2.32 Fatty Acids

Fatty acids are lipids themselves, and they are also components of triglycerides and phospholipids. Like carbohydrates, fatty acids are made up of carbon (C), hydrogen (H), and oxygen (O).

On one end of a fatty acid is a methyl group (CH₃) that is known as the methyl or omega end. On the opposite end of a fatty acid is a carboxylic acid (COOH). This end is known as the acid or alpha end. The figure below shows the structure of fatty acids.

![Figure 2.321 Structure of a saturated fatty acid](image)

There are a number of fatty acids in nature that we consume that differ from one another in three ways:

1. Carbon chain length (i.e. 6 carbons vs. 18 carbons)
2. Saturation/unsaturation
3. Double bond configuration (cis vs. trans)

1. Carbon Chain Length

Fatty acids differ in their carbon chain length (number of carbons in the fatty acid). Most fatty acids contain somewhere between 4-24 carbons, with even numbers (i.e. 8, 18) of carbons occurring more frequently than odd numbers (i.e. 9, 19). Fatty acids are classified as short-chain fatty acids, medium-chain fatty acids, and long-chain fatty acids based on their carbon chain length using the criteria shown in the table below.

<table>
<thead>
<tr>
<th>Classification</th>
<th># of carbons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short-Chain Fatty Acid</td>
<td>&lt; 6</td>
</tr>
<tr>
<td>Medium-Chain Fatty Acid</td>
<td>6-10</td>
</tr>
<tr>
<td>Long-Chain Fatty Acid</td>
<td>≥12</td>
</tr>
</tbody>
</table>
Carbon chain length also impacts the physical properties of the fatty acid. As the number of carbons in a fatty acid chain increases, so does the melting point as illustrated in the figure below.

![Graph showing melting point of saturated fatty acids of varied lengths](image)

Figure 2.322 The melting point of saturated fatty acids of varied lengths

Thus, shorter chain fatty acids are more likely to be liquid, while longer chain fatty acids are more likely to be solid at room temperature (20-25°C, 68-77°F).

2. Saturation/Unsaturation

A saturated fatty acid is one that contains the maximum number of hydrogens possible, and no carbon-carbon double bonds. Carbon normally has four bonds to it. Thus, a saturated fatty acid has hydrogens at every position except carbon-carbon single bonds and carbon-oxygen bonds on the acid end. Two examples of the same 18 carbon saturated fatty acid (stearic acid/stearate) are shown in Figures 2.321 and 2.323. Figure 2.323 is the simplified view of the this fatty acid.

![Simplified view of 18 carbon saturated fatty acid stearic acid](image)

Figure 2.323 A simplified view of 18 carbon saturated fatty acid stearic acid. Each corner of the zigzag pattern represents a carbon, and the hydrogens are not shown to allow quicker recognition of the carbon chain

Check Yourself

How many carbons are in this fatty acid (lauric acid)?
Unsaturation means the fatty acid doesn't contain the maximum number of hydrogens on each of its carbons. Instead, unsaturated fatty acids contain a carbon-carbon double bond and only 1 hydrogen off each carbon. The simplest example of unsaturation is a monounsaturated fatty acid. Mono means one, so these are fatty acids with one degree of unsaturation, or one double bond (shown below).

![Figure 2.324 Structure of the monounsaturated fatty acid (oleic acid)](image)

Any fatty acid that has two or more double bonds is considered a polyunsaturated fatty acid. As you may remember from the polysaccharide section, poly means many. A simple example of a polyunsaturated fatty acid is linoleic acid (shown below).

![Figure 2.326 Structure of the polyunsaturated fatty acid linoleic acid, a polyunsaturated fatty acid with two carbon-carbon double bonds](image)

3. Double Bond Configuration (Shape)

Double bonds in unsaturated fatty acids are in one of two structural orientations: cis or trans. In a trans orientation, the hydrogens on the carbons involved in the double bond are opposite of one another. In the cis orientation the hydrogens are on the same side of the bond. Steric hindrance in the cis orientation causes the chain to take on a more bent shape.
BYU has a nice website that allows you to interactively see the difference between cis and trans conformation.

Web Link

**BYU: Cis vs. Trans**

Most natural unsaturated fatty acids are in the cis conformation. As can be seen in Figure 2.327, the cis fatty acids have a more of kinked shape, which means they do not pack together as well as the saturated or trans fatty acids. As a result, the melting point is much lower for cis fatty acids compared to trans and saturated fatty acids. To illustrate this difference, the figure below shows the difference in the melting points of saturated, trans-, and cis-monounsaturated 18 carbon fatty acids.
There are some naturally occurring trans fatty acids, such as conjugated linoleic acid (CLA), in dairy products. However, for the most part, trans fatty acids in our diets are not natural, instead they have been produced synthetically. The primary source of trans fatty acids in our food supply is partially hydrogenated vegetable oil. The 'hydrogenated' means that the oil has gone through the process of hydrogenation. Hydrogenation, like the name implies, is the addition of hydrogen. If an unsaturated fatty acid is completely hydrogenated it would be converted to a saturated fatty acid as shown below.

However, this isn't/wasn't always desirable, thus partially hydrogenated vegetable oil became widely used. To visualize the difference in the amount of hydrogenation consider the difference between tub margarine and stick margarine.
Stick margarine is more fully hydrogenated leading it to have a much harder texture. This is one of the two reasons to hydrogenate, to get a more solid texture. The second reason is that it makes it more shelf stable, because the double bond(s) of unsaturated fatty acids are susceptible to oxidation, which causes them to become rancid.

Partial hydrogenation causes the conversion of cis to trans fatty acids. Originally, it was thought that trans fatty acids would be a better alternative to saturated fat (think margarine vs. butter). However, it turns out that trans fat is actually worse than saturated fat in altering biomarkers associated with cardiovascular disease. This has led New York City to ban trans fats as described in the first link below. But this does not mean that butter is a better choice than margarine as described in the second link.

**Web Links**

- MSNBC: New York Bans Trans Fats
- Butter vs. Margarine: Which is better for my heart?

**References & Links**


**Links**

- BYU: Cis vs. Trans - http://ps100.byu.edu/molecule_sg/trans_fats.html