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INDUSTRIAL FRYING OIL

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INDUSTRIAL FRYING OIL – BASIC ASPECTS

by
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The frying of certain foods in oil on an industrial scale is common practice and an established food process. Different foods such as fish, chicken and snacks will require different processing machinery but the purpose of frying is the same for all foods:

- to remove excess water
- to cook the food (gelatinize starch in the case of starchy products)
- to create a characteristic taste and texture

During the frying process, oil is used to transfer heat to the product. Oil is a good conductor of heat and the temperature is above the boiling point of water. As water moves out of the product it prevents burning of the food outer surface. Steam is generated and it moves through the hot oil to escape at the top of the fryer. There is conduction and convection transfer of energy. Starch is cooked by the water in the starch gel and the transfer of heat must be well regulated to achieve optimal cooking. Water vapour bubbles escape vigorously from the oil causing movement of the oil. Four stages have been defined by BE Farkas which indicate the start and end of the frying cycle.

Stage 1: The initial heating stage where the surface of the food is submerged in hot oil. It lasts a few seconds and no water vapourization takes place.

Stage 2: Surface boiling takes place, turbulence in the oil surrounding the food changes the heat transfer process and the foodstuff starts to form a crust on its surface.

Stage 3: During the falling rate more internal moisture leaves the food and the internal temperature (core) rises to boiling point. Gelatinization and cooking takes place in the internal part. After some time the vapour transfer at the surface decreases.

Stage 4: The bubble end point is reached after extended frying and no more bubbles are seen to escape from the foodstuff surface.

Different vegetable or plant oils differ in their suitability for deep frying and the suitability will also depend on the type of food to be fried. Of particular concern to savoury snack manufacturers is blandness in taste, acceptable colour and shelf stability. Snacks are normally exposed to a long distribution chain where extreme temperatures can be experienced. When the consumer eats his/her snack the perception of "freshness" should still be there, *i.e.* there should be absolutely no trace of rancidity. Rancidity must, however, be differentiated from "staleness" which is invariably associated with moisture. Even a small uptake of moisture during storage of snacks will result in staleness, especially potato chips and extruded products. For this reason many manufacturers are using foil laminated bags to pack their snack products.

The South African savoury snack industry, which uses about 10 000 tonnes of frying oil per annum, introduced palm olein in 1985 mainly due to its stability and competitive price. Up to that stage groundnut oil was the primary frying oil but the price became exorbitant. Hydrogenation of local oils (primarily sunflower) was not considered at that time because of the controversy on *trans* fatty acids and also due to price considerations. A lot of research was done and many countries where palm olein was already used were consulted before it was introduced in South Africa. Local snack manufacturers had to modify their installations to accommodate palm olein, especially in respect of lagging of piping and heating of storage tanks. Good cooperation between suppliers and snack manufacturers was also necessary, in order to make the transition as smooth as possible.

Although 100% palm olein is an excellent medium for deep frying, it was found that a blend of 70% palm olein (minimum) and 30% local vegetable oil (maximum) gave satisfactory results, especially in terms of stability requirements. In this case a palm olein and sunflower oil blend has proved to be very successful and the tocopherols in sunflower oil seems to have a synergistic effect on stability. The component of sunflower oil makes better handling during the colder winter months.

The requirement for oil stability was mentioned before. In South Africa a snack shelf-life of at least 12 weeks has to be achieved. Snacks are normally delivered in trucks and where outlying areas are to be serviced, product can remain in these vehicles for up to a week. It has been found that the interior of these trucks could reach temperatures of up to 50°C. The temperature inside warehouses where snacks are stored also reach abnormally high levels during hot summer months.

The Market for Savoury Snacks

It is estimated that the world production of savoury snacks is about 4.2 billion tonnes with a value

Paper presented at the Seminar on Palm Based Frying Mediums for the Snack Food Industry of GCC in Jeddah, Damman and Dubai on November 24-28, 1996 organized by the Technical Advisory Services Unit, PORIM.

of over US$ 25 billion. The salty snack market in South Africa is worth US$ 290 million (51 million kg). Frying oil constitutes a large share of the tonnage referred to above - about 35% in the case of potato chips. Great care and attention to the management of frying oil is, therefore, of utmost importance. The emergence of low-fat snack categories could, of course, have a dramatic effect on oil usage for snack frying.

Palm Olein

Characteristics of palm oil and comparative frying studies on palm products vis-a vis other vegetable oils are the subjects of other presentations. This presentation deals with the product of palm oil fractionation, *e.g.* palm olein. Palm olein's fatty acid composition is unique in respect of vegetable oils - high oleic (C18:1 ~ 45%) and low linolenic (C18:3 ~ 0.3%). This gives palm olein excellent stability without the need for hydrogenation. Furthermore the oil has a bland taste and well refined oil has an acceptable colour. Although a high percentage of vitamin E is lost during oil refining, significant amounts are still present to enhance the stability of palm olein. There are very few substitutes, if any, to match palm olein in deep frying. Palm olein also improves the oxidative stability of other vegetable oils.

Perhaps the best criterion to compare two oils in respect of frying ability is to do a comparative study. For example, before switching from groundnut to palm olein in South Africa a comparative study between groundnut and cottonseed oil was done by making use of frying on industrial scale (Du Plesis *et al.*, 1981). The results confirmed that groundnut oil can be replaced by cottonseed oil and aspects such as tocopherol and TBHQ retention, product storage behaviour and organoleptic differences could be accounted for.

Nutritional Aspects

Nutritionists generally are in agreement that snacking in moderation serves a good nutritional purpose, but balanced and sensible consumer education must be practised in order that there are no misconceptions about snacks, *per se*.

When discussing nutritional aspects of palm olein, one has to be clear on the difference between palm kernel oil on one hand and palm oil and olein on the other hand. Palm oil and olein is physically and chemically different from palm kernel oil which is highly saturated. These differences must be made clear in order that the negative connotations attached to "palm" are not ascribed to palm olein.

A lot of research has been done on the nutritional benefits of palm olein and there can be no doubt that it is a safe oil to use. The International Nutrition Advisory Council and the Nutrition Advisory Committee of the USA/Canada confirmed this in a compilation of the nutritional effects of palm and palm olein.

One advantage of palm olein is that it can be used without hydrogenation thereby excluding the possible dietary effects of *trans* fatty acids. Palm olein contains 40% mono-unsaturated and 10% polyunsaturated oils and of course contains no cholesterol. Palm olein also contains significant amounts of tocopherol which gives it a further nutritional advantage.

The American Heart Association recommends a ratio of 1:1:1 for saturated: mono-unsaturated:poly-unsaturated in oil composition. It was mentioned earlier that a mixture of 70:30 palm olein: sunflower oil gave satisfactory results in deep-frying. It is interesting to note that this mixture approaches this ratio.

Measurement of Oil Stability

Oil stability can be defined as the resistance of the oil to chemical change or to physical disintegration (Warner K and Eskin NAM). The subject can be interpreted in many different ways by different persons.

The different parameters associated with oil stability are:

- oxidative
- emulsion
- flavour
- crystal
- colour
- heat
- hydrolytic
- light
- foam
- enzymatic

It is clear that a wide range of measuring techniques are required if the above stability characteristics are to be followed. The issue is even further complicated by the fact that oil stability is affected by oil extraction and refining processes, storage, *etc.* Pro-oxidant levels and anti-oxidant treatments can have major effects on oil stability.

In the paper on practical aspect a list of oil parameters is given to be used for specification purposes. For detailed specifications, data by Warner and Eskin, and Allen and Hamilton (Rancidity in Foods) are recommended.

The accelerated stability methods such as Schaal Oven Test, Active Oxygen Method (AOM), Oil Stability Index (OSI) are all well described. The Rancimat Instrument and Omnion apparatus are automated OSI measuring techniques and their importance is confirmed by the fact that the Rancimat test is accepted by the AOCS (method Cd 12b-92) and ISO (Draft standard ISO/DIS 6886) as official method. The Rancimat induction period is a primary quality specification for frying oils. It is one of the best tests to determine the oil's resistance to oxidative degradation.

Other methods for evaluation of the oxidative quality of frying oils are peroxide value, conjugated diene value (ultra violet absorption), anisidine value and carbonyl value. The peroxide value measurement is valuable to evaluate the initial stages of oxidation. It is not suitable to monitor oil changes taking place at frying temperatures (Warner and Eskin). The conjugated diene measurement is better suited for this type of monitoring.

It is frequently necessary to evaluate the unrefined oil for its potential to produce a good quality refined oil. Some palm oil refiners rely on the anisidine value to evaluate the unrefined oil. They specify that the anisidine value of the crude oil should not exceed 6.0 units.

It is necessary to point out that different oil stability requirements exists for industrial deep frying, fast food outlets and restaurants and household use. The reasons for selecting a high stability mono-unsaturated oil for the local snack market have been given under the sections "palm olein" and "The safety of frying oil".

Monitoring Oil Quality

Oil quality must be monitored carefully during the frying operation to detect changes in composition and to decide when to discard the oil. Oil quality parameters listed (see the section on safety of frying oil) can be grouped into three categories:

i) subjective observation such as flavour, appearance, colour, turbidity, foaming, *etc.* that are difficult to quantify, but can be very useful tools in the hands of an experienced operator

ii) chemical and physical changes that can be measured by means of sophisticated equipment/ methods

iii) chemical/physical changes that can be measured by quick inexpensive methods. The so-called quick methods are of practical importance since it can be applied to predict the discard point when necessary.

CSIR conducted several comparative tests and the following guidelines are given:

In the case of poly-unsaturated oils (cottonseed, sunflower, *etc.*) the total polymerised triglycerides can be predicted by viscosity measurement. The polar component levels of these oils are well correlated with the dielectric constant changes (Food Oil Sensor). Free fatty acid changes are sufficiently sensitive to provide useful data on the frying operation.

More stable mono-unsaturated oils (palm olein, hydrogenated oils/ fats, *etc.*) tend to change less drastic and polymer formation (viscosity changes) is not pronounced (see *Table 1*). Our experience was that the total tocopherol content of the frying oil correlated very well with the legal specifications (total polymerised triglycerides and total polar components) as well as with some of the quick methods. Dielectric constant correlated well enough with the other measured quality parameters, especially with total polar component levels, that it can be recommended as a monitoring method in an industrial frying operation. It was also surprising to find that free fatty acid value changes correlated consistently with many of the other oil quality changes.

CSIR is presently preparing a training module to give production staff, R&D personnel and regulatory officials a sound background of the deep frying process, its technology, legal requirements and monitoring techniques.

Financial Implications of Poor Oil Quality

The major implications of bad quality and mediocre oil management are:

- loss of oil (oil has to be discarded)
- loss of product
- consumer complaints and resistance
- bad brand image.

All these have a crucial impact on profitability. Discarding of oil and loss of product means an increase in production cost, *i.e.* product unit cost while consumer resistance and bad brand image will reduce sales.

For this reason one has to deal with a reputable oil supplier who understands his client's business and is in a position to supply good quality oil on a continuous basis.

The Safety of Frying Oil

The effect of prolonged heating on the safety of frying oil has been a contentious issue for many years as well as the subject of many research projects. Changes are primarily the result of hydrolytic and oxidative processes taking place during frying. Scientists in many countries have tried to correlate safety levels with the changes in chemical and physical properties of oil during frying. These include colour, sediment, moisture, smoke point, melt/slip point, acid value, carbonyl value, cyclic fatty acids, dielectric constant, total polar compounds, viscosity, anisidine value, epoxides, iodine value, polymerised glycerides, refractive index, diene value and petroleum ether insolubles. From the literature it became obvious that the most important or significant properties are total polar compounds, smell/ taste, colour, smoke point and acid value.

As far as could be ascertained, six countries have formal regulations in respect of the maximum levels of specific byproducts formed during the frying process. The countries are Austria, Belgium, France, Italy, Netherlands and Switzerland. South Africa has just joined this list through the South African Department of Health publishing "regulations prohibiting chemicals in vegetable oil". In the regulations, these compounds are defined as follows:-

- "polar components: means monoglycerides, diglycerides and free fatty acids as well as oxidative degradation products of these components and their parent triglycerides as determined by column chromatography..."
- "polymerised triglycerides" means degradation products formed by carbon to carbon and/or carbon to oxygen linkages between triglyceride bound fatty acids to produce dimeric or higher polymeric triglycerides as determined by gel permeation chromatography. Vegetable oil is deemed to be harmful or injurious to human health, unless it contains:

  a) less than 16% polymerised triglycerides; and/or

  b) less than 25% of polar components.

One of the serious concerns is that discarded oil would be sold to small outlets or to underprivileged people.

Certain researchers correlate the figures quotes for polymer compounds (PC) and total polar compounds (TPC) with 0.7% cyclic monomers which is considered the actual toxic component. TPC are defined as the sum total of the materials that are not triglycerides. TPC being non-volatile composition products which develop during the frying process, are partially absorbed by the products being fried in oil. Some workers are of the opinion that consumers will reject products on the basis of taste and flavour long before the legislated values for TPC and PC are reached.

It is very important to note that fresh (unused) vegetable oil could contain up to 5% TPC and for this reason even the crude oil should be of acceptable quality and its origin and history known to ensure compliance when oil is used for frying.

Generally it can be said that the stability of frying oil is decreased with increased degrees of unsaturation in the constituent fatty acids. The more unsaturated an oil, the greater the tendency to form polymeric rather than polar degradation products. Palm olein, which is about 50% unsaturated (primarily mono-unsaturated) will therefore produce more TPC and less PC.

Limited reference could be found to the levels of polymer compounds and total polar compounds in snacks fried in palm olein. Razali and Nor'aini (1994) investigated the effect of frying coated chicken in a fast food outlet for five consecutive days at eight hours per day. It can be assumed that the oil turnover in this case is far less than for potato chips, for example, where oil absorption could reach nearly 40%. After five days of frying the free fatty acid content of the oil was 0.9%, polymer compounds 4% and total polar compounds 2.4%.

Because of the adverse effect unfounded press reporting on the safety of snacks could have, trials in two factories of the two biggest snack producers in South Africa were done. The results are given in *Table 1*, where oil at three different stages of frying is compared:-

- Fresh oil (palm olein)
- "Intermediate" oil (FFA *ca.* 0.3)
- "Boil out" oil (FFA>0.40).

From the results in *Table 1*, it is clear that the values for total polar compounds and total polymerized triglycerides are far below those set out in the proposed regulations (25% and 16% respectively). The conclusion can, therefore, be drawn that potato chips manufactured under the conditions of the test are safe for human consumption.

Conclusion

Palm olein has been found to be an excellent oil for the frying of snacks on an industrial scale and at the same time will satisfy nutritional and safety requirements. Like any process, oil characteristics must be monitored during the frying process and the correct and appropriate measuring techniques will have to be applied.

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Table 1. FFA, Total Polar Compounds and Total Polymerized Glycerides in Oil Formed During Various Stages of Frying

Sample	FFA	Total Polar Compounds	Total Polymerized Glycerides
Fresh	0.07	0	<1
Intermediate	0.30	3.4	3.5
Boil out	0.45	4.5	2.4

RESEARCH HIGHLIGHTS

BIOTECHNOLOGY OF OIL PALM: BIOENGINEERING, BIOMODIFICATION AND BIOCONVERSION

by
B.S. Jalani & S.C. Cheah

As the crop with the highest oil yield, the oil palm has the potential to become the major supplier of both edible oil and renewable industrial feedstocks. Biotechnology offers several means by which this potential can be realised. Plants producing novel oils have been created using the techniques of genetic engineering. PORIM's objective in applying these techniques to the palm is directed towards the production of high monounsaturated oils for edible purposes. There is much interest in bioengineering the palm for producing industrial oils as well. Efforts are focused on a research programme to isolate and manipulate the genes for increasing the efficiency of conversion of palmitate to oleate. In line with this, a molecular map to locate the genetic loci controlling oil quality is being constructed. Enzymic modification offers yet another route for altering oil composition. The use of lipase catalysed interesteri-fication of palm oil has been shown to be commercially feasible. However, much research is still needed for biomodification of the oil using reactions such as reduction, oxidation, hydroxylation, epoxidation and hydrogenation. Microbial conversion of the oil to high value products such as thermoplastics and therapuetic agents may be feasible, but there is the possibility that the palm itself can be made to produce such novel chemicals by genetic engineering.

Abstracts of papers presented at the AOCS World Conference on Oilseed and Edible Oils Processing: Engineering Technologies, Current Practices, Quality Control, Technology Transfer and Environmental Issues. 6-10 October 1996, Istanbul, Turkey.

NATURAL ANTIOXIDANTS FROM PALM OIL

by Hazura Abd Hamid & Choo Yuen May

There are a number of natural antioxidants in crude palm oil. Unsaponifiable materials of crude palm oil which account for 1% of the oil are rich in carotenes and vitamin E (tocopherols and tocotrienols). The carotenoids (500-700 ppm) and vitamin E (600-1000 ppm) are traditionally the most important biological antioxidants. They are considered safe with no serious side effects. Recently ubiquinone-9 (UQ9) was detected at 5 ppm and ubiquinone-10 (UQ10) at 80 ppm in crude palm oil but in palm oil products more UQ10 was found in the olein (liquid) than in stearin (solid) fractions. Apart from their roles as electron transport in oxidative phosphorylation, UQs have also been reported to show antioxidant activity.

THE FORMULATION OF *TRANS* FATTY ACIDS FREE MARGARINES

by M.S.A. Yusoff, H.Kifli, H.M.D. Noor Lida & M.P. Rozie

Margarines are semi-solid or consistent fats originally developed to imitate dairy butter. The fat component of margarine, representing 80-85% of the product, usually consists of a blend of hydrogenated fats and liquid vegetable oils. However, it is known that during the hydrogenation of vegetable oils, *trans* fatty acids isomers are produced which are currently the subject of controversy because of their ability to increase the risk for coronary heart disease. Several margarine formulations using unhydrogenated fats are available at PORIM.

THE USE OF PALM OLEIN-HARD MILKFAT BLENDS AS BAKERY SHORTENINGS

by NorAini I., C.H. Che Maimon & H.Hanirah

The study was conducted to evaluate characteristics and performance of palm olein milkfat blends as bakery shortenings. Blending palm with milkfat product offers several benefits such as improved flavour, functionality and performance. Three formulations were selected for pilot plant shortening products namely:

A. 80% palm olein & 20% hard milk fat fraction
B. 60% palm olein & 40% hard milk fat fraction
C. 40% palm olein & 60% hard milk fat fraction

Slip melting point of the shortenings ranged from 33.2 to 38.8°C. Iodine values indicated that shortening A had the highest degree of unsaturation followed by shortenings B and C. Shortening A containing the highest percentage of palm olein at 80% showed the best creaming performance. In terms of cake specific volume, shortening B produced very promising results with specific cake volume of 2.62cm³/g. Shortening A was excellent for rolled type of cookies. For pressed cookies, shortening C would be recommended as it produced cookies which maintained their shape better and thus would be easier to handle than pressed cookies made with the other two shortenings.

QUALITY IMPROVEMENT IN THE PRODUCTION OF MALAYSIAN PALM OIL

by Mohamed Razali Mahidin

To ensure quality of Malaysian palm oil, PORIM had introduced a technical audit scheme for the mills and refineries. Although the participation in the audit scheme is on voluntarily basis, the audit results from the scheme have received wide acceptance from the mills and refiners as part of quality assurance process for the last twelve years.

IN BRIEF

UNILEVER GHANA REINVESTS IN ITS FOOD BUSINESS AND IN OIL PALM PLANTATIONS

by J.R. Santhiapillai

Unilever Ghana, a company with roots in West Africa dating back two centuries, is refocusing its activities to concentrate on and reinvest in its mainstream food and soaps business.

The Chairman, Ismail Yamson said the company had pulled out of earth-moving equipment and was doing the same with vehicle and textile distribution.

In 1996-97, the company plans to reinvest £6 million of the money raised and expand its foods factory and privatised state-owned oil palm plantations.

Distancing himself from the election-year (1996) caution of some potential investors, Yamson said that the company is in a competitive industry and that it could not afford to drag its feet.

"We are at the moment looking at entering into the (Ghana government's) divestment programme, so that we can buy some of the state owned palm oil plantations," he said. "The rest of our £6 million investment will go into expanding our foods factory in Tema" he said.

Unilever Ghana employs about 1,500 people, manufacturing soaps, detergents and foods such as cooking oil, margarines and fats. The foods factory produces culinary oil and fats. The company plans to add more value to its oil and put a variety of savoury products on the market.

The company has already raised cash from hiving off certain companies outside its mainstream business and other sales are to follow.

"We have sold some of our own companies. We divested our Caterpillar franchise, which had 55 percent of the earth-moving equipment market", Yamson said.

"We are divesting the entire motors business *(Suzuki, Isuzu)* and the entire textiles distribution business. We intend to raise $13 million to $16 million by that." he continued.

British Unilever is the main shareholder with a 66 percent stake. Ghanaian institutional investors hold 18 percent and private Ghanaian shareholders, 16 percent.

Unilever Ghana's net assets total 50 billion cedis. The company's turnover in 1995 was about 160 billion cedis, as against 106 billion cedis in 1994. After tax, profit, in 1995 was 10 billion cedis, compared with 8 million cedis in 1994. Yamson said that over the past five years, Unilever Ghana has invested about £10 million into rehabilitating and expanding its existing factories.

Source: Mercury Business Report, South Africa

PALM OIL & OTHER OILS NATURAL VARIATIONS IN FATTY ACID COMPOSITION

by B.A. Elias & T.P. Pantzaris

The food manufacturing industry, is increasingly geared to continuous processes and mass production methods which demand the greatest possible degree of uniformity in the characteristics and properties of their raw materials. Unfortunately all natural products have an inherent degree of variability and oils and fats are no exception. How well does palm oil meet this need?

Performance characteristics such as melting point, solid fat content, *etc.*, reflect the chemical composition of the oil and many researchers who have carried out surveys have often commented on the high degree of uniformity in the fatty acid composition of Malaysian palm oil; but how high is "high" and how does palm oil compare with other oils in this respect. These matters are examined below.

Experimental

Variability can be measured either in absolute terms or in relative terms and which one is the most important depends on the circumstances. As far as consistent performance of an oil in use is concerned, it is easily seen that what matters most is the absolute variability. Palm oil contains about 44% palmitic acid and 10% linoleic acid and a variation of 2% points in the oleic acid would most probably pass unnoticed, while nine percentage points in the palmitic acid would certainly be felt. Yet both represent the same relative variation.

Next, one must consider which is the most appropriate measure of variability. Some researchers regularly fall into the trap of using the sample range, it being the simplest and most easily understood measure, but this is absolutely wrong in statistical theory as well as on common sense grounds. The range of a sample is a very biased and crude estimator of variability in the underlying population, and is not amenable to any further statistical manipulation. To make things worse the samples compared are hardly ever the same size. It is clear that the bigger the sample (*i.e.* the bigger the number of specimens in it), the bigger its range is likely to be. The correct parameter for comparisons is the standard deviation as this is the most efficient and unbiased estimator of variability.

Table 1 shows the nine largest vegetable oils in world production (plus Malaysian palm oil), with their principal fatty acid, its mean concentration and the standard deviation, as reported in the latest available surveys. These were the PORIM 1989 survey of Malaysian palm oil and the Leatherhead Food R.A. surveys of the oils which included sub-samples from all producing countries and can be said therefore to reflect the world quality for that oil.

It is seen (from the last column) that Malaysian palm oil has only 84% of the variability of world palm oil which is the least variable of all major oils in world production. Soya oil is 25% more variable and groundnut oil more than six times. As we left out the major animal fats-lard, tallow and butterfat, which are even more variable depending very much on what the animals had been feeding on.

This short study provides quantitative data behind our claims for superior uniformity in the fatty acid composition of palm oil over other world oils and for the special position of Malaysian palm oil, in relation to world palm oil.

It is pertinent that we commend on the high quality of the PORIM surveys. Not only are they consistently far bigger, but they also include more tests, more interrelationships and more statistical parameters than any other surveys we have seen.

Table 1. Malaysian Palm Oil and Other Major Vegetable Oils: Major Fatty Acid Mean Concentration and Standard Deviation (%)

Oil	Sample Size	Major Fatty Acid	Mean	Sd*	Variability Index #
Malaysian Palm	(n=244)	16:0	44.1	1.05	0.84
Palm	(n=55)	16:0	44.8	1.25	2.00
Coconut	(n=33)	12:0	47.8	1.29	1.03
Soyabean	(n-39)	18:2	53.9	1.56	1.25
Palm Kernel	(n=71)	12:0	47.8	1.77	1.42
Cottonseed	(n=55)	18:2	33.0	2.70	2.16
Rapessed	(n=71)	18:1	58.5	2.75	2.20
Sunflower	(n=29)	18:2	50.9	6.87	4.75
Maize	(n=38)	18:2	50.9	6.87	5.50
Groundnut	(n-71)	18:1	45.3	7.70	6.16

*Sd = Standard deviation

#Variability index = $\frac{\text{Sd of the oil}}{\text{Sd of world PO (=1.25)}}$

Sources:

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We invite readers to send in their comments, suggestions and technical news which could be published in this newsletter.

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