

# An Introduction to Random Interesterification of Palm Oil

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## INTRODUCTION

Interesterification (IE) is the process of re-arranging the fatty esters within and between triglycerides resulting in most cases, a change in the physical properties of the oil/fat. It is a useful modification method to give the oil/fat the functionality required for a finished product. However, because of several reasons, IE has not been given due attention in the food industry as hydrogenation which is the preferred process specifically in the production of plastic products such as margarine and shortening. Only 10% of all edible oils and fats in the world are fractionated or interesterified while one-third is hydrogenated (Haumann, 1994).

Of late, IE fats have gained more attention as an alternative to hydrogenated fats due to increased concern of the negative effects of *trans* fatty acids, a product of hydrogenation. In Europe, some 300 000 t of oils and fats are interesterified every year to produce a variety of products with low *trans* fatty acid contents (Lim, 2001).

IE fats are also used in Canadian margarines by interesterifying palm oil and/or palm kernel oil with canola oil (Haumann, 1994). In the USA, hydrogenation is used predominantly. The use of IE is limited to improving the melting characteristics of specialty fats but the increased awareness on the ill effects of *trans* fatty acids and the forthcoming labelling legislation on *trans* by the FDA have motivated food processors in the country to look into IE fats in an attempt to reduce the *trans* fatty acid contents of their products.

In the production of plastic fats, hydrogenation hardens oils

while IE blends soft oils with hard fats to a desired functionality and consistency. Palm oil and its hard fraction, stearin, are excellent hard stocks for IE. By combining IE and other modification processes, many products such as shortenings, margarines and vegetable ghee with low *trans* or no *trans* at all can be formulated.

## INTERESTERIFICATION (IE) PROCESS

The random or chemical IE is the most applied IE modification process of oils and fats as it is simpler, cheaper and easier to carry out compared to directed or enzymatic IE. Chemical IE can be carried out by applying the following conditions:

- heat at > 300°C;
- heat with caustic soda at 200°C;
- heat with sodium methoxide or ethoxide at 80°C-100°C;
- heat with metallic sodium at 100°C-120°C; and
- heat with sodium/potassium alloy at 0°C.

Although IE can occur without a catalyst, the process requires a long time and high temperatures such as 300°C, which can cause the formation of undesirable by-products. On the other hand, the catalyst speeds up the reaction and lowers the temperature of reaction. Only the third and fourth of the processing conditions are widely used today. The commonly used catalysts are sodium methylate and ethylate followed by sodium metal, Na/K alloy and the hydroxides of Na and K in combination with glycerol. Some of these catalysts are shown in *Table 1*.

Sodium methylate and ethylate can be used as a dry powder or liquid *i.e.*, dispersed in a solvent such as xylene. They are inexpensive, easy to handle, react at low temperatures of 50°C-70°C, used in very low rates (0.1% if the starting material is well refined and dried; 0.2%-0.4% on average) and easily removed by simple water washing after the reaction.

However, the drawbacks are their widely varied quality, the need for an induction period before the reaction starts and the loss of oil due to formation of soap and methyl esters upon removal of the catalyst by washing with water (Sreenivasan, 1976). Though the loss of oil can be minimized by introducing carbon dioxide along with water during deactivation of the catalyst, the system will only work efficiently if there is a time lag between the catalyst neutralization and centrifuge separation of the fat and water phases (Going, 1967).

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TABLE 1. INTERESTERIFICATION CATALYSTS

Type	Example	Required dosage (% oil weight)	Time
<b>High temperature (120°C -260°C)</b>			
Metal salts	Acetates, carbonates, chloride, oxides of Zn, Fe, etc.	0.1%– 0.2% 0.2%	0.5 - 6 hr under vacuum
Alkali hydroxides	NaOH, KOH, LiOH or Sodium hydroxide + glycerol	0.5%– 1.0%	45 min - 1.5 hr under vacuum
Metal soaps	Sodium stearate + glycerol	0.5% – 1.0%	1 hr under vacuum
<b>Low temperature (25°C-270°C)</b>			
Metal alkylates	Sodium methylate	0.1%– 1.0%	5-120 min
Alkali metals	Na, K Na/K alloy	0.2%– 0.5%	3-120 min
Alkali metal hydrides	Sodium hydride	0.2%– 2.0%	30-120 min
Alkali metal amides	Sodium amide	0.15%– 2.0%	10-60 min

Sources: Sreenivasan (1978); Going (1967).

TABLE 2. FEEDSTOCK QUALITY AND REACTION CONDITIONS FOR INTERESTERIFICATION (IE)

Feedstock	
Oil/fat	Refined, bleached, deodorized
Water	< 0.02% preferably < 0.01%
FFA	< 0.1% preferably < 0.05%
PV	< 3 meq kg <sup>-1</sup> preferably < 1 meq kg <sup>-1</sup>
Phosphatides	< 0.01% preferably max 5 ppm
Conditions	
Catalyst	0.05%-0.1%
Temperature	90°C -150°C
Pressure	< 50 mbar
Reaction time	60 min

Source: Kellens (2000).

For an optimized IE reaction, the quality of the feedstock should be in the most refined condition possible (Table 2). The presence of water, fatty acids and peroxides will retard the catalytic activity of the catalysts. Thus, the oil should be neutralized or deodorized and dried under vacuum prior to the IE reaction to ensure a good result and to optimize the catalyst consumption. Palm oil and its fractions are readily available stocks for IE because they are available in refined, bleached and deodorized form.

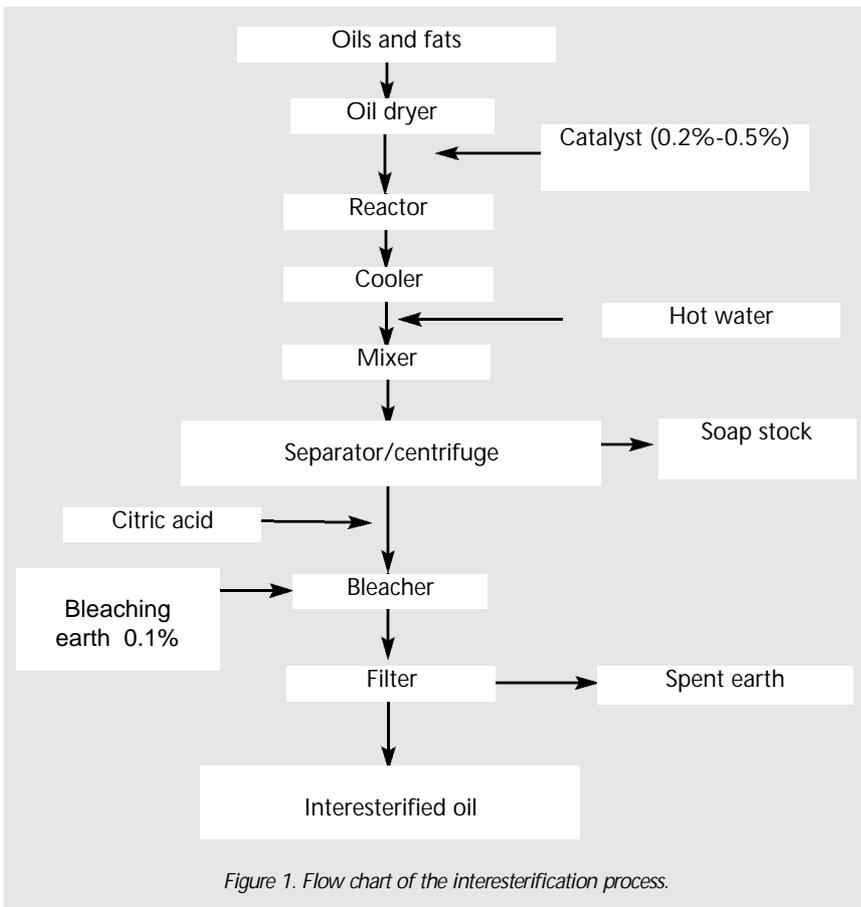
TABLE 3. INACTIVATION OF CATALYST BY CATALYST POISONS

Poison		Catalyst Inactivated (lbs/1000 lbs of oil)		
Type	Level	Na	CH <sub>3</sub> ONa	NaOH
Water	0.01%	0.13	0.3	-
Fatty acids	0.05%	0.04	0.1	0.07
Peroxides	1.0 meq kg <sup>-1</sup>	0.023	0.054	0.04
Total catalyst inactivated		0.193	0.454	0.11

Source: Kellens (2000).

Among the catalyst poisons (Table 3), water is the most potent and also the most difficult to be removed from the fat. The ideal water content is 0.01% which is difficult to achieve. The presence of 0.033% water will deactivate about 0.1% catalyst (Cook, 2000). To overcome the problem, he introduced partial pressure using nitrogen as the carrier gas to remove water during IE reaction. The system operates in a similar manner to that of the deodorization process.

Water is also used to terminate the IE reaction once equilibrium is achieved. This is the common



practice by the industry. The subsequent process is washing and drying of the IE fat. The process flow chart is shown in Figure 1.

The end point of the IE reaction can be determined by observing the colour changes during the operation. Once the reaction is completed, the colour of the oil changes from brown to dark brown. Usually, the reaction is allowed to continue for a couple of minutes more to ensure a complete IE process before termination. There are also other methods to determine the end point of the IE reaction, *i.e.*, by analysing the melting point of the oil, triglyceride profile and solid fat contents (SFC).

The melting point is a common method used to determine the end point of the IE process as it can give a faster result compared to other analytical methods. However, the melting point is less effective when there is little difference in the figures between the raw materials and end product. Glyceride analysis by TLC can also be used especially for a blend of soft oil with hard fat. Gas chromatography

of triglycerides is also a useful method to determine the end point of IE as the triglyceride profiles of the fat before and after IE are different. If the IE changes the melting characteristics of the fat of blend, SFC analysis can be employed (Kheiri, undated).

#### ECONOMICS OF INTERESTERIFICATION (IE)

About 40% of the operating cost is due to oil losses caused by the catalytic side reaction. The side reactions result in the formation of fatty acid methyl esters, soaps and mono- and di-glycerides. Theoretically, each 0.1% MeONa will produce: 0.58% fatty acid methyl ester, 0.58% soap, 1.2%-2.4% mono- and di-glycerides.

These products are removed during processing and subsequent treatments (neutralization, bleaching and deodorization). Theoretically, IE with 0.1% catalyst may cause processing losses of well over 2% (Cook, 2000). The loss can be minimized if the process is controlled carefully. During a

factory trial, Kheiri *et al.* (1989) were able to control the processing losses to below 2% using a higher catalyst dosage of 0.2%.

With high quality feedstock such as RBD palm oil with low moisture and free fatty acid (FFA) contents and low peroxide value (PV) value, the consumption of catalyst can be reduced to as low as 0.3%-0.5%. For example, if the consumption of catalyst is reduced from 1 kg t<sup>-1</sup> oil to 0.5 kg t<sup>-1</sup> oil, the overall operating cost can be reduced by about 40% or *e.g.* from US\$ 38 t<sup>-1</sup> to US\$ 23 t<sup>-1</sup> (Kellens, 2000). In general, the comparative operating costs of hydrogenation, IE and fractionation are given in Table 4.

IE is cheaper than hydrogenation in terms of operating cost. Judging from the fact that IE can use cheaper raw materials, such as palm stearin, *etc.*, the overall cost of production of IE fats can be well below the cost of hydrogenated oil. Kheiri *et al.* (1989) calculated the cost advantage of using IE to produce vanaspati [IE blend of SBO:POs (40:60)] in comparison with hydrogenation in a factory trial:

Saving in chemicals (Rs t <sup>-1</sup> )	-97.60
Saving in electricity (Rs t <sup>-1</sup> )	+178.60
Saving in fat blend (Rs t <sup>-1</sup> )	+282.60
<b>Total savings per tonne of oil</b>	<b>+363.60*</b>

- Notes: i. Electricity consumption was calculated at Rs1 kW<sup>-1</sup>  
 ii. Rs = Pakistani rupee.  
 \* Equivalent to about US\$ 20 at the exchange rate then.

The capital cost to build an IE plant with a capacity of 100 t<sup>-1</sup> day of oils and fats is lower than that for a hydrogenation or fractionation plant of the same capacity (Lim, 2001). In fact, with some modification, any neutralization or bleaching vessel can be used for IE. Some plant manufacturers have even built a switchable IE-hydrogenation plant.

**TABLE 4. OPERATING COSTS OF HYDROGENATION, INTERESTERIFICATION (IE) AND FRACTIONATION**

Process	Operating cost/t (RM)	Major operating cost
Hydrogenation	30-70	Hydrogen, catalyst
IE	25-40	Oil loss, catalyst
Fractionation	5-10	Utilities

Source: Lim (2001).

**EFFECTS OF INTERESTERIFICATION (IE) ON OILS AND FATS PROPERTIES**

The physical nature of any fat or oil is determined by the chain length of the fatty acids, the unsaturation

of the fatty acids and the fatty acids distribution among the three hydroxyl groups. On IE of an oil or fat or their mixture, there is no change in their first two properties, *i.e.* chain length and saturation. However, there is a significant

change in the distribution of the fatty acids among the three hydroxyl groups of the glyceride molecules. This redistribution significantly alters the physical properties of the mixtures. The important changes are in their melting and crystallization properties.

**Effects on Melting Points**

IE may increase or decrease the melting point of an oil/fat. The effects of IE on a number of oils and fats are given in *Table 5*.

Each type of oil/fat or blend has its own pattern of melting point after IE. Randomization of a blend of oils and fats will usually have

**TABLE 5. MELTING POINT CHANGES DUE TO INTERESTERIFICATION (IE)**

Fat	Melting point (°C)	
	Before	After
*Soyabean oil	- 7	5.5
*Cottonseed oil	10.5	34
*Coconut oil	26	27.9
*Palm oil	39.8	47
*Cocoa butter	34.4	52.2
*Tallow	46.4	44.6
*Hyd. cotton oil:coconut oil (40:60)	57.8	41.1
*Hyd. palm oil:hyd. palm kernel oil (25:75)	50	40.3
**Soyabean oil:hyd. palm stearin (40:60)	45	38.6

Sources: \*Swern-Daniel (1964). \*\* Nor Lida *et al.* (2001).

**TABLE 6. EFFECTS OF INTERESTERIFICATION (IE) ON SOLID FAT CONTENT (SFC)**

SFI (°C)	Palm oil		Palm kernel oil		Palm mid fraction	
	Before	After	Before	After	Before	After
10	54.7	59.8	72.3	65.1	89.9	80.4
15	39.1	48.4	59.8	49.7	80.9	70.2
20	26.2	37.7	45.4	31.0	72.5	63.9
25	14.7	27.1	19.6	7.6	48.7	50.4
30	9.5	20.9	-	-	10.4	38.9
35	7.1	14.7	-	-	4.3	28.4
40	5.9	10.9	-	-	-	21.2

Note: SFI = solid fat index.  
Source: Flingoh *et al.* (1986).

significant differences in the melting point of the resultant oil/fat blend but, sometimes, the change is just within the experimental error which is quite difficult to interpret.

Randomization of liquid vegetable oils on their own causes an increase in their melting point. Randomization of non-lauric fats

with non-lauric liquid oils or with fats having lauric or other lower chain fatty acids reduces the melting point of the resultant fats.

**Effects on Solid Fat Content/Solid Fat Index**

IE will also change the melting behaviour of a fat or blend due to

the changes in the triglyceride components (*Table 6*). For instant, cocoa butter, which has a sharp melting profile, changes into a rather flat melting behaviour after IE due to the formation of high melting triglycerides.

**TABLE 7a. PARTIAL LIST OF TRIGLYCERIDE CARBON NUMBERS BEFORE AND AFTER INTERESTERIFICATION (IE)**

Carbon number	Palm kernel oil	IE palm kernel oil
36	21.1	16.4
38	16.2	16.2
40	9.6	12.7
42	9.2	18.6
44	6.8	10.4
46	5.5	5.8

Source: Sreenivasan (1978).

**TABLE 7b. EFFECTS OF INTERESTERIFICATION (IE) ON TRIGLYCERIDE CARBON NUMBERS**

Sample	Palm oil		Palm mid fraction		Palm kernel oil	
	Before	After	Before	After	Before	After
C28	-	-	-	-	0.5	1.3
C30	-	-	-	-	1.3	1.6
C32	-	-	-	-	6.3	5.4
C34	-	-	-	-	8.5	6.0
C36	-	-	-	-	22.3	17.1
C38	-	-	-	-	16.9	16.3
C40	-	-	-	-	9.7	12.3
C42	-	-	-	-	8.9	17.0
C44	-	-	-	-	6.6	9.6
C46	0.4	1.2	0.5	1.2	5.2	5.3
C48	6.2	11.0	4.2	18.6	5.9	5.1
C50	40.4	32.9	66.2	40.2	2.6	1.8
C52	41.2	37.9	24.3	31.0	2.5	0.7
C54	11.2	16.2	4.6	8.5	2.8	0.5
C56	0.5	0.2	0.3	0.4	0.1	0.1
C58	-	-	-	0.1	-	-

Source: Flingoh *et al.* (1986).

## Effects on TG Carbon Number

There is no change in fatty acid composition before and after IE. However, the carbon number of the oil or blend will change as the fatty acids have been rearranged randomly within and between the triglycerides (*Tables 7a and 7b*).

## CONCLUSION

IE is an alternative process for hydrogenation in the production of plastic fats such as margarine, shortening and even vanaspati. With the development of new technology over the past few decades, the major problem in IE, *i.e.*, high process losses, can be overcome. Furthermore, cheap raw materials such as stearin can be optimized in fat product formulations, which in turn, should be able to offset the loss during processing. The role of IE in fat modification will inevitably become more significant in future, as more and more people are more concerned about *trans* fatty acids. It is already a trend in some countries to use IE in the production of margarine and shortening. Sooner or later, food processors will have to opt for IE or risk losing their market share.

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