Fractionation and Winterization of Edible Fats and Oils

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ABSTRACT

Processes for fractionation and winterization are reviewed. Properties of solid and liquid fractions from various fats and oils are discussed. In view of the current interest in palm oil, the operation and economics of a small palm oil processing plant including fractionation are described.

INTRODUCTION

Fractionation and winterization operations in the processing of edible oils are basically the separation of oils into two or more fractions with different melting points. In the winterization process, the oils are cooled in a simple way and kept at a low temperature for some time. The liquid and the solid fractions are generally separated by filtration. In fractionation processes, the cooling of the oil and the separation of the fractions are done in a more sophisticated way under controlled conditions.

Fractionation processes have a broad application in edible oil technology. The production of cocoa butter equivalents from palm oil, palmkernel oil, and shea fat and from hydrogenated soybean and cottonseed oils is common knowledge.

In many countries in the Far East, South America, and West Africa, where coconut oil and peanut oil are traditionally used for cooking purposes, there is a tendency towards use of the liquid part of fractionated palm oil as a substitute for the more expensive traditional oils. In a period of scarcely 5 years, at least 20 palm oil fractionation plants with a total capacity of ca. 2,000 tons of crude oil per day were established in Malaysia, Indonesia, Singapore, Ivory Coast, and Colombia.

Although a world market for palm oil fractions still has to be established, it is obvious that, regardless of the reasons which may have caused the striking increase of fractionation capacity, the manufacture of palm oil fractions in palm oil producing countries has passed its experimental stage.

PRINCIPLES OF FRACTIONATION

Separation of the oil fractions is based on a distribution of the triglycerides between different phases. Although the selective extraction of oil fractions in a system of two immiscible liquid phases might offer possibilities for future developments, the only important method of edible oil fractionation on a commercial scale up to now is by partial crystallization in a liquid phase.

In this method, three successive stages can be distinguished:

1. Cooling of the liquid oil to supersaturation, resulting in the formation of nuclei for crystallization.
2. Progressive growth of the crystals by gradual cooling.
3. Separation of the crystalline and liquid phases.

The efficiency of the separation of the liquid and solid fractions depends particularly on the method of cooling, which determines the form and size of the crystals. Rapid cooling causes heavy supersaturation and gives a great number of small crystals, resulting in the formation of an amorphous, micro-crystalline, softish precipitate with poor filtration properties. This form will be slowly transformed into the metastable alpha form, with characteristics of micro-crystallinity and a tendency to develop mixed crystals. Gradual cooling of the supersaturated oil results in stable beta and beta prime macro-crystals, which can be separated easily from the liquid phase by filtration.

Therefore, fractionation installations contain one or more crystallizers in which the oil is cooled gradually over an extended period of time. The long time required for crystallization implies long retention time and large installations.

The separated liquid and solid fractions show a significant difference in physical and chemical properties. It is, however, remarkable to notice that the distribution of the fatty acids in the separated fractions is less pronounced than might be expected.

Fractionation of a sample of palm oil from Zaire (West Africa) resulted in the gas chromatographic analyses shown in Table I. The experiment shows that the shifting of fatty acids from one fraction to the other is relatively minor. However, the difference in iodine values and melting points between the fractions is considerable.

Separation of an oil into fractions does not lead to effective separation of the different types of fatty acids. From this point of view, the object of fractionation is, in general, a modification of the texture, crystallization, and melting behavior, which are defined by the composition of the triglycerides.

FRACTIONATION PROCESSES

In recent years, three palm oil fractionation processes have found industrial application: (a) dry fractionation through batch crystallization of the oil by controlled cooling and subsequent continuous filtration on a belt filter; (b) Lanza fractionation through batch crystallization of the oil by controlled cooling and separation of the fractions by centrifugation after addition of a surface active agent; and (c) solvent fractionation through continuous crystallization of the oil in a solvent followed by separation of the liquid and the solid fraction through a continuous type of drum filter.

Another process that probably has interesting aspects is the continuous isopropyl alcohol fractionation method developed by the H.L.S. Industrial Engineering Co. in Israel. The palm oil is dissolved in isopropyl alcohol in the

TABLE I

Fractionated Palm Oil

Fatty acid	Liquid fraction (%)	Solid fraction (%)
Lauric	0.1	0.1
Myristic	0.6	0.7
Palmitic	35.7	45.3
Stearic	4.0	5.0
Oleic	46.3	40.4
Linoleic	12.5	7.6
Linolenic	0.3	0.2
Arachidic	0.3	0.4
Palmitoleic	0.3	0.3
Iodine value	60.8	42.9
Melting point (C)	20	48

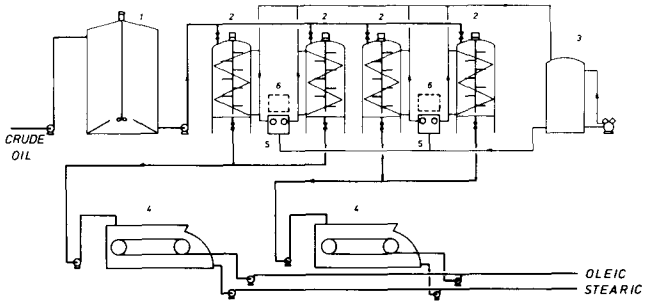

FIG. 1. Flow diagram of Tirtiaux fractionation plant.

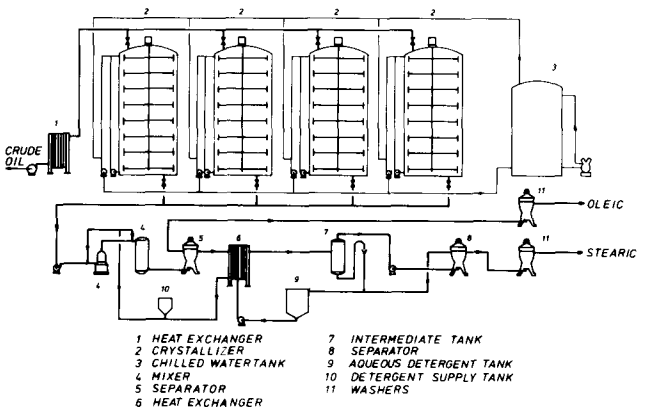

FIG. 2. Flow diagram of Alfa-Laval fractionation plant.

ratio 1:1. The mixture is cooled in one or two steps, and the crystals are separated from the liquid by decantation of the upper layer containing the solid fat in crystal form in isopropyl alcohol. Although extensive tests have been made in Israel with a pilot plant of a capacity of 500 kg/hr, this method has so far found no industrial application.

Dry Fractionation

The principle of this fractionation process is based on the cooling of oil under controlled conditions without the addition of chemicals. The liquid and the solid phases are separated by filtration of the natural product.

The best known example of this type of fractionation is the Tirtiaux process. The principle features of a semicontinuous Tirtiaux fractionation plant are shown in Figure 1. A fractionation plant with a capacity of 80 tons/day contains a precrystallizer [1] of ca. 100 tons in which the crude oil is stirred and kept at a temperature of 50 C. Four crystallizers [2] of 20 tons each are filled with oil from the seeder in intervals of 6 hr. The filling and heating to 70 C takes 2 hr. The crystallizers are provided with agitators, cooling serpentines, and a double cooling wall. The oil is cooled under controlled conditions with cold water[3] in 6 hr to ca. 40 C and kept at this temperature for a period of 4 hr. The slurry is cooled to 20 C in 6 hr and filtrated in 6 hr over a continuous belt filter [4]. The cooling of the oil is controlled by a circulating unit [5] and a general control unit [6]. If semirefined oil is fractionated, the time cycle takes 20 hr and the oil is cooled to a filtration temperature of 17 C.

Lanza Fractionation

The principle of this type of fractionation is similar to dry fractionation based on the cooling of oil under controlled conditions without the addition of a solvent. The liquid and solid phases are separated by centrifugation after an aqueous detergent solution has been added. The surface

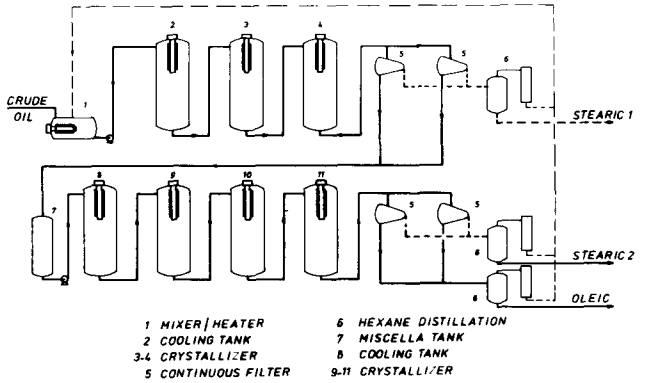

FIG. 3. Flow diagram of Bernardini fractionation plant.

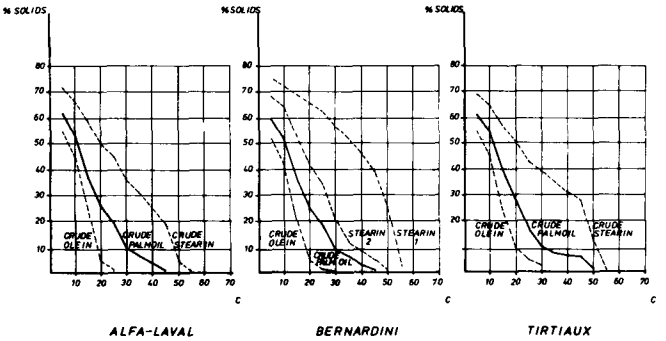

FIG. 4. Dilatation curves.

active agent replaces the oil phase on the surface of the crystals. The crystals and the aqueous solution form a suspension which can be separated from the liquid oil phase by centrifugation.

The Alfa-Laval Lipofrac system is the best known example of this type of fractionation. The flow diagram in Figure 2 shows the principle of a semicontinuous Alfa-Laval fractionation plant. A plant with a capacity of 80 tons/day is equipped with four crystallizers of 20 tons each. The fat, precooled in a heat exchanger [1] if required, is pumped into the crystallizers [2], where it is cooled to the required temperature. The cooling tanks may be used alternately or arranged in series to give a continuous feed to the separators. The cooling of the fat and the removal of heat released during crystallization of the fat are effected by a cooling liquid sprayed on the outside of the tanks. The temperature of the cooling liquid, normally water, is automatically regulated to obtain a suitable temperature difference between the fat and the cooling agent. As soon as the crystallization has been completed, the semisolid mass is pumped to the separation plant and mixed with a detergent solution [4]. This solution contains 0.5% sodium lauryl sulphate and magnesium sulphate as an electrolyte. The crystal suspension is separated from the liquid phase in a separator [5]. The fat crystals are melted in a heat exchanger [6] by the hot detergent solution and by steam. The hot oil-water mixture is transferred through an intermediate tank [7] to a separator [8] which separates the stearic fraction. The detergent solution is recycled into the process. The oleic and stearic fractions are washed in centrifuges [11].

Solvent Fractionation

Cooling of a fat diluted with a solvent generally results in the formation of crystals of the stable beta and beta prime type and reduces the tendency to form mixed crystals. The incoming oil is mixed in a certain ratio with an organic solvent. The resulting miscella is subjected to preliminary cooling and is pumped to the crystallization vessels, in which part of the glycerides precipitate due to

TABLE II

Analyses of Crude Palm Oils and Fractions

	Bernardini				Alfa-Laval			Tirtiaux			Tirtiaux
	Crude PO	Crude olein	Crude stear 1	Crude stear 2	Crude PO	Crude olein	Crude stearic	Crude PO	Crude olein	Crude stearic	Double fract. olein
Free fatty acid	3.17	4.21	2.64	2.76	3.94	4.07	3.57	2.60	2.69	1.82	
Iodine value–Theoretical	55.6	59.2	39.6	47.9	55.5	57.9	44.0	53.7	58.3	42.7	59.1
Iodine value-Hanus	54.7	58.1	35.6	45.0	55.3	58.7	43.6	53.3	57.5	41.5	59.2
Slip melting point (DGF.C.IV 3a[52])	37.7	20.2	53.4	39.3	35.2	18.2	46.7	37.8	18.4	50.9	19.2
Cloud test (AOCS Cc 6-25)		8.6				6.9			7.9		7.1
Cold test (17-18 C, 4 days)		a				a			a		a
Cold test (20.5 C, 4 days)		b				c			a		c
Cold test (21.9 C, 4 days)		b				c			b		c
Fatty acid composition											
C12	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
C14	1.0	1.1	1.3	1.1	1.1	1.2	1.4	1.0	0.9	1.2	1.1
C16	41.6	38.4	55.2	47.5	41.7	39.2	50.8	43.1	38.6	52.3	38.3
C18	5.0	4.3	5.3	5.2	4.8	4.3	5.1	4.6	4.7	5.1	4.5
C18:1	39.5	42.9	29.5	35.8	39.7	42.7	33.2	39.7	43.2	32.4	42.8
C18:2	12.1	12.5	8.0	9.5	11.9	11.9	8.6	10.9	11.9	8.3	12.5
C18:3	0.3	0.3	0.2	0.2	0.2	0.3	0.2	0.2	0.3	0.2	0.3
C20	0.2	0.2	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Oleic fraction (%)		65				70			65		
Stearic 1 fraction (%)			15				30			35	
Stearic 2 fraction (%)				20							

[a]Dense crystallization.

[b]Slight crystallization.

[c]Liquid.

crystallization. The mixture is separated into a liquid phase of oil and solvent and into a solid phase of glyceride crystals and solvent. Both fractions are separated from the solvent by distillation. Acetone is generally used in fractionation processes producing cocoa butter equivalents from hydrogenated liquid oils, shea fat, and palm oil. The solvent 2-nitro-propane can also be mentioned in this respect.

In the palm oil fractionation technique, the hexane solvent process of Bernardini has found industrial application. The flow diagram in Figure 3 shows the principle of the continuous Bernardini fractionation plant in Johore, Malaysia. Crude palm oil is heated to 45 C in a mixer-heater [1], where the oil is mixed in a ratio 1:1 with hexane, and pumped into the cooling tank [2] of the first stage, in which the oil is cooled to 30-33 C. The miscella is pumped into the first crystallizer [3], where it is cooled to 20 C. In the second crystallization vessel [4], the miscella is cooled to 10 C. The crystallized mass is then passed through two continuous drum filters [5], separating the liquid oil and solvent phase from the solid glyceride and solvent phase. The solid phase is dumped into a tank and pumped to the distillation unit [6], where it is separated from the hexane, which is recirculated into the process. The liquid phase is pumped from a miscella tank [7] to the cooling tank [8] of the second stage and to the first crystallizer [9], where it is cooled from 10 C to 7 C. It is then pumped to the second crystallizer [10], where the miscella is cooled to ca. 4 C. The final cooling to 2 C takes place in the third crystallizer [11]. In the second filtration, the solid glycerides are separated from the liquid phase. Both fractions are freed from hexane by distillation.

DEVELOPMENT OF PALM OIL FRACTIONATION IN TROPICAL COUNTRIES

The fractionation of palm oil in tropical countries was started in about 1970. The Blohorn Cy in Ivory Coast used a Bernardini plant, Lam Soon in Singapore an Alfa-Laval plant, and Grasco in Colombia a Tirtiaux fractionation plant. In 1971, 1972, and 1973, Blohorn extended the capacity of the Bernardini plant with a Tirtiaux unit. In 1974, the Edible Oils Products Co. (EOP) in Johore, Malaysia, obtained a Bernardini plant. Unitata in Teluk Anson, Malaysia, started with a Tirtiaux installation in 1975. The fractionation capacity of Lam Soon was extended with two Alfa-Laval plants in Malaysia. In 1974, PNP-VI in Sumatra, Indonesia, commissioned a Tirtiaux plant. It will start operations this year.

Another 10 palm oil fractionation plants in Malaysia are now ready for operation or will be completed in the course of this year. The commission of these 10 installations was largely due to the fact that the duty on exported processed palm oil was considerably reduced by the Malaysian government. Due to the fact that the rate of the duty is related to the cif value of the crude oil, the spectacular increase of the palm oil price in 1974 resulted in a benefit of ca. U.S. $190/ton of processed and exported palm oil for the processor.

The drop in the world market prices as well as the local shortage of crude oil have reduced the profit margins of palm oil processors to such an extent that for the newcomers the sole fractionation of crude palm oil for export is hardly a paying proposition. It is expected that only producers with an experienced staff, a strong sales organization, ample research facilities, and an integrated processing industry are in a position to survive the threat of a possible future reduction in duty exemption by the Malaysian government. These producers are improving their fractionation processes in order to produce semimanufactured and final products for the local market and for export.

Average samples of palm oil fractions from the Lam Soon, EOP, and Unitata fractionation plants, representing the Alfa-Laval, Bernardini, and Tirtiaux processes, were obtained from the manufacturers and analyzed. The dilatation curves of the crude palm oils, oleic fractions, and stearic fractions are shown in Figure 4. The first stearic fraction of the Bernardini process has a higher dilatation at 15 and 50 C and a higher melting point than the stearic fractions of the Alfa-Laval and Tirtiaux processes, which were produced by single fractionation. The dilatations of the stearic fraction of the Tirtiaux process at 5, 10, and 15 C are slightly lower than the corresponding fractions of the Alfa-Laval process. The dilatation of the stearic fraction of the Tirtiaux process at 50 C is more or less equal to the dilatation of the corresponding Alfa-Laval fraction.

A summary of the melting and crystallization behaviors, iodine values, and fatty acid compositions of the crude palm oils, stearic fractions, and oleic fractions is shown in Table II. The oleic fractions show only small differences in fatty acid composition and cold test behavior. The oleic fraction of the Tirtiaux process is only completely liquid at 21.9 C after double fractionation. The melting point of the stearic fraction of the Tirtiaux process is higher than the stearic fraction of the Alfa-Laval process.

OPERATION OF A SMALL PALM OIL FRACTIONATION PLANT

The fractionation and refining of palm oil and coconut oil in a small scale plant can be of interest for the development of an edible oil processing industry in tropical countries. The mixture of the liquid palm oil fraction and coconut oil results in a suitable cooking oil after refining. Part of the solid palm oil fraction can be blended with palm oil and coconut oil for margarine production. The balance of the solid fraction is suitable for the production of bakery fat and frying fat.

In the Caribbean area, a fractionation plant plus refinery with a total capacity of 16 tons per day is presently under construction and will be operating later this year. A quantity of 2,700 tons of crude palm oil and 1,300 tons of coconut oil will be fractionated and refined for the production of 1,000 tons of margarine blend, 2,400 tons of cooking oil, and 440 tons of shortening. The fractionation system to be used is the Tirtiaux dry fractionation method. The oil is refined by a physical system whereby the fatty acids are removed through steam distillation under high vacuum. The total investment in the turnkey project is ca. U.S. $1.5 million.

Processing costs for refining are ca. U.S. $75/ton at a capacity of 4,000 tons/annum. Costs of fractionation are U.S. $27/ton of oil at full capacity or U.S. $80/ton at a capacity of 2,000 tons of palm oil/annum.

Investment in a small scale vegetable oil processing plant including fractionation with a capacity of ca. 4,000 tons/annum can be justified if a market of 500,000-800,000 potential consumers is available.