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FEATURE

Linoleic acid, 'vitamin F6' — is the Western World getting too much? Probably

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The present level of consumption of linoleic acid in the human diet in the more economically-developed nations has risen far beyond historical levels. Yet as early as 1965 concern was being expressed that a high-linoleic diet might be harmful. These concerns continue and have been reinforced in more recent times by research on the significance of the dietary n-*6*/n-*3 ratio. In 1999 the International Society for the Study of Fatty Acids and Lipids (ISSFAL) generated a table which included 'adequate intake' and 'upper limit' levels for linoleic acid but present intakes in the Western World are 2 or 3 times greater than this upper limit.*

Introduction

The bodies of animals, including humans, can make saturated and monounsaturated fats but not polyunsaturated fats which must be eaten. Effectively, this means the polyunsaturated fats can be defined as 'vitamins' and, indeed, they were once called vitamin F. There are two families of polyunsaturates, with their first 'bend' at either the third or the sixth carbon atom from the fatty end, and known respectively as *n*-3 and *n*-6 (omega-3 and omega-6) fatty acids.

This article discusses the most prevalent and shortest of the *n*-6 fatty acids, the diunsaturated linoleic acid (C_{18} with two approximately 60° bends in the molecule; 18:2*n*-6) which we can transform into the C_{20} arachidonic acid with four bends; 20:4*n*-6). This is a major brain component and the parent of an entire class of hormone-like control molecules (such as prostaglandins and thromboxane). It is these molecules, the *n*-3 and *n*-6 fatty acids and molecules made from them, that regulate and control part of cell function, pain, blood clotting, and more.

About half of the saturated fats and a smaller part of the monounsaturates in the body of an average person living in the more developed countries are self-made from starches and sugars. However, all the polyunsaturates are derived pre-formed from food at some point.

Vitamin F6: linoleic acid

Let us think of linoleic acid as a vitamin and consider it to be vitamin F6. As a vitamin, one can consider it a reactive and controlling molecule, and as with other vitamins, that there may be a proper dose and an over-dose.

With, for example, an average American having between 1 and 2 kg of linoleic acid in his or her body, lack of intake is probably not an issue for those of us eating a diet typical of such a country. But how about excess intake? Well, this could be a problem because some of the most common vegetable oils — soybean, corn (maize), cottonseed, sunflower and safflower — all have between 50% and 75% linoleic acid (**Table 1**). That is a lot of any kind of vitamin!

What is more, our intake of *n*-6 has risen dramatically since the invention of solvent extraction that made *n*-6-rich oils such as soybean oil more readily available,

Table 1. Proportions of saturated, *n*–6 polyunsaturated, *n*–3 polyunsaturated and *n*–7 + *n*–9 monounsaturated fatty acids (as % of total) in various fats and oils[1].

Fat or oil	Saturated	*n*-6 PUFA	*n*-3 PUFA	*n*-7 + *n*-9 MUFA
Canola	8	21	10	61
Safflower	7	78	0	15
Sunflower	11	69	0	20
Corn	13	61	1	25
Soy (salad)	16	53	7	24
Soy (cooking)[2]	16	36	3	45
Cottonseed	27	54	0	19
Peanut	18	34	0	48
Olive	14	8	1	77
Chicken fat	[3]MC 31	21	1	47
Pork fat	MC 41	11	1	47
Beef fat	LC 52	3	1	44
Palm oil	LC 51	10	0	39
Butter	SC 66	2	2	30
Coconut	SC 92	2	0	6
Fish (salmon)	21	3	40	31
Fish (sardine)	32	4	29	35
Flax (linseed)	10	13	56	21

[1] Proportions calculated from the US Department of Agriculture food database (http://www.nal.usda.gov/fnic/cgi-bin/nut_search.pl). Some *trans* fat can be included in *n*–3 and *n*–6 analysis. Butter contains *trans* acids among the monounsaturates. Salmon does not add up to 100%.

[2] Partially-hydrogenated; as an approximate rule, hydrogenation destroys trieness about 10 times faster than dienes, which in turn are destroyed faster than monoenes.

[3] Relative carbon chain lengths of the saturated fatty acids (author's assessment), MC = medium, LC = long and SC = short chain. Note: the canola oil fatty acid balance approaches the ISSFAL working group 1999 "adequate intake" proportions although more saturates could be added. Similarly, consumer blends approaching the ISSFAL "adequate intake" can be obtained, for example, from flax with olive, butter, coconut, or palm oil.

and animal feeds began to be high in *n*-6-rich corn and soybean. The usage per person in the USA of soybean oil alone has gone from zero 65 years ago to about 31 g/day in recent times. And, unlike *n*-3 α-linolenic acid, the *n*-6 linoleic acid stores well in tissue and is found in increasing amounts in the lipid deposits in arteries as consumption goes up.

Vitamin F3: α-linolenic acid

To complicate this, none of these oils, other than soybean, contain appreciable amounts of *n*-3 α-linolenic acid (three bends; 18:3*n*-3). Let us call it and its longer derivatives vitamin F3. This vitamin F3 is needed to counter-balance the effects of the *n*-6 family of molecules. However, such balance can be disturbed for at least two reasons.

First, there are so few sources of *n*-3 fatty acids. There is flax/linseed oil at about 56%; canola and walnut oil 10%; soybean oil 7%, and fatty fish like salmon, mackerel, sardine, cod liver, or oils from other fish — and really not much else.

Second, the 90 year old process of industrial hydrogenation of fats and oils destroys *n*-3 fatty acids about ten times more effectively and faster than *n*-6 linoleic acid. Hydrogenation was first introduced into North America by Proctor & Gamble in 1911 and its *Crisco* cook book was first published in 1912 with the sub-title: *The absolutely new product for Frying, for Shortening, for Cake Making.*

Coincidentally, the first published description of 'heart attacks' was also in 1912, in an article written by Dr James Herrick in the *Journal of the American Medical Association*, dated 7 December. What no-one could have imagined then was that hydrogenation destroys essential vitamin-like nutrients. The high *n*-3 trials of the last dozen years have demonstrated dramatically the enormous importance of the *n*-3 fatty acids for heart health and for survival.

Presently, about one-third to one-half of soybean and canola oils (for human consumption) are reportedly hydrogenated. This process destroys just about all the *n*-3 but only part of the linoleic acid (in fact, we could say that it "trans-forms" — makes *trans* fats out of — the polyunsaturates). This affects nearly all commercial vegetable deep-fry oils and shortenings, and many margarines, as well as commercially-baked goods and snack foods.

Table 2. Recommended adequate and maximum adult intakes for fatty acids per 2000 kcal diet based on the 1999 table compiled by the International Society for the Study of Fatty Acids and Lipids (see page 83) with modifications by the author (ISSFAL; www.issfal.org.uk/adequateintakes.htm).

Fatty acid	Recommended intake in g/day average	Quantity in tablespoons (T) or teaspoons (t)
Linoleic (*n*–6) Most western diets have 2 to 3 times the maximum	Adequate 4.5 g Maximum 6.7 g	Maximum: corn 2t, sunflower 2t, safflower 2t, soybean 2T, canola 2T peanut 2T, flaxseed 3T, olive 5T
Alpha-linolenic *n*–3 oils derived from plants	Adequate 2.2 g	Flax 1t, canola 2T (soybean 2T but too high in linoleic) US intake only half of the "adequate" level
EPA + DHA *n*–3 fish oils	Adequate 0.7 g Minimum 0.2 g of each	1/40th ounce, 1 pill, 1/4t cod-liver oil or some fatty fish. Common intake only 1/4 of the "adequate" level
Trans Zero *trans* per serving can be 10% *trans*, "all vegetable" shortening 25%	Maximum 2 g	The actual US intake is 5 times this level from fries, doughnuts, margarine, shortening, baked goods. Europeans also consume *trans* fats but at significantly lower levels
Saturated Solid fat. Some is "conditionally" essential	Maximum 18 g	Coconut 5t, butter 3T; also from meats and made by the body from sugar and starch
Monounsaturated *n*–7 and *n*–9 unsaturates	Balance	Balance from olive, canola, peanut, meats

Why were high levels of linoleic once promoted for heart health?

There is little doubt that the consumption of large amounts of high-linoleic vegetable oil will reduce the amount of cholesterol in one's blood, at least for a while. This gave rise to several trials in people with, or at risk of, heart disease. The first trial, as early as 1965, was a small one where animal fats were replaced with corn oil (1). On the old diet, 72% of the men remained "coronary event free" for 2 years — but only 52% of the corn oil group was so lucky. Despite the small size of the trial, it showed that there was a lack of benefit of linoleic acid, while indicating possible harm.

At this same time, a large study called the 'Veteran's Trial' was under way in Los Angeles, USA. Here, again, animal products and saturated fats were essentially replaced with equivalent amounts of fat from corn oil (2). Compared with the old diet, the veterans consuming the high-linoleic diet suffered considerably more cancer deaths, with cancer mortality offsetting any heart disease benefit. In both groups, there were 58.4% +/-0.6% survivors after 8 years but there was an increase in cancer mortality that was almost statistically-significant and would have reached the statistically-significant 95% probability level in the year after the study's end.

The cholesterol levels were down 13% on average in the linoleic acid group, which consumed about 41 g linoleic acid per day, compared with 11 g in the regular food group. The ratio of *n*–6 to *n*–3 was 24 in the corn oil group and 14 in the control group — still a high ratio (see also E.C. Leonard on *n*–6/*n*–3 ratios in *Lipid Technology*, September 1999, pp.110–114). Linoleic acid stored in fat tissue nearly doubled to over 30%, and the amount in artery lesions reached almost 40% in the corn oil group. The authors remarked: "It is important to remember that no population under study has been consuming a diet high in polyunsaturated fats over long periods of time." But now, in the economically developed countries, most of us are consuming a diet high in polyunsaturated fats and have done so for a long time.

This was effectively the last trial of high-linoleic diets ever done. The newer dietary trials had considerably more of *n*–3 components, such as GISSI (fish oil supplement), the Lyon Diet Heart Study (canola oil) or the Indo-Mediterranean study (mustard seed oil).

Concern about the health effects of a high linoleic acid intake has been raised by the US authors Lands, Simopoulos, and Holman, and also by several Japanese scientists (see, for instance, H. Okuyama in *Lipid Technology Newsletter*, December 2000, pp.128–132). In Israel, E.M. Berry even proposed the concept of the 'Israeli Paradox', in which a supposedly healthy low-saturates

diet, combined with possibly the worlds highest linoleic acid intake, is statistically associated with high incidences of cancer and heart disease (3)

Linoleic acid's effect on levels of *n*–3 based molecules

There is little doubt that a high intake of linoleic acid (probably in the amounts many of us in the developed countries consume) reduces the amounts of the longer-chain *n*–3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) that we humans synthesize from the shorter chain α-linolenic acid, i.e. from the plant-based *n*–3.

A major brain fatty acid is DHA and we either have to consume it from fish, or make it from α-linolenic acid. For this reason alone it might be prudent to consume low, 'paleolithic' (as in primitive man) amounts of linoleic acid. Humans are the only primate with fish nets and hooks, but before that we must have managed on plant-based *n*–3 and without the large amounts of linoleic-rich soybean oil that became available with the advent of solvent extraction.

Excluding the water content, the human brain is a fat-machine with many of the 'moving parts', such as signalling molecules and membrane components, being polyunsaturated lipids. Remove the fat from a cell membrane and you have nothing to keep the cell contents together, leaving little more than a puddle of water. We humans function as living *Lipid Technology*, so that our choice of lipids in the diet is absolutely crucial.

What does ISSFAL say?

In 1999, the International Society for the Study of Fatty Acids and Lipids (known as ISSFAL and representing the cream of the world's fat experts) generated a table with 'adequate intakes' and 'upper limits', including ones for linoleic acid (adequate 2%, and upper limit 3% of energy intake; see the ISSFAL web site: www.issfal.org.uk/adequateintakes.htm). Present intakes in the Western world are 2 or 3 times greater than this upper limit.

This recommendation was the result of a conference in which some 50 of the world's fatty acid scientists took part. The upper limit recommendation of 3% of one's energy as linoleic acid (see **Table 2**) was striking as it went against the dominant ideas of most heart health and medical organizations, which promoted lowering cholesterol with polyunsaturates (in real life, this meant eating large amounts of linoleic acid).

Which way is the fat pendulum swinging?

Clearly, the scare over saturated fats in the diet is receding, with books such as *The Healing Miracles of Coconut Oil* (high in the C_{12} saturate lauric acid) being published (author Bruce Fife, ISBN 0941-599515) and with the high-saturates and cholesterol 'Atkins Diet' actually causing weight loss and higher levels of HDL, the 'good' cholesterol (4). Significantly, the first author (R.O. Bonow) of the latter reference is the current president of the American Heart Association, and the studies are to be found in the 22 May 2003 issue of one of the most prestigious medical journals, the *New England Journal of Medicine.*

Consequently heart-health recommendations are slowly backing away from 'high polyunsaturates' (linoleic acid), to consuming "up to" 10% of one's energy as polyunsaturates, and that would include the *n*–3 fatty acids. This trend of reducing the individual's intake of *n*–6 is likely to continue. Fat phobia is clearly receding and recommendations are changing.

Gone are the days of the advertisements for high-linoleic corn oil on the back of *National Geographic* journals that read, in 1975: "Take this ad to your doctor; cholesterol lowering diet."

There are safe upper levels for most if not all of the polyunsaturates — and the present high consumption of linoleic acid in the more economically-developed nations is far beyond historical levels (that much is obvious). I believe that these modern, high intake levels of linoleic acid are likely to be detrimental to health.

The 'bottom line' is moderation and consumption of a proper balance of all the fatty acids, from the C_{12} coconut/palm kernel lauric acid to any of the *n*–3 fatty acids, with linoleic acid already plentifully supplied for the majority of us. Moderation in linoleic acid may well be prudent while, on the other hand, *n*–3 intakes are typically excessively low.

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