Omega 3 Essential Fatty Acids

Introduction

The term lipid means fat whether it is a liquid oil or solid fat. Lipids have physical, chemical and physiological properties that make them important both in nutrition and in food technology. Both plant and animal foods contain a wide variety of different fats with different biological properties. All living cells contain some fat within their structure, as fatty acids (the building blocks of fat) are essential components of cell walls and intracellular membranes. Fatty acids are considered the physiologically active form of fats but as well as this, the human body also uses fat for energy storage. Interestingly plants manufacture fats through photosynthesis, which is the same process they use to manufacture carbohydrates. Animals meanwhile can manufacture fats from carbohydrate or protein in addition to reformulating fats directly from dietary intake.

We are all made constantly aware of the storage properties of fats in the body by the array of dieting magazines thrusting themselves at us every time we enter a newsagent's. What about some of the other properties of fat though? What benefits does it have that we should think about and remember before slating it as the scourge of our lives?

Essential Fatty Acids

One clearly beneficial type of fat is the essential fatty acids, so described because we have to take them in through our diet, we cannot manufacture them in our own bodies.

There are two families of essential fatty acids (EFAs), one called omega 3 and the other omega 6. Each family has a parent molecule from which the other members can be manufactured in the body. As such there are in fact only two essential fatty acids, Linoleic Acid (omega 6 parent) and Alpha Linolenic Acid (omega 3 parent).

Theoretically as long as we consume enough of these parent molecules then we will have sufficient essential fatty acids in our body to perform all the various functions we need them to. However, should there be an enzyme malfunction in the body, or if competition for enzymes from one family is too great then a problem might arise with the generation of the other family members, as you can see from the diagrams below. In addition to this the modern average diet tends to concentrate on the omega 6 family rather than the omega 3 family hence many people choose to supplement their diet with omega 3 fatty acids.

Why are the essential fatty acids (EFA) so important?

Fundamentally EFA are so important because they form a vital part of all cell membranes in all tissues. They keep cells flexible so help to improve communication between cells and allow for transfer of nutrients into cells. Specifically essential fatty acids form key structural building blocks and provide vital functions for the development and maintenance of healthy eyes and brain. From the fact that long chain polyunsaturated fatty acids and the sub group of these which are the essential fatty acids are crucial for the health of every cell in the body, it is therefore not surprising that an EFA deficiency can lead to a variety of problems throughout the body.

As well as having important structural roles EFA are the building blocks of active biochemical structures called Eicosanoids and also loosely categorised as “tissue hormones” such as:

- Prostaglandins
- Leukotrienes
- Prostacyclins
- Thromboxanes.

The functions of these vary enormously from helping in the coagulation of blood through to providing a balanced inflammatory response as supported by prostaglandins.

Prostaglandins

Prostaglandins are molecules that switch on or off special processes within the body cells. This enables the body to constantly react to the changing environment inside and outside the cells. Unlike hormones, which are synthesised by specific glands and transported in blood to where they are needed, prostaglandins are generally made where they are needed and then destroyed when they have completed their job so that their activity is potent, but short lived.

The prostaglandins are formed in body cells from either omega 3 or omega 6 polyunsaturated fatty acids. The story is a complex one, but the basic difference between the effects that the two families of fatty acids have upon the prostaglandins is one of opposing actions. If we take the case of blood cells aggregating (joining) together to plug a wound for example we can see how with a correct balance of fatty acids the platelet aggregation system can work correctly. If we trace the mechanisms back to their origins it is revealed that omega 6 fatty acids are responsible for the stimulation of rapid and dramatic aggregation of cells while omega 3 fatty acids inhibit excessive aggregation whilst only promoting mild aggregation. Therefore in order to achieve the desired level of aggregation to plug the hole, both are necessary and together will maintain a balance in these types of systems, a balance which is called ‘tissue homeostasis’.

Another example of the tissue balance is with inflammation. Broadly speaking the series 1 prostaglandins are mildly anti-inflammatory, the **series 2 prostaglandins are strongly pro-inflammatory** while the series **3 are strongly anti-inflammatory** and so getting the balance right between the intake of omega3 and 6 can help to make sure the appropriate inflammatory response is initiated.

The Omega 6 and Omega 3 Fatty Acid Families
The order of manufacture in the body and the where the prostaglandins are produced

	Omega 6 Family	Shared Enzymes	Omega 3 Family
1)	**Linoleic acid (C18:2ω6)**		**Alpha Linolenic acid (C18:3 ω3)**
		delta 6 desaturase	
2)	Gamma Linolenic acid (C18:3 ω6) (GLA) ↓		Stearidonic acid (C18:4 ω3) ↓
		elongase	
3)	**Dihomo Gamma Linolenc acid** (C20:3 ω6) (DGLA) ↓		Eicosatetraenoic acid (C20:4 ω3) ↓
	Series 1 prostaglandins		
		delta 5 desaturase	
4)	**Arachidonic acid** (C20:4 ω6) ↓		**Eicosapentaenoic acid (EPA)** (C20:5 ω3) ↓
	Series 2 prostaglandins		***Series 3 Prostaglandins***
		elongase	
5)	Docosatetraenoic acid(C22:4 ω6) ↓		Docosapentaenoic acid (C22:5 ω3) ↓
		elongase	
	(C24:4 ω6) ↓		(C24:5 ω3) ↓
		delta 6 desaturase	
	(C24:5 ω6) ↓		(C24:6 ω3) ↓
		beta oxidation	
6)	Docosapentaenoic acid (C22:5 ω6)		**Docosahexaenoic acid (DHA)** (C22:6 ω3)

Notes:

a) The key metabolic components of each pathway have been highlighted in bold. These are the ones worth knowing and recognising as they can have a profound effect on health.

b) The two intermediates between step 5 and 6 above do not have common names or recognised functions in their own right but have been added in for completeness.

c) Although both chains have Docosapentaenoic Acid in them it is important to note that these DPA molecules are different in each family. This is confusing but because the common name **Docosapentaenoic acid** designates any straight chain 22:5 it means that by name both appear the same. The omega 3 one however has a double bond at the omega 3 carbon but the omega 6 one doesn't have its first double bond until the omega 6 carbon in the chain.

Explanation of the above flowchart

The flowchart above shows the two parent molecules of the omega 3 and omega 6 families and the conversions they go through in order to produce the key fatty acids that research has indicated are so important in our daily lives.

Key Omega 6 fatty acids
Linoleic Acid – from which all other omega 6 fatty acids can be made in the body
Dihomo Gamma Linoleic Acid – from which the series 1 prostaglandins are made
Arachidonic Acid – from which series 2 prostaglandins are made as well as being an important structural fatty acid.

Key Omega 3 fatty acids
Alpha Linolenic Acid - from which all other omega 3 fatty acids can be made in the body
Eicosapentaenoic Acid (EPA) –active molecule from which series 3 prostaglandins are made
Docosahexaenoic Acid (DHA) – important structural fatty acid within all cells (particularly brain and eye)

An RDA for Omega 3?

Although there is no Recommended Daily Amount of Omega 3 that we should consume daily, a recent opinion from the European Food Safety Agency has proposed a Recommended Nutrient Intake (RNI) of 2g per day of Alpha Linolenic Acid. Alpha Linolenic Acid is present in small quantities in many plant foods but plants do not supply the preformed EPA and DHA, which are so useful to our bodies. At this stage there is no equivalent RNI if the omega 3 is taken directly as EPA and DHA because different people convert the parent omega 3 through to the EPA and DHA at different rates.

An indication of the level of EPA and DHA needed is provided by some authorities such as The International Society for the Study of Fatty Acids who suggest a combined EPA and DHA of 500mg per day or the UK government's Scientific Advisory Committee on Nutrition in 2004 who suggested a minimum of 450mg per day which can be obtained from consuming 2 portions of fish a week (one of which oily). However in many EU populations intakes of Alpha Linolenic Acid, EPA and DHA are typically lower than either of these recommendations. In the UK the typical EPA+DHA intake is around 250mg per day, hence many people may find it beneficial to supplement their diet and the easiest way to do this is through the consumption of fish oils.

Internal conversion of the essential fatty acids

The efficiency of conversion from the parent molecules through to the active long chain members is typically not great because the delta 6 desaturase is inefficient and the rate limiting step, bypassing this first step with GLA or EPA is therefore a sensible approach. Prof. Basant Puri of Imperial College London a world wide recognized expert in essential fatty acids recommends supplementation with other members of the omega 3 and 6 families rather than the parent molecules. His conviction is supported by Udo Erasmus in his book "Fats that Heal Fats that Kill" who quotes research suggesting that the conversion from Alpha Linolenic Acid to

EPA may be as low as 2.7%. This theory is further supported by Gerster who published a review of fatty acid conversion levels in the International Journal of Vitamin and Nutrition Research (68) 1998 who stated that in people with a saturated fat rich diet the conversion from ALA to EPA would be about 6% and 3.8% to DHA, these conversions would be about half as effective in people with an omega 6 rich diet (omega 6 to 3 ratio of at least 4:1).. On this basis the 2g of Alpha Linolenic acid quoted above could lead to as little as 60mg (3%)EPA and 40mg (2%)DHA, which is why some people choose to supplement with EPA and DHA if their diet is inadequate in these important fatty acids. Similar results were also found by James et al in *Am J Clin Nutr* 2003;77:1140–5 who compared ALA to Stearidonic Acid to EPA and found that the conversion of ALA to EPA was approximately 7%. Based on this slightly better score the following figures would result:

> 100mg Alpha Linolenic Acid will lead to approximately 7mg of EPA.
> 100mg Stearidonic Acid will lead to approximately 30mg EPA
> 100mg EPA will lead to 100mg EPA.

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Why is there a need to increase EPA and DHA consumption?

From the earliest civilisations thorough to about 100 years ago it was normal for the intake of omega 3 and 6 to be roughly equal. Today the typical western diet contains approximately 10 times as much omega 6 as omega 3. As a lot of the omega 6 is in the form of Linoleic acid this tends to monopolise the use of the delta 6 desaturase making it difficult to offset the balance between the two fatty acid families. Although one can try to combat this through supplementation with Alpha Linolenic Acid this doesn't help significantly because of the inefficiency of this rate limiting step and so in effect it is more efficient to supplement with the longer chain omega 3 fatty acids in order to best bring balance back to the diet and support positive health.

Some people choose to supplement with members of the fatty acid families other than the parent essential molecules. GLA (Gamma Linolenic Acid) or EPA and DHA from fish oil if their diet is inadequate in these important fatty acids are popular choices. Another option available to vegetarians is the use of stearidonic acid as a source of omega 3. Stearidonic is found in many foods but probably in richest concentration (2.5-4.5%) in blackcurrant seed oil. The ability to increase tissue concentrations of EPA by supplementing with stearidonic is 4 times better than from alpha linolenic acid but only about a third as effective as supplementing EPA directly.

A group at particular risk is the young. Babies obtain their supply of EPA and DHA from their mothers milk as they have a limited capacity to synthesise either from Alpha Linolenic Acid. During the first few months, perhaps up to the first year and a half (Prof. Basant Puri personal communication, 2006) of childhood development supplementing with DHA is particularly important as it makes up approximately 30% of the structural lipids in the grey matter of the brain and is very difficult for the child to manufacture its own. After this time though, the focus must shift to supplementing with EPA as it provides a more flexible option to the body. The body is capable and can choose to convert it into DHA if it wishes but otherwise can use it for example for the manufacture of the key series 3 prostaglandins and other eicosanoids.

Sources

There are many different dietary sources both animal and vegetable available to us for omega 3 and omega 6 fatty acids but the greatest activity comes from meat for omega 6 and fish for omega 3 as animals will provide the preformed long chain members of these fatty acid families. Interestingly it is because of the fact that fish consume algae which themselves are rich sources of EPA and DHA that fish is a much better source of omega 3 than land animals. New research is now leading to the development of algae farms to deliver these fatty acids to the supplementation market to provide sustainable supplies without the potential dangers associated with over fishing. As far as dietary sources are concerned it is simplest to consider fish as the best source of omega 3. Both fatty and white fish can supply omega 3 but while fatty fish can supply it to the diet, white fish only supply a significant amount through the processing of their livers into oil.

EPA and DHA

As far as supplementation is concerned the two primary sources of EPA and DHA are currently either Cod Liver Oil or Fish Body Oil from fatty fish such as Tuna, Anchovy or Sardines. Either are acceptable as sources of EPA and DHA but on the whole Cod Liver Oil tends to be less concentrated in the fatty acids while also providing vitamins A and D. The actual EPA and DHA content will vary significantly from one supplier to another and so it is always important to read the label and compare the actual EPA and DHA content with in most cases looking for the product that provides the most EPA.

Although fish are commonly seen as the most important source of omega 3 fatty acids they are not so good at providing the parent essential fatty acid Alpha Linolenic Acid (ALA). If people supplement with EPA and DHA there is a tendency to then forget about ALA however recent research has shown that ALA may lead to effects in the body different to EPA and DHA. The exact mechanisms as to why this may be the case, are yet to be understood and may or may not be relevant but for completeness they are worth mentioning at this point.

ALA

Research published by a team from Maastricht university in the European Journal of Clinical Nutrition (Vol. 60, pp. 978-984) has shown than eating a diet rich in the omega-3 fatty acid, alpha-linolenic acid (ALA), may positively affect LDL cholesterol levels in the elderly. The study also suggested that EPA and DHA, had negative impacts on LDL cholesterol levels, but did lead to beneficial effects to levels of a protein that affects blood clotting. Although this research needs to be repeated to check its validity the results do fundamentally support the need for a varied, balanced and fresh food diet as the basis for good health as many different ingredients within foods will have their own health supporting effects.

The richest source of Alpha Linolenic Acid is from Flaxseeds, which provide about 60% of their 35% fat content as ALA. Naturally when seeds are pressed to extract the oil the omega 3 content is increased as the product increases its fat content. As a result there are a number of good plant sourced oils for supplying ALA such as hemp, soya, walnut, rape and wheat germ oils, but for most people the greatest quantities probably come from dark green vegetables. Oils in the green parts of plants are EFA rich with more than half (60-70%) of the fatty acids in dark green leaves in the form of ALA (Udo Erasmus, Fats that Heal, Fats that Kill,1996). The Polyunsaturated (PUFA) fat content of selected vegetables are declared in McCance and Widdowson 5th edition as follows:

	PUFA Fat content	Approximate ALA content per 100g
Carrots, Courgettes	0.2%	120mg
Cabbage	0.3%	180mg
Broccoli	0.4%	240mg
Cauliflower	0.5%	300mg (predominantly in green leaves)

With a recommended intake of 2g ALA per day it is clear to see that even with a consumption of 5 portions of fruit and vegetables a day (typical portion 80g) it is not possible to reach a 2g intake without incorporating fish or a more concentrated ALA source such as flaxseed oil. Fruits tend to have a lower ALA content than vegetables (Udo Erasmus, 1996)

Conclusion

Essential Fatty Acids are as essential to us as vitamins and minerals, in fact some people refer to them as Vitamin F. A good balanced diet containing 2 portions of fresh fish with at least one being oily fish will help support your omega 3 intake but if you do not consume fresh fish or are looking to increase your intake of omega 3 fatty acids then choose a high quality fish oil supplement that is protected from oxidation and provides a good intake of the long chain omega 3 fatty acids in particular EPA to help support positive health of the body and mind.

Concentrate on the omega 3, not for all the benefits as shown by the latest research but because the typical diet contains on average half of the daily requirement and often too much omega 6 making this shortfall seem even worse. With an average diet providing 10 times as much omega 6 as omega 3 our fatty acids are out of balance so focus on the intake of both your omega 3 and 6 to make sure you not only get enough but a balanced intake of both. A suggested ratio is 2:1 omega 6:omega 3. With this in mind your body then has the right balance of fats to keep it healthy and happy.