Trans fatty acids – the options

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Fats in general seem to be having a difficult time of it in the popular media with both obesity and trans fats hitting the headlines – so what can we as food manufacturers do to address these issues? In this article I will look at the ins and outs of one of these problem areas – trans fatty acids.

What are trans fatty acids?

Fatty acids fall into two main groups – saturated and unsaturated. Saturated fatty acids contain no carbon-carbon double bonds and are naturally found in animal fats and in 'harder' vegetable oils such as cocoa butter, coconut oil, palm kernel oil and palm oil.

Unsaturated fatty acids have one or more double bonds in the carbon-carbon fatty acid chain. If they contain one double bond they are called 'monounsaturated'; if they contain more than one double bond they are called 'polyunsaturated'. Monounsaturated fatty acids are found in olive oil, palm oil, rapeseed oil; polyunsaturated fatty acids are found in sunflower oil, soyabean oil and safflower oil.

Apart from the number of double bonds an unsaturated fatty acid has, there is another distinction to be made and this is where 'trans' comes in. These double bonds can exist in two distinct molecular forms – the 'cis' form and the 'trans' form (Fig 1.) The naturally occurring form – at least, as far as vegetable oils are concerned – is the cis form. Some processes can produce the trans form.

How are trans fatty acids formed?

There are three main ways in which trans fatty acids can be formed in fats.

The first way can be considered to be the 'natural' way and is a result of microbial hydrogenation. It has long been known that trans fatty acids are present naturally in some animal fats, particularly in both the milk fats and the carcass fats of ruminant animals such as cattle and sheep. They are produced by microbial hydrogenation of polyunsaturated fats within the animal's rumen. Typically trans fatty acids levels between 3% and 8% are produced in this way, so we have been consuming trans fatty acids from these sources for centuries! In the new Danish legislation trans fatty acids in animal fats such as these are specifically excluded. Excluding trans fatty acids from animal sources in this way is likely to cause considerable problems in 'policing' the legislation because current analytical methods are unable to distinguish accurately between trans fatty acids from vegetable sources and those from animal sources. It is also the view of FEDIOL, the European Federation of Oil Processors that there is no scientific substantiation to say that the impact of vegetable-derived trans fatty acids on cholesterol levels is worse than animal-derived trans fatty acids.

A second way or forming trans fatty acids is by subjecting oils and fats to excessive heat. If fats are subjected to very high temperatures then the cis double bonds naturally present in the oil can start to isomerise to trans double bonds. Normally the processing conditions used to refine oils and fats are such that this isomerisation is minimized to below 1% and therefore, this transformation is not considered to result in a major source of trans fatty acids in the diet.

Much more important as a way of introducing and forming trans fatty acids is partial hydrogenation. Because of its widespread use this is the process that is coming under major scrutiny, debate and legislation. Hydrogenation is a process in which an oil is reacted with hydrogen in the presence of a catalyst. During hydrogenation there are two competing processes that can occur. The first is saturation in which a molecule of hydrogen is added directly across the double bond to give a saturated single bond. This process does not generate trans fatty acids. The second process is one in which a cis double bond isomerizes to give a trans double bond. The result is a fat with a completely different melting point and melting profile to that of the starting oil. This then has enabled an oils and fats producer to define very specifically fats with particular levels of trans fatty acids and, indeed, saturated fatty acids to give specific attributes and functionality to the end product.

Why have hydrogenated fats been used?

There have been a number of reasons.

Firstly it has enabled food manufacturers to have access to fats with a wide range of melting profiles and melting points from what are initially simple oils. Secondly, it has been used to improve oxidative stability both by reducing the levels of the more unstable polyunsaturated fatty acids and by converting cis fatty acids into the more oxidatively stable trans fatty acids. Finally, hydrogenated fats do have some very specific functional characteristics, such as crystallization and aeration properties, that may be difficult to achieve by other means.

What are the options?

Having summarised what trans fatty acids are and how they are formed during hydrogenation, we now come to the very important question of what are the options? What can we do to replace these fats with trans-free alternatives?

The first question that needs to be asked is 'why are you using a hydrogenated fat?' This then will lead on to numerous other questions:

- Is the fat being used to give a particular melting profile or melting point to the food or to provide some form of structure to the food?
- Or is it to enhance the oxidative stability of the product or process?
- Is the product to be aerated?
- Is gloss retention important?
- Are some processing options, for example tempering of a coating or a filling, to be excluded simply because the equipment is not available?
- Is crystallization rate a critical factor in the process?
- …..and many others.

Because there are many reasons why you might be using a hydrogenated fat I have chosen to look mainly at what is probably the main reason for using these fats, that of providing structure, solid fat, a melting profile or melting point to the end product.

If we think of, for example, confectionery products then clearly confectionery coatings need to have a fairly high level of solid fat at ambient temperatures yet they also need to have melted completely at mouth temperature. So a specific melting profile is necessary meaning that some solid fat is needed. If this solid fat cannot be generated by means of hydrogenation then at least we must start from oils that have naturally occurring amounts of solid fat.

Many of the basic oils used to produce the fats used in the food industry are liquid at 20C (Table 1). In order to have some solid fat in a basic unprocessed oil it is necessary to base products on oils such as coconut oil, palm kernel oil, palm oil, cocoa butter

Having defined what basic oils we can use, what processing options do we have to produce trans-free fats?

F**ractionation**.
Fractionation is a process in which an oil is held at a specific temperature such that it is partially liquid and partially solid. The two phases are then separated by filtration to give a liquid and a solid fraction. The solid fraction has clear uses and benefits as an alternative to a hydrogenated fat.

Complete hydrogenation
One of the possibilities with hydrogenation is to completely hydrogenate an oil. This means that all of the original unsaturated double bonds are converted to saturated single bonds. As there is no unsaturation remaining at the end of the process there are then no trans fatty acids remaining so the product can then be considered to be effectively trans-free. However, there are two drawbacks with this process as it stands. Firstly, the oil must still be declared as 'hydrogenated' in the ingredient listing. Secondly, most vegetable oils when they are completely hydrogenated have a melting point well above mouth temperature and are therefore in themselves quite unpalatable.

This means that, whilst fully hydrogenated oils can be used they then have to undergo some further processing to ensure palatability of the end product. For example …

Interesterification.

Interesterification is a process in which the fatty acids on the triglyceride molecules change their positions and effectively interchange with each other. Interesterification will, therefore allow a fully saturated fat such as that obtained by complete hydrogenation to interchange with, say, a non-hydrogenated but much more unsaturated oil to give a mix of triglycerides that have a final melting profile tailored to specific applications. In such a case it would again be necessary to declare the fat as 'hydrogenated'. However, it is also possible to interesterify non-hydrogenated fats (which may also have been fractionated) together to give the desired melting profile. In this case the declaration would simply be 'vegetable fat'.

Blending

This is the simplest of all process options, but is one which allows considerable flexibility because any of the products of the processes already considered can then be used as components of a blend. This means that blends of unfractionated, non-hydrogenated fats, fractionated, non-hydrogenated fats, fully hydrogenated fats and interesterified fats can be produced, all of which will allow a trans-free declaration (although perhaps not a 'non-hydrogenated' declaration).

Having said that the main feedstocks to these processes (in terms of oils which already contain some solid triglycerides) are palm oil, palm kernel oil, coconut oil and cocoa butter, the most versatile and flexible of these four oils is palm oil. Why? Firstly, cocoa butter is much more expensive than the other oils and therefore only of use in very specialized applications. Secondly, the high levels of saturates in palm kernel oil and coconut oil means that using these as alternatives to trans-containing systems could mean increasing the saturates level unduly in the trans-free alternative.

Palm oil, however, has a composition such that:

- it will allow three (and, possibly, even more) fractions of distinctively different composition, functionality and application to be produced by fractionation,
- one of these is very high melting and can function in similar ways to a completely hydrogenated system – without the need to declare hydrogenation on the label,
- each of these fractions can then be used in other processes (interesterification and/or blending) to give a very broad spectrum of final products,
- the naturally high levels of tocopherols present in palm oil will help to maintain oxidative stability whilst keeping the saturates levels in the end product much lower than could be obtained with palm kernel oil or coconut oil.

There is however a warning to be attached to these options. It is not always simply a matter of matching the melting profile of whatever hydrogenated fat is being replaced. There are often other factors that need to be taken into consideration in making this change.

- In many products, the hydrogenated fat being replaced is not the only fat in the system. Fats of different types interact with each other in different ways so it is important to also consider the characteristics of the total fat phase, especially in terms of melting profile and crystallization.
- Because hydrogenated fats and their non-hydrogenated 'equivalents' can sometimes crystallize in different ways it may be necessary to modify cooling or crystallization conditions. In some instances it may be necessary to include either a pre-crystallisation or even a tempering stage.
- Fats can also behave differently on storage. Hydrogenated fats can show a tendency to post-harden on storage. In other words the solid fat content can increase with time. In some cases the product may be designed with this in mind and if it doesn't happen because the hydrogenated fat has been replaced, then the characteristics of the product could change. On the other hand, this lack of post-hardening in a non-hydrogenated fat could be seen as an advantage.
- Hydrogenation improves oxidative stability so replacing a hydrogenated fat with a non-hydrogenated alternative may affect stability. This is not to say that it will but it is always something that needs to be considered.
- And, finally, replacing hydrogenation with other processes which may be more expensive can also have an effect on the price of the final oil.

So, what should you do?

First, decide what your limitations are.

- Does the product simply have to be trans-free or does it also have to be non-hydrogenated?

- Are potential changes to processing conditions a problem?

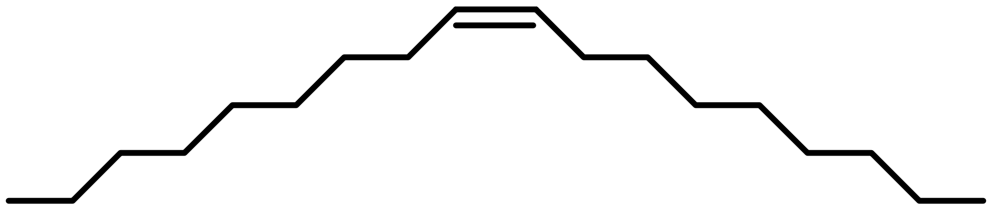
- What limitations are there on post-production shelf-life and stability, both in terms of oxidative changes and physical changes such as post-hardening?

Having defined what your constraints and limitations are the best approach is then to discuss these with the experts in the oils and fats industry for advice on what the alternatives are and for assistance with their introduction into your products and applications. Loders Croklaan has over a century of experience in the production and application of oils and fats in the food industry. As a fully global company it is ideally placed to help and advise on trans-free alternatives wherever in the world you are and whatever your application might be.

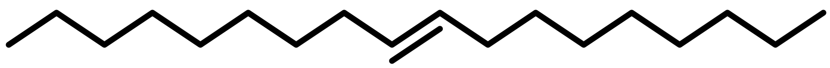
Table 1 **Solid Fat Contents of Vegetable Oils at 20°C**

Sunflower oil	Liquid
Soyabean oil	Liquid
Groundnut oil	Liquid
Cottonseed oil	Liquid
Rapeseed oil	Liquid
Olive oil	Liquid
Coconut oil	38%
Palm kernel oil	43%
Palm oil	25%
Cocoa butter	76%

Figure 1 **Configurations of cis and trans fatty acids**



Cis - monounsaturated chain



Trans-monounsaturated chain