Technological Developments for the Production of High Oleic Palm Oil

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INTRODUCTION

Oleic acid is the most common monounsaturated fatty acid in the plant kingdom. When compared with polyunsaturated fatty acids, it is considered neutral with respect to coronary heart disease. In addition, it is more stable than polyunsaturated fatty acids. Palm oil and palm olein can be considered to have high oleic acid content, with levels of 39% and 45%, respectively. However, when compared with olive oil which has 80% oleic acid and with other high oleic (HO) oils produced through genetic modification and plant breeding, they fall into the low range category. For vegetable oils with a high degree of polyunsaturation, the target is to produce lower polyunsaturation and higher monounsaturation, while maintaining a low saturation content. The 'Mediterranean diet' comprises a combination of olive oil, fruits, vegetables, cereals and pasta. As the life expectancy of people living in the Mediterranean regions is among the highest in the world, with the populace having low rates of chronic diseases, the connection with consumption of olive oil is to be expected.

Some studies have shown the beneficial effects of diets high in monounsaturation. In a long-term study conducted at the Universidad Autonoma of Madrid, 46 men and 32 women (with a mean age of 42 years) recruited from closed religious communities were placed on a diet rich in polyunsaturated fat (from sunflower oil) for 12 weeks, and then switched to an alternative monounsaturated diet (based on olive oil) for 16 weeks (men) or 28 weeks (women). The total fat content of the alternative diet was 37% for the men and 36% for the women.

Compared with the polyunsaturated diet, the monounsaturated diet produced no change in total cholesterol in the men while resulting in a 9% decrease in the women. High-density lipoprotein (HDL) cholesterol increased by 17% in the men and 30% in the women. Total/HDL cholesterol ratio decreased significantly in both the sexes. Low-density lipoprotein (LDL) and triglyceride levels did not change significantly in either sex.

The authors concluded that monounsaturates, when compared with polyunsaturates, improved the atherogenic risk profile in both sexes (Mata *et al*., 1992). The findings confirm those of previous, shorter-term studies on olive oil. Many other investigators have shown that when substituted for dietary saturated fatty acids, monounsaturated fatty acids have a hypocholesterolemic effect (Mensink and Katan, 1992; Valsta *et al*., 1992).

High oleic oils are therefore in demand, while high saturation is considered a 'no-no' for healthy diets. In addition, the high oleic oils are suitable for replacing high *trans* fatty acid oils and are also stable for frying purposes. Comparative studies have shown that high oleic oils are comparable to palm olein in frying operations. However, there is limited availability of such oils, while production costs are generally high.

For palm oil, the target is to reduce saturation and increase monounsaturation and polyunsaturation to cater to certain consumers' requirements. Programmes to change the fatty acid profiles of most of the annual oil crops have been on-going for many years, and the results have been successful to different degrees. However, due to difficulties in achieving good agricultural properties and economic yields, only very few varieties of crops yielding high oleic oils are commercially available. Palm oil is

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thus a natural oil in which high oleic content can be found. By physical modification and other means of processing, it can be economically viable to produce high oleic oils for trade. This article examines the high oleic palm oils that can be found in nature, and also new innovative ways for producing oils which have lower saturation as required by consumers, but without compromising on oil stability. Properties and characteristics of such oils are given as they show exciting possibilities for new uses.

TABLE 1. OLEIC CONTENT (%) OF VEGETABLE OILS

	Monounsaturates (oleic content)	Total saturates	Total polyunsaturates
Palm oil (IV 52)	36-41	45.8-54.5	9.2-12.2
Palm olein (IV 56-58)	40-45	42-50	11-14
Palm olein (IV 60-65)	43-49	34-43	11-16
Super olein (IV 68)	49-51	35-36	14-15
Top olein (IV 73)	51-52	32	16
Olive oil	55-83	8-27.6	3.5-21
Canola oil	62	6	31
High oleic sunflower oil	80-90	9-10	5-10
Mid oleic sunflower oil	55-75	<10	15-35
High oleic soyabean oil	75-85	9-15	4-10
High oleic safflower oil	75-80	6	14-16

COMPOSITION OF PALM OIL AND PALM OLEIN

Palm oil has the well-quoted 'balanced' fatty acid composition, *i.e.* having equal amounts of saturation and unsaturation, of which oleic acid forms about 39%-40%. By the simple fractionation process of winterisation and filtration, the unsaturated triacylglycerols are partitioned into the liquid olein phase, giving rise to palm olein of iodine value (IV) 56-58 and with 42%-45% oleic acid. With further fractionation of such oleins or by optimised single fractionation techniques, it is possible to obtain an oil with a higher IV of above 60, with an oleic content in the range of 44%-49% (Siew, 1998). Compared with other oils in the high oleic category (*Table 1*), palm oil and olein have the lowest oleic content.

What is the potential for palm oil products to achieve the high oleic contents presented in *Table 1*? We need about 3% more oleic content to reach the minimum observed in olive oil, and as much as 31% more to reach the highest level in olive oil. Can this be achieved by processing, or by breeding and genetic modification? MPOB's approach in producing high oleic oil is through multi-pronged strategies, *vis-à-vis* chemical and enzymatic as mentioned above, by breeding (Kushairi *et al.*, 2000; Rajanaidu *et al.*, 2000) and genetic engineering (Parveez *et al.*, 2015).

HIGH OLEIC PALM OILS VIA PLANT MODIFICATION

MPOB's Nigerian germplasm of about 3000 palm accessions have been screened for high IV. The mean and range of the data along with their fatty acid composition are given in *Table 2* (Rajanaidu *et al.*, 2000). The wide variation in oleic content (ranging from 27.7%-55.9%) shows that it is possible to select palms for high oleic content. Palms with high IV have been selected, selfed, crossed and then evaluated. Selected second generation *dura* palms crossed with *pisifera* were developed as high IV palms identified as PS2. While their IV are high, varying from 60-75, the oleic contents are not much higher than that of normal palm olein, being in the range of 30%-49%. The negative correlation of oleic content with linoleic content observed in oil palm is due to the more active palmitoyl-ACP elongase and stearoyl-ACP desaturase. IV and oleic contents of *E. oleifera* are about 80% and 56%, respectively. Interspecific hybrids between *E. guineensis* and *E. oleifera* have oleic contents of 51.8% (*Table 3*), while the range may vary from 23.7% to 60.9% (Rajanaidu *et al.*, 1994). One of the highest oleic content is found in an *E. oleifera* accession from Suriname, with 25% palmitic, 70.5% oleic and 3.6% linoleic acids. However, oil yields of the hybrids and the *E. oleifera* accession are too low for commercial exploitation (Rajanaidu *et al.*, 2000).

MPOB has offered for technology transfer 15 palms with oleic contents of above 48% as the PS12 breeding population (Isa *et al.*, 2006). Their average IV is 60.7, with oleic content ranging from 48.0%

TABLE 2. FATTY ACID COMPOSITION OF NIGERIAN GERMPLASM

Fatty acid and IV	Nigerian population		Current DxP	
	Mean	Range	Mean	Range
C16:0	38.6	27.4-54.8	44.0	41.8-46.8
C18:0	6.2	7.4-12.6	4.5	4.2-5.1
C18:1	41.8	27.7-55.9	39.2	37.3-40.8
C18:2	10.8	6.5-17.6	10.1	9.1-11.0
Iodine value	54.7	43.8-69.8	53.3	51.0-55.3

TABLE 3. FATTY ACID COMPOSITION OF OILS FROM *E. guineensis, E. oleifera* AND THEIR HYBRIDS

Fatty acid and IV	*E. guineensis* (*Eg*)	*E. oleifera* (*Eo*)	*Eo x Eg* hybrid
C16:0	44.3	18.7	32.2
C18:0	4.3	0.9	3.2
C18:1	39.3	56.1	51.8
C18:2	10.0	21.1	10.8
Iodine value	55.0	85.0	67.5

to 52.5% (a mean of 49.4%).

Parveez (2006) presented a report which provides evidence for antisense expression of palmitoyl ACP thioesterase in reducing levels of palmitic acid in palm oil. Biochemical studies show that the limiting factor for obtaining higher oleic is the β-ketoacyl ACP synthase II (KAS II) activity in the oil palm, which results in a 'bottleneck' of palmitic acid, and that the thioesterase activity towards palmitic acid is very high, resulting in high palmitic acid content. In order to achieve higher oleic content, the strategy is to lower the activity of the palmitoyl ACP thioesterase, and to increase the activity of KAS II. Endogenous gene expression can be silenced by transforming with antisense gene constructs. Experiments carried out in MPOB have introduced the gene, resulting in a change in fatty acid composition. So far, some samples have shown a reduction in palmitic acid and an increment in oleic acid in the transgenic oil palm embryoids. Results will be confirmed when the palms are mature and bearing fruit. Oil yield of palms from such modification is a critical factor to consider for commercial planting.

FRACTIONATION OF HIGH OLEIC PALM OIL

Samples of crude palm oil extracted from specially selected palms (of the PS12 population) were fractionated in the laboratory, then cooled down from melt to temperatures of 15°C and 20°C. IV of olein obtained varied from 57 to 65, with single fractionation. The higher IV are of particular interest as they are easily achievable even at temperatures of 20°C. Thus, with further optimisation of the fractionation process and with multiple fractionations, it should be possible to obtain oleins with IV of about 75. Upon evaluation of the triacylglycerol (TAG) compositions, triolein (OOO) varies from 7% to 12%, as compared with commercial palm oleins which have a maximum of about 6%.

MODIFICATION BY PROCESSING

Processing can use either a physical or chemical method. Physical separation of the saturated fatty acids involves winterisation at suitable temperatures, followed by filtration. Ramli (2016) reported on super olein production in which by a multiple fractionation process, it was possible to obtain a top olein of IV 72.7, with oleic content of 51.5%. This olein satisfied the cold stability test. However, the yield of such olein is poor. By chemical interesterification followed by fractionation, oleins with 51%-53% oleic contents can be obtained (Siew, 2006); however, their physical properties are not as promising, especially in terms of clarity. As shown in *Table 4*, improvements in oleic content can be achieved by lower temperature fractionation, but at the expense of yield. In the process, no additional raw material is added. The chemical interesterification randomises TAG, resulting in more PPP being formed which is then removed via fractionation.

CHEMICAL INTERESTERIFICATION WITH OLEIC ESTER

Oleic enhancement up to 60% can also be achieved by chemical interesterification of palm oil or olein with an oleic ester, with an absolute increment of 11% oleic over the original oleic content of palm olein (Ramli, 2007). The chemical interesterification process was performed in a 200-kg pilot plant using palm olein as raw material. The high oleic stearin is soft and applicable as shortening or margarine. Properties of the high oleic stearin are shown in *Table 5*.

OLEIC ENHANCEMENT BY ENZYMATIC ACIDOLYSIS

Acidolysis to incorporate oleic acid into palm olein using various lipases (enzymes) as catalysts to increase the oleic content of the oil was also investigated. Immobilised lipases (lipase PLG, Lipozyme TLIM, Lipozyme RMIM and Novozym 435) and non-immobilised lipase (lipase PL) were used to compare the effectiveness of the selected lipases in catalysing the reaction to produce a high oleic oil. The results show that the oleic-linoleic-oleic (OLO) content was increased at least 4-fold and that the triolein (OOO) content was increased at least 3-fold when a 5% enzyme load was used. Lipase PL produced the greatest increase in triunsaturated TAGs content (*Figure 1*). A pilot scale experiment conducted using TLIM enzyme, followed by recovery of the oil and fractionation allows for the production of oils with varying oleic contents. A high oleic content of 56% was achievable, as shown in *Table 6*.

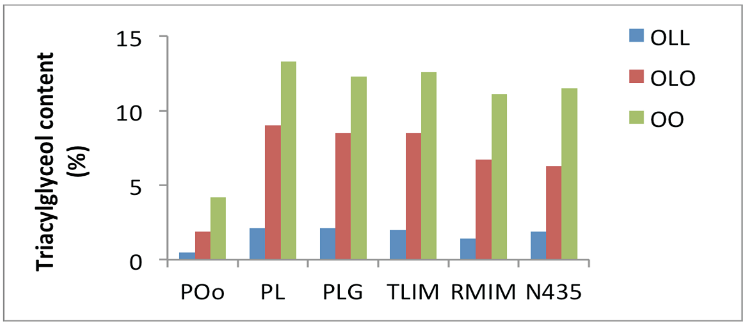

Figure 1. Distribution of triunsaturated TAGs in oleins treated with different enzymes.

TABLE 6. ENHANCEMENT OF OLEIC ACID CONTENT BY ACIDOLYSIS AND FRACTIONATION

Item	C12:0	C14:0	C16:0	C18:0	C18:1	C18:2	C18:3
Palm olein	0.2	1.1	40.7	4.0	41.9	11.2	0.3
Modified olein	0.6	0.9	31.6	3.5	50.0	12.8	0.2
Olein 8°C	0.6	0.8	25.1	2.7	55.8	14.5	0.2
Olein 10°C	0.6	0.8	25.7	2.7	55.3	14.3	0.2
Olein 15°C	0.6	0.8	26.2	2.8	54.9	14.0	0.2

TABLE 4. COMPOSITION OF INTERESTERIFIED OLEINS FROM FRACTIONATION AT DIFFERENT TEMPERATURES

Item	C12:0	C14:0	C16:0	C18:0	C18:1	C18:2	C18:3
Olein 10°C	0.3	0.9	27.4	3.0	52.6	14.9	0.2
Olein 15°C	0.3	0.9	28.6	3.1	51.1	14.6	0.2
Olein 18°C	0.3	1.0	29.0	3.2	51.2	14.4	0.2
Olein 20°C	0.3	1.0	29.2	3.2	50.9	14.4	0.3
Olein 22°C	0.3	1.0	29.2	3.2	51.0	14.4	0.2

TABLE 5. HIGH OLEIC PALM OILS PRODUCED VIA CHEMICAL PROCESS

Item	C12:0	C14:0	C16:0	C18:0	C18:1	C18:2	C18:3
Palm olein	0.2	1.1	35.7	3.5	45.7	12.9	0.3
HO palm oil	0.2	0.5	16.7	7.0	59.4	15.3	0.3
HO palm olein	0.2	0.5	15.5	5.4	61.5	15.9	0.3
Olive oil	0.0	0.0	13.7	2.5	71.1	10.0	0.6
HO safflower oil	0.0	0.1	5.5	2.2	79.7	12.0	0.2
HO palm stearin	0.2	0.7	27.6	11.5	47.2	11.6	0.2

CONCLUSION

While genetic modification studies are progressing rapidly, nevertheless many years are still required before the fruits of this research can be available commercially. In the meantime, further work on processing technology appears to be the fastest and cheapest route towards producing high oleic oils from palm.

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