Omega-3 fatty acid

Types of fats in food

- Unsaturated fat
  - Monounsaturated fat
  - Polyunsaturated fat
  - Trans fat
  - Omega numbering:
    - **ω−3**
    - ω−6
    - ω−7
    - ω−9
- Saturated fat
  - Interesterified fat

See also

- Fatty acid
- Essential fatty acid

- V
- T
- E

Omega-3 fatty acids (also called ω-3 fatty acids or *n*-3 fatty acids[1]) are polyunsaturated fatty acids with a double bond (C=C) at the third carbon atom from the end of the carbon chain.[2] The fatty acids have two ends, the carboxylic acid (-COOH) end, which is considered the beginning of the chain, thus "alpha", and the methyl (CH_3) end, which is considered the "tail" of the chain, thus "omega." The nomenclature of the fatty acid is taken from the location of the first double bond, counted from the methyl end, that is, the omega (ω-) or the n- end.

The three types of omega-3 fatty acids involved in human physiology are ALA (found in plant oils), EPA, and DHA (both commonly found in marine oils). Common sources of animal omega-3 EPA and DHA fatty acids include fish oils, egg oil, squid oils, krill oil, while some plant oils contain the omega 3 ALA fatty acid such as walnut, seabuckthorn and chia seeds, along with berry oils, clary sage seed oil, algal oil,flaxseed oil, Sacha Inchi oil, *Echium* oil, and hemp oil.

Omega-3 fatty acids are important for normal metabolism,[3] but the health benefits of supplementation appear to be few if any. Omega-3s are considered essential fatty acids, meaning that they cannot be synthesized by the human body. However, mammals have a limited ability to synthesize omega-3 fats when the diet includes the shorter-chain omega-3 fatty acid ALA (α-linolenic acid, 18 carbons and 3 double bonds) to form the more important long-chain omega-3 fatty acids, EPA (eicosapentaenoic acid, 20 carbons and 5 double bonds) and then from EPA, the most crucial, DHA (docosahexaenoic acid, 22 carbons and 6 double bonds) with even greater inefficiency.[3] The ability to make the longer-chain omega-3 fatty acids from ALA may also be impaired in aging.[4][5] In foods exposed to air, unsaturated fatty acids are vulnerable to oxidation and rancidity.[6]

Health effects

Supplementation does not appear to be associated with a lower risk of all-cause mortality.[7]

Cancer

The evidence linking the consumption of fish to the risk of cancer is poor.[8] Supplementation with omega-3 fatty acids does not appear to affect this either.[9]

A 2006 review concluded that there was no link between omega-3 fatty acids consumption and cancer.[10] This is similar to the findings of a review of studies up to February 2002 that failed to find clear effects of long and shorter chain omega-3 fats on total risk of death, combined cardiovascular events and cancer.[11][12] In those with advanced cancer and cachexia, omega-3 fatty acids supplements may be of benefit, improving appetite, weight, and quality of life.[13] There is tentative evidence that marine omega-3 polyunsaturated fatty acids reduce the risk of breast cancer but this is not conclusive.[14][15]

The effect of consumption on prostate cancer is not conclusive.[15] There is a decreased risk with higher blood levels of DPA, but an increased risk of more aggressive prostate cancer with higher blood levels of combined EPA and DHA(found in fatty fish oil).[16]

Cardiovascular disease

Evidence does not support a beneficial role for omega-3 fatty acid supplementation in preventing cardiovascular disease (including myocardial infarction and sudden cardiac death) or stroke.[7][17] Fish oil supplementation has not been shown to benefit revascularization or arrythmia and has no effect on heart failure admission rates.[18] Eating a diet high in fish that contain long chain omega-3 fatty acids does appear to decrease the risk of stroke.[19]

Large amounts may increase low-density lipoproteins (LDL) (see below), up to 46%, although LDL changes from small to larger, buoyant, less atherogenic particles.[20]

Omega-3 fatty acids may have a modest effect on systolic blood pressure, though studies have produced inconsistent results.[21] The 18 carbon α-linolenic acid (ALA) has not been shown to have the same cardiovascular benefits that DHA or EPA may have.[22]

Some evidence suggests that people with certain circulatory problems, such as varicose veins, may benefit from the consumption of EPA and DHA, which may stimulate blood circulation, increase the breakdown of fibrin, a compound involved in clot and scar formation, and, in addition, may reduce blood pressure.[23][24] Evidently, omega-3 fatty acids reduce blood triglyceride levels,[25][26][27] and regular intake may reduce the risk of secondary and primary heart attack.[28] ALA does not confer the cardiovascular health benefits of EPA and DHA.[29]

Large amounts may increase the risk of hemorrhagic stroke in women; lower amounts are not related to this risk.[30]

Inflammation

Some research suggests that the anti-inflammatory activity of long-chain omega-3 fatty acids may translate into clinical effects.[31]

For rheumatoid arthritis (RA), one systematic review found a consistent, but modest, evidence for the effect of marine n-3 PUFAs on symptoms such as "joint swelling and pain, duration of morning stiffness, global assessments of pain and disease activity" as well as the use of non-steroidal anti-inflammatory drugs.[32] However, the American College of Rheumatology (ACR) has stated that there may be modest benefit from the use of fish oils, but that it may take months for effects to be seen, and cautions for possible gastrointestinal side effects and the possibility of the supplements containing mercury or vitamin A at toxic levels. Due to the lack of regulations for safety and efficacy, the ACR does not recommend herbal supplements and feels there is an overall lack of "sound scientific evidence" for their use.[33] The National Center for Complementary and Alternative Medicine has concluded that "[n]o dietary supplement has shown clear benefits for RA", but that there is preliminary evidence that fish oil may be beneficial, and called for further study.[34]

Developmental disorders

Although not supported by current scientific evidence as a primary treatment for ADHD, autism spectrum disorders, and other developmental differences,[35][36] omega-3 fatty acids have gained popularity for children with these conditions.[35]

A Cochrane review found "there is little evidence that PUFA supplementation provides any benefit for the symptoms of ADHD in children and adolescents",[37] while a different review found "insufficient evidence to draw any conclusion about the use of PUFAs for children with specific learning disorders."[38] Another review concluded that the evidence is inconclusive for the use of omega-3 fatty acids in behavior and non-neurodegenerative neuropsychiatric disorders such ADHD and depression.[39] A different systematic review concluded there is a modest effect for omega-3 fatty acids in ADHD, but its effect is less than more traditional pharmaceutical medications.[40]

Fish oil has only a small benefit on the risk of early birth.[41][42]

Mental health

There is some evidence that omega-3 fatty acids are related to mental health,[43] including that they may tentatively be useful as an add-on for the treatment of depression associated with bipolar disorder[44] and there is preliminary evidence that EPA supplementation is helpful in cases of depression.[45] There is, however, a significant difficulty in interpreting the literature due to participant recall and systematic differences in diets.[46]

Cognitive aging

Epidemiological studies suggest that consumption of omega-3 fatty acids can reduce the risk of dementia, but evidence of a treatment effect in dementia patients is inconclusive.[47] However, clinical evidence suggests benefits of treatment specifically in patients who show signs of cognitive decline but who are not sufficiently impaired to meet criteria for dementia.[48]

List of omega-3 fatty acids

This table lists several different names for the most common omega-3 fatty acids found in nature.

Common name	Lipid name	Chemical name
Hexadecatrienoic acid (HTA)	16:3 (*n*-3)	*all-cis*-7,10,13-hexadecatrienoic acid
α-Linolenic acid (ALA)	18:3 (*n*-3)	*all-cis*-9,12,15-octadecatrienoic acid
Stearidonic acid (SDA)	18:4 (*n*-3)	*all-cis*-6,9,12,15-octadecatetraenoic acid
Eicosatrienoic acid (ETE)	20:3 (*n*-3)	*all-cis*-11,14,17-eicosatrienoic acid
Eicosatetraenoic acid (ETA)	20:4 (*n*-3)	*all-cis*-8,11,14,17-eicosatetraenoic acid
Eicosapentaenoic acid (EPA)	20:5 (*n*-3)	*all-cis*-5,8,11,14,17-eicosapentaenoic acid

Heneicosapentaenoic acid (HPA)	21:5 (*n*-3)	*all-cis*-6,9,12,15,18-heneicosapentaenoic acid
Docosapentaenoic acid (DPA), Clupanodonic acid	22:5 (*n*-3)	*all-cis*-7,10,13,16,19-docosapentaenoic acid
Docosahexaenoic acid (DHA)	22:6 (*n*-3)	*all-cis*-4,7,10,13,16,19-docosahexaenoic acid
Tetracosapentaenoic acid	24:5 (*n*-3)	*all-cis*-9,12,15,18,21-tetracosapentaenoic acid
Tetracosahexaenoic acid (Nisinic acid)	24:6 (*n*-3)	*all-cis*-6,9,12,15,18,21-tetracosahexaenoic acid

Mechanism of action

The 'essential' fatty acids were given their name when researchers found that they are essential to normal growth in young children and animals, though the modern definition of 'essential' is more strict. A small amount of omega-3 in the diet (~1% of total calories) enabled normal growth, and increasing the amount had little to no additional effect on growth.[49]

Likewise, researchers found that omega-6 fatty acids (such as γ-linolenic acid and arachidonic acid) play a similar role in normal growth. However, they also found that omega-6 was "better" at supporting dermal integrity, renal function, andparturition. These preliminary findings led researchers to concentrate their studies on omega-6, and it is only in recent decades that omega-3 has become of interest.[49]

In 1964, it was discovered that enzymes found in sheep tissues convert omega-6 arachidonic acid into the inflammatory agent called prostaglandin E,$_2$,[50] which both causes the sensation of pain and expedites healing and immune response in traumatized and infected tissues.[49] By 1979, more of what are now known as eicosanoids were discovered: thromboxanes, prostacyclins, and the leukotrienes.[49] The eicosanoids, which have important biological functions, typically have a short active lifetime in the body, starting with synthesis from fatty acids and ending with metabolism by enzymes. However, if the rate of synthesis exceeds the rate of metabolism, the excess eicosanoids may have deleterious effects.[49] Researchers found that certain omega-3 fatty acids are also converted into eicosanoids, but at a much slower rate. Eicosanoids made from omega-3 fatty acids are often referred to as anti-inflammatory, but in fact they are just less inflammatory than those made from omega-6 fats. If both omega-3 and omega-6 fatty acids are present, they will "compete" to be transformed,[49] so the ratio of long-chain omega-3:omega-6 fatty acids directly affects the type of eicosanoids that are produced.[49]
This competition was recognized as important when it was found that thromboxane is a factor in the clumping of platelets, which can both cause death by thrombosis and prevent death by bleeding. Likewise, the leukotrienes were found to be important in immune/inflammatory-system response, and therefore relevant to arthritis, lupus, asthma, and recovery from infections. These discoveries led to greater interest in finding ways to control the synthesis of omega-6 eicosanoids. The simplest way would be by consuming more omega-3 and fewer omega-6 fatty acids.[49]

They are required during the prenatal period for the formation of synapses and cell membranes. These processes are also essential in postnatal human development for injury response of the central nervous system and retinal stimulation.[51]

Interconversion

Conversion efficiency of ALA to EPA and DHA

Humans can convert short-chain omega-3 fatty acids to long-chain forms (EPA, DHA) with an efficiency below 5%.[52][53] The omega-3 conversion efficiency is greater in women than in men, but less-studied.[54]

These conversions occur competitively with omega-6 fatty acids, which are essential closely related chemical analogues that are derived from linoleic acid. Both the omega-3 α-linolenic acid and omega-6 linoleic acid must be obtained from food. Synthesis of the longer omega-3 fatty acids from linolenic acid within the body is competitively slowed by the omega-6 analogues. Thus, accumulation of long-chain omega-3 fatty acids in tissues is more effective when they are obtained directly from food or when competing amounts of omega-6 analogues do not greatly exceed the amounts of omega-3.

The conversion of ALA to EPA and further to DHA in humans has been reported to be limited, but varies with individuals.[55][56] Women have higher ALA conversion efficiency than men, which is presumed to be due to the lower rate of use of dietary ALA for beta-oxidation. This suggests that biological engineering of ALA conversion efficiency is possible. Goyens *et al.* argue that it is the absolute amount of ALA, rather than the ratio of omega-3 and omega-6 fatty acids, that controls the conversion efficiency.[57]

The omega-6 to omega-3 ratio

Main article: Essential fatty acid interactions

Some older clinical studies[49][58] indicate that the ingested ratio of omega-6 to omega-3 (especially linoleic vs alpha-linolenic) fatty acids is important to maintaining cardiovascular health. However, three studies published in 2005, 2007 and 2008, including a randomized controlled trial, found that, while omega-3 polyunsaturated fatty acids are extremely beneficial in preventing heart disease in humans, the levels of omega-6 polyunsaturated fatty acids (and, therefore, the ratios) did not matter.[59][60][61]

Both omega-6 and omega-3 fatty acids are essential; i.e., humans must consume them in their diet. Omega-6 and omega-3 eighteen-carbon polyunsaturated fatty acids compete for the same metabolic enzymes, thus the omega-6:omega-3 ratio of ingested fatty acids has significant influence on the ratio and rate of production of eicosanoids, a group of hormones intimately involved in the body's inflammatory and homeostatic processes, which include the prostaglandins, leukotrienes, and thromboxanes, among others. Altering this ratio can change the body's metabolic and inflammatory state.[62] In general, grass-fed animals accumulate more omega-3 than do grain-fed animals, which accumulate relatively more omega-6.[63] Metabolites of omega-6 are more inflammatory (esp. arachidonic acid) than those of omega-3. This necessitates that omega-6 and omega-3 be consumed in a balanced proportion; healthy ratios of omega-6:omega-3, according to some authors, range from 1:1 to 1:4 (an individual needs more omega-3 than omega-6).[64] Other authors believe that ratio 4:1 (when the amount of omega-6 is only 4 times greater than that of omega-3) is already healthy.[65][66] Studies suggest the evolutionary human diet, rich in game animals, seafood, and other sources of omega-3, may have provided such a ratio.[67][68]

Typical Western diets provide ratios of between 10:1 and 30:1 (i.e., dramatically higher levels of omega-6 than omega-3).[69] The ratios of omega-6 to omega-3 fatty acids in some common vegetable oils are: canola 2:1, hemp 2-3:1,[70] soybean7:1, olive 3–13:1, sunflower (no omega-3), flax 1:3,[71] cottonseed (almost no omega-3), peanut (no omega-3), grapeseed oil (almost no omega-3) and corn oil 46:1 ratio of omega-6 to omega-3.[72]

History

Although omega-3 fatty acids have been known as essential to normal growth and health since the 1930s, awareness of their health benefits has dramatically increased since the 1980s.[73][74]

On September 8, 2004, the U.S. Food and Drug Administration gave "qualified health claim" status to EPA and DHA omega-3 fatty acids, stating, "supportive but not conclusive research shows that consumption of EPA and DHA [omega-3] fatty acids may reduce the risk of coronary

heart disease."[75] This updated and modified their health risk advice letter of 2001 (see below). As of this writing, regulatory agencies[*who?*] do not accept that there is sufficient evidence for any of the suggested benefits of DHA and EPA other than for cardiovascular health, and further claims should be treated with caution.

The Canadian government has recognized the importance of DHA omega-3 and permits the following biological role claim for DHA: "DHA, an omega-3 fatty acid, supports the normal development of the brain, eyes and nerves."[76]

Dietary sources

Grams of omega-3 per 3oz (85g) serving[77] [78]

Common name	grams omega-3
Flax	11.4 [79]
Herring, sardines	1.3–2
Mackerel: Spanish/Atlantic/Pacific	1.1–1.7
Salmon	1.1–1.9
Halibut	0.60–1.12
Tuna	0.21–1.1
Swordfish	0.97
Greenshell/lipped mussels	0.95[79]
Tilefish	0.9
Tuna (canned, light)	0.17–0.24
Pollock	0.45

Cod	0.15–0.24
Catfish	0.22–0.3
Flounder	0.48
Grouper	0.23
Mahi mahi	0.13
Orange roughy	0.028
Red snapper	0.29
Shark	0.83
King mackerel	0.36
Hoki (blue grenadier)	0.41[79]
Gemfish	0.40[79]
Blue eye cod	0.31[79]
Sydney rock oysters	0.30[79]
Tuna, canned	0.23[79]
Snapper	0.22[79]
Eggs, large regular	0.109[79]
Strawberry or Kiwifruit	0.10-0.20

Broccoli	0.10-0.20
Barramundi, saltwater	0.100[79]
Giant tiger prawn	0.100[79]
Lean red meat	0.031[79]
Turkey	0.030[79]
Cereals, rice, pasta, etc.	0.00[79]
Fruit	0.00[79]
Milk, regular	0.00[79]
Bread, regular	0.00[79]
Vegetables	0.00[79]

Daily values

As macronutrients, fats are not assigned Dietary Reference Intakes. Macronutrients have acceptable intake (AI) levels and acceptable macronutrient distribution ranges (AMDRs) instead of RDAs. The AI for omega-3 is 1.6 grams/day for men and 1.1 grams/day for women, while the AMDR is 0.6% to 1.2% of total energy.[80]

A growing body of literature suggests that higher intakes of α-linolenic acid (ALA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA) may afford some degree of protection against coronary disease. Because the physiological potency of EPA and DHA is much greater than that of ALA, it is not possible to estimate one AMDR for all omega-3 fatty acids. Approximately 10 percent of the AMDR can be consumed as EPA and/or DHA."[80] There was insufficient evidence as of 2005 to set an upper tolerable limit for omega-3 fatty acids.[80]

Heavy metal poisoning by the body's accumulation of traces of heavy metals, in particular mercury, lead, nickel, arsenic, and cadmium, is a possible risk from consuming fish oil supplements.[*medical citation needed*] Also, other contaminants (PCBs, furans, dioxins, and PBDEs) might be found, especially in less-refined fish oil supplements.[*citation needed*] In reality, however, heavy metal toxicity from consuming fish oil supplements is highly unlikely, because heavy metals selectively bind with protein in the fish flesh rather than accumulate in the oil. An independent test in 2005 of 44 fish oils on the US market found all of the products passed safety standards for potential contaminants.[81][*unreliable source?*]

The FDA has advised that adults can safely consume a total of 3 grams per day of combined DHA and EPA, with no more than 2 g per day coming from dietary supplements.[82]

Throughout their history, the Council for Responsible Nutrition and the World Health Organization have published acceptable standards regarding contaminants in fish oil. The most stringent current standard is the International Fish Oils Standard.[83][*non-primary source needed*] Fish oils that are molecularly distilled under vacuum typically make this highest-grade, and have measurable levels of contaminants (measured parts per billion and parts per trillion).[*citation needed*]

A recent trend has been to fortify food with omega-3 fatty acid supplements. Global food companies have launched omega-3 fatty acid fortified bread, mayonnaise, pizza, yogurt, orange juice, children's pasta, milk, eggs, popcorn, confections, and infant formula.[*citation needed*]

The American Heart Association has set up dietary recommendations for EPA and DHA due to their cardiovascular benefits: Individuals with no history of coronary heart disease or myocardial infarction should consume oily fish or fish oils two times per week; those having been diagnosed with coronary heart disease after infarction should consume 1 g EPA and DHA per day from oily fish or supplements; those wishing to lower blood triglycerides should consume 2–4 g of EPA and DHA per day in the form of supplements.[84][*dated info*]

Fish

The most widely available dietary source of EPA and DHA is cold water oily fish, such as salmon, herring, mackerel, anchovies, and sardines. Oils from these fish have a profile of around seven times as much omega-3 as omega-6. Other oily fish, such as tuna, also contain *n*-3 in somewhat lesser amounts. Consumers of oily fish should be aware of the potential presence of heavy metals and fat-soluble pollutants like PCBs and dioxins, which are known to accumulate up the food chain. After extensive review, researchers fromHarvard's School of Public Health in the *Journal of the American Medical Association* (2006) reported that the benefits of fish intake generally far outweigh the potential risks. Although fish are a dietary source of omega-3 fatty acids, fish do not synthesize them; they obtain them from the algae (microalgae in particular) or plankton in their diets.[85]

Fish oil

See also: Fish oil

Marine and freshwater fish oil vary in content of arachidonic acid, EPA and DHA.[86] They also differ in their effects on organ lipids.[86] Not all forms of fish oil may be equally digestible. Of four studies that compare bioavailability of the glyceryl ester form of fish oil vs. the ethyl ester form, two have concluded the natural glyceryl ester form is better, and the other two studies did not find a significant difference. No studies have shown the ethyl ester form to be superior, although it is cheaper to manufacture.[87][88]

Krill

Krill oil is a newly[*when?*] discovered source of omega-3 fatty acids. Various claims are made in support of krill oil as a superior[*citation needed*] source of omega-3 fatty acids. The effect of krill oil, at a lower dose of EPA + DHA (62.8%), was demonstrated to be similar to that of fish oil.[89]

Calamari oil

Calamari oil (also known as Squid oil) is another source of omega-3 fatty acid.[90] Calamari is considered to be more environmentally friendly than fish or krill oil, due to it being prepared from the largely unused portions of calamari catches.[91]

Plant sources

These tables are incomplete.

Table 1. ALA content as the percentage of the seed oil.[92]

Common name	Alternative name	Linnaean name	% ALA

Kiwifruit seed oil	Chinese gooseberry	*Actinidia deliciosa*	63[93]
Perilla	Shiso	*Perilla frutescens*	61
Chia seed	chia sage	*Salvia hispanica*	58
Flax	Linseed	*Linum usitatissimum*	53[94] – 59[95]
Lingonberry	Cowberry	*Vaccinium vitis-idaea*	49
Camelina	Gold-of-pleasure	*Camelina sativa*	36
Purslane	Portulaca	*Portulaca oleracea*	35
Black raspberry		*Rubus occidentalis*	33
Hemp		*Cannabis sativa*	19
Canola			9[94] – 11

Table 2. ALA content as the percentage of the whole food.[94][96]

Common name	Linnaean name	% ALA
Flaxseed	*Linum usitatissimum*	18.1
Butternuts	*Juglans cinerea*	8.7
Hempseed	*Cannabis sativa*	8.7
Persian walnuts	*Juglans regia*	6.3
Pecan nuts	*Carya illinoinensis*	0.6

Hazel nuts	*Corylus avellana*	0.1

Flaxseed (or linseed) (*Linum usitatissimum*) and its oil are perhaps the most widely available botanical source of the omega-3 fatty acid ALA. Flaxseed oil consists of approximately 55% ALA, which makes it six times richer than most fish oils in omega-3 fatty acids.[97] A portion of this is converted by the body to EPA and DHA, though the actual converted percentage may differ between men and women.[98]

100 g of the leaves of Purslane contains 300–400 mg ALA.[99]

In 2013 Rothamsted Research in the UK reported they had developed a genetically modified form of the plant Camelina that produced EPA and DHA. Oil from the seeds of this plant contained on average 11% EPA and 8% DHA in one development and 24% EPA in another.[100][101]

Eggs

Eggs produced by hens fed a diet of greens and insects contain higher levels of omega-3 fatty acids than those produced by chickens fed corn or soybeans.[102] In addition to feeding chickens insects and greens, fish oils may be added to their diets to increase the omega-3 fatty acid concentrations in eggs.[103]

The addition of flax and canola seeds to the diets of chickens, both good sources of alpha-linolenic acid, increases the omega-3 content of the eggs, predominantly DHA.[104]

The addition of green algae or seaweed to the diets boosts the content of DHA and EPA content, which are the forms of omega-3 approved by the FDA for medical claims. A common consumer complaint is "Omega-3 eggs can sometimes have a fishy taste if the hens are fed marine oils."[105]

Meat

Omega 3 fatty acids are formed in the chloroplasts of green leaves and algae. While seaweeds and algae are the source of omega 3 fatty acids present in fish, grass is the source of omega 3 fatty acids present in grass fed animals.[106]When cattle are taken off omega 3 fatty acid rich grass and shipped to a feedlot to be fattened on omega 3 fatty acid deficient grain, they begin losing their store of this beneficial fat. Each day that an animal spends in the feedlot, the amount of omega 3 fatty acids in its meat is diminished.[107]

The omega-6-to-omega-3 ratio of grass-fed beef is about 2:1, making it a more useful source of omega-3 than grain-fed beef, which usually has a ratio of 4:1.[63]

In a 2009 joint study by the USDA and researchers at Clemson University in South Carolina, grass-fed beef was compared with grain-finished beef. The researchers found that grass-finished beef is higher in moisture content, 42.5% lower total lipid content, 54% lower in total fatty acids, 54% higher in beta-carotene, 288% higher in vitamin E (alpha-tocopherol), higher in the B-vitamins thiamin and riboflavin, higher in the minerals calcium, magnesium, and potassium, 193% higher in total omega-3s, 117% higher in CLA (cis-9 trans-11, which is a potential cancer fighter), 90% higher in vaccenic acid (which can be transformed into CLA), lower in the saturated fats linked with heart disease, and has a healthier ratio of omega-6 to omega-3 fatty acids (1.65 vs 4.84). Protein and cholesterol content were equal.[63]

In most countries, commercially available lamb is typically grass-fed, and thus higher in omega-3 than other grain-fed or grain-finished meat sources. In the United States, lamb is often finished (i.e., fattened before slaughter) with grain, resulting in lower omega-3.[108]

The omega-3 content of chicken meat may be enhanced by increasing the animals' dietary intake of grains high in omega-3, such as flax, chia, and canola.[109]

Kangaroo meat is also a source of omega-3, with fillet and steak containing 74 mg per 100 g of raw meat.[110]

Mammalian brains and eyes

The brains and eyes of mammals are extremely rich in DHA as well as other omega-3 fatty acids.[111] DHA is a major structural component of the mammalian brain, and is in fact the most abundant omega-3 fatty acid in the brain.[112]

Seal oil

Seal oil is a source of EPA, DPA, and DHA. According to Health Canada, it helps to support the development of the brain, eyes, and nerves in children up to 12 years of age.[113] However, like all seal products, it is not allowed for import into the European Union.[114]

Other sources

The microalgae *Crypthecodinium cohnii* and *Schizochytrium* are rich sources of DHA but not EPA, and can be produced commercially in bioreactors.[*citation needed*]

Oil from brown algae (kelp) is a source of EPA.[115]

In 2006 the Journal of Dairy Science published a study entitled, "The Linear Relationship between the Proportion of Fresh Grass in the Cow Diet, Milk Fatty Acid Composition, and Butter Properties". The study found that butter made from the milk of grass-fed cows contains substantially more CLA, vitamin E, beta-carotene, and omega-3 fatty acids than butter made from the milk of cows that have limited access to pasture.[116]

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Omega-6 fatty acid

Types of fats in food

- Unsaturated fat
  - Monounsaturated fat
  - Polyunsaturated fat
  - Trans fat
  - Omega numbering:
    - ω−3
    - **ω−6**
    - ω−7
    - ω−9
- Saturated fat
  - Interesterified fat

See also

- Fatty acid
- Essential fatty acid

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Omega-6 fatty acids (also referred to as **ω-6 fatty acids** or ***n*-6 fatty acids**) are a family of polyunsaturated fatty acids[1] that have in common a final carbon-carbon double bond in the *n*-6 position, that is, the sixth bond, counting from the methyl end.[2] Some medical research suggests that eating a lot of certain omega−6 fatty acids may lead to some diseases.

The biological effects of the omega-6 fatty acids are largely mediated by their conversion to omega-6 eicosanoids that bind to diverse receptors found in every tissue of the body. The conversion of tissuearachidonic acid (20:4n-6) to omega-6 prostaglandin and omega-6 leukotriene hormones provides many targets for pharmaceutical drug development and treatment to diminish excessive omega-6 actions inatherosclerosis,[3] asthma, arthritis, vascular disease, thrombosis, immune-inflammatory processes, and tumor proliferation. Competitive interactions with the omega-3 fatty acids affect the relative storage, mobilization, conversion and action of the omega-3 and omega-6 eicosanoid precursors (see Essential fatty acid interactions).

Key omega−6 fatty acids

Linoleic acid (18:2, *n*−6), the shortest-chained omega−6 fatty acid, is an essential fatty acid. Arachidonic acid (20:4) is a physiologically significant omega−6 fatty acid and is the precursor for prostaglandins, endocannabinoids and other physiologically active molecules.

Suggested negative health effects

Some medical research suggests that excessive levels of certain omega−6 fatty acids relative to certain omega-3 fatty acids may increase the probability of a number of diseases.[4][5][6] However, scientific research indicates that air pollution,smoking, second-hand smoke, and other exogenous toxins cause the initial inflammation in the cells which leads to the overexpression of the COX-2 enzyme and subsequently to the overproduction of inflammatory promoting prostaglandinsfrom Arachidonic acid for the purpose of alerting the immune system of the cell damage and eventually to the production of anti-

inflammatory prostaglandins during the resolution phase of inflammation, after the cell damage has been repaired.[7][8][9][10][11]

Modern Western diets typically have ratios of omega−6 to omega−3 in excess of 10 to 1, some as high as 30 to 1; the average ratio of omega-6 to omega-3 in the Western diet is 15/1–16.7/1.[3] Humans are thought to have evolved with a diet of a 1-to-1 ratio of omega-6 to omega-3 and the optimal ratio is thought to be 4 to 1 or lower,[3][12] and it is even better if there is more omega−3 than omega−6 (especially healthy ratio of omega−6 to omega−3 is from 1:1 to 1:4).[13] A ratio of 2–3/1 omega 6 to omega 3 helped reduce inflammation in patients with rheumatoid arthritis.[3] A ratio of 5/1 had a beneficial effect on patients with asthma but a 10/1 ratio had a negative effect.[3] A ratio of 2.5/1 reduced rectal cell proliferation in patients with colorectal cancer, whereas a ratio of 4/1 had no effect.[3]

Excess omega−6 fatty acids from vegetable oils interfere with the health benefits of omega−3 fats, in part because they compete for the same rate-limiting enzymes. A high proportion of omega−6 to omega−3 fat in the diet shifts the physiological state in the tissues toward the pathogenesis of many diseases: prothrombotic, proinflammatory and proconstrictive.[14]
Chronic excessive production of omega−6 eicosanoids is correlated with arthritis, inflammation, and cancer. Many of the medications used to treat and manage these conditions work by blocking the effects of the COX-2 enzyme.[15] Many steps in formation and action of omega-6 prostaglandins from omega-6 arachidonic acid proceed more vigorously than the corresponding competitive steps in formation and action of omega-3 hormones from omega-3 eicosapentaenoic acid.[16] The COX-1 and COX-2 inhibitor medications, used to treat inflammation and pain, work by preventing the COX enzymes from turning arachidonic acid into inflammatory compounds.[17] (See Cyclooxygenase for more information.) The LOX inhibitor medications often used to treat asthma, work by preventing the LOX enzyme from converting arachidonic acid into the leukotrienes.[18][19] Many of the anti-mania medications used to treat bipolar disorder work by targeting thearachidonic acid cascade in the brain.[20]

A high consumption of oxidized polyunsaturated fatty acids (PUFAs), which are found in most types of vegetable oil, may increase the likelihood that postmenopausal women will develop breast cancer.[21] Similar effect was observed onprostate cancer, but the study was performed on mice.[22] Another "analysis suggested an inverse association between total polyunsaturated fatty acids and breast cancer risk, but individual polyunsaturated fatty acids behaved differently [from each other]. [...] a 20:2 derivative of linoleic acid [...] was inversely associated with the risk of breast cancer".[23]

List of omega−6 fatty acids

Common name	Lipid name	Chemical name
Linoleic acid (LA)	18:2 (*n*−6)	*all-cis*-9,12-octadecadienoic acid
Gamma-linolenic acid (GLA)	18:3 (*n*−6)	*all-cis*-6,9,12-octadecatrienoic acid
Calendic acid	18:3 (*n*−6)	8E,10E,12Z-octadecatrienoic acid

Eicosadienoic acid	20:2 (*n*−6)	*all-cis*-11,14-eicosadienoic acid
Dihomo-gamma-linolenic acid (DGLA)	20:3 (*n*−6)	*all-cis*-8,11,14-eicosatrienoic acid
Arachidonic acid (AA)	20:4 (*n*−6)	*all-cis*-5,8,11,14-eicosatetraenoic acid
Docosadienoic acid	22:2 (*n*−6)	*all-cis*-13,16-docosadienoic acid
Adrenic acid	22:4 (*n*−6)	*all-cis*-7,10,13,16-docosatetraenoic acid
Docosapentaenoic acid	22:5 (*n*−6)	*all-cis*-4,7,10,13,16-docosapentaenoic acid
Tetracosatetraenoic acid	24:4 (*n*−6)	*all-cis*-9,12,15,18-tetracosatetraenoic acid
Tetracosapentaenoic acid	24:5 (*n*−6)	*all-cis*-6,9,12,15,18-tetracosapentaenoic acid

Dietary linoleic acid requirement

Adding more controversy to the omega−6 fat issue is that the dietary requirement for linoleic acid has been questioned, because of a significant methodology error proposed by University of Toronto scientist Stephen Cunnane.[24] Cunnane proposed that the seminal research used to determine the dietary requirement for linoleic acid was based on feeding animals linoleic acid-deficient diets, which were simultaneously deficient in omega−3 fats. The omega−3 deficiency was not taken into account. The omega−6 oils added back systematically to correct the deficiency also contained trace amounts of omega−3 fats. Therefore the researchers were inadvertently correcting the omega−3 deficiency as well. Ultimately, it took more oil to correct both deficiencies. According to Cunnane, this error overestimates linoleic acid requirements by 5 to 15 times.

Dietary sources

Four major food oils (palm, soybean, rapeseed, and sunflower) provide more than 100 million metric tons annually, providing more than 32 million metric tons of omega-6 linoleic acid and 4 million metric tons of omega-3 alpha-linolenic acid.[25]

Dietary sources of omega−6 fatty acids include:[26]

- poultry
- nuts
- cereals
- durum wheat
- whole-grain breads
- most vegetable oils
- evening primrose oil
- borage oil
- blackcurrant seed oil

- flax/linseed oil
- rapeseed or canola oil
- hemp oil
- soybean oil
- cottonseed oil
- sunflower seed oil
- corn oil
- safflower oil
- pumpkin seeds
- acai berry[*citation needed*]
- cashews
- pecans
- pine nuts
- walnuts[27]
- spirulina[*citation needed*], [28]

See also

- Essential fatty acid interactions
- Essential nutrients
- Linolenic acid
- Omega-3 fatty acid
- Omega-7 fatty acid
- Omega-9 fatty acid
- Wheat germ oil
- Lipid peroxidation
- Inflammation

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Omega-9 fatty acid

Types of fats in food

- Unsaturated fat
  - Monounsaturated fat
  - Polyunsaturated fat
  - Trans fat
  - Omega numbering:
    - ω−3
    - ω−6
    - ω−7
    - **ω−9**
- Saturated fat
  - Interesterified fat

See also

- Fatty acid
- Essential fatty acid

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Omega-9 fatty acids (**ω−9 fatty acids** or ***n*−9 fatty acids**) are a family of unsaturated fatty acids which have in common a final carbon–carbon double bond in the omega−9 position; that is, the ninth bond from the methyl end of the fatty acid.

Background

Some omega−9 fatty acids are common components of animal fat and vegetable oil. Two omega−9 fatty acids important in industry are:

- Oleic acid (18:1, *n*−9), which is a main component of olive oil, macadamia oil and other monounsaturated fats
- Erucic acid (22:1, *n*−9), which is found in rapeseed, wallflower seed, and mustard seed. Rapeseed with high erucic acid content is grown for commercial use in paintings and coatings as a drying oil.Canola oil comes from a cultivar of the rapeseed plant that has been bred, or in some cases genetically modified, to contain very little erucic acid.

Unlike omega-3 fatty acids and omega-6 fatty acid, omega−9 fatty acids are not classed as essential fatty acids (EFA). This is both because they can be created by the human body from unsaturated fat, and are therefore not essential in the diet, and because the lack of an omega−6 double bond keeps them from participating in the reactions that form the eicosanoids. Under severe conditions of EFA deprivation, mammals will elongate and desaturate oleic acid to make mead acid, (20:3, *n*−9).[1] This has been documented to a lesser extent in one study following vegans, vegetarians and semi-vegetarianswho followed unbalanced diets.[2]

Omega−9 fatty acids

Common name	Lipid name	Chemical name
oleic acid	18:1 (*n*−9)	9-octadecenoic acid
elaidic acid	18:1 (*n*−9)	(*E*)-octadec-9-enoic acid
gondoic acid	20:1 (*n*−9)	11-eicosenoic acid
mead acid	20:3 (*n*−9)	5,8,11-eicosatrienoic acid
erucic acid	22:1 (*n*−9)	13-docosenoic acid
nervonic acid	24:1 (*n*−9)	15-tetracosenoic acid

See also

- Polyunsaturated fatty acid, lists of fatty acids including omega−3, omega−6, and omega−9 fatty acids
- Omega-3 fatty acid
- Omega-6 fatty acid
- Omega-7 fatty acid

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