Omega-3 Phospholipids from Krill
SUPERBA™ KRILL POWDER

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Aker BioMarine’s krill powder — called Superba™ Krill powder — is prepared from an aqueous extract of krill without the use of organic solvents. The production process involves heating, separation, drying and cooling steps. The resulting powder consists primarily of protein (around 25%) and fat (around 55%), including phospholipids rich in omega-3 fatty acids (see Table 1). No components are chemically altered during the extraction process.

ANTARCTIC KRILL, Euphausia superba

With only an average body length of 5 centimeters, krill represent one of the largest biomasses on Earth. They are shrimp-like in appearance, with big black eyes and a reddish, semi-transparent shell (see Figure 1). Antarctic krill (Euphausia superba) live in huge swarms in the icy cold waters of the Southern Ocean where they are harvested from the wild.

The most biologically active omega-3 fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), have proven to be essential for early human development and also later in life in supporting health and fitness. Not only do the body’s cells and tissues need these fatty acids for normal functioning, they also have important clinical roles as therapeutic agents. DHA is especially crucial in brain and heart cells and in the rods and cones of the eye. Thus, a good supply of DHA early in life is crucial for optimal brain, eye and heart development and function. Both EPA and DHA play a role in regulating blood lipids, inflammation, immune function, blood coagulation, blood pressure, bone turnover, and insulin sensitivity, along with many other physiological functions. Moreover, EPA and DHA have been documented for decreasing high blood lipids and reducing the risk of heart disease. They can also be effective in the treatment of inflammatory diseases like arthritis. More recent research has shown some benefits in psychiatric and psychological disorders as well as cognitive decline.

Omega-3 benefits, and the recommendations that have resulted, have created a global demand for EPA and DHA, which is currently mainly met by fish. However, increasing pressure on fish stocks has prompted the omega-3 market to explore other sources that are more sustainable. Since krill oil contains EPA and DHA, it has similar health benefits as fish oil. There is however an additional aspect to this comparative consideration: in fish oil the EPA and DHA are mainly bound to triglycerides, while in krill oil these fatty acids are bound to phospholipids.

This difference in chemical structure may be of relevance to human health since some studies have shown that fatty acids bound to phospholipids are more effectively incorporated into cells and tissues compared to triglycerides (1-4).

This means that krill oil confers the benefits of fish oil but at a lower intake of EPA and DHA. Moreover, krill oil is a powerful combination of omega-3 fatty acids, phospholipids, choline, phosphorus and astaxanthin, which are all essential nutrients with their own health benefits (see Table 2).
In general, proteins can be enzymatically cut into peptides, which are short amino acid sequences. Amino acids are key constituents of a healthy diet and particularly important in recovery after injury, surgery or disease. Further, specific amino acid supplements were proposed to help physiological processes that include immune function, cognition or even exercise performance (5).

Proteins of marine origin have revealed positive effects on blood triglyceride and cholesterol levels (6, 7), as well as on inflammation (8). In fact, the combination of omega-3 fatty acids with proteins is proposed to have additive effects, particularly when their lipid lowering potential was investigated in rodent models (9, 10).

On the other hand krill powder as a bioactive food ingredient has been investigated in the form of a krill protein concentrate that includes omega-3 fatty acids (11). The protein/omega-3 fatty acid combination prevented renal injury in rats (12). Other studies have shown the anti-hypertensive effects of an Antarctic krill peptide powder without lipids (13) and reduction of triglyceride accumulation with a water-soluble extract of Pacific krill (14).

The long-chain omega-3 fatty acids EPA and DHA are polyunsaturated fatty acids that are crucial for maintaining and improving cellular health. They are referred to as polyunsaturated because they contain more than one double bond that is “unsaturated” with hydrogen atoms. Unsaturated fatty acids are grouped into different classes depending on the position of the first double bond from the methyl end of the fatty acid chain. Hence, omega-3 fatty acids have their first double bond at carbon atom number three and omega-6 fatty acids at carbon atom number six from their methyl end. The precursors for omega-3 fatty acids (α-linolenic acid, ALA) and omega-6 fatty acids (linoleic acid, LA) cannot be made by the human body and must be obtained through the diet. This is why they are referred to as “essential” fatty acids. The human body can convert ALA into the longer-chain fatty acids, EPA and DHA, but only at a low rate (15-17). Both omega-3 and omega-6 fatty acids are needed for optimal health. However, since the Western diet is abundant in omega-6 fatty acids and relatively deficient in omega-3 fatty acids, the balance between the two is highly disturbed (18, 19).
The high prevalence of omega-6 fatty acids is directly related to the overconsumption of vegetable oils rich in these fatty acids, as well as industrially produced meat. At the same time, the consumption of omega-3-rich fish has decreased markedly during the last several decades. Today, the ratio between omega-6 to omega-3 can be as high as 10-20:1, whereas historically it was as low as 1-2:1 (20). Most recent recommendations call for a ratio of 5:1 (21).

Striking the right balance between omega-6 and omega-3 fatty acids is important for health. This is because omega-6 fatty acids produce too many pro-inflammatory molecules that can lead to increased blood clotting, impaired immune response, and systemic inflammation. In addition, omega-6 and omega-3 fatty acids compete for the same enzymes to be converted into pro-inflammatory or anti-inflammatory hormones, respectively (See Figure 2).

While triglycerides consist of three fatty acids bound to a glycerol backbone, phospholipids only have two fatty acids and a phosphorus group that is further linked to a head group, such as choline (see Figure 3). The percentage of phospholipids in krill powder is 22% (see Table 1).

In addition to the combined or complementary effects of omega-3 fatty acids bound to phospholipids, consumption of phospholipids and choline alone has also been shown to be important for brain, lipid and liver metabolism.

In particular, choline is an important component of phospholipids. It is also used by the body to produce acetylcholine, a neurotransmitter associated with memory. This is important because aging decreases the availability of neurotransmitters like acetylcholine. Hence, it has been hypothesized by some researchers that supplementation of choline-containing compounds, such as phosphatidylcholine, might stimulate the production of acetylcholine and confer a possible beneficial impact on the central nervous system (22).

Choline supplementation is especially important for vegetarians, vegans and people who over-consume alcohol, since these groups are known to have an elevated risk of choline deficiency. Choline deficiency not only increases the risk of developing liver dysfunction (23-25), but it could also interfere with memory function (26).
**ASTAXANTHIN IS PRESENT IN KRILL POWDER**

Astaxanthin is the antioxidant carotenoid that gives krill powder its reddish color (see Figure 4). Astaxanthin is a very potent antioxidant with anti-inflammatory properties and the ability to cross the blood-brain barrier (27, 28). It can neutralize free radicals, which are unstable molecules that can damage cells and increase the risk for age-related diseases, cancer, and heart disease. Astaxanthin has been associated with protecting lipids and low-density lipoproteins (LDL) from oxidation (29, 30). Furthermore, research suggests that higher doses might be beneficial for cardiovascular health because it increases the “good” HDL-cholesterol and lowers triglyceride levels in both animals and humans (27, 28, 31-33).

**SUPERBA™ KRILL POWDER STUDIES**

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| Inflammation  | Mice overexpressing TNFα    | 6 weeks      | - Increased lipid degradation  
- Reduced lipid generation  
- Reduced glucose and cholesterol metabolism  
- Improved blood and liver lipid levels  
- Reduced liver inflammation | (34) |
| Obesity       | Mildly obese men            | 24 weeks     | - Decreased endocannabinoid overactivity  
- Improved blood lipid levels  
- Decreased waist/hip ratio  
- Decreased visceral fat/skeletal muscle mass ratio | (36) |
| Gene regulation| Healthy mice                | 12 weeks     | - Beneficial hepatic gene regulation  
- Reduced fatty acid and amino acid degradation  
- Increased energy metabolism | (38) |

**Krill powder increases liver lipid catabolism and reduces glucose mobilization in tumor necrosis factor-alpha transgenic mice fed a high-fat diet (34)**

Obesity is associated with chronic low-grade inflammation that negatively affects lipid metabolism. This leads to increased adiposity, liver fat accumulation and insulin resistance (35). Superba™ Krill powder was tested in a transgenic mouse model of chronic inflammation (human tumor necrosis factor-alpha (hTNFα) mice) to see if it could positively affect lipid metabolism in the liver. To this end, young male hTNFα mice received a high-fat-diet containing Superba™ Krill powder for six weeks. At the end of the study, the liver of mice eating the krill powder diet revealed increased degradation of lipids, reduced generation of new lipids and reduced cholesterol and glucose metabolism compared to the mice fed the high-fat diet alone. As a result, the krill powder-fed animals showed improved blood and liver lipid levels.
Chronic treatment with krill powder reduces plasma triglyceride and anandamide levels in mildly obese men (36)

To investigate if Superba™ Krill powder has lipid-lowering effects and has the potential to ameliorate obesity-associated parameters in humans, a pilot study in mildly obese men was performed (36). Researchers gave 4g of krill powder daily to 11 subjects for 24 weeks. Blood triglyceride levels, a risk factor for heart disease, were reduced 22% already after 12 weeks of Superba™ Krill powder supplementation. By the end of the study a ~3% decrease in waist/hip ratio was observed. These changes were accompanied by re-equilibration of the blood endocannabinoid levels that correlate with obesity-associated dysmetabolism (37).

A krill powder-diet reduces fatty acid and amino acid catabolism while increasing mitochondrial oxidative phosphorylation, a study of the hepatic transcriptome in mice (38)

To demonstrate how Superba™ Krill powder affects hepatic gene expression in a non-obese, non-inflammatory animal model, a krill powder supplemented diet was given for three months to mice. The study revealed that pathways of metabolic processes were down-regulated, including glucose metabolism and degradation of lipids and amino acids. However, energy metabolism was up-regulated at the gene level. Krill powder as a mixture of omega-3 fatty acids and peptides could therefore have potential to prevent age-related decline in weight and energy due to the preservation of amino acids in combination with increased energy production.

Of interest is also the comparison to krill oil that affected less pathways compared to krill powder in the same study (72 vs. 52) (39). Hence, the presence of krill proteins in addition to the bioactive omega-3 fatty acids might lead to a wider activity range than krill oil does alone.

Conclusion

Dietary intake of the marine omega-3 fatty acids EPA and DHA has been linked to many health benefits, from improved cardiovascular health and cognitive function, to reduced levels of inflammation. Due to its inherent advantages – i.e., omega-3 fatty acids bound to phospholipids, highly digestible peptides, naturally pure and stable, sourced sustainably – krill powder has enormous potential in supplying omega-3 fatty acids in powder form.

References