HEALTH BENEFITS OF OILS RICH IN OMEGA-3, OMEGA-6 AND OMEGA-9 FATTY ACIDS

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Use of the term 'omega', or 'n-x' when signifying a particular unsaturated fatty acid, refers to the position of the first double bond from the methyl (-CH3) end of the fatty acid molecule. For example, omega-9 or n-9 means that the double bond is located at the ninth carbon atom from the -CH3 group.

Of the main fatty acids in the diet, polyunsaturated fatty acids (PUFA) are subdivided into omega-6 (n-6), omega-3 (n-3), and omega-3 long-chain or very long chain (n-3 LC) PUFA. The monounsaturated fatty acid (MUFA) oleic acid is classified as cis-omega-9, while two of the main trans-MUFA are classified as omega-9 and omega-7 (Table 1).

ROLES IN THE BODY

Omega-3, omega-6 and cis-omega-9 fatty acids have important roles in the diet. Cis-omega-9 MUFA can be oxidised to provide energy, incorporated into tissues or converted into other fatty acids. Since they can be synthesised in the body, there is no specific dietary requirement for these fatty acids. In contrast, the parent omega-3 fatty acid (alpha-linolenic acid) and the parent omega-6 fatty acid (linoleic acid) are defined as essential. They are precursors of biologically active substances such as prostaglandins, prostacyclins and leukotrienes which are important, for example, for immunological reactions and the regulation of blood pressure. LC PUFA are important for the structure of cell membranes and help to control membrane functions such as fluidity and permeability.

REQUIREMENTS

In Europe, requirements for fatty acids were assessed by EFSA in 2010[1]. No Dietary Reference Values were set for total PUFA, total MUFA or for oleic acid specifically. For adults, daily requirements for Average Intakes for linoleic acid were set at 4.0% energy, for alpha-linolenic acid at 0.5% energy, and for EPA + DHA at 250mg/day, with an additional 100-200mg DHA/day required for pregnancy and lactation.

In the USA, a recent development is that the 2015 Dietary Guidelines Advisory Committee Report[2], a systematic review of the literature that provides evidence-based recommendations to inform revision of the Dietary Guidelines for Americans, has not recommended an upper limit on total fat consumption.

The Committee concluded that dietary advice should emphasise optimising the types of fat in the diet rather than reducing total fat intake. This may result in more prominence being given to replacing saturated fats with PUFA rather than with carbohydrate in the American diet, the Committee concluding that for every 1.0% energy from saturated fat that is replaced with PUFA the incidence of coronary heart disease is reduced by 2.0-3.0%, whereas replacing total fat with overall carbohydrates does not lower cardiovascular disease risk.

HEALTH BENEFITS

The evidence for health benefits of fatty acids has been assessed in recent years as part of the exercise of authorising nutrition and health claims in Europe[3]. The list of authorised health claims provides a good summary of the generally accepted health benefits for omega-3, -6 and -9 fatty acids and the required amounts to achieve the claimed effects (Table 2).

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This demonstrates that most of the authorised health claims in Europe are for omega-3 LC PUFA, with other claims mostly recognising the physiological benefits of the essential fatty acids. The approved claim for oleic acid (omega-9) recognises the benefit of replacing saturated fats with unsaturated fats in order to maintain normal levels of blood cholesterol.

The list also demonstrates the wide range of beneficial effects of these fatty acids including benefits for markers of heart health, heart function, blood pressure, the development and maintenance of normal vision and brain function, development of the eye and for growth and development in children. Further, it shows that the target groups that can benefit from omega-3 oils include the foetus, infants, children, pregnant and lactating women as well as the general population.

For some of the claims, the required intakes are higher than the DRVs set for adults in Europe. For example, the claim that DHA and EPA intake contributes to the maintenance of normal blood pressure requires a daily adult intake of 5.0g EPA and DHA combined.

MAIN DIETARY SOURCES

Linoleic acid is found in oils, particularly corn, soybean and sunflower-seed oils, alpha-linolenic acid in walnuts, linseeds and rapeseed oil, while LC omega-3 PUFA are mainly found in fish oils. Oleic acid is found in seeds and nuts and in olive, high-oleic sunflower-seed and rapeseed oils. A further source of these fatty acids is dietary supplements, which provide concentrated amounts in different combinations and from varying sources. These can make a useful addition to the diet, particularly where high intakes are required to achieve the health benefit and for people who do not like, or who do not frequently consume, oily fish.

Table 1: The main omega-3, -6, -7 and -9 fatty acids in the diet

Common name	Systematic Name	Abbreviation
Monounsaturated fatty acids (MUFA)		
Cis-monounsaturated fatty acids (*cis*-MUFA)		
Oleic acid	(Octadecenoic acid)	18:1 (omega-9)
Trans-monounsaturated fatty acids (*trans*-MUFA)		
Elaidic acid	(Octadecenoic acid)	18:1 (omega-9)
Trans-vaccenic acid	(Octadecenoic acid)	18:1 (omega-7)
Polyunsaturated fatty acids (PUFA)		
n-6 Polyunsaturated fatty acids (n-6 PUFA)		
Linoleic acid	(Octadecadienoic acid)	18:2 (omega-6)
γ-Linolenic acid	(Octadecatrienoic acid)	18:3 (omega-6)
Arachidonic acid	(Eicosatetraenoic acid)	20:4 (omega-6)
n-3 Polyunsaturated fatty acids (n-3 PUFA)		
α-Linolenic	(Octadecatrienoic acid)	18:3 (omega-3)
n-3 Polyunsaturated long chain fatty acids (n-3 LCPUFA)		
EPA	(Eicosapentaenoic acid)	20:5 (omega-3)
DPA	(Docosapentaenoic acid)	22:5 (omega-3)
DHA	(Docosahexaenoic acid)	22:6 (omega-3)

Table 2: Authorised EU health claims for omega-3,-6 and -9 fatty acids

Fatty acid type	Fatty acid	Claim wording	Conditions of use
Article 13.1: 'General function claim'			
Omega-3	α-Linolenic acid	ALA contributes to the maintenance of normal blood cholesterol levels	Foods bearing this claim must meet the conditions to make a nutrition claim for 'Source of ALA', as referred to in the claim 'Source of omega 3 fatty acids', and consumers are to be informed that the beneficial effect is obtained with a daily intake of 2.0g ALA.
Omega-3	Docosahexaenoic acid and eicosapentaenoic acid	DHA and EPA contribute to the maintenance of normal blood pressure	Foods bearing this claim must provide a daily intake of 3.0g EPA and DHA, and consumers are to be informed that the beneficial effect is obtained with a daily intake of 3.0g EPA and DHA. When used on food supplements and/or fortified foods, consumers are to be informed not to exceed a supplemental daily intake of 5.0g EPA and DHA combined. The claim is not for use on foods targeting children.
Omega-3	Docosahexaenoic acid and eicosapentaenoic acid	DHA and EPA contribute to the maintenance of normal blood triglyceride levels	Foods bearing this claim must provide a daily intake of 2.0g EPA and DHA, and consumers are to be informed that the beneficial effect is obtained with a daily intake of 2.0g EPA and DHA. When used on food supplements and/or fortified foods, consumers are to be informed not to exceed a supplemental daily intake of 5.0g EPA and DHA combined. The claim is not for use on foods targeting children.
Omega-3	Docosahexaenoic acid	DHA contributes to maintenance of normal brain function	Foods bearing this claim must contain at least 40mg DHA per 100g and per 100kcal, and consumers are to be informed that the beneficial effect is obtained with a daily intake of 250mg DHA.
Omega-3	Docosahexaenoic acid	DHA contributes to the maintenance of normal blood triglyceride levels	Foods bearing this claim must provide a daily intake of 2.0g DHA and must contain DHA in combination with EPA. Consumers are to be informed that the beneficial effect is obtained with a daily intake of 2.0g DHA. When used on food supplements and/or fortified foods, consumers are to be informed not to exceed a supplemental daily intake of 5.0g EPA and DHA combined. The claim is not for use on foods targeting children.
Omega-3	Docosahexaenoic acid	DHA contributes to the maintenance of normal vision	Foods bearing this claim must contain at least 40mg DHA per 100g and per 100kcal. Consumers are to be informed that the beneficial effect is obtained with a daily intake of 250mg DHA.
Omega-3	Eicosapentaenoic acid and docosahexaenoic acid	EPA and DHA contribute to the normal function of the heart	Foods bearing this claim must meet the conditions to make a nutrition claim for 'Source of EPA and DHA' as referred to in the claim 'Source of omega-3 fatty acids'. Consumers are to be informed that the beneficial effect is obtained with a daily intake of 250mg EPA and DHA.

Omega-6	Linoleic acid	LA contributes to the maintenance of normal blood cholesterol levels	Foods bearing this claim must provide at least 1.5g LA per 100g and per 100kcal. Consumers are to be informed that the beneficial effect is obtained with a daily intake of 10g LA.
Omega-9	Oleic acid	Replacing saturated fats in the diet with unsaturated fats contributes to the maintenance of normal blood cholesterol levels. Oleic acid is an unsaturated fat.	To bear the claim, foods must be high in unsaturated fatty acids, as referred to in the nutrition claim 'High unsaturated fat'.
Omega-3, -6, -9	Monounsaturated and/or polyunsaturated fatty acids	Replacing saturated fats with unsaturated fats in the diet contributes to the maintenance of normal blood cholesterol levels [MUFA and PUFA are unsaturated fats].	To bear the claim, foods must be high in unsaturated fatty acids, as referred to in the nutrition claim 'High unsaturated fat'.
Article 14.1(b): 'Children's development and health claim'			
Omega-3	Docosahexaenoic acid	DHA intake contributes to the normal visual development of infants up to 12 months of age	Consumers must be informed that the beneficial effect is obtained with a daily intake of 100mg DHA. To bear the claim, follow-on formula must contain at least 0.3% of the total fatty acids as DHA.
Omega-3	Docosahexaenoic acid	DHA maternal intake contributes to the normal brain development of the foetus and breastfed infants	To bear the claim, foods must provide a daily intake of at least 200mg DHA. Information to be given to pregnant and lactating women that the beneficial effect is obtained with a daily intake of 200mg DHA in addition to the recommended daily intake for omega-3 fatty acids for adults, i.e. 250mg DHA and EPA in total.
Omega-3	Docosahexaenoic acid	DHA maternal intake contributes to the normal development of the eye of the foetus and breastfed infants	To bear the claim, foods must provide a daily intake of at least 200mg DHA. Information to be given to pregnant and lactating women that the beneficial effect is obtained with a daily intake of 200mg of DHA in addition to the recommended daily intake for omega-3 fatty acids for adults, i.e. 250mg DHA and EPA in total.
Omega-3	α-Linolenic acid & linoleic acid, essential fatty acids	Essential fatty acids are needed for normal growth and development of children	Consumers are to be informed that the beneficial effect is obtained with a daily intake of 2g ALA and a daily intake of 10g LA.

ALA: α-Linolenic acid; DHA: Docosahexaenoic acid; EPA: Eicosapentaenoic acid; LA: Linoleic acid.

DIETARY INTAKES OF LC PUFA

To achieve adequate intake of the LC omega-3 PUFA, it is recommended in the UK to eat one portion of oily fish (140g)/week. The latest NDNS survey results[4] show consumption is well below this in all age groups, particularly in younger people, being equivalent to 11g/week for 11- to 15-year-olds, 21g/week for 16- to 24-year-olds, 47g/week for 25- to 49-year-olds, 76g/week for 50- to 64-year-olds and 90g/week (103g for men and 81g for women) for 65+-year-olds. While adults aged 65 years and over have the highest consumption of oily fish, this still fell below the recommended one portion/week.

As well as intake increasing with age, intake also increases from the lowest to highest quintile

The age group with the highest percent of oily fish consumers over the four-day recording period was older adults (aged 65+ years) of which 38% were consumers

of income for men and women aged 19 to 64 years. The age group with the highest percent of oily fish consumers over the four-day recording period was older adults (aged 65+ years) of which 38% were consumers, followed by adults aged 19 to 64 years of which only 23% were consumers. Only 8.0 to 12% of children consumed oily fish over the recording period.

Comparing mean intakes of oily fish consumption for years 1 and 2 of the NDNS rolling programme with years 3 and 4, shows that intakes were similar in all age and sex groups. This indicates that there has been no trend towards increasing intakes over this time period.

NOVEL SOURCES OF LC OMEGA-3S

Given that oily fish is the richest source of LC omega-3 fatty acids and, given that intakes remain stubbornly low, the search is on for novel sources that can be used to increase supplies of these fatty acids in the diet. Also, concerns have been raised about lower levels of LC omega-3 fatty acids in farmed fish, which is mainly due to the use of a combination of fish and vegetable oils in fish feeds due to the lack of availability and increasing costs of pure fish oils. After many years, a collaborative research project between the University of Stirling and Rothamsted Research has resulted in the development of genetically modified (GM) plants that can produce up to 20% of EPA. In this research programme, five microalgal and fungal genes were transferred to Camelina plants (*Camelina sativa*) in order to generate a renewable terrestrial sustainable source of omega-3 oils. The oil extracted from these plants was then tested in fish feeds for farmed Atlantic salmon.

In the study[5], three diets were fed to (contained) fish for seven weeks, one containing standard fish oil, one containing oil from Camelina plants that were not been genetically modified, and one containing oil derived from the GM plants. The results showed that oil derived from the GM plants was an effective substitute for fish oil in salmon feed with growth performance, feed efficiency, fish health and nutritional quality for the human consumer unaffected by the oil from the GM plants.

Clearly GM technology is controversial, but its use to deliver a direct consumer benefit may be more acceptable to consumers than previous uses of the technology.

CONCLUSIONS

Omega oils are important for human health, particularly the omega-3 and omega-6 series of fatty acids for which a number of health benefits have been defined at varying levels of intake and for various sub-groups of the population. The importance of using PUFA as opposed to carbohydrate to replace saturated fats to reduce CVD risk has been given more emphasis by the latest review that will inform revision of the Dietary Guidelines for Americans. In the UK, dietary intakes of oily fish, the main source of LC omega-3 PUFA, remain low and coupled with concerns about the content of omega-3 fatty acids in farmed fish, sustainable ways to maintain high levels of omega-3 are being investigated.

References

1 EFSA (2010). Scientific Opinion on Dietary Reference values for fat including saturated fatty acids, polyunsaturated fatty acids, monounsaturated fatty acids, trans fatty acids and cholesterol. EFSA Journal 8(3) 1461

2 Dietary Guidelines Advisory Committee; Scientific Report of the 2015 Dietary Guidelines Advisory Committee (2015). www.health.gov/dietaryguidelines/2015-scientific-report

3 Community list of claims: http://ec.europa.eu/nuhclaims

4 Public Health England, Food Standards Agency, 2014. National Diet and Nutrition Survey: Results from Years 1, 2, 3 and 4 combined of the rolling programme (2008/9-2011-12)

5 Betancor et al (2015). A nutritionally-enhanced oil from transgenic Camelina sativa effectively replaces fish oil as a source of eicosapentaenoic acid for fish. Scientific Reports. 5: 8104 | DOI: 10.1038/srep08104