

HYDROGENATION IS OFTEN UNNECESSARY WITH PALM OIL

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The hydrogenation of oils is a well-known and long-established process in which the oils are made to react with hydrogen in the presence of a catalyst. This results in the conversion of many of the double bonds in unsaturated fatty acid residues into single bonds, *i.e.* the overall unsaturation of an oil treated in this way is reduced. This increases both the melting point and the stability of the oil to oxidation.

The increase in the melting point of an oil following hydrogenation can convert it into a solid or a semi-solid, an effect referred to as 'hardening'. The hardening of most vegetable oils is necessary before they can be used to make such products as margarine, shortenings and coating fats.

In addition, highly unsaturated oils are vulnerable to oxidative breakdown, which is initiated by oxygen attacking double bonds, and which gives rise to products with unpleasant flavours. By reducing the number of double bonds in an oil, hydrogenation also reduces its susceptibility to oxidative breakdown and accordingly improves its flavour stability.

The common edible oils and fats differ widely in their fatty acid composition, and consequently in their degree of unsaturation (*Table 1*). Soyabean oil is an example of a highly unsaturated oil which needs to be hydrogenated for most product applications (Sullivan, 1978; Applewhite, 1981). Hydrogenation reduces its unsaturation, thereby lowering its iodine value, raising the melting point and solid fat content, and improving the flavour stability. (The unhydrogenated oil has low stability and an unacceptable fishy flavour, and is therefore not normally used in commercial frying operations in Canada or in the USA, where a great deal of the oil is produced).

Table 2, taken from a survey by de Man (1989), shows the melting points and solid fat contents typical for frying oils and fats used in North America, and also the relevant properties of soya bean oil and palm oil. It is obvious that soya bean oil needs a considerable degree of hydrogenation to produce the required physical properties, whereas the properties of unhydrogenated palm oil are already close to those needed.

Hydrogenation of oils causes changes in the molecular structure of unsaturated fatty acids besides the removal of some of the double bonds, and several of these changes are being increasingly regarded as undesirable in relation to human nutrition. Thus the double bonds in natural oils and fats are mainly in the *cis* configuration, but in hydrogenated oils some of those remaining after the process have the 'unnatural' *trans* configuration, *i.e.* isomerization has occurred. For example some of the linoleic acid residues, which have two *cis* double bonds, are isomerized to the *cis, trans, trans, cis* or *trans, trans* configuration. The fatty acids of (unhydrogenated) soya bean oil include about 51% of *cis, cis* linoleic acid.

In addition to generating *trans* double bonds, hydrogenation can also induce the migration of *cis* double bonds to new positions. For example, in natural oleic acid the single *cis* double bond is at the n9 position, and during hydrogenation of an oil containing oleic acid residues the bond can shift to any position between n5 and n17. The *cis* monounsaturated isomers of oleic acid produced in this way are also 'unnatural' and their metabolism in humans is somewhat problematical.

The purpose of hydrogenating an oil is to increase its saturation but, as the survey by de Man (1989) shows, the degree of saturation of a hydrogenated oil which was originally highly unsaturated can exceed that of unhydrogenated palm oil. Also, the content of linoleic acid, an essential fatty acid, can be reduced to extremely low levels by hydrogenation (*Table 3*).

NUTRITIONAL EFFECTS OF TRANS FATTY ACIDS

In recent years there has been considerable research on the effects of *trans* fatty acids in the human diet (Booyens *et al.*, 1988; Enig, 1988; Mensink and Katan, 1990; PORIM, 1987; Vergroesen, 1972; Vergroesen and Gottenbos, 1975). In some respects the *trans* fatty acids behave like saturated acids (which is why the two categories are added together in *Table 3* and elsewhere). Early studies by Vergroesen (1972) and by Vergroesen and Gottenbos (1975) suggested that *trans* isomers of oleic acid raise cholesterol levels, though less markedly than saturated fatty acids.

TABLE 1. FATTY ACID COMPOSITION OF COMMON OILS AND FATS (%)

| Fatty acids | Coconut | Corn | Cotton seed | Olive | Palm | Palm kernel | Peanut | Safflower | Sesame | Soyabean | Sunflower | Lard | Tallow (Beef) |
|-----------------|---------|------|-------------|-------|------|-------------|--------|-----------|--------|----------|-----------|------|---------------|
| C8:0 | 6.0 | - | - | - | - | 3.0 | - | - | - | - | - | - | - |
| C10:0 | 6.0 | - | - | - | - | 4.0 | - | - | - | - | - | - | 0.1 |
| C12:0 | 44.0 | - | - | - | - | 51.0 | - | - | - | - | - | - | 0.3 |
| C14:0 | 18.0 | - | 1.0 | - | 1.0 | 17.0 | - | - | - | - | - | 1.5 | 3.1 |
| C15:0 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| C16:0 | 11.0 | 13.0 | 29.0 | 14.0 | 48.0 | 8.0 | 6.0 | 8.0 | 10.0 | 11.0 | 11.0 | 22.0 | 23.4 |
| C18:0 | 6.0 | 4.0 | 4.0 | 2.0 | 4.0 | 2.0 | 5.0 | 3.0 | 5.0 | 4.0 | 6.0 | 11.0 | 27.8 |
| C18:1 | 7.0 | 29.0 | 24.0 | 64.0 | 38.0 | 13.0 | 61.0 | 13.0 | 40.0 | 25.0 | 29.0 | 47.0 | 39.0 |
| C18:2 | 2.0 | 54.0 | 40.0 | 16.0 | 9.0 | 2.0 | 22.0 | 75.0 | 43.0 | 51.0 | 52.0 | 11.5 | 2.6 |
| C18:3 | - | - | - | 2.0 | - | - | - | 1.0 | 2.0 | 9.0 | 2.0 | - | 0.2 |
| C20:0 | - | - | - | - | - | - | 2.0 | - | - | - | - | - | 0.5 |
| C22:4 | - | - | - | - | - | - | - | - | - | - | - | - | 0.8 |
| Saturates | 91.0 | 17.0 | 34.0 | 16.0 | 53.0 | 85.0 | 13.0 | 11.0 | 15.0 | 15.0 | 17.0 | 34.5 | 55.8 |
| Monounsaturates | 7.0 | 29.0 | 24.0 | 64.0 | 38.0 | 13.0 | 61.0 | 13.0 | 40.0 | 25.0 | 29.0 | 47.0 | 39.1 |
| Polyunsaturates | 2.0 | 54.0 | 40.0 | 18.0 | 9.0 | 2.0 | 22.0 | 76.0 | 45.0 | 60.0 | 54.0 | 11.5 | 3.6 |

TABLE 2. MELTING POINT AND SOLID FAT CONTENT OF FRYING FATS ^a

| Sample | Drop Point (°C) | Solid fat content at temperature indicated (%) | | | | | |
|--------------|-----------------|--|------|------|--------|------|------|
| | | 5°C | 10°C | 20°C | 25°C | 30°C | 35°C |
| 1 | 41.1 | 73.9 | 67.2 | 47.2 | 41.5 | 29.5 | 14.9 |
| 2 | 45.8 | 55.4 | 58.6 | 34.3 | 31.1 | 24.5 | 16.5 |
| 3 | 44.8 | 49.9 | 44.0 | 29.1 | 25.9 | 20.2 | 12.7 |
| 4 | 44.5 | 51.6 | 44.9 | 27.3 | 23.5 | 16.1 | 8.7 |
| 5 | 42.5 | 56.5 | 50.7 | 34.2 | 29.1 | 19.5 | 10.4 |
| Soyabean oil | liquid | | | | liquid | | |
| Palm oil | 39.8 | 67.6 | 57.8 | 26.8 | 16.1 | 9.5 | 6.7 |

^a from de Man (1989).

TABLE 3. FATTY ACID COMPOSITION OF FRYING FATS (%)^a

| Fatty Acids | 1 | 2 | 3 | 4 | 5 | Soyabean oil | Palm oil |
|----------------------|--------------|----------|----------------------------------|----------|------------------|--------------|----------|
| C12:0 | 5.8 | 0.1 | 0.1 | trace | trace | - | - |
| C14:0 | 2.1 | 3.4 | 3.0 | 0.1 | 0.1 | - | - |
| C16:0 | 10.4 | 26.1 | 24.9 | 13.1 | 5.0 | 11.0 | 46.2 |
| C18:0 | 13.1 | 22.1 | 20.1 | 9.9 | 14.5 | 4.0 | 4.1 |
| C18:1 | 67.2 | 40.8 | 41.0 | 68.2 | 75.1 | 25.1 | 37.2 |
| C18:2 | 0.5 | 0.4 | 6.0 | 7.5 | 0.6 | 51.0 | 9.6 |
| C18:3 | 0.3 | 0.4 | 0.5 | 0.5 | 0.9 | 9.0 | 0.7 |
| Total <i>trans</i> | 46.4 | 4.2 | 5.7 | 36.9 | 40.0 | - | - |
| Saturates | 31.4 | 51.6 | 48.1 | 23.1 | 19.6 | 15.0 | 52.0 |
| Total | 77.8 | 55.8 | 53.8 | 60.0 | 59.6 | - | 52.0 |
| Probable composition | CNO PhSBO | Beef fat | Beef fat and Ph vegetable oil | Corn oil | Ph vegetable oil | SBO | Palm oil |

^a from de Man (1989)

CNO = coconut oil

Ph = partially hydrogenated

SBO = soyabean oil

TABLE 4. FATTY ACID COMPOSITION (%) OF SOME SHORTENINGS IN THE USA

| Fatty Acids | Crisco Shortening | All vegetable Shortening | Palm Stearin and SBO 60:40 |
|--------------------------------|-------------------|--------------------------|----------------------------|
| C14:0 | 0.3 | 0.4 | 0.9 |
| C16:0 | 17.9 | 20.6 | 38.6 |
| C18:0 | 8.3 | 10.5 | 4.1 |
| C18:1 <i>trans</i> | 14.5 | 18.8 | 0.1 |
| C18:1 <i>cis</i> | 23.9 | 28.7 | 29.8 |
| C18:1(modified) | 10.9 | 11.1 | - |
| C18:2 <i>trans,trans</i> | 0.3 | 1.5 | - |
| C18:2 <i>cis,cis</i> | 20.8 | 7.1 | 21.0 |
| C18:3 | 1.3 | 1.0 | 3.0 |
| C20:0 | 0.6 | 0.3 | - |
| C22:0 | 0.3 | - | - |
| Saturates | 28.3 | 31.8 | 43.6 |
| Monounsaturates | 49.3 | 58.6 | 29.9 |
| Polyunsaturates | 22.4 | 9.6 | 21.0 |
| <i>Trans</i> fatty acids | 14.8 | 20.3 | 0.1 |
| Modified <i>cis</i> fatty acid | 10.9 | 11.1 | - |
| Total saturates | 42.1 | 52.1 | 43.7 |
| Total modified acids | 25.7 | 31.4 | - |
| Composition | PhSBO+Palm | PhSBO+PhCSO | Palm+Soya |

TABLE 5. 'TRANS-FREE' MARGARINES: INGREDIENTS AND FATTY ACID COMPOSITION (%)

| Fatty Acids | Ingredients | |
|-----------------|--|--|
| | Palm Oil: 57 Palm Olein: 23 Canola: 20 | Interesterified mixture: 66 ^a Sunflower Seed Oil: 34 |
| C8:0 | - | 0.7 |
| C10:0 | - | 0.5 |
| C12:0 | 0.3 | 6.6 |
| C14:0 | 0.9 | 2.6 |
| C16:0 | 35.9 | 28.6 |
| C18:0 | 3.7 | 3.9 |
| C18:1 t+i | 0.7 | - |
| C18:1C | 43.4 | 27.2 |
| C18:2 TC | 0.2 | - |
| C18:2 CT | 0.2 | - |
| C18:2 CC | 11.4 | 28.6 |
| C20:0 | 0.5 | 0.2 |
| C18:3 | 2.2 | 0.3 |
| Others | 0.8 | - |
| Saturates | 41.3 | 43.1 |
| Monounsaturates | 44.1 | 27.2 |
| Polyunsaturates | 13.8 | 28.9 |
| <i>Trans</i> | 0.9 | - |

^a The interesterified mixture contained palm stearin (60), palm kernel olein (20), sunflower seed oil (20).

More recently, Mensink and Katan (1990) concluded that *trans* fatty acids were hypercholesterolemic as compared with oleic acid, and that they produced an unfavourable lipoprotein profile: the level of LDL cholesterol was higher and that of HDL cholesterol lower on a diet with *trans* fatty acids than on one with saturated fat, so that the ratio of LDL to HDL cholesterol was raised.

Research in this area continues and caution is now being suggested with regard to the intake of *trans* fatty acids, especially for patients at increased risk of atherosclerosis.

PALM OIL OFTEN NEEDS NO HYDROGENATION

In the preparation of margarines and shortenings, the fat must possess a certain plasticity, which implies that fully liquid oils must be hardened to the right consistency before use, and in fact hardened vegetable oils constitute the main ingredient of margarines, shortenings and frying fats. Palm oil, though also of course a vegetable oil, requires no hydrogenation in many applications. Being semi-solid it can be used as a major ingredient in blends with other oils and fats. The availability of palm stearin, which is harder than unfractionated palm oil, offers further possibilities for producing blends of a particular consistency.

A survey of some margarines and shortenings in the USA (de Man, 1989) showed that the *trans* fatty acid content and the saturation level varied between different brands. A comparison between shortenings made entirely of hydrogenated vegetable oils and one made from palm stearin and soya bean oil showed that the latter was virtually free of *trans* fatty acids, whereas the former had significant levels of them. The blend with palm stearin was also free of the modified (isomerized) *cis* fatty acids derived from hydrogenated oils and present in the shortenings made from them. Finally, since *trans* fatty acids are taken to be dietetically equivalent to saturated fatty acids, the blend of palm stearin and soya bean oil had a lower total saturation level than the other products (Table 4).

In preparing 'trans-free' margarine from palm oil or its fractions, interesterification as well as blending can be effective (Table 5).

Palm oil, palm stearin and palm olein are versatile materials with many applications in food products. Since they are free of *trans* fatty acids they can answer a demand which seems likely to grow as a result of the recommendation by nutritionists to reduce the intake of such fatty acids. There is also, of course, an underlying cost saving in the use of oils which require no hydrogenation.

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