DHAid™ – The vegetarian source

**Abstract:** In humans, DHA occurs naturally as a cell membrane fatty acid in the brain, retina, testes and sperm, and has been reported to be essential in the development of these organs and cells. There it is crucial for the functioning of embedded proteins, i.e. rhodopsin for vision and postsynaptic receptors for neurotransmission. In phospholipids in general, DHA contributes to membrane properties such as fluidity, flexibility and permeability. A deficiency in DHA can lead to memory loss, learning disabilities and impaired visual acuity. Limited storage of DHA in adipose tissue suggests that a continuous supply is needed. These facts clearly demonstrate the physiological importance of DHA for humans and have resulted, for example, in the recommendation of increasing dietary intake of DHA during pregnancy and lactation. Also in the maintenance of cardiovascular health, DHA plays an important role. DHAid™ is a pure vegetarian source of omega-3 docosahexaenoic acid (DHA). It is produced from microalgae in a controlled process in fermentation vessels by the Swiss life-science company Lonza. Due to its renewable sources, DHAid™ is environmentally friendly. DHAid™ is allergen free and is free of potential contaminants that are discussed for seafood.

**Key words:** docosahexaenoic acid, DHA, microalgae oil, omega-3, polyunsaturated fatty acids

**What is DHA (docosahexaenoic acid)?**

Fatty acids are classified according to their degree of saturation (number of double bonds), into saturated fatty acids, monounsaturated fatty acids (MUFAbs) and polyunsaturated fatty acids (PUFAs). PUFAs can further be classified into two different series that cannot be converted into each other: omega-3 and omega-6 PUFAs [1]. There are distinct types of omega-3 fatty acids that are ingested with the diet and used by the body. These are docosahexaenoic acid (DHA), eicosapentaenoic acid (EPA) as well as alphalinolenic acid (ALA). Whereas ALA can be found most abundantly in foods, it has become clear that DHA is the most important omega-3 fatty acid for human health, particularly in the areas of brain, heart and eye health. It occurs naturally as a building block of cell membranes [1, 2] and contributes to membrane properties such as fluidity, flexibility and permeability [3].

**Sources of DHA**

DHA in the body is derived mainly from intake of fish and seafood. Fatty fish, such as herring, mackerel, tuna or wild salmon, is the most substantial source of DHA [4]. Table 1 gives an overview of the DHA contents in fish and seafood. Nevertheless it is well-known that dietary DHA intake with a typical Western diet is well below recommended values. It is also clear that vegetarians and those who do not eat fish get very little DHA with their diet [5]. Therefore, the consumption of dietary supplements and functional food enriched with DHAid™ constitutes an attractive option in order to achieve the recommended intake. It is important to note that DHAid™ represents an allergen-free and vegetarian source of DHA that comes from renewable resources and does not contribute to the common problem of overfishing of the sea.

**Conversion between different omega-3 fatty acids**

Nature has foreseen a pathway to produce DHA from the precursor omega-3 fatty acid ALA in the human body. During this process, ALA is enzymatically converted to EPA and further to DHA. An important question is whether dietary intake of ALA, can provide sufficient amounts of EPA and DHA by conversion through the omega-3 PUFA elongation-desaturation pathway. ALA is present in marked amounts in plant sources, including green leafy vegetables and commonly-consumed oils such as rape-seed and soybean oils, so that increased intake of this fatty acid would be easier to achieve than an increase in fish consumption. However, it has become clear that the dietary intake of the precursor ALA cannot make up for the low dietary intake of DHA. Humans are very poor DHA synthesizers from precursor omega-3 fatty acids [6]. Aging, illness and stress, as well as excessive amounts of omega-6 rich oils (corn, safflower, sunflower, cotton seed) can all compromise conversion [7]. Various human supplementation studies have addressed the question of the bioconversion process and have concluded that conversion of ALA to EPA is limited and conversion further to DHA is extremely low [8-10]. Aging, illness and stress contribute to this limited conversion process as well as the excessive intake of omega-6 rich oils due to competition for the same enzymes [7]. In addition, there is also a certain degree of retro-conversion from DHA back to EPA [11]. EPA but not DHA concentrations in plasma were observed to increase in response to dietary EPA intake.

In respect of this background, uptake of dietary DHA might be critical for maintaining adequate membrane DHA concentrations [12].

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**Table 1. DHA content of fish and seafood [4].**

<table>
<thead>
<tr>
<th>Fish species</th>
<th>DHA (mg/100 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlantic salmon</td>
<td>1,457</td>
</tr>
<tr>
<td>Pacific mackerel</td>
<td>1,195</td>
</tr>
<tr>
<td>Atlantic herring</td>
<td>1,105</td>
</tr>
<tr>
<td>Tuna</td>
<td>223</td>
</tr>
<tr>
<td>Haddock</td>
<td>162</td>
</tr>
<tr>
<td>Shrimps</td>
<td>144</td>
</tr>
<tr>
<td>Alaska king crab</td>
<td>118</td>
</tr>
</tbody>
</table>
Levels, which may be explained by increased

tion also increased EPA plasma phospholipid

mentioning that exclusive DHA supplementa-

with DHAid™ (g/100 g fatty acid) [17].

The DHA content of the breast milk is

obtain DHA from the mother via breast milk

After birth, the newborn baby continues to

during pregnancy and lactation to at least

therefore recommend increasing DHA intake

Most national and international authorities the-

Figures 1.


directly related to the dietary DHA intake of the

mother, supplementation with DHA increases

the DHA content in human milk [23, 24]. Pre-

natal and early postnatal positive DHA status is

thought to have important consequences on the

growth and function of the central nervous

system (CNS) and, consequently, on neurolo-

gical and cognitive development of the child

[22, 25-27].

In addition, human pregnancy supplementa-
tion trials with omega-3 fatty acids have shown

a significant reduction in the incidence of pre-
mature delivery [28, 29], and also of post-natal

depressions of the mother [30, 31].

**Benefits from DHAid™**

**Pregnancy**

Under the present dietary conditions, maternal

intake of omega-3 fatty acids is insufficient to

keep up with the increased demand during

pregnancy [18]. Especially in the last trimester,

the period during which much of the fetus’

brain, eye and nervous system development

occurs, maternal DHA levels decline signifi-
cantly [19]. Maternal and infant DHA status

becomes reduced after each following pre-
nancy, which is especially important in pre-

gnancies spaced at short intervals or with mul-

tiple births [20].

Most national and international authorities the-

therefore recommend increasing DHA intake

during pregnancy and lactation to at least

200 mg/day [13, 15, 21].

After birth, the newborn baby continues to

obtain DHA from the mother via breast milk

[22]. The DHA content of the breast milk is

may offer long-term developmental benefits to

their children [18, 22].

In adolescents, DHA supplementation was

found to prevent aggression enhancement
during times of mental stress, such as in exam

periods [36]. In adults, DHA maintains normal

brain function, and scientific evidence links

reduced DHA levels to a number of mental

disorders including depression, dementia, schi-

zophrenia and Alzheimer’s disease [2, 37-42].

Depression and other mental diseases in elderly

subjects are associated with significantly lower

omega-3 fatty acid levels than in same age

control subjects [7, 43-45].

Psychological stress in humans induces the pro-
duction of proinflammatory cytokines of the

omega-6 series which can be increased by an

imbalance of omega-6 to omega-3 fatty acids in

the blood. There is evidence that such an

overproduction is involved in the pathophysio-

logy of major depression [7]. DHAid™ may

contribute to a healthy brain throughout life.

**Visual function**

The importance of DHA in retinal function is

reflected by the high concentration of DHA

especially in the retinal photoreceptor. About

30-40% of the fatty acid composition of the

rod photoreceptor outer segments of the retina

is DHA. Increased dietary intake of omega-3

fatty acids increases the omega-3 fatty acid

content of the rod outer segments. Biophysical

and biochemical properties of DHA may affect

photoreceptor membrane function by altering

permeability, fluidity, thickness and lipid phase

properties [26]. The tissue DHA status affects

retinal cell signalling mechanisms involved in

signal transduction [46].

DHA is involved in the intercellular signalling

pathway that transforms light signals to neuro-

nal activity. Thus, DHA plays an important role in

eye health during the prenatal phase and in

the first years of life as well as in the elderly [26, 46].

Several human studies support the importance

of adequate maternal DHA consumption
during pregnancy for the maturation of the

visual system of infants [18, 47]. Various clinical

studies in infants and meta-analyses suggest

that greater visual acuity in infancy is associa-
ted with increased intake of long-chain PUFAs.

Reduced visual acuity has consistently been

observed in primate and rodent offspring sub-

jected to dietary conditions during gestation

that result in significant reductions in retinal

concentrations of DHA. Further it has been

observed that functions of the retina mature

earlier when infants are supplemented with

DHA [18, 34].

In addition, diets high in omega-3 fatty acids

and especially DHA may act in a protective role

against age-associated pathology to the vascu-

lar and neuronal retina in the elderly [48, 49].
**Cardiovascular health**

Although a traditional Eskimo diet contains much more fat than commonly recommended, Eskimo populations seem to be immune to heart disease [6, 50]. It is now recognized that this is thanks to the intake of large amounts of fish and marine mammals, which are rich in omega-3 PUFAs [51]. Similar studies in Japan, comparing inhabitants from fishing villages with farming villagers, also showed that a higher intake of oily fish resulted in a reduced risk of heart disease.

Various scientific studies clearly demonstrate that a high intake of omega-3 fatty acids, especially DHA, correlates with heart health [52, 53]. Interestingly, the dietary precursor essential fatty acid of EPA and DHA, alpha-linolenic acid (ALA), has not consistently been found to have beneficial effects on cardiovascular health [54, 55].

The heart health effects of DHA include effects on triglycerides (figure 2), high-density lipoprotein cholesterol, platelet function, endothelial and vascular function, blood pressure, cardiac excitability, measures of oxidative stress as well as pro- and anti-inflammatory cytokines [17, 56-62]. Increased consumption of dietary omega-3 PUFAs increases the concentration of omega-3 PUFA in plasma phospholipids, which is associated with a protective effect on cardiovascular diseases and lower plasma homocysteine levels [63].

Two large intervention studies have shown that fish or fish oil consumption have a significant protective effect against fatal cardiovascular disease. The DART-Study (Diet and Reinforcement Trial) demonstrated that relatively low dosages of omega-3 fatty acids reduced the risk of a secondary coronary event and resulted in a 30% reduction in mortality attributable to a reduction in CVD death [60]. In the GISSI Prevenzione Trial, which included more than 11,000 subjects that had survived a heart attack, the risk of cardiovascular death was significantly lowered by 17% after 3 months of supplementation with DHA/EPA [64, 65].

A low (≤ 4%) red blood cell membrane content of EPA + DHA (omega-3 index) has recently been identified as an indicator for increased risk of death from coronary heart disease, whereas an omega-3 index ≥ 8% was associated with the greatest cardio-protection [66]. In a double-blind, placebo-controlled intervention study with 114 healthy vegetarian subjects, supplementation with DHAid™ during 8 weeks could significantly increase the omega-3 index [17].

Mori and colleagues concluded from a study with 59 mildly hyperlipidemic but otherwise healthy men that DHA supplementation is the principal omega-3 fatty acid in fish, since DHA but not EPA was found to lower blood pressure and heart rate in humans [67].

Current dietary intakes of DHA in North America and Europe are well below those recommended by the American Heart Association for the management of patients with coronary heart disease [68]. Dietary supplements and food containing DHAid™ therefore can be regarded as an ideal way to increase DHA levels and thus increase cardiovascular health.

**DHAid™ production process**

Using naturally occurring microalgae, Lonza’s innovative technology allows DHA oils to be produced with superior quality. During the unique production process in fermentation vessels, microalgae are grown in large volumes and accumulate significant quantities of DHA. Then, DHA is extracted from the dried microalgae and refined in processes that are very similar to those used in the production of conventional vegetable oils.

**DHAid™ quality & safety**

**DHAid™ quality at a glance:**
- Accordance with HACCP and GMP standards for food products.
- Production ISO 9001 certified.
- Production based on renewable resources.
- Full traceability.
- Free of any materials of animal origin.
- Free of any genetically modified organisms (GMOs).
- Allergen free.
- Vegetable source of DHA.
- High concentration of DHA.
- Clean taste.

**DHAid™ safety at a glance:**
- Self-affirmed GRAS.
- Solvent free production process.
- Approved according to Novel Food in EU, Australia and New Zealand.
- Free of any potential contaminants that are discussed for seafood [69].
- Multi-step fermentation process of DHAid™ uses a non-toxic and non-pathogenic marine protist, Ulkenia sp.
- Extensive human, animal and *in vitro* Tox studies confirm the safety of DHAid™ from microalgae [70-72].

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**Figure 2. Reduction in blood triglyceride levels following 8 weeks of DHAid™ supplementation as compared with the placebo group [61].**

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