palm oil will compete well with petroleum-derived materials and rank as one of the significant materials for detergents in the near future.

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Other Oleochemical Uses: Palm Oil Products

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ABSTRACT

Production and consumption of palm oil and its products are discussed as they relate to industrial products. The large volumes of palm oil being produced and projected for future production should increase the use of its byproducts in oleochemicals. Tallow is the most competitive fat to palm oil in these applications, but its market share (at least in Japan) seems to be declining. An enzymatic process for hydrolyzing fats and oils by a solid phase process is described.

INTRODUCTION

In the near future, palm oil is expected to be one of the largest fat and oil resources along with soybean oil. The main use of palm oil is in food products. Technologies such as fractionation, hydrogenation, and interesterification have made it possible to use more palm oil for these edible purposes. Industrial uses of palm oil could be learned based on those of tallow, whose fatty acid composition is similar to that of palm oil. This presentation discusses mainly what kinds of palm oil products should be considered as the raw materials for industrial uses; what kinds of technological improvements will be expected for the development of industrial applications, and what are potential new uses.

OUTLOOK FOR PALM OIL

The high potential for palm oil is described in relation to: world fat and oil production; palm oil production in Malaysia; vegetable oil production and fatty acid composition.

World Fat and Oil Production

World fat and oil production has reached 56.6 million tons with an increase of 16.7 million tons in the last ten years (Table I). In particular, the growth of vegetable oils for food was very remarkable, i.e., palm oil production was tripled, and soybean and rapeseed oils were doubled. Animal fat production showed less than 20% growth, but tallow and butter production did increase. It is remarkable that the proportion of vegetable oils for edible uses in world fat and oil production increased from 61% to 69%. The growth of world fat and oil production in the past 10 years was due to the large harvests of palm, soybean and rapeseed oils. It is assumed that this tendency will continue in the future.

TABLE I

World Oil and Fat Production in 1970 and 1980

	1970	1980	Decade growth (%)
	(10,000 metric tons)		
Edible vegetable oils			
Soybean	608	1,222	201
Palm	172	506	294
Sunflower	380	478	126
Rapeseed	188	387	206
Coconut	214	326	152
Cottonseed	262	321	123
Peanut	327	280	86
Olive	125	193	154
Others	161	220	137
Subtotal	2,437	3,933	161
Industrial vegetable oils			
Linseed	111	64	
Others	64	63	
Subtotal	175	127	73
Marine animal oils			
Fish	104	117	
Others	21	7	
Subtotal	125	124	99
Animal fats			
Tallow and grease	435	604	139
Lard	413	383	93
Others	411	493	120
Subtotal	1,259	1,480	118
Total	3,996	5,664	142

Source: U.S. Department of Agriculture.

Palm Oil Production in Malaysia

Palm oil production, which showed the largest growth compared with other fat and oil resources, has reached 13% of world vegetable oil consumption for food in 1980, up from 7% in 1970. Palm oil production in Malaysia, having reached 3.5 million tons (60% of world production) in 1982, is expected to rise to 4 million tons in 1985, and to 6 million tons in 1990s (Table II). The big increase of palm oil in Malaysia is mainly dependent upon cultivation of idle land by FELDA, new hybrid seeds yielding bigger harvest and oil and pollination by the weevil.

Malaysia exported 3 million tons of palm oil and products in 1982, 93% of which was palm oil products (Table III). This figure was equivalent to 85% of total production. Taking these into account, the development of industrial applications of palm oil and products is getting more and more important.

Vegetable Oil Production

The Dura species was first introduced into Malaysia, where it produced 2.5 tons per hectare of palm oil. Then, the hybrid species Tenera from Dura and Pisitera (1) increased productivity to 3.5-4.5 tons/hectare in the 1960's. Now, the new hybrid species of *Elaeis guineensis* (Africa) and *Elaeis oleifera* (South America) are cultivated to grow short-height palm trees. The average vegetable oil productivity is shown in Table IV (2). The productivity of palm oil in Malaysia is considerably higher than in other places because of the mild climate and good soils for growth. For example, the productivity of soybean oil is only 0.3 tons/hectare.

TABLE II

Production of Palm Oil Including Projected Growth to the Year 2000

	1970/72 (Average)	1980	1985	1990	2000
			(1,000 metric tons)		
World	2,220	5,060	6,000	6,900	8,000
Malaysia	580	2,580	4,000	5,000	6,500

Source: FAO and Hewin International, PORIM Occasional Paper, Palm Oil Update.

TABLE III

Exports of Crude Palm Oil and Palm Oil Products from Malaysia

Year	Crude palm oil	Palm oil products	Total	Palm oil products as percent of total exports
	(1,000 metric tons)			
1975	757	203	1,160	17.5
1976	877	457	1,334	34.3
1977	701	726	1,427	50.9
1978	574	1,116	1,690	66.0
1979	358	1,595	1,953	81.7
1980	197	2,086	2,283	91.4
1981	153	2,330	2,483	93.8
1982	201	2,784	2,985	93.3

Source: Oil Palm Monthly Statistics of Malaysia.

TABLE IV

Average Oil Yield of Oilseed Crops (2)

Crop	Average oil yield (kilograms/hectare)	Index
Soybean (U.S.)	319	9
Palm (Malaysia)	3,475	100
Sunflower (U.S.)	589	17
Rapeseed (Canada)	409	12
Cottonseed (U.S.)	140	4
Peanut (U.S.)	790	23

Fatty Acid Composition

Fatty acid compositions and characteristics of palm oil (3), soybean oil and tallow are shown in Table V. The palm oil, consisting mainly of palmitic and oleic acids, has a high melting point compared with other vegetable oils. In comparison with tallow, the iodine value is about the same. Although the iodine values are similar, the balance of palmitic, stearic and linoleic acids are different. The palm oil has the potential to substitute either for soybean oil in food or for tallow in industrial purposes.

Palm oil will become a more important resource in world trade market in the future because it shows a steady increase in production, it can provide liquid or solid edible fats and it is a potential substitute for tallow.

OLEOCHEMICAL PROCESSES, DERIVATIVES AND APPLICATIONS

Oleochemical Processes

The main oleochemical processes and oleochemicals derived from palm oil are shown in Figure 1. Oleochemical processes are divided into hydrolysis and methanolysis. One must choose the process by considering the final products to be produced. The basic oleochemicals are fatty acids, methyl esters, fatty alcohols, fatty amines and glycerine.

Derivatives and Applications

Industrial uses of palm oil are fundamentally similar to those of tallow. Various kinds of fatty derivatives and applications derived from basic oleochemicals are shown below:

1. Fatty acids could be used for soaps, rubbers or surfactants.
2. Hydrogenated fatty acids could be used for metal soaps, surfactants or slipping agents.
3. Oleic acid could be used for amides, slipping agents or surfactants for textiles. Amides are important slipping agents for polyolefins.
4. Sulfated or ethoxylated alcohols could be used for detergents or surfactants for textiles.
5. Fatty acid esters derived from methyl, butyl or octyl alcohol could be used for plastics, textile processing or metal processing.
6. Fatty amines are used to produce cationic or amphoteric surfactants, and ethoxylated fatty amines for nonionic surfactants. Softening agents and dialkyl-dimethyl ammonium compounds for hair rinse ingredients constitute the biggest, most valuable area for fatty amines.
7. Glycerine is used for cosmetics and pharmaceuticals, and

TABLE V

Characteristics of Selected Oils and Fats

Product	Sop. value	Iodine value	Titer ('C)	Fatty acid composition (%)							
				C_{14}	C_{16}	C_{17}	C_{18}	$C_{16:1}$	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$
Palm oil	198.6	53.3	43	1.1	44.0	–	4.5	–	39.2	10.1	0.4
Palm olein	201.0	58.0	20	1.2	39.0	–	4.4	0.2	42.0	12.2	0.5
Palm stearin	200.7	41.9	50	0.4	54.2	–	5.0	–	31.6	7.1	0.2
Tallow (fancy)	197.0	49.0	44	2.7	24.3	1.2	18.0	4.4	44.7	3.0	0.5
Soybean oil	195.0	141.0	–		10.5	–	3.2	–	22.3	54.5	8.3

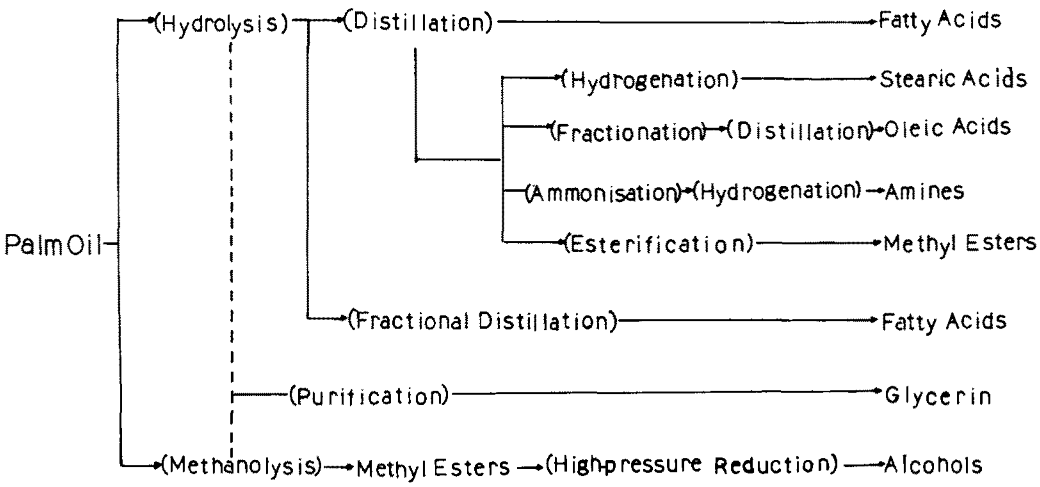

FIG. 1. Oleochemical processes and basic oleochemicals.

TABLE VI

Average Malaysian Locally Delivered Prices of Palm Oil and Palm Oil Products, 1982 (4)

Product	Actual price	Relative price
Crude palm oil	359	100
RBD palm oil	418	115
Crude palm stearin	334	90
Fatty acid distillate	275	75
Acid oil	276	75

Source: Acidchem Purchasing Department.

TABLE VII

Demand of Oils and Fats in Japan (Domestic)

Product	1971	1981
Edible use		
Vegetable oils	815 (74)	1,537 (82)
Animal fats	282 (26)	327 (18)
Subtotal	1,097	1,864
Industrial use		
Vegetable oils	205 (50)	206 (52)
Animal fats	203 (50)	188 (48)
Subtotal	408	394
Vegetable oils	1,020 (68)	1,743 (77)
Animal fats	485 (32)	515 (23)
Total	1,505	2.258

Source: Statistics of Japanese Ministry of Agriculture, Forestry & Fisheries.

( ): as percent of total or subtotal.

TABLE VIII

Imports of Palm Oil and Tallow to Japan

Product	1978	1979	1980	1981	1982
	(1,000 metric tons)				
Palm oil	141	139	148	141	148
Tallow	184	152	170	132	116
(Domestic)	(50)	(47)	(47)	(51)	(52)

Source: Statistics of Japanese Ministry of Finance, etc.
Palm stearin excluded.

the glycerine esters are used in the food industry. Products derived from vegetable oils are favored in these fields, so palm oil has a better position than tallow.

In order to use palm oil products for these purposes in the near future, technical data in comparison with tallow derivatives will be urgently needed.

PALM OIL PRODUCTS

The type of palm oil products to be used for industrial purposes will depend on the prices. Average Malaysian locally delivered prices of palm oil products are shown in Table VI (4). It is obvious that fatty acid distillate and acid oil formed by physical or alkali refining process would be potential resources for industrial uses. Recently, these byproducts have been considered for industrial uses in Malaysia with the development of fatty acid industries. Now, the physical refining process is favored over the alkali refining process by which more oil could be lost, although the latter process leaves more tocopherols in oils. Fatty acid distillate production will reach 200 thousand tons, about 5% of crude palm oil production, in 1990.

Malaysia exports large amounts of palm oil products, which added up to 93% of total production in 1982 (Table III). One reason for high imports is that the Malaysian Government imposes more export tax on crude palm oil than on palm oil products, in order to protect the domestic industries. Therefore, it is not favorable for oil importing countries to use crude palm oil from Malaysia for industrial uses. Palm stearin (35-40% palm oil fractionated) will be a potential substitute for tallow because palm olein will be in great demand as liquid oil for food. For these reasons we should consider that fatty acid distillate, acid oil, and palm stearin are the useful resources for industrial uses.

APPLICATIONS FOR PALM OIL IN JAPAN

Fat and oil consumption in Japan, with about 4% of world production, is shown in Table VII. Many kinds of oleochemical derivatives are produced from fats and oils. Palm oil products and tallow imports in Japan during the last 5 years are shown in Table VIII. Most palm oil products were from Malaysia, with 90 thousand tons of RBD palm oil, 60 thousand tons of RBD palm olein and 20 thousand tons of palm stearin imported in 1982. The total imports correspond to 5% of total exports from Malaysia, and most of them are used for food.

Fatty acid production in Japan was approximately 170 thousand tons in 1982, estimated from the consumption of

TABLE IX

Consumption of Oils and Fats as Raw Materials for Fatty Acid Production in Japan

Product	1978	1979	1980	1981	1982
	(1,000 metric tons)				
Tallow	70	64	89	104	94
Lard	a	a	21	20	33
Coconut oil	14	17	17	20	18
Others	16	26	18	19	22
Total	100	107	145	163	167

Source: Statistics of Japanese Ministry of International Trade & Industry.

[a] Included in others.

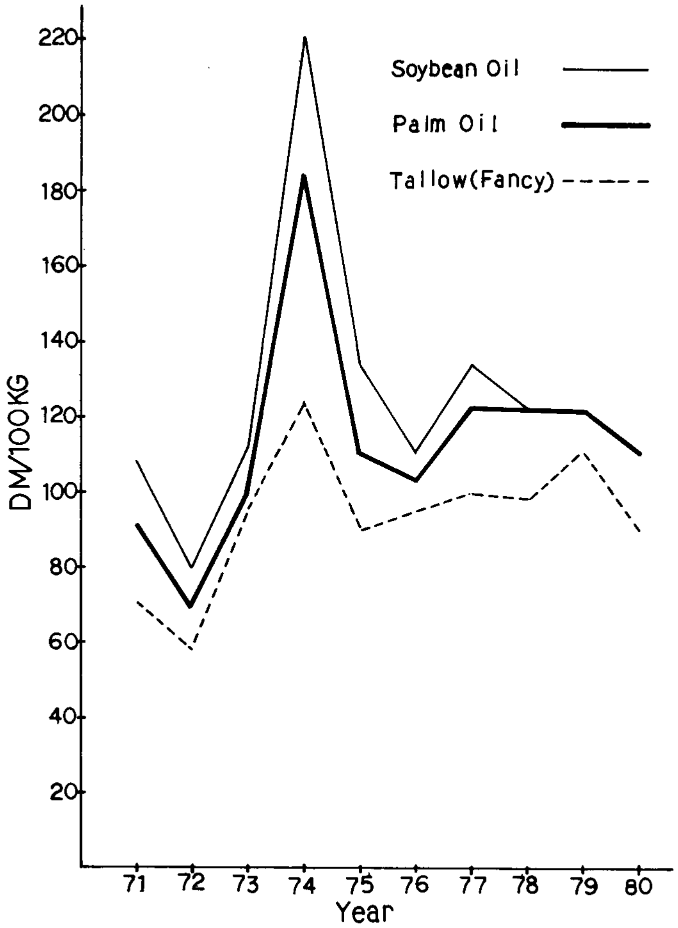

FIG. 2. Market price development, 1971-1980 (DM/100 kg, CIF Rotterdam).

TABLE X

C_{16}/C_{18} Distribution of Hydrogenated Fatty Acid from Palm Oil and Tallow

Product	C_{16}	C_{18}
Palm oil	64	54
Palm stearin	54	44
Tallow	28	67
Tallow stearic acid	41	52

fats and oils (Table IX). The annual imports of tallow are decreasing year after year on a percentage basis. This tendency is due to poor quality of imported tallow, increased domestic tallow production, including lard and a switch from tallow to vegetable oil (palm oil) for food. Eighty per cent tallow consumption is for industrial uses, mainly for hydrogenated fatty acids, split fatty acids and soaps.

The fatty acid industries are in a difficult situation with excessive production capacities and depression of the chemical industries themselves. Especially, slow growth of the rubber and plastic industries makes abundant stearic acid (hydrogenated fatty acid) a problem. As for palm oil products, only a small part of palm stearin has been used for the industrial uses in Japan.

PROBLEMS OF PALM OIL PRODUCTS FOR INDUSTRIAL USES

There seem to be two reasons why very little palm oil has been used for industrial uses. One is sufficient demand for food industry such as margarines and shortenings, and the other is its higher price relative to that of tallow.

Market Price

Price variations of crude palm oil, soybean oil and tallow during the last 10 years are shown in Figure 2. The price of palm oil has always kept its position between those of soybean and tallow. The price of tallow is relatively stable and the lowest of these resources, while the price of crude palm oil fluctuates following that of soybean oil. This tendency will continue to make tallow favorable. So it is accurate to say that the development of palm oil for industrial field is dependent upon its price. Palm oil is expected to exceed soybean oil in the world fat and oil trade, although current production is less than that of soybean oil.

Characteristics and Fatty Acid Compositions

Characteristics and fatty acid compositions of palm oil products and tallow are shown in Table V. The representative fatty acids of oleochemicals, stearic/palmitic (hydrogenated) and oleic acids are discussed in detail below.

Hydrogenated Fatty Acid (Stearic Acid)

Fatty acid compositions of palm oil, palm stearin and fractionated tallow (by the Henkel process) after hydrogenation are shown in Table X. The fatty acid composition of hydrogenated palm oil is similar to that of tallow stearic acid; however, hydrogenated tallow has approximately 15% more stearic acid than does hydrogenated palm oil. The ratio of palmitic acid to stearic acid makes a difference of melting point or crystalline structure, so tallow stearic acid is distinguished from tallow fatty acid. Palm stearin is characterized with high palmitic acid content, and this would change the property of metal soaps which are main derivatives of commercial stearic acids.

There are two types of commercial production processes for oleic acid. One is a crystallization process (5) such as Emersol or Henkel, and the other is fractional distillation. Characteristics of oleic acids obtained from fractional distillation of palm oil fatty acid (4) and from Henkel process of tallow fatty acid are shown in Table XI. These two oleic acids differ in titer and in content of stearic and linoleic acid. Higher percentage of stearic acid changes the property from liquid to solid, and the presence of linoleic acid makes the product more susceptible to autoxidation. Linoleic acid must be removed.

TABLE XI

Comparison of Oleic Acid Derived from Palm Oil with Tallow

				Fatty acid composition (%)							
Product	Acid value	Iodine value	Titer ('C)	C_{14}	C_{16}	$C_{16:1}$	C_{17}	C_{18}	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$
Palm oleic acid (fractional distillate)	195-203	94-98	29	–	0.5	–	–	7-9	70-74	17-18	1
Tallow oleic acid (Henkel process)	198-204	84-92	8↓	3	6	6-7	1	1	73-75	7-8	1

TECHNOLOGICAL SUBJECTS

Fractional Crystallization

Fractional crystallization of palm oil has been well studied for the development of food uses; however, less study has been done on their fatty acids. Fractional crystallization of palm oil fatty acids with hydrophilization leaves more palmitic acid in the liquid phase, because its higher palmitic acid content than tallow causes insufficient separation between liquid and solid phases. Therefore, the improvement of the hydrophilization process is needed for better separation of liquid and solid fatty acids in the future.

Selective Hydrogenation

In order to reduce the linoleic acid content in palm oleic acids from fractional distillation or fractional crystallization process, selective hydrogenation could be applicable, which will stabilize the quality of these products against oxidation. Generally, the palm oleic acids from both processes, without selective hydrogenation, may contain linoleic acid two to three times greater than tallow oleic acid contains. It is therefore necessary to reduce the linoleic acid content in palm oleic acid from the standpoints of stability and market specification.

Quality and Refining

Refining crude palm oil gives two kinds of byproducts: acid oil and fatty acid distillate. The latter is believed to be more important for future uses. For industrial uses, better quality with less color and less odor is needed. Refining processes are needed that will meet all requirements.

Hybridization

In Malaysia hybridization with tissue culture has been studied; it yielded bigger harvests. Some examples of hybrids include safflower oil with higher oleic content and rapeseed oil, called Canola, with lower erucic content. The target for palm oil in Malaysia seems to be an increase of unsaturated fatty acid content, an element that would be convenient for food uses with its higher polyunsaturated fatty acids. On the other hand, palm oil low in palmitic and linoleic acid would be favorable for industrial purposes.

ENZYMATIC HYDROLYSIS OF PALM OIL AND PALM STEARIN

We have studied enzymatic hydrolysis of fats and oils and would like to discuss it in regard to palm oil and stearin. There are two types of processes for the production of soaps: saponification and neutralization. The necessity of waste water treatment and glycerine recovery makes the saponification process unfavorable. Generally, fat splitting processes employing high pressure and temperature (50 atm x 250 C) are being used worldwide. However, new processes involving less energy consumption are needed. The contamination of unsaponified esters in fatty acids is no longer a problem for the production of soaps.

Lipase, a well known catalyst for hydrolysis of fats and oils, has not been used commercially. One reason is that solid resources, such as tallow, are not suitable for enzymatic hydrolysis, because usual lipase maximizes its activity at 35-37 C. The temperature, higher than the melting point of tallow, makes lipase less active or inactive, which causes insufficient hydrolysis. The other reason is the slow reaction rate of lipase. A few days' continuous stirring is mechanically difficult, although a large volume of fat and oil and lipase aqueous solution should be effectively contacted with each other by sufficient agitation.

We developed a new enzymatic hydrolysis method, Solid Phase Hydrolysis, to resolve the above problems. This method is shown in Figure 3. The points of this new process are:

- Temperature of liquefied fats and oils is maintained at 35-45 C, then lipase aqueous solution is kept at 10-25 C.
- Both are mixed with homomixer to make emulsion like margarines. The temperature of the mixture will be 30-35 C; therefore, the mixture is solidified. Hydrolysis proceeds without agitation, and then completes during one to three days, depending upon the fats and oils.
- After the completion of hydrolysis, the temperature of the mixture is raised to 50-60 C to separate fatty acids from the aqueous glycerine solution. The hydrolysis rate by this process is very high and equivalent to that of general splitting process.

The comparison of the solid phase hydrolysis (SPH) and the liquid phase enzymatic hydrolysis (LPH) using tallow is shown in Figure 4, and the results for other fats and oils are shown in Table XII. Better hydrolysis rates (96-98%) were obtained in the case of palm oil products. I think that the SPH process is highly recommendable to produce fatty acids for soap production in Malaysia, where the climate is very suitable for the SPH process.

Fatty acids for soaps can be produced by using enzymatic hydrolysis without distillation. However, toilet soaps require fatty acids with rather higher quality, so refining of raw fats and oils should be required before enzymatic hydrolysis is used.

NEW POTENTIAL USES

Diesel Fuel

Ethanol, so-called biofuel, is used as a fuel in Brazil. The study of vegetable oils as diesel fuels is also being made in many countries. PORIM in Malaysia studied the use of palm methyl ester for this purpose. However, economical and technological problems remain to be solved.

A Substitute of *n*-Paraffins for Fermentation

It is well known that organic acids or amino acids can be

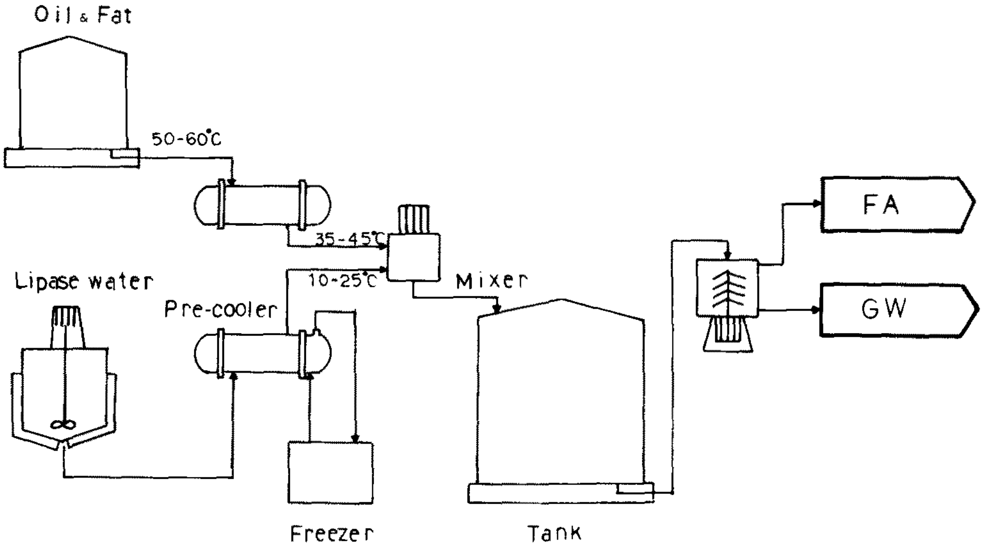

FIG. 3. Enzymatic hydrolysis process (SPH).

TABLE XII

Hydrolysis of Selected Oils and Fats

Enzymatic hydrolysis method		Hydrolysis (%)	
		Enzym. process	High-press. process
Solid phase	Bleachable fancy tallow	92	97-98
	Domestic tallow	95	97-98
	Palm oil	98	–
	Palm olein	97	–
	Palm stearin	96	–
Liquid phase	Soybean oil	96	–

Remarks: water/oil: 0.7; lipase: 100 unit/g-oil; 30 'C X 1 day.

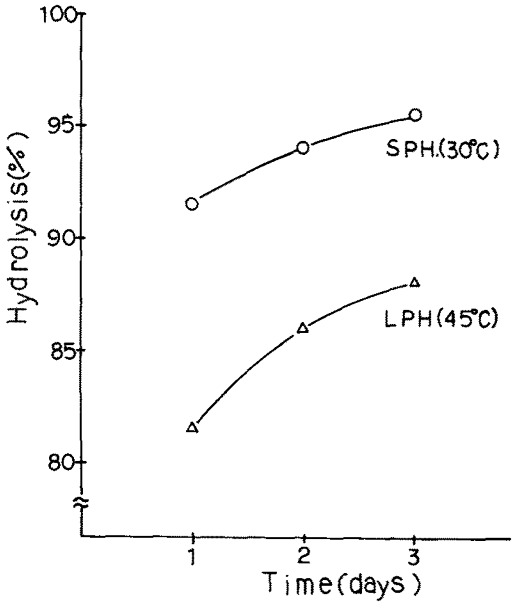

FIG. 4. Comparison of solid phase hydrolysis (SPH) with liquid phase hydrolysis (LPH) using tallow. Remarks: water/oil: 0.7; lipase: 100 unit/g-oil.

produced by fermentation of *n*-paraffins. Similar studies are made by using vegetable oils instead of *n*-paraffins. For example, Ikeno et al. reported that citric acid was obtained from palmitic, stearic and oleic acids with 100% yield by using the mutant of *Candida lipolytica* 281, and was also obtained from palm oil with 155% yield (6). The best conversion of *n*-paraffins could be obtained by using alkyl chain length of 16-18 carbons, and this is advantageous for palm oil. However, the usefulness of vegetable oils for other purposes, as well as economical problems with *n*-paraffins, seem to make people reluctant to commercialize *n*-paraffins.

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