

Refining and Downstreaming Processing of Palm and Palm Kernel Oils

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PROCESSING OF PALM AND PALM KERNEL OILS

Introduction

The year 1974 witnessed an important event in the colorful history of the Malaysian palm oil industry. Encouraged by government incentives for the establishment of value-added processing industries, palm oil refining made its emergence on the country's industrial scene. It marked the beginning of an activity that contributed significantly to the development of the Malaysian palm oil industry. Encouraged by government incentives for the establishment of value-added processing industries, palm oil refining made its emergence on the country's industrial scene. It marked the beginning of an activity that contributed significantly to the development of the Malaysian palm oil industry. Within two years, a total of 15 refineries were installed thus making Malaysia the largest palm oil refining country in the world. Today, Malaysia is reputed to have the largest edible oil refining capacity in the world.

In its early years of inception the palm oil refining industry of Malaysia was mainly alkali-refining based. Alkali refining then was the more established process for edible oils. It was not until the late 1970s, that physical refining of palm oil in Malaysia started to emerge as a better alternative, in many ways, to alkali refining. Over the years, physical refining has proven to be very successful for palm oil, and modern refineries in Malaysia are mainly using physical refining routes. In recent years, physical refined products have accounted for more than 95% of the total exports of palm products from Malaysia compared to less than 40% a decade ago.

The success story in the development of physical refining for palm oil in Malaysia has resulted in the setting up of large modern and efficient refinery complexes. Today, there are more than half a dozen complexes with a daily refining capacity of over 1000 tonnes. The largest operates at 3000 tonnes per day using technologies developed in Malaysia and overseas.

In order to cater for a wide range of markets, the Malaysian refiners have palm oil fractionation facilities in their refinery complexes and thus fractionation has become an integral part of the processing industry. Some refiners also undertake refining and fractionation of palm kernel oil and its products.

Aim of refining

Palm and palm kernel oils consist mainly of glycerides and, like other oils in their crude form may consist of small and variable portions of non-glyceride components as well. In order to render the oils to an edible form, some of these non-glycerides need to be either removed or reduced to an acceptable levels.

The non-glycerides are of two broad types: oil insoluble and oil soluble. The insoluble impurities consisting of mainly fruit fibers, nut shells and free moisture which

are readily removed. The oil soluble non-glycerides which include free fatty acids, phospholipids, trace metals, carotenoids, tocopherols/tocotrienols, oxidation products and sterols, are more difficult to remove and thus, the oil needs to under-go various stages of refining.

Not all of the above non-glyceride components are undesirable. The tocopherols and tocotrienols not only help to protect the oil from oxidation, which is detrimental to flavor and keep ability of the finished oil, but also have nutritional attributes. α - and β -carotene, the major constituents of carotenoids, are precursors of Vitamin A. The other impurities generally are detrimental to the oil's flavor, odor, color and keep ability and thus influence the oil's usefulness.

The aim of refining is therefore to convert the crude oil to quality edible oil by removing objectionable impurities to the desired levels in the most efficient manner. This also means that, where possible, losses in the desirable components are kept minimal.

Pilot plant studies conducted by MPOB have shown that it is possible to produce a red-color, carotene-rich oil by light refining which removes only the undesirable free fatty acids, oxidation products and odoriferous components while retaining the beneficial carotenes, tocopherols and tocotrienols. These components are known to possess special nutritional attributes. It is expected that this new red-cooking oil will soon be available commercially.

Generally speaking, the refining routes of palm oil and palm kernel oil are quite identical. There are two routes which can be taken to process crude oil into refined oil; chemical/alkali refining and physical refining. The methods differ basically in the way the free fatty acids are removed from the oil. Chemical refining, which has a higher cost of refining and generally found in older refineries, utilizes an alkali to neutralize most of the fatty acids which are removed as soap. Physical refining, which eliminates the need for an effluent plant for the soap stock, involves subjecting the oil to steam distillation under high temperature and vacuum for removal of the free fatty acids.

There are very little, if any, differences between the qualities of refined oils produced via these methods. However, there are certain consumer preferences for products made via the chemical route and normally, small premiums are involved.

Chemical (alkali) refining

As the name implies, this method of refining uses chemicals in the form of alkalies and normally caustic soda is used. The process involves the addition of an alkali solution to the crude oil which results in chemical reactions and physical changes.

Chemical refining can be carried out either by batch or by continuous process and undergoes the following process flow (*Appendix I*).

Before the start of the off-take from the crude oil tank, the oil undergoes heating at a steady rate, up to the required temperature (about 45° C) for ease of pumping and kept homogenized to provide a final product consistency.

The crude oil then undergoes gum conditioning. The crude oil is pumped through a heat exchanger where its temperature is raised to about 80° C. The oil is then treated with 0.05% - 0.10% food grade orthophosphoric acid in a mixer. A reaction time of 15 minutes is allowed during which the gums (phosphatides) are precipitated making them easily removable at the next stage.

The acid treated oil is then continuously dosed with caustic soda. The concentration and amount of the alkali to be used will vary with the free fatty acid (FFA) content of the oil.

Intimate contact between the alkali and the oil is ensured by the choice of a well designed mixer. The alkali reacts with the FFA forming precipitated soaps which are removed either through centrifuge or settling and washing. The light phase discharge is mainly refined oil containing traces of soap and moisture while the heavy discharge is primarily soap, insoluble materials, gums, free alkali and minute quantity of neutralized oil.

A certain amount of neutral oil is saponified along with the FFA and is lost by emulsification. The efficiency of the process is checked by the use of a Refining Factor (RF).

$$RF = \frac{\text{oil loss \%}}{\text{FFA}}$$

Values of 1.5 to 2.0 were normal for chemical refining plants.

The neutralized oil then undergoes washing. Here the oil is washed with water to remove the soap impurities present. The oil-water mixture is passes through a centrifuge separator where the heavy phase discharge contains soapy water and the light phase discharge is water-washed oil with a soap content of less than 80 ppm which is subsequently removed at the next bleaching stage (*Appendix II*).

The water-washed oil is then dried in a vacuum dryer and the resulting oil is a semi-refined oil termed neutralized oil. In the case of palm oil, neutralized palm oil (NPO) is exported to some overseas customers (*Table 1*).

TABLE 1. PORAM STANDARD SPECIFICATIONS FOR NPO

FFA (as palmitic)	0.25% max
M&I	0.1% max
IV (Wijs)	50-55
M.pt (° C)	
AOS (Cc3-25)	33-39

The soap produced by this process is spitted with mineral acid (usually sulphuric acid) and sold as a by-product called acid oil (*Table 2*).

TABLE 2. PORAM STANDARD SPECIFICATIONS FOR PALM ACID OIL

Total Fatty Matter	95% min
M&I	3% max
FFA (as palmitic)	50% min

After the above steps of phosphoric acid treatment for gum removal and neutralization for FFA reduction, the oil still contains undesirable impurities, odors and color pigments that need to be removed before the finished product will be acceptable to the buyer. Some of these remaining impurities are removed in quantity by the process of bleaching or using a more appropriate term of Adsorptive Cleansing.

The practice of bleaching involves the addition of activated clay (bleaching earth) to remove any undesirable impurities and this improves the initial taste, final flavor and oxidative stability of product. It also helps to overcome problems in subsequent processing by adsorption of soap traces, pro-oxidant metal ions, decomposes peroxides and adsorbs other minor impurities.

Bleaching is carried out under vacuum at a temperature of about 100° C and given a reaction time of half an hour. The dosage of earth varies with the type and quantity of starting oil and is usually in the range of 0.5% - 1.0%. As mentioned earlier the primary function of the bleaching earth is to reduce undesirable impurities through adsorption.

However, a certain amount of bleaching (color reduction) by pigment adsorption occurs as a bonus effect. Color reduction is actually affected in the next stage through high temperature thermal destruction of the pigments.

The slurry containing the oil and earth is then passed through the main filter to give a clear, free-from-earth particles oil. Usually a second check filter is used in series with the main filter to doubly ensure that no earth slips occur. The presence of earth fouls deodorizes, reduces the oxidative stability of the product oil and acts as a catalyst for dimerization and polymerization activities.

Some oil is lost through entrapment in the waste earth and it is usually in the order of 20% - 45% of the weight of dry earth. The neutralized bleached oil is termed NB Oil (*Table 3*).

TABLE 3. PORAM STANDARD SPECIFICATIONS FOR NB PALM OIL

FFA (as palmitic)	0.25% max
M&I	0.1% max
IV (Wijs)	50-55
M.pt (° C)	
AOS (Cc3-25)	33-39
Color (5 ¼ " cell)	20 red max

NB oil then proceeds to the next stage where the free fatty acid content and color are further reduced and, more important, it is deodorized to produce a product which is stable and bland in flavor.

Deodorization is basically a high temperature, high vacuum, steam distillation process. A deodorization operates in the following manner: deaerates the oil, heats up the oil, steam strips the oil and cools the oil before it leaves the system (*Appendix III*). All materials of contact are stainless steel.

Deodorization can be carried out in batch, continuous or semi-continuous style. The present practices in Malaysia are to go for the more efficient and less costly continuous and semi-continuous processes.

In a continuous alkali refining route, the oil is generally heated 220°C - 240°C under vacuum. A vacuum of 2 - 5 mbar is usually maintained by the use of ejectors and boosters. Heat bleaching of the oil occurs at this temperature through the thermal destruction of the carotenoid pigments.

The use of direct stripping steam ensures readily removal of residual free fatty acids, aldehydes and ketones which are responsible for unacceptable odors and flavors.

The oil leaves the deodorizer still under vacuum and cooled down to less than 60°C. It passes through a polishing filter before it is sent to the storage tank. The oil is now termed as neutralized, bleached and deodorized or NBD oil (*Table 4 and 5*).

TABLE 4. PORAM STANDARD SPECIFICATIONS FOR NB/RBD PALM OIL

FFA (as palmitic)	0.1% max
M&I	0.1% max
M.pt (° C)	
AOS (Cc3-25)	33-39
Color (5 ¼ " Lovibond cell)	3 or 6 red max

TABLE 5. NBD/RBD PALM KERNEL OIL SPECIFICATIONS FOR EXPORT

FFA (as palmitic)	0.1% max
M&I	0.1% max
IV (Wijs)	19 max at time of shipment
Color (5 ¼ " Lovibond cell)	Red 1.5 max

At the request of buyers, antioxidants such as BHA, BHT, TBHQ and critic acid are usually added at the ex-deodorized stage for maximum efficiency.

Physical refining

As mentioned earlier, physical refining of crude oil is the more common process in Malaysia for the simple reasons of its higher efficiency, less losses (R.F < 1.3), less operating costs, less capital input and less effluent to handle.

The present modern refineries using the physical refining route are of the continuous types.

The pre-treatment stage of physical refining is exactly the same as that of the alkali route (*Appendix IV*). Once again, phosphoric acid is used. At the bleaching stage, however, relatively higher dosages of earth are used. The "excess" earth is used to adsorb impurities which are removed with the soapstock and by washing in the chemical route. Earth dosage used for PKO is usually less than 1%. The filtered bleached oil is termed Degummed Bleached (DB) oil.

The pre-treated oil enters the deodorizer at an FFA content which is much higher than NB oil. As such, deodorization has to be of a much heavier duty using higher temperatures of 250°C - 270°C for palm kernel oil, more stripping steam and a bigger vacuum (*Appendix V*). The fatty acids distilled-off are condensed and collected. They are termed Fatty Acid Distillate (*Tables 6 and 7*).

TABLE 6. PORAM STANDARD SPECIFICATIONS FOR PALM FATTY ACID DISTILLATE (PFAD)

Saponifiable Matter	95% min (basis 97%)
M&I	1.0% max
FFA (as palmitic)	70% min

**TABLE 7. PALM KERNEL FATTY ACID DISTILLATE (PKFAD)
SPECIFICATIONS FOR EXPORT**

FFA (as palmitic)	50% max (basis 97%)
M&I	1% max
TFM	95% min

The oil leaves the deodorizer as a refined, bleached and deodorized or RBD oil. Export specifications of RBD oils are the same as NBD oils.

Fractionation of palm and palm kernel oils

In order to cater for a wide range of markets, the Malaysian refiners also offer products which are 'harder' (stearin) and 'more liquid' (olein) than palm oil or palm kernel oil. These are accomplished through a simple process of fractionation.

Fractionation of palm and palm kernel oils can be described as follows. The triglycerides found in the oil have different melting points. At certain temperatures, the lower melting temperature triglycerides will stay liquid while the higher melting temperature triglycerides will crystallize into solid separating the oils into both liquid (olein) and solid (stearin) fractions. The fractions can then be separated by filtration.

It is worth mentioning that in palm oil fractionation, palm olein is the premium product and the palm stearin is the discount product. However, the reverse is true for palm kernel oil fractionated products.

Fractionation of palm oil

In Malaysia, fractionation of palm oil into palm olein and palm stearin is accomplished using two types of processes *viz* dry and detergent fractionation. A third method, which uses solvent, is no longer economically feasible for the normal olein-stearin fractionation (*Figure 1*).

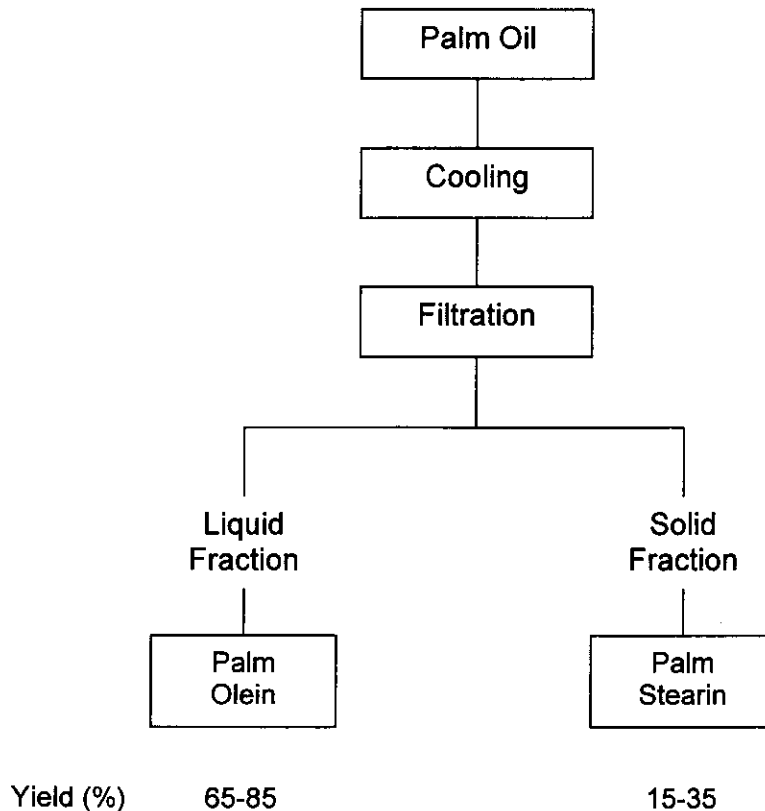


Figure 1. Fractionation of Palm Oil

Dry fractionation

The more common of the two processes, dry fractionation, operates in the following fashion (*Appendix VI*). The oil is kept homogenized at about 70°C before the start of crystallization. The idea is to destroy any crystals present and to induce crystallization in a controlled manner in the crystallizers. Crystal formation and growth occurs as the oil is agitated and cooled using chilled water circulation in the jackets or cooling coils of the crystallizers. Cooling can be governed by controlling either the oil or water temperature.

When the oil reaches the required temperature, usually around 22°C, cooling is stopped. The oil, which appears as a thick semi-solid mass, termed slurry, now contains stearin crystals in liquid olein and is ready for filtration. The slurry is then fed continuously to a filter in a controlled manner. The types of filters used are drum rotary filters (Stockdale) and stainless steel belt filters (Florentine) which operates using vacuum suction to separate the liquid olein from the stearin crystals (*Appendix VII*). Over the last eight years or so, membrane recessed plate Filter Presses, using 'squeezing techniques', have gained popularity.

Generally, bigger crystals are required for ease of filtration using the vacuum suction type filters. However, this tends to make the crystals group together in clumps which will occlude part of the liquid and, as a result, some olein is lost in the stearin.

Olein yields of 65% to 68% are normal for filtration using vacuum suction filters via the dry fractionation route. The stearin obtained is generally termed soft stearin (*Table 8*).

TABLE 8. DRY FRACTIONATION-PRODUCT CHARACTERISTICS

	Palm olein	Palm stearin
Cloud point (°C)	8 - 10	-
Iodine value (Wijs)	56 - 59	42 - 46
Melting point (°C)	22 - 24	48 - 52

Occluded olein can be removed by applying pressure on the stearin cake. Here another type of filter needs to be used *i.e.* the membrane filter press. This plate and frame type filter is operated by pumping the slurry through the filter cloth covered chambers of the filter (*Appendix VII*). The stearin crystals coat the cloth and build up in the chambers. When the chambers are full, the pumping is stopped and pressure is applied to the flexible membrane walls of the chambers to squeeze out entrained olein. Olein yields of 75% to 78% are obtained. The quality of olein obtained is unchanged as pressure is applied only to recover trapped liquid olein. However, the stearin is harder (*Table 9*).

TABLE 9. PALM STEARIN FROM MEMBRANE FILTERS

Iodine value (Wijs)	33 - 37
Melting point (°C)	52 - 54

For the production of high IV/low cloud point olein, dubbed super olein, different sets of processing conditions are used, either using one-stage or more stages of fractionation (*Table 10*).

TABLE 10. SUPEROLEIN FROM PALM OIL BY DRY FRACTIONATION

Iodine value (Wijs)	80 - 65
Cloud point (°C)	3 - 6
Slip Melting point, (°C)	13 - 16

Detergent fractionation

Before the introduction of membrane filters, detergent fractionation enjoyed a distinct advantage over dry fractionation by offering about 15% more olein yield. In Malaysia, detergent fractionation is only carried out with crude oils.

The process involves cooling palm oil (crystallization) and separation of its fractions (fractionation) aided by a detergent (sodium lauryl sulphate solution) and an electrolyte (magnesium sulphate).

As in dry fractionation, the oil in the crystallizers is cooled using chilled water and is allowed to crystallize. When the oil reaches a set temperature of about 22°C, the semi-solid mass is pumped to the fractionation stage where it is mixed with an aqueous solution containing the electrolyte and the detergent at the same temperatures as the fat mass. Fractionation is carried out by centrifugal techniques.

The electrolyte helps in the agglomeration of the oil droplets formed during the mixing process. The presence of the detergent helps in fractionation as it wets the stearin crystals and displaces occluded and entrained olein. The stearin fraction and the detergent then form a discrete phase of higher density which is easily separated by centrifuging.

The lighter phase leaving the centrifuge consists of olein and traces of detergent. This is washed, dried and the olein is sent for storage. The heavier phase containing most of the detergent is heated to melt the stearin and then sent to a second centrifuge where the stearin is separated from the detergent. The stearin is then washed, dried and stored while the detergent is recycled (*Table 11*).

TABLE 11. DETERGENT FRACTIONATION-PRODUCT CHARACTERISTICS

	Palm olein	Palm stearin
Cloud point (°C)	8 - 10	-
Iodine value (Wijs)	56 - 59	32 - 38
Melting point (°C)	-	50 - 55

In Malaysia, Alfa-Laval Lipofrac (*Appendix IX*) is the popular detergent process and as mentioned earlier uses crude palm oil. The crude olein and crude stearin produced are either marketed or undergo refining and made into edible grades as NBD or RBD oils.

Solvent fractionation

As mentioned earlier, it is merely uneconomical at present to fractionate palm oil for normal olein-stearin products via the solvent route. High investment cost is involved due to stringent safety features and the solvent recovery equipment that needs to be incorporated. Operating costs are also high as skilled manpower and additional processing for the solvent recovery and purification are required. It is not surprising to know that by 1981, two out of three solvent fractionation plants in Malaysia ceased operations while the third was converted to produce high value fractionated products like palm mid fraction (PMF).

The process involves crystallizing the oil in a solvent (*Figure 2*). The two common solvents used are hexane and acetone. Solvent is mixed with oil in a 1:3 ratio and then pumped into the crystallizers (*see Appendix X*). Cooling is done either by chilled water or brine. Brine is used if very low temperature crystallization is required. The miscella containing partially crystallized oil and solvent is then sent to a filter where vacuum suction is used to separate the olein from the stearin. The olein/solvent and

stearin/solvent mixtures are then sent to solvent recovery plants where the solvent is separated from the oil fractions and recycles. Olein yields are in the range of 80% - 83%.

If there is a need for special double-fractionated products, the olein is rerouted back into the plant to produce PMF and double-fractionated olein or superolein with a low cloud point and a high iodine value.

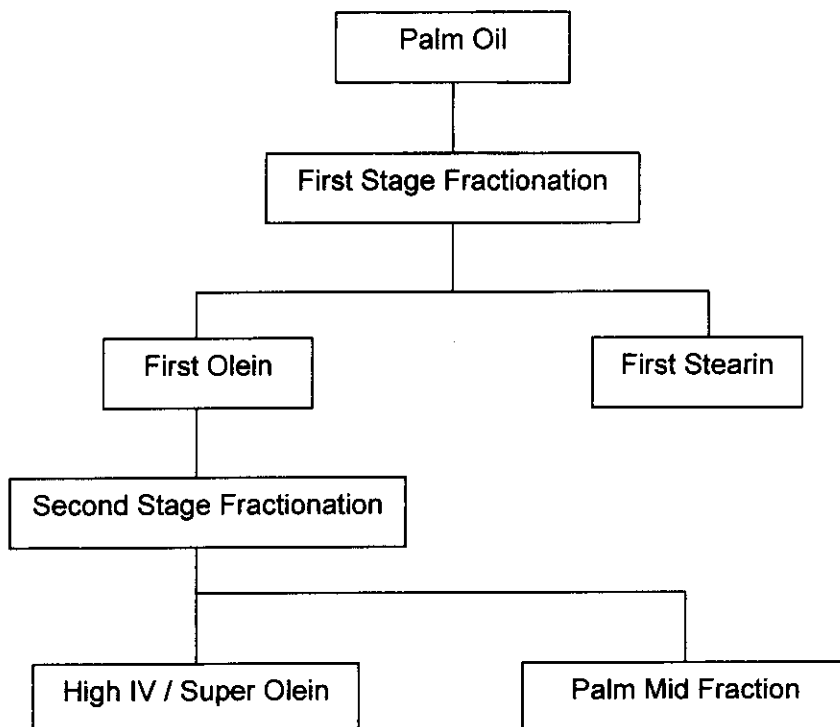


Figure 2. Flow diagram of simple two-stage solvent fractionation

TABLE 12. TYPICAL ANALYSIS OF SUPER OLEIN AND PALM MID FRACTION

	Palm olein	Palm stearin
Cloud point (°C)	8 - 10	-
Iodine value (Wijs)	56 - 59	32 - 38
Melting point (°C)	-	50 - 55

TABLE 13. PORAM STANDARD SPECIFICATIONS FOR PALM OLEIN PRODUCTS

1.	Crude Palm Olein	FFA (As Palmitic) M&I I.V. (Wijs) M.Pt °C (AOCS Cc3-25)	5.0% max 0.25% max 56 min 24 max
2.	Neutralized Palm Olein	FFA (As Palmitic) M&I I.V. (Wijs) M.Pt °C (AOCS Cc3-25)	0.25% max 0.1% max 56 min 24 max
3.	Neutralized & Bleached Palm Olein	FFA (As Palmitic) M&I I.V. (Wijs) M.Pt °C (AOCS Cc3-25) Color (5 ¼ " Lovibond cell)	0.25% max 0.1% max 56 min 24 max 20 Red max
4.	Refined, Bleached & Deodorized (RBD) / Neutralized, Bleached & Deodorized (NBD) Palm Olein	FFA (As Palmitic) M&I I.V. (Wijs) M.Pt °C (AOCS Cc3-25) Color (5 ¼ " Lovibond cell)	0.1% max 0.1% max 56 min 24 max 3 or 6 Red max
5.	Double Fractionated Palm Olein	FFA (As Palmitic) M&I I.V. (Wijs) M.Pt °C (AOCS Cc3-25) Color (5 ¼ " Lovibond cell)	0.1% max 0.1% max 60 min 19 max 3 Red max

Fractionation of palm kernel oil

Just like palm oil, palm kernel oil can also be fractionated via the detergent, solvent and dry processes. The principles applied in processing are quite identical. As mentioned earlier, in palm kernel oil fractionation, the stearin is the premium product and, therefore, higher stearin yields are sought. Stearin yields vary between 20% to 40%.

A fourth method involving hydraulic pressing of the chilled cakes is also practiced.

TABLE 14. PORAM STANDARD SPECIFICATIONS FOR PALM STEARIN PRODUCTS

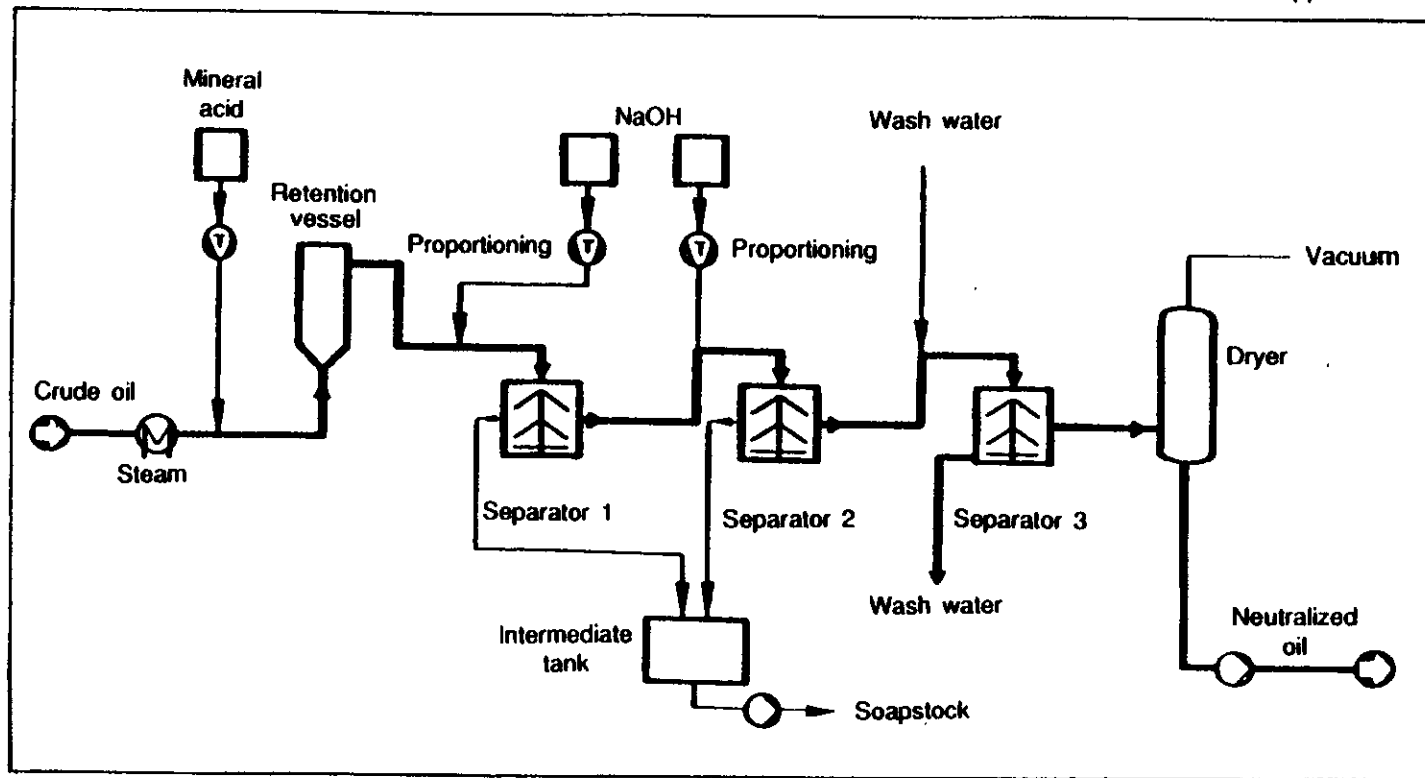
1.	Crude Palm Stearin	FFA (As Palmitic) M&I I.V. (Wijs) M.Pt °C (AOCS Cc3-25)	5.0% max 0.25% max 48 min 44 min
2.	Neutralized Palm Stearin	FFA (As Palmitic) M&I I.V. (Wijs) M.Pt °C (AOCS Cc3-25)	0.25% max 0.1% max 48 max 44 min
3.	Neutralized & Bleached Palm Stearin	FFA (As Palmitic) M&I I.V. (Wijs) M.Pt °C (AOCS Cc3-25) Color (5 ¼ " Lovibond cell)	0.25% max 0.1% max 56 min 24 max 20 Red max
4.	Refined, Bleached & Deodorized (RBD) / Neutralized, Bleached & Deodorized (NBD) Palm Stearin	FFA (As Palmitic) M&I I.V. (Wijs) M.Pt °C (AOCS Cc3-25) Color (5 ¼ " Lovibond cell)	0.2% max 0.15% max 48 max 44 min 3 or 6 Red max

TABLE 15. SPECIFICATIN FOR EXPORT MARKETS (MEOMA): PALM KERNEL OIL FRACTIONATED PRODUCTS

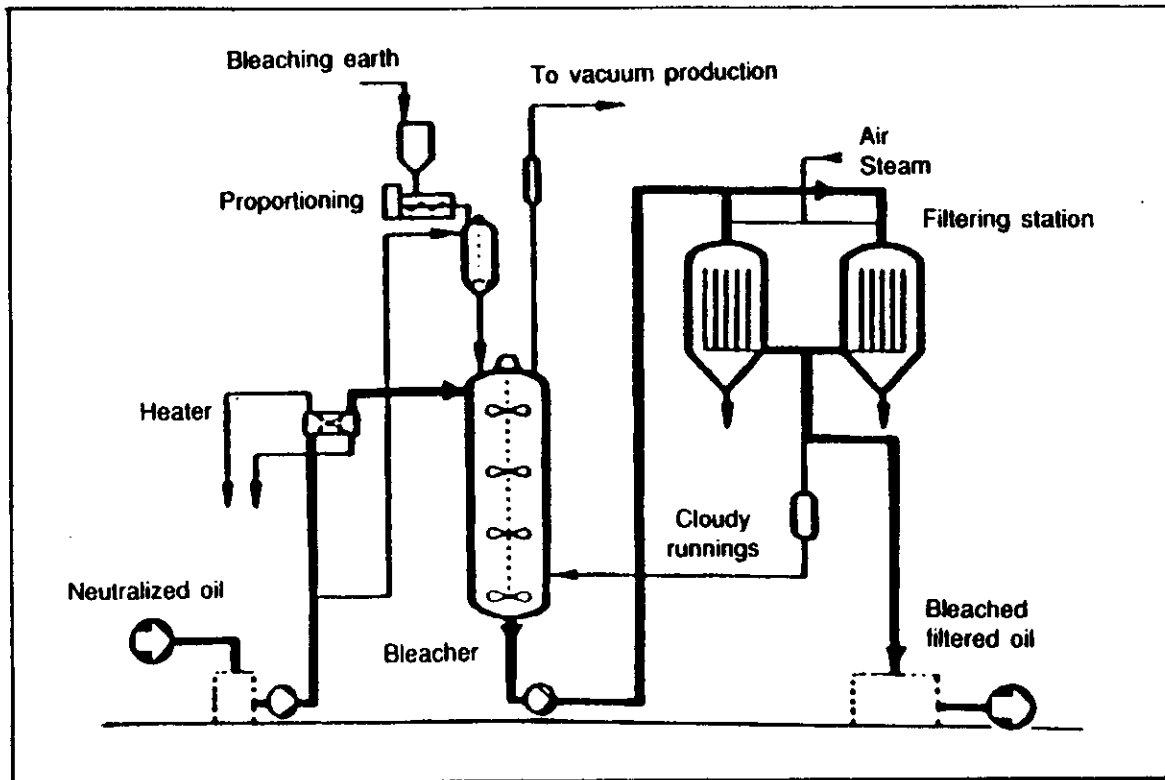
1.	Crude Palm Kernel Olein	FFA (As lauric) M&I I.V. (Wijs)	5.0% max 0.5% max 21 min
2.	Crude Palm Kernel Stearin	FFA (As lauric) M&I I.V. (Wijs)	5.0% max 0.5% max 8 max
3.	RBD Palm Kernel Stearin	FFA (As lauric) M&I I.V. (Wijs) Color (5 ¼ " Lovibond cell)	0.1% max 0.1% max 21 min Red 1.5 max
4.	RBD Palm Kernel Stearin	FFA (As lauric) M&I I.V. (Wijs) Color (5 ¼ " Lovibond cell)	0.1% max 0.1% max 8 max Red 1.5 max

Chemical refining continuous neutralization

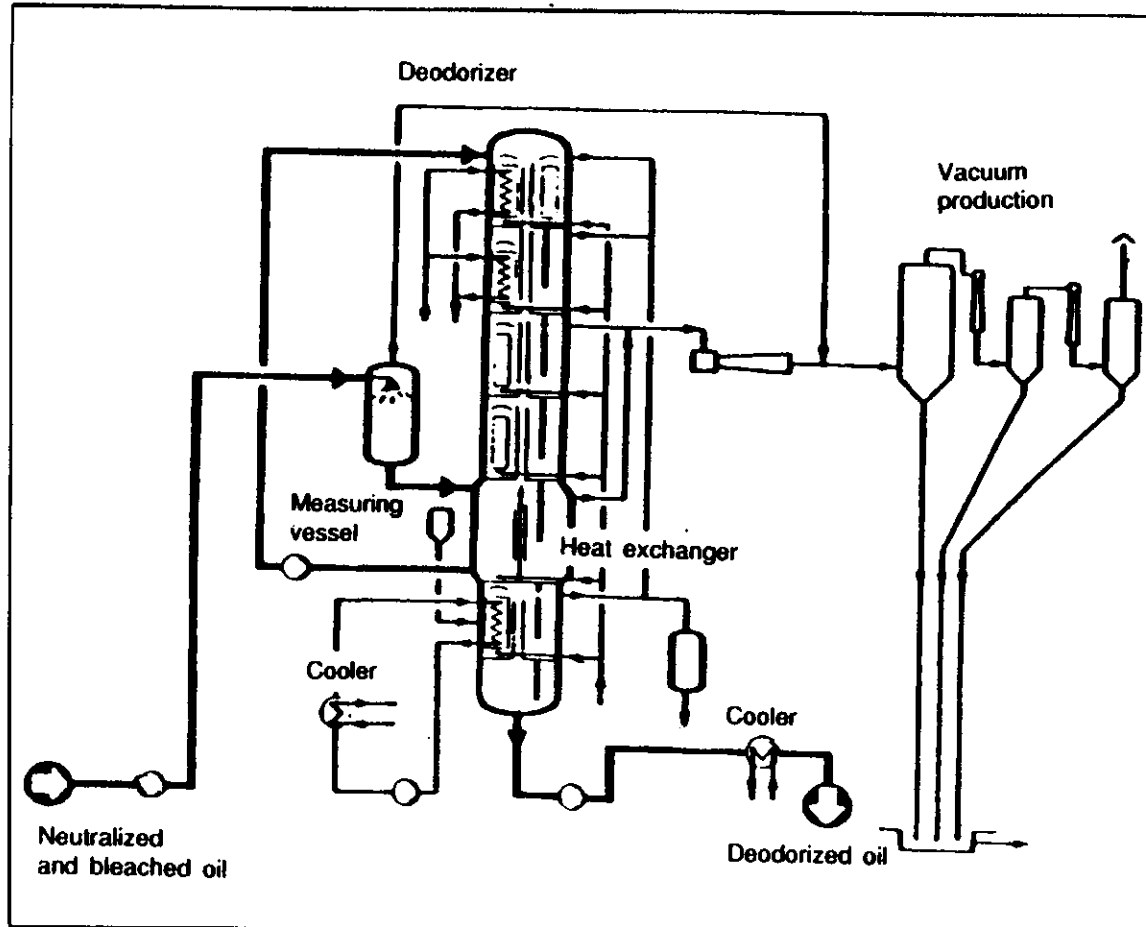
Appendix I

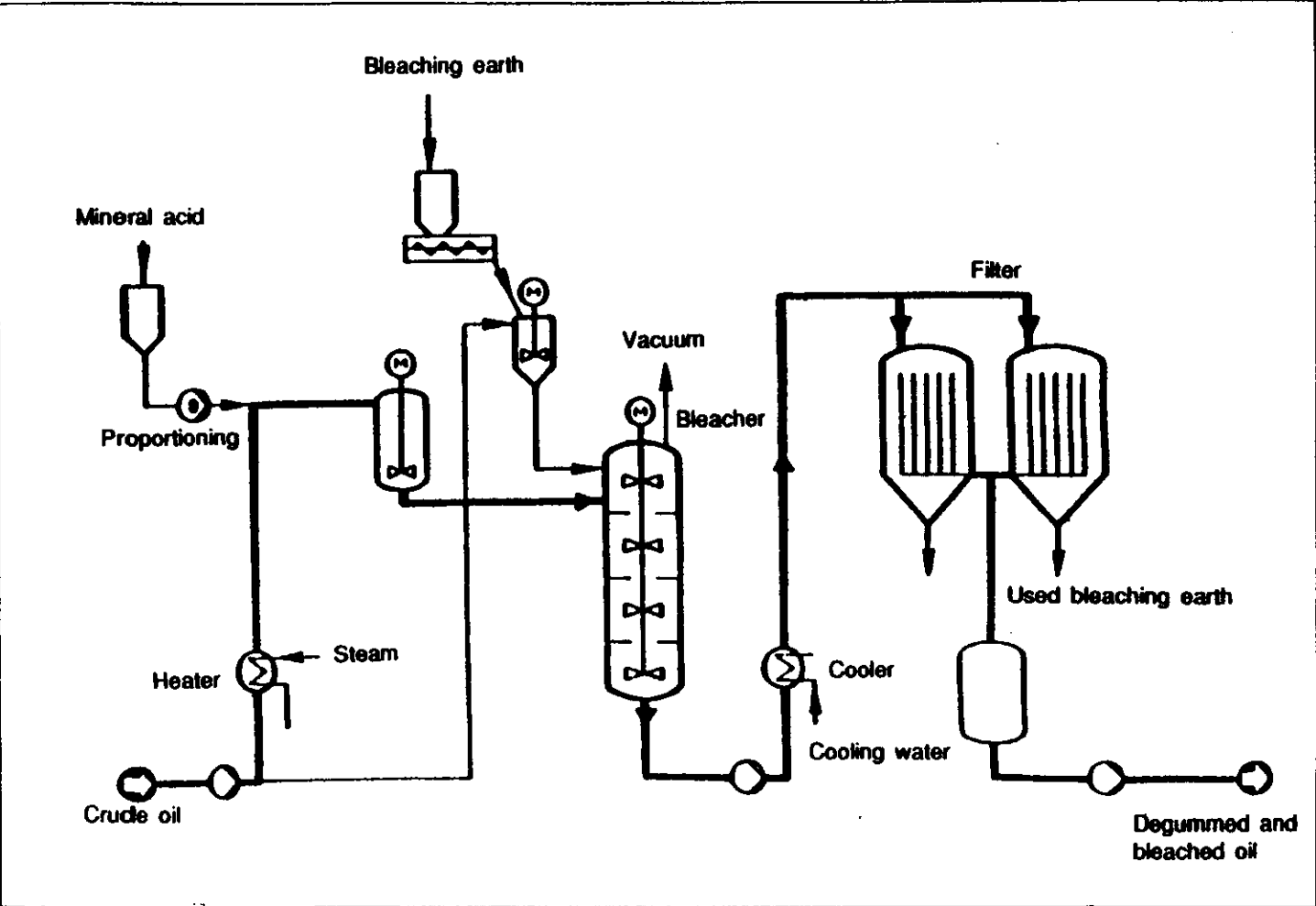


Chemical refining continuous bleaching

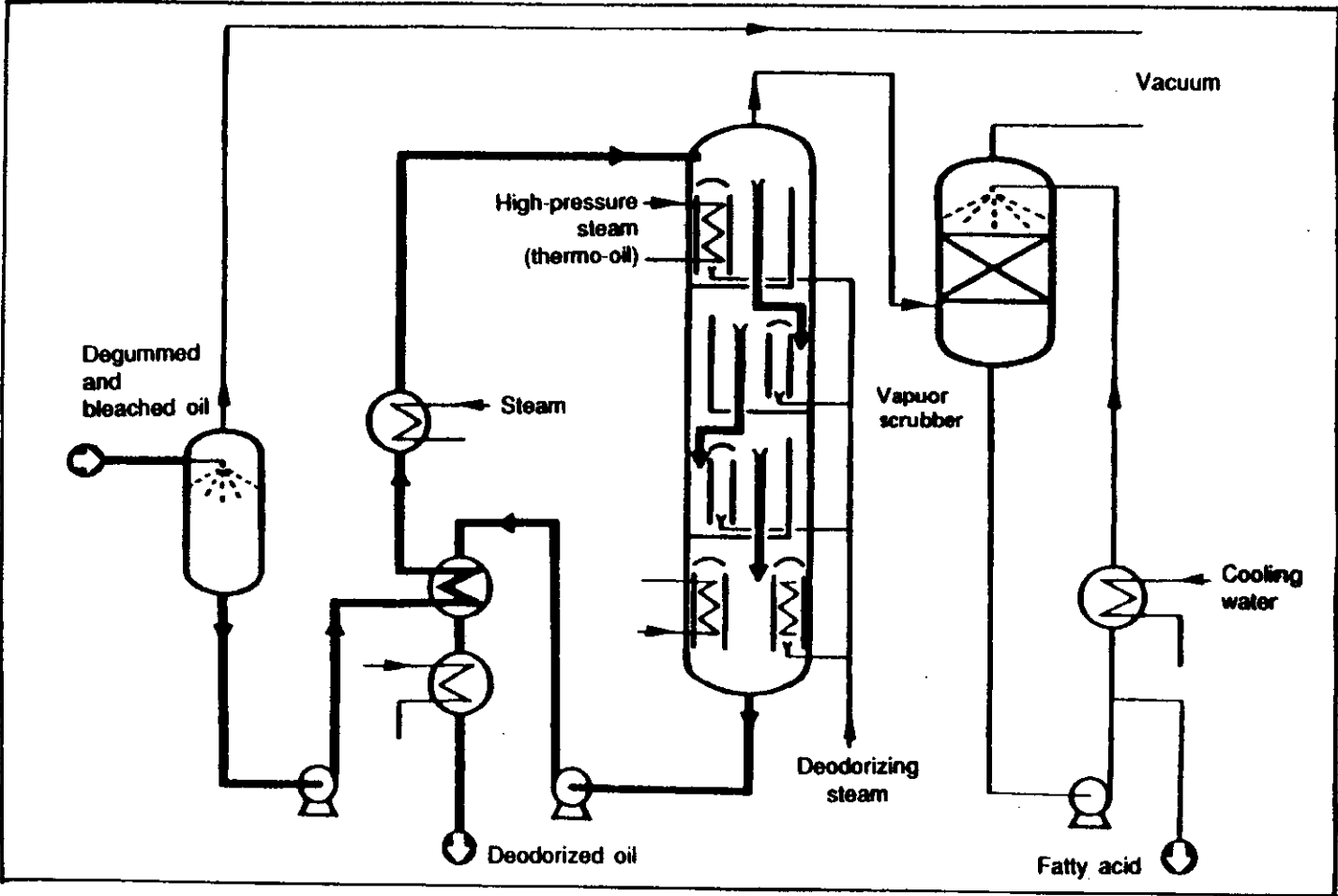


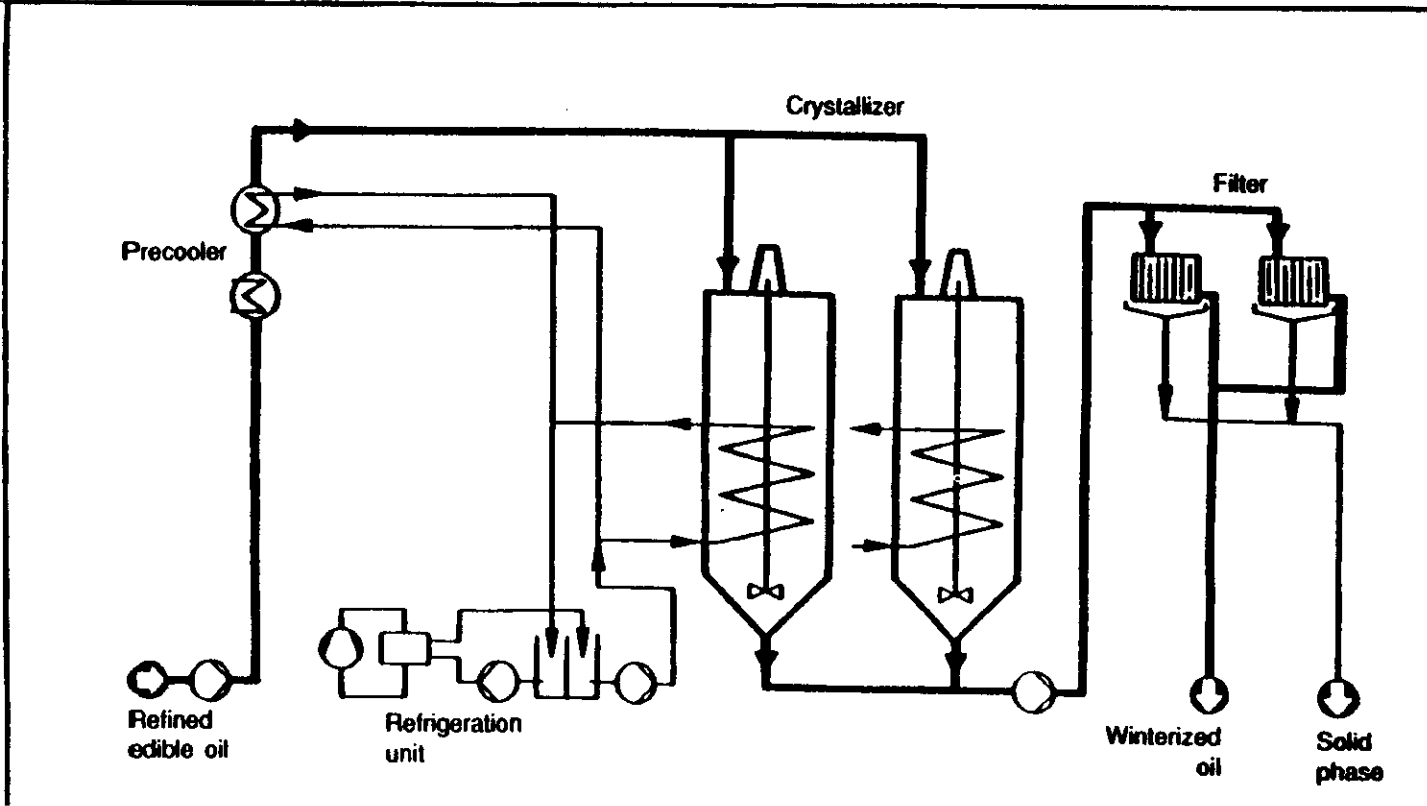
Chemical refining deodorization



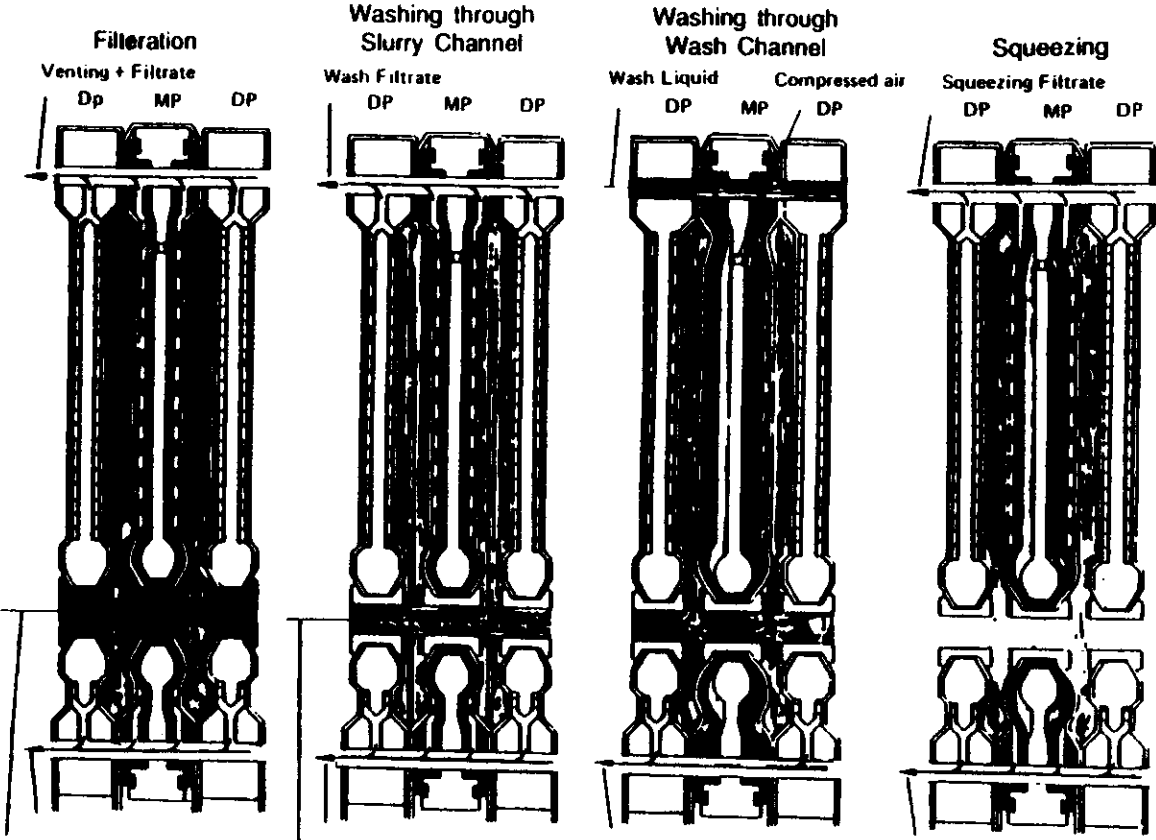


Physical refining deacidification by distillation and deodorization



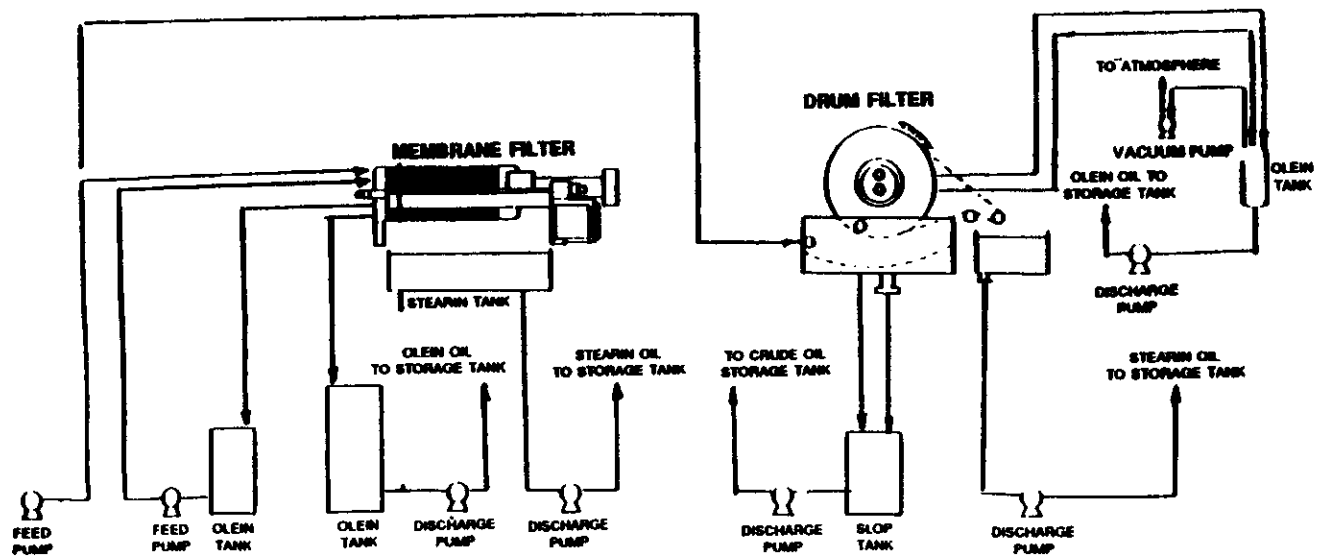


Process steps of membrane technology

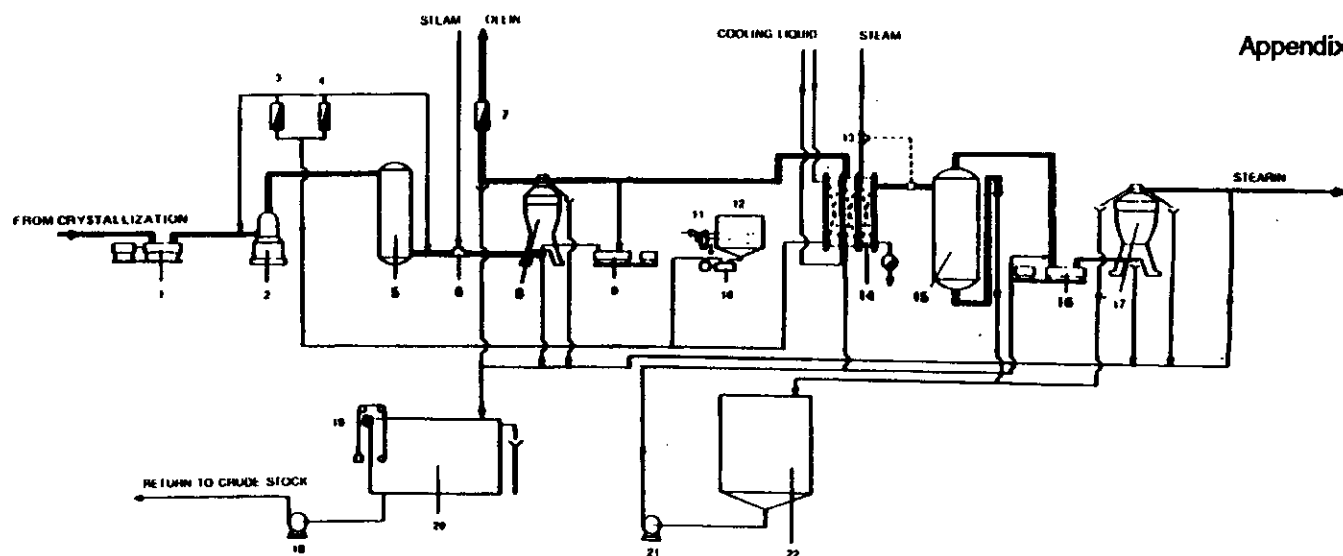


Dry fractionation plant (filtration section)

Appendix VIII

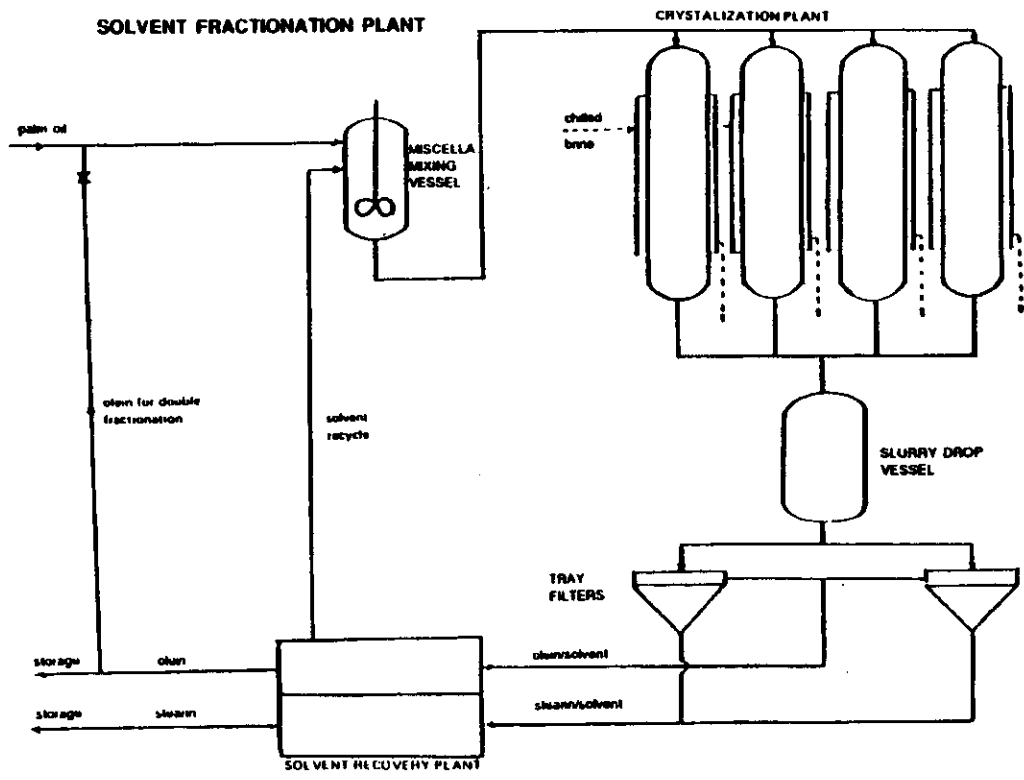


Continuous detergent fractionation



Appendix IX

- | | | | | | |
|---|-----------------------|----|------------------------|----|------------------|
| 1 | Feed pump | 9 | Recirculation pump | 17 | Separator |
| 2 | Knife mixer | 10 | Detergent pump | 18 | Stop pump |
| 3 | Detergent flow meter | 11 | Temperature controller | 19 | Level controller |
| 4 | Detergent flow meter | 12 | Detergent tank | 20 | Catch basin pump |
| 5 | Paddle mixer | 13 | Temperature controller | 21 | Detergent pump |
| 6 | Direct steam injector | 14 | Plate heat exchanger | 22 | Detergent tank |
| 7 | Olein flow meter | 15 | Intermediate tank | | |
| 8 | Separator | 16 | Transferring pump | | |



APPENDIX X