Steam Refining

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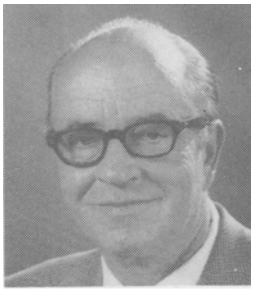

ABSTRACT

Steam refining of fatty oils to reduce the partially high free fatty acid content of certain crude oils before conventional refining has been practiced in Europe for many years. Intensive laboratory testing indicated that crude palm oil could be pretreated to remove trace metals and certain heat resistant organic compounds. This pretreated oil could then be steam refined and simultaneously steam deodorized to produce a high quality finished edible oil. Analytical data on crude and finished oil quality and operating yields are presented to illustrate the steam refining/deodorization process. Laboratory results obtained by steam refining a variety of other oils also are presented.

INTRODUCTION

The refining of crude oils and fats, henceforth termed fatty oils, usually involves the basic steps of free fatty acid removal (deacidification), bleaching for color removal, and final steam deodorization to produce a bland, stable, finished edible oil. The deacidification step has generally been accomplished by reaction of caustic soda with the free fatty acids (FFA) followed by centrifugal separation to produce a neutral fatty oil. To avoid excess losses of neutral oil when processing certain high FFA crude oils, steam refining has been utilized. The basic technique of steam distilling fatty acids from the crude oils was first suggested by G. Hefter (1) some 70 years ago. Steam refining of certain high FFA oils has been carried out in Europe for many years—normally, however, only to the extent of deacidifying down to an FFA content of 0.2-0.5%. The partially neutralized oils were then finished refined using the conventional caustic soda process, followed by clay bleaching and final steam deodorization (2).

STEAM REFINING

The economics for deacidification by steam refining vs. caustic soda normally favor steam refining only when processing high acidity fatty oils. While much of the fundamental technical information on steam refining has been available, most of the fatty oils commonly used for salad or cooking oils, margarine, and shortening did not lend themselves to steam refining due to their relatively low FFA contents.

In the U.S., the principal crude oil used for shortening and salad oil manufacture was crude cottonseed oil, which predominated the market up to the late 1940s. This dark colored oil was best processed by using the conventional caustic soda system to remove acidity as well as certain color bodies before subjecting the oil to bleaching and steam deodorization. High temperatures which are required in steam deodorization would only intensify the color bodies.

Cottonseed oil was followed by soybean oil, again an oil which did not require steam refining to remove acidity, as crude soybean oils have only 0.5-1.0% FFA content.

Recent changes in crude oil supply have accelerated interest in steam deacidification. Certain high acidity oils which lend themselves to steam refining—such as the lauric acid oils of the coconut, palmkernel, or babassu variety and certain animal fats, and especially palm oil—have in recent years become available in large quantities to commercial producers of edible oil products. As recently as 1950, production of Malaysian palm oil was only 50,000 tons/year. Production estimates for palm oil by 1980, from Malaysia alone, are in the range of 2,000,000 tons/year (3).

STEAM REFINING/DEODORIZATION

Work was started in our laboratory to develop a process for steam refining and simultaneously steam deodorizing crude palm oil. The literature (4) has well documented that crude oils must be thoroughly purified to remove most non-oil constituents before subjecting to high temperature distillation. In addition to degumming, if phosphatides are present, prebleaching is necessary to remove certain heat sensitive color bodies. A further requirement is a pretreatment to remove essentially all trace metals. Small amounts of iron are probably the greatest cause of heat darkening during distillation.

Our typical laboratory setup (Fig. 1) is used to determine the various parameters required for a successful

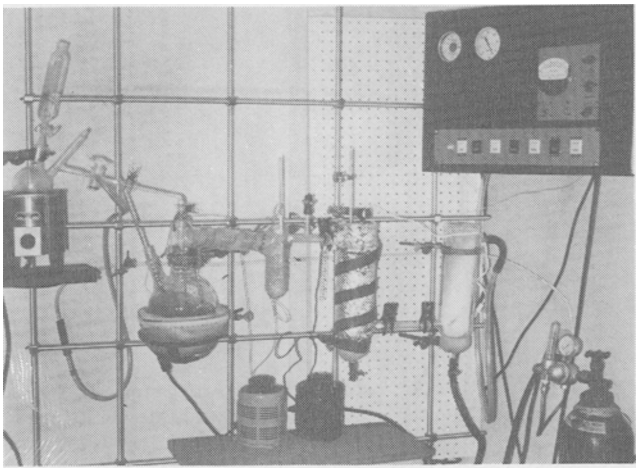

FIG. 1. Laboratory set-up for steam refining/deodorization.

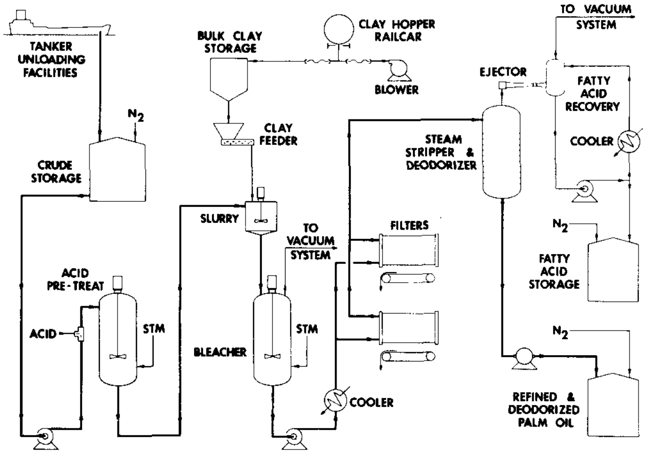

FIG. 2. Basic flow diagram illustrating the steam refining/deodorization process.

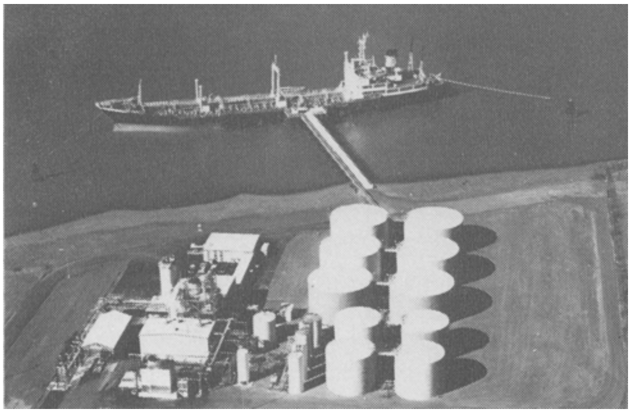

FIG. 3. The Palmco, Inc., plant at Portland, Oregon.

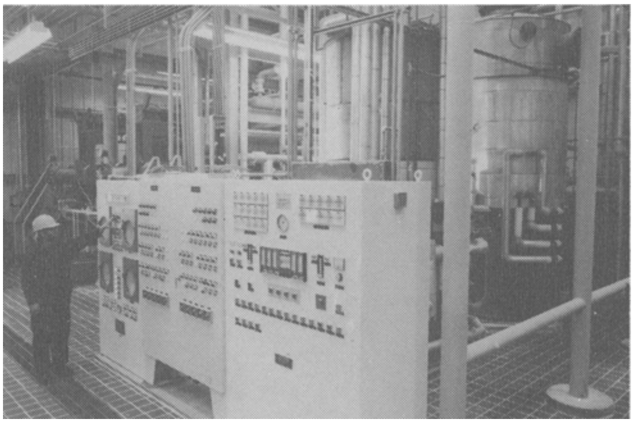

FIG. 4. Operating control panel at Palmco, Inc.

commercial operation whereby crude palm oil could be steam refined and deodorized to produce a light colored finished edible product. Valuable data were developed indicating conditions for trace metal removal, B-carotene removal in the case of palm oil, and phospholipid removal in the case of soybean and similar oils.

Palmco, Inc. (Portland, Oregon) put their palm oil processing plant on stream in December 1973 to produce a high quality deodorized edible palm oil using the steam refining/deodorizing technique. This plant processes crude palm oil at the rate of 10 metric tons/hr in a continuous system of pretreatment and steam refining with simultaneous deodorization.

The basic process flow is shown in Figure 2. Crude palm oil is received by tanker ship, usually from a Malaysian or Indonesian source. The crude oil is stored in insulated tanks provided with heating coils, agitation, and means for inert gas blanketing. The overall plant is shown in Figure 3, with the processing area and central control panel in Figure 4. The entire processing, as shown on the basic flow sheet, can easily be handled by one operator. The plant is currently being expanded to 14 tons/hr capacity.

The quality of crude palm oil as obtained at the plantations, for example in Malaysia, has improved greatly over the years due to a better understanding of the technology in processing the oil from the palm fruits (5,6).

To produce a stable finished deodorized oil using either the conventional caustic refining, bleaching, deodorization process, or the steam refining/deodorization process, the crude oil must be of good quality. The technical staff at Karlshamns Oljefabriker, Sweden, has developed several interesting methods of analyses to determine oxidation in the crude oils as well as the finished deodorized oils. Their data further confirm that it is important to *minimize oxidation* in the crude oils.

Swedish technical studies have shown a definite relationship between the total oxidation values of a fat and the keeping quality of the finished product. The total oxidation value, or Totox, is an empirical value derived from the peroxide value (PV) and the anisidine value (AV). Therefore, Totox = (2xPV) + AV, where PV is a measure of the peroxide formation and AV is a measure of the secondary oxidation products.

Johansson and Persmark (7) have reported on many batches of crude palm oil followed completely through to the finished oils. Johansson (6) further reported on a series of palm oils which were processed by conventional caustic refining, bleaching, and deodorization. The average AV of the deodorized oil was 6.0, which with a zero PV gave a Totox of 6.0. In his review of the Swedish quality requirements for palm oil used in margarine, Johansson (8) also reported that a good margarine oil should have a Totox below 4.0.

The usual crude palm oils received in the U.S. will have the following analyses:

FFA	= 3-5% (average 3.5%)
B-carotene	= 450-500 ppm
PV	= 3-6 meq/kg
AV	= 4-7
Totox	= 10-19 (average 12-15)

This crude palm oil, when processed from crude to deodorized finished oil using the steam refining/deodorizing technique as illustrated on the flow process shown in Figure 2, could have the following analyses:

Color	= 1.5R-2.5R (5¼ in. Lovibond)
FFA	= 0.02%
PV	= 0.0
AV	= 1.0-3.0
Totox	= 1.0-3.0
Active oxygen method stability	= 60 hr (min)

Comparisons have been made between finished palm oil produced by Karlshamns and finished palm oil produced by the steam refining/deodorization technique to illustrate the excellent stability and keeping quality of steam refined/deodorized palm oil. The finished product will usually analyze 1.5 AV (Totox = 1.5) with a maximum 3.0 AV (Totox = 3.0).

As mentioned previously, an important requirement in the pretreatment of crude palm oil prior to high temperature steam refining/deodorization is the removal of trace metals, especially iron. Another important consideration in the pretreatment is the removal of most of the B-carotene prior to the high temperature treatment. B-carotene is a heat degradable material which is converted to a colorless polycyclic nonvolatile product by conventional heat bleaching; however, the heat degraded residues are still left in the oil, which can reduce stability. By removal of the B-carotene prior to high temperature treatment, such as practiced at Portland, a more stable finished edible oil is produced. As shown, the typical crude palm oil received in the U.S. will contain 450-500 ppm B-carotene. The filtered oil, after metal removal and clay bleaching, will contain only 25-30 ppm B-carotene. This is the feed stock which is steam refined/deodorized to produce the finished edible oil.

From the data presented, it becomes obvious that high quality finished edible oil can only be produced from good quality crude oils. Crude palm oils contain natural antioxidants, for example tocopherols, which help in reducing the rate of oxidation while in the crude oil. Pike and Carter (9) have reported test results whereby crude palm oil was further protected at the time of shipment from Malaysia by the addition of antioxidants, as well as protection by nitrogen blanketing. These all helped to reduce oxidation during transit. A sample of crude palm oil received from H & C which had 0.01% tertiary butylhydroquinone added before shipment was steam refined/deodorized with a finished oil color of < 0.6R.

Interesting results were reported by Johansson (6) regarding stability of caustic soda refined palm oil. It was reported that caustic soda refining removes or destroys a part of the natural antioxidants, and hence the refined oil is not as stable as the crude oil. This became apparent when crude oils were caustic soda refined at the plantations and shipped as a once-refined oil (only caustic-soda refined). Certain of these oils have analyzed, upon receipt in the U.S., with Totox value between 60 and 100.

ECONOMICS

For a process to be considered commercially acceptable, it is necessary to produce a high quality finished product and produce this finished product in an economical manner. Steam refining with simultaneous deodorizing of a crude palm oil will yield more finished oil than the conventional process of caustic refining, bleaching, and deodorizing. Likewise, the FFA are distilled from the crude oil and collected as a valuable by-product. The caustic soda process, however, will remove the FFA as a soap which must be acidulated to recover a low grade fatty acid (acid oil). Acidulation also results in a large amount of high biochemical oxygen demand waste material.

The typical crude oil as received in the U.S. contains 3.5% FFA, as palmitic, and will be used as a base for cost comparison between the two methods of processing. Usually the crude oil will be pretreated with bleach clay in amounts of 1.5-1.8% by wt of the oil. The finished oil yield will be 94.5-95.5 lb of deodorized oil per 100 lb of crude oil. For our cost comparison, the average yield of 95.0 lb will be used.

The same crude oil, if processed by the conventional caustic soda refining, bleaching, and steam deodorization method, will yield 92.3 lb deodorized oil per 100 lb of crude oil. This yield was based on a caustic refining loss of twice the FFA (6) and a clay bleach of 0.75%. In the U.S., the usual losses from caustic refining are even higher, in the range of 2.4-2.5 times the FFA.

By using actual operating costs from plants producing finished oil by conventional caustic soda refining, bleaching, and deodorizing, the cost to produce 100 lb of deodorized oil may be calculated. Likewise, the cost to produce 100 lb of deodorized palm oil may be calculated when using the steam refining/deodorizing technique. The operating costs included all direct and indirect costs for each system.

The cost to produce 100 lb finished deodorized palm oil, based on a crude oil cost of $20.00 per 100 lb crude oil landed U.S., is as follows:

1. For conventional process = $23.54 per 100 lb finished oil.
2. For steam refining/deodorization = $21.90 per 100 lb finished oil.

Or, on the basis of a monthly production of 10,000,000 lb deodorized edible palm oil shipments, the steam refining/deodorization process will yield a greater return on investment of ca. $150,000/month.

STEAM REFINING OF OILS OTHER THAN PALM OIL

The laboratory steam distillation apparatus as shown in Figure 1 has been used to process numerous samples of palm oils. Crude, pretreated, and finished palm oil samples are received from the operating plant at Palmco. The results obtained from the small scale laboratory steam refining/deodorization system are easily correlated to the results obtained from full size plant operation. By this means, the laboratory projections of commercial results are verified.

Oils other than crude palm have been processed using this laboratory technique. Among those successfully processed have been soybean oil, corn oil, peanut oil, sesame oil, olive oil, coconut oil, babassu and palmkernel oils, as well as tallow and lard.

Each type of crude oil will usually require some minor variation in the pretreatment prior to high temperature steam refining/deodorization. Oils containing phospholipids, for example soybean oil, require a thorough water degumming to remove all or nearly all water hydratable phosphorous compounds. The gums from the water degumming operation may be dried and sold as animal feed, or, if the crude oil is free of meal, the dried material may be sold as edible lecithin. The finished deodorized soybean oil was equal to or better than deodorized oil produced by the conventional processing in its keeping quality characteristics.

The principal advantage for steam refining/deodorizing a low acidity oil such as soybean or peanut oil is in the reduction of plant pollution commonly caused by the acidulation of soapstock produced from conventional caustic refining.

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