fixed	300 bar, trickle	Lurgi
2000s	Fatty acids	Fixed	300 bar, trickle	Lurgi
	Wax ester	Fixed	70 bar, trickle	Lurgi
	Methyl ester	Fixed	40 bar, vapour	Davy

Table 1. Development of fatty alcohol technology

The Davy process is very much favoured today. There still remains the technology of Henkel, P&G and Kao. We should remind ourselves of the synthetic fatty alcohols technology viz Ziegler and Hydroformylation.

After the Oil Embargo in 1973 by OPEC on USA, natural fatty alcohols started to gain market share. In 2003 producers in Europe, USA and Japan started to close inefficient units. Today the low oil prices are seeing synthetic plants being debottlenecked as well as new ones installed. The natural excess capacity will now be further aggravated by the new capacities coming on stream. At the moment synthetics supply about a third of the market requirements.

3. Soap Noodles

One of the first applications of distilled fatty acids from the first oleochemical plants in Malaysia was for soap making outside the country. Fatty acids do not travel well and the resultant soap was of rather low quality. At that time even soap made from freshly distilled fatty acids resulted in beige soap with an odour. In 1982 Unichema successfully made soap noodles from DFA which was white with no odour and its soap noodles were the feedstock for Lux soap bars produced by Unilever in Malaysia. This opened the door for a new approach to the industry where the soap maker focuses only on his market and uses soap noodles of his specifications with which he makes into soap bars with his own additives and style. The messy part of soap making is no longer his responsibility.

This development is little talked about but it will be an evergreen market as the move to liquid soaps take place only when the annual usage of bars exceed a kilogramme per person per year.

4. Biodiesel

Malaysia started early in biodiesel with MPOB commencing the R&D project in 1982. Successful field trials were conducted over a long period from 1866 to 1994 before the commercial pilot plant was run from 2000 to 2006. In 2008 the Biofuel Industry Act 2007 was passed with B5 enacted in 2011, B7 in 2014 and B10 in 2016. Indonesia and Thailand have made much more rapid progress.

Many companies are able to offer efficient transesterification technologies with the technology continuously improving to meet standards that are getting stringent. With pressure on costs there is now a move towards cheaper raw materials such as PFAD and UCO (used cooking oil).

5. Raw Materials

Before 1980 tallow and coconut oil were the main raw materials for the oleochemical industry. After 1980 palm oil and palm kernel oil started to replace tallow and coconut oil. There were applications users claimed could not replace tallow but after the BSE event in 2000 more users switch to vegetable oils including palm oil.

Tallow type oleic acid is in demand. Distillative fractionation of palm oil fatty acids resulted in carry over of stearic acid which increased the cloud point and the linoleic acid content was too high. Still it had applications. Crystallisation fractionation of palm kernel bottoms from distillative fractionation yields oleic acid of 78%, a product that matches closely tallow type oleic acid.

6. Process Safety

In the 1990s the oleochemical industry in Malaysia had a number of process safety incidents. See Table 2.

Stearic acid warehouse fire	**1992 Bellows rupture in Johor**

1993 Selangor 1994 Penang	**1997 Explosion H2 generation plant in Selangor**

Table 2. Oleochemical incidents in Malaysia

The industry reputation was at a low and was not insurable or at a high premium. The situation improved after 1998. Many manufacturers outsourced their hydrogen gas supply to Linde or Air Products.

Dame Judith Hackitt, the chair of UK HSE (2013) said, "...there are no new accidents. Rather there are new accidents repeated by new people .."

The industry took a number of steps to address the issue. The MOMG Technical Committee started in 1992 to have a forum to share and discuss technical issues as well as share process safety best practices. In 2007 this was elevated to the ASEAN level with the AOMG Technical Committee formed. The AOMG Technical Committee has organised annual process safety workshops since 2011 with the latest the 7th AOMG Process Safety Workshop 27-28th July 2017 in Yogyakarta, Indonesia. Many members have implement Process Safety Management (PSM).

7. Sustainability

AOMG members had no role to play in RSPO as the GreenPalm certificates was a virtual system. AOMG pushed hard for physical transition for oleochemicals and helped to draft the rules which were approved in July 2013. AOMG members are RSPO Supply Chain Certificate holders for MB (Mass Balance) and/or SG (Segregated).

MOMG members have an ongoing LCA exercise with MPOB.

GOING FORWARD

1.Bioproducts

There is growth in end-use industries for bioproducts eg. personal care, surfactants, lubricants and polyols which drives the demand for bio-based oleochemicals. It is useful to define what a biorefinery is. It is facility that integrates biomass conversion processes and equipment to produce fuels, power, heat and value-added chemicals from biomass. It is analogous to a petroleum refinery which produces multiple fuels and products from petroleum.

An example is biolubricants which has advantages of energy saving, high viscosity index, biodegradability and is non-toxic in nature. It is usually esters with high oleic acid content and in industrial segments has replaced more than half of petroleum based lubricants. Examples of this is in drilling, metal working fluids and process oils.

2.Bio-processes

Bioprocess engineering focuses on the role of living organisms in the manufacturing process. An example is the enzymatic process in biodiesel production. As mentioned earlier there is a move to using cheaper feedstocks with a range of free fatty acids eg UCO and PFAD. For oils the transesterification catalyst is alkali eg sodium methoxide and for fatty acids esterification catalyst is acid eg PTSA. As both cannot work together fatty acids are usually esterified first before undergoing transesterification. Enzymes eg Novozymes Eversa Transform 2.0 can do both and there are already several plants in operation using enzymes to produce palm biodiesel.

Another example is yeast fermentation to produce diacids eg adipic acid. This was previously based on petroleum but now it uses lauric acid. Verdezyne claims lower cost and less pollutants. This is a key component of nylon 6,6.

EPP 7 is Bio oil from biomass-to-liquid technology. Biochemical conversion is where the fermentation is with unique or genetically modified bacteria. Such plants producing biogas are being offered and/or operating in Malaysia and Indonesia. The gas to liquid by the Fisher-Tropsch process requires high energy investment.

3. Metathesis

Elevance's core technology is based on Nobel Prize-winning innovations in metathesis catalysis by Dr. Robert H. Grubbs, Dr. Yves Chauvin, and Dr. Richard Schrock. It was awarded in 2005. Metathesis means to change places.

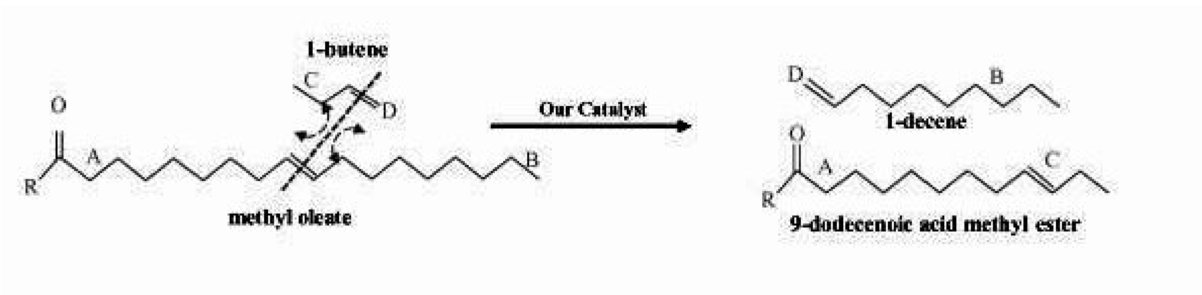

Figure 1 Elevance Metathesis Technology

Metathesis can break carbon-carbon double bonds. A petrochemical is combined with an oleochemical. The molecules recombine into new di-functional molecules. There are three product streams viz

1. Olefins – 1-decene for co-polymers such as ABS (acrylonitrile butadiene styrene).
2. Speciality chemicals with di-functional products from oleochemicals and petrochemicals in a single molecule eg 9DDDA (9-dodecenoic acid) is a key product for nylon 6,12

3. Oleochemicals – C16 and C18 methyl esters for MES (methyl ester sulphonates)

The Elevance Wilmar JV Biorefinery in Indonesia has been in operation since 2013 whilst the Genting Integrated Biorefinery Sdn Bhd in Malaysia is being commissioned in stages.

The Elevance Natchez biorefinery in Mississippi has been sold to World Energy in 2016 for its bio-diesel capability. Plummeting petroleum prices made their products more expensive than the petroleum products they aimed to replace.

The push for bio-products was spurred at the end of 2011 when palm oil and palm kernel prices stopped tracking Brent crude oil prices (see Figure 2). Whilst Brent crude prices stayed stayed high at the $100/barrel level till the end of 2014, palm oil and palm kernel prices came down making oleochemical equivalents of petrochemicals attractive, bringing to the fore, new technologies to replace petrochemicals. Unfortunately from 2015 the plunge of Brent crude oil to the level of $50/barrel and the rise of palm oil and palm kernel prices make these new technologies less attractive for the time being.

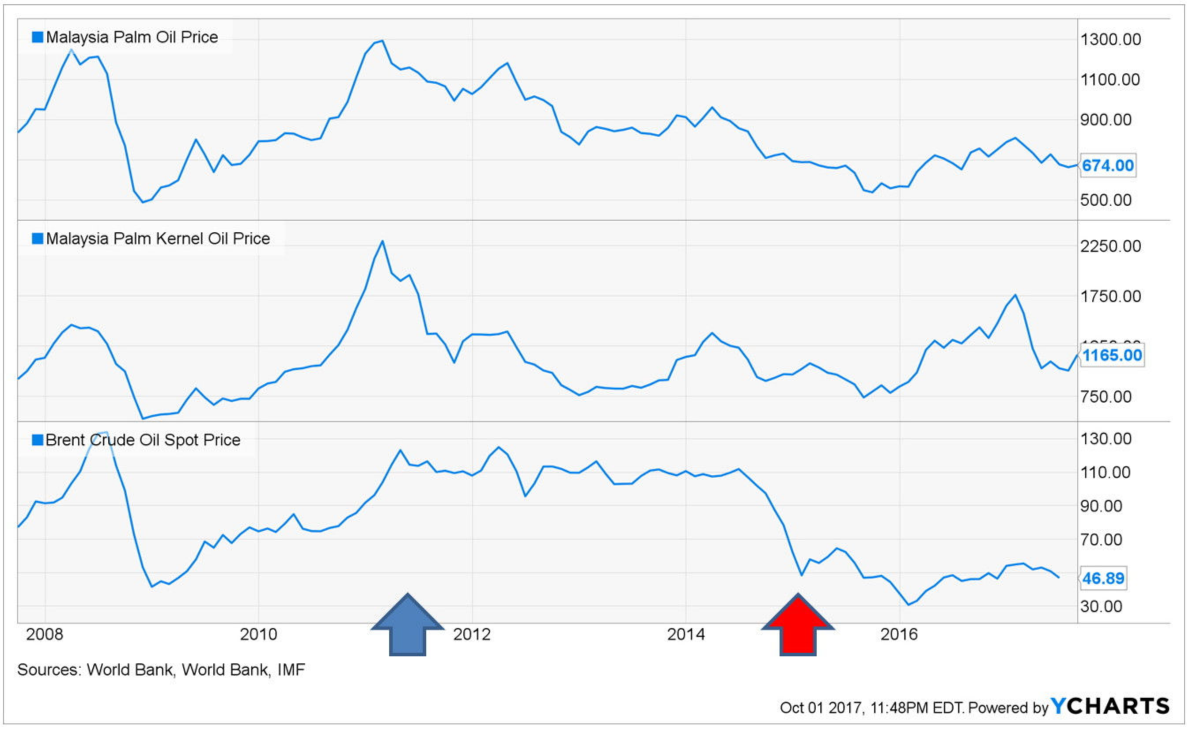

Figure 2 10 Year Historical Prices in US$ for palm oil, palm kernel oil and Brent crude oil

4. 2nd Generation Oleochemical Complex

When the first plants were set up in ASEAN they were for a specific purpose eg DFA for soap making, fractionation for fatty acid cuts and then adding trans-esterification leading to fatty alcohols and surfactants (see Figure 3).

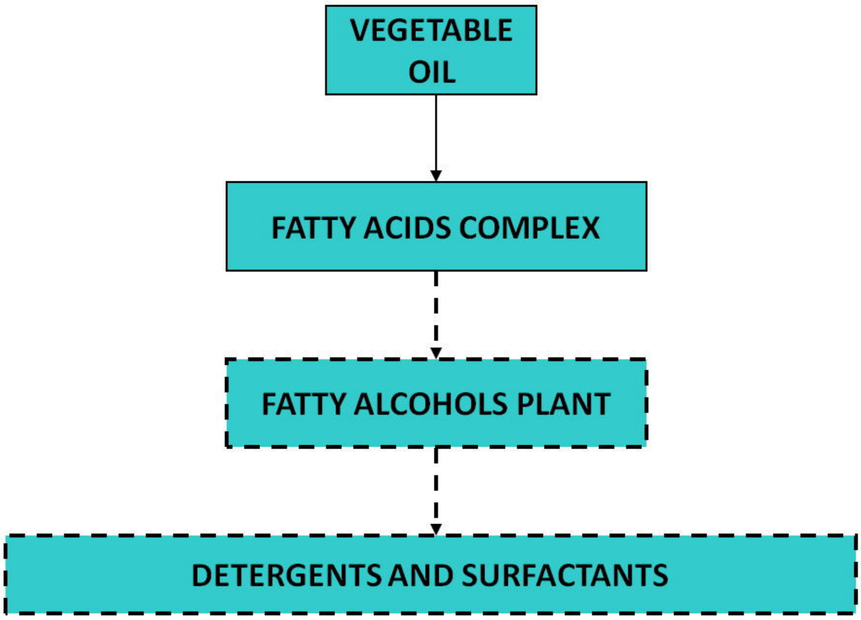

Figure 3 Classic 1st Generation oleochemical plant

Going forward and taking into account the demands of the market which is also influenced by mandates and crude oil prices, a flexible 2nd generation multi-purpose complex may be the answer (see Figure 4). It could also include an edible oil refinery to supply some of the feed.

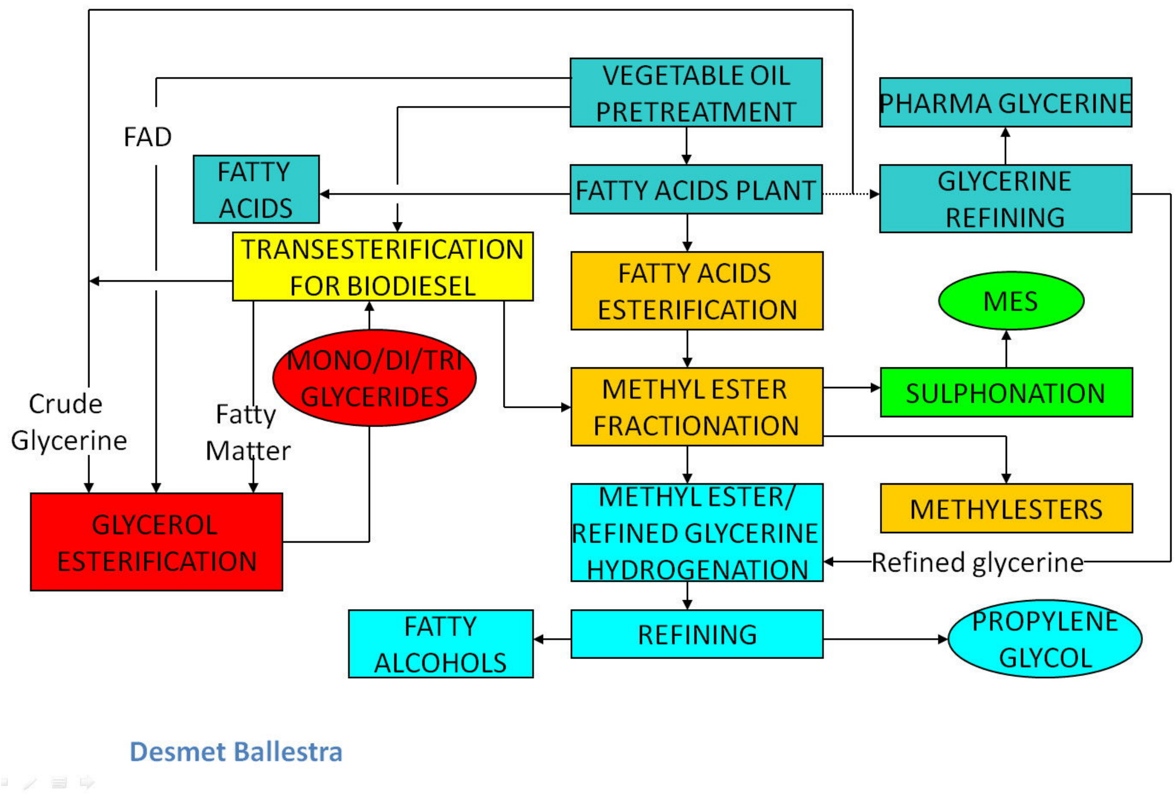

Figure 4 Multi-purpose 2nd Generation oleochemical complex

5. Further downstream

As you get further downstream into high value speciality oleochemicals there are a number of challenges. The tonnages are lower and the production carried out in batch reactors. The know-how does not lie with plant suppliers and often production intervention is needed by experienced staff. Specifications alone is not enough to define the product and there needs to be specialized applications research and marketing.

Speciality esters could include product categories such as sorbitan esters, glycol esters, lactate esters, TMP esters, etc. Owing to its feasible chemical characteristics, glycol esters have witnessed increased demand as emulsifier in soap, shampoos, and other personal care consumables.

6.Position of oleochemicals processing

At a seminar organised by the Institution of Chemicals Engineers on 8th August 2017 in Kuala Lumpur, a distinguished panel of influential personalities in the palm oil industry were asked the question “Can Malaysia continue to the global technology leader in processing its Golden Crop?” They answered yes and observed that the refining and oleochemical sector were the most advanced in palm oil processing.

Industry 4.0 is a buzz word these days as the only way for industries to compete in the future is through embracing the technologies that are emerging. The central feature of industry 4.0 is effective communication not only between humans but also between machines as well as the human and machine interface. Given the demands in the oleochemical industry I believe that the oleochemical is poised with the palm oil industry to be there first.

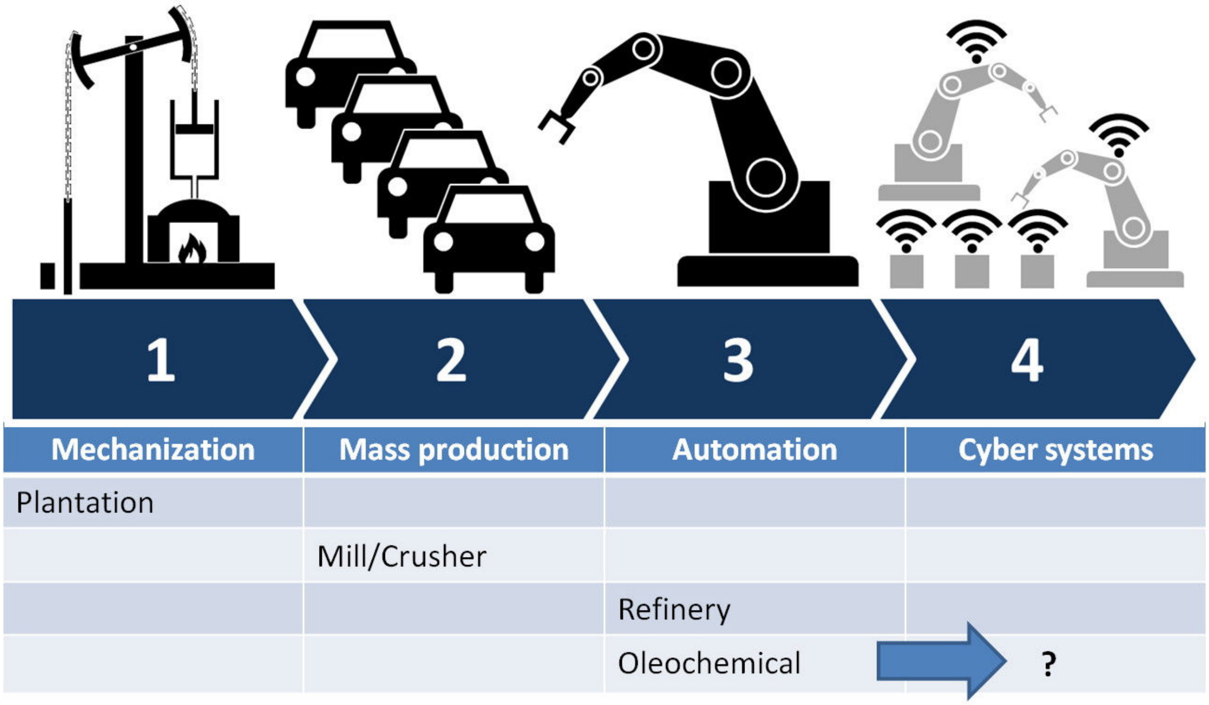

Figure 4 The future of the oleochemical industry

CONCLUSION

It has been 192 years since the beginning of oleochemical but only 37 years in ASEAN during which time we have seen unprecented progress. Nevertheless many challenges remain in the industry such as overcapacity and low crude oil prices. The industry has shown resilience and process engineering and innovations will continue to overcome some of the issues.

Palm oil and palm kernel remain the raw material of choice in most instances helped by innovation. The industry today is safer and reliable and supports sustainability tangibly. The future is in multi-purpose plants and bio-processes with the differentiation between oleochemicals and petrochemicals blurring. Current low petroleum prices favour petrochemicals.