

BORAGE OIL

INTRODUCTION

What is Borage?

Borage (*Borago officinalis*) is an annual plant that grows to about 2 feet (60 cm) in height. Its leaves are large, oval and pubescent (hairy) and smell and taste similar to cucumber. Its flowers are star-shaped and blue, white or pink in colour. Although borage is native to the Mediterranean region, it is now widely grown all over Europe and North America.



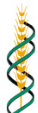
How is Borage Oil Used?

Historically, borage was used as a medicinal and culinary herb. Its leaves and flowers were used to make tea, season soups and flavour wines and salads. It is borage seed oil however, that has been gaining popularity recently due to its nutritional quality and wide range of potential health benefits. Borage oil is taken as a nutritional supplement and is not normally used as a food ingredient. It is available in bottled or in gel capsule form and is often sold in combined preparations with flax oil, fish oil or minerals and vitamins for added benefits. Borage oil should be refrigerated in a sealed opaque container to prevent oxidation of its polyunsaturated fatty acids.



Is Borage Oil Expensive?

Scientific studies have suggested that supplementation with borage oil may be effective in treating or preventing conditions associated with abnormal essential fatty acid metabolism. Although borage oil is not particularly expensive, several months of supplementation may be necessary before results appear. Therefore, costs of treatment with borage oil will accumulate. Gamma-linolenic acid (GLA) is believed to be the active constituent of borage oil. Compared to evening primrose oil (another source of GLA), borage oil contains twice as much GLA and is usually similarly priced. However, it is still unclear whether or not the higher GLA content of borage oil makes it more effective than evening primrose oil.



NUTRITIONAL INFORMATION

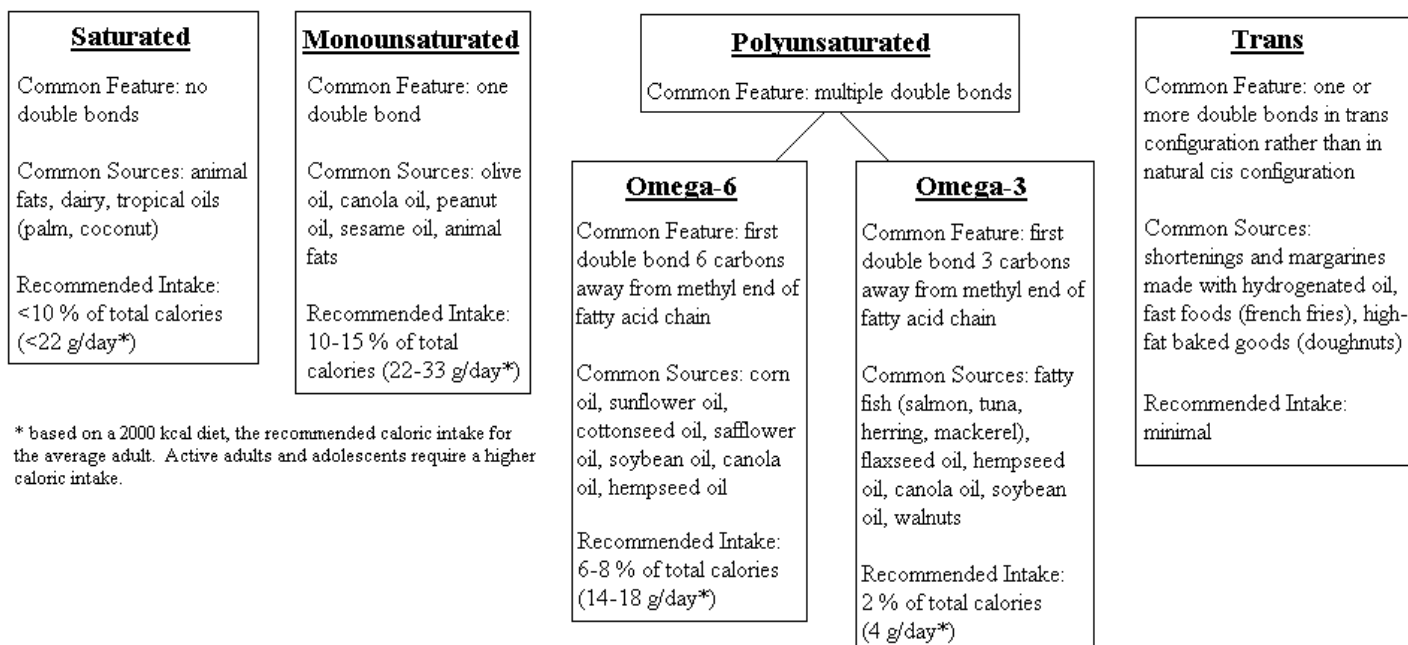
Borage Oil as a Source of “Good Fat”

What is “Good Fat”?

Fat is made up of carbon-based molecules known as fatty acids. Fatty acids are categorized as saturated, monounsaturated or polyunsaturated according to the number of double bonds in their carbon chain. Whereas saturated fatty acids have no double bonds and monounsaturated fatty acids have one, polyunsaturated fatty acids have multiple double bonds in their carbon chain. There are two categories of polyunsaturated fatty acids, the omega-6 and omega-3, which differ in the placement of their double bonds. Trans fatty acids are unsaturated fatty acids whose double bonds have been altered from the natural cis configuration to the trans configuration.

In general, saturated fatty acids and trans fatty acids are considered harmful and should not be consumed in excess (“bad fat”). Polyunsaturated and monounsaturated fatty acids on the other hand, are beneficial when consumed in the recommended amounts (“good fat”). It is generally recommended that approximately 30 % of calories in the diet be acquired from total fat, under 10 % from saturated fat (and trans fat), 10-15 % from monounsaturated fat and 8-10 % from polyunsaturated fat (1 g of fat provides 9 calories of energy). Although an optimal intake of omega-6 and omega-3 polyunsaturated fatty acids has yet to be established, it is often recommended that omega-6 and omega-3 fatty acids be consumed in ratio of approximately 4:1 to maximize their health benefits (Kris-Etherton et al, 2000). In other words, approximately 80 % of polyunsaturated intake should be omega-6 fatty acids and the remaining 20 % omega-3 fatty acids. Most people who consume a conventional North American diet acquire omega-6 and omega-3 fatty acids in a much higher ratio (10-20:1).

Classification of Fatty Acids



* based on a 2000 kcal diet, the recommended caloric intake for the average adult. Active adults and adolescents require a higher caloric intake.

Essential Fatty Acids

It is especially important to consume adequate amounts of polyunsaturated fatty acids in the diet. Saturated and monounsaturated fatty acids can be produced by the body from excess carbohydrate and are therefore not essential in the diet. Polyunsaturated fatty acids on the other hand, cannot be produced by the body and must be acquired from the diet. For this reason, polyunsaturated fatty acids are also known as essential fatty acids.

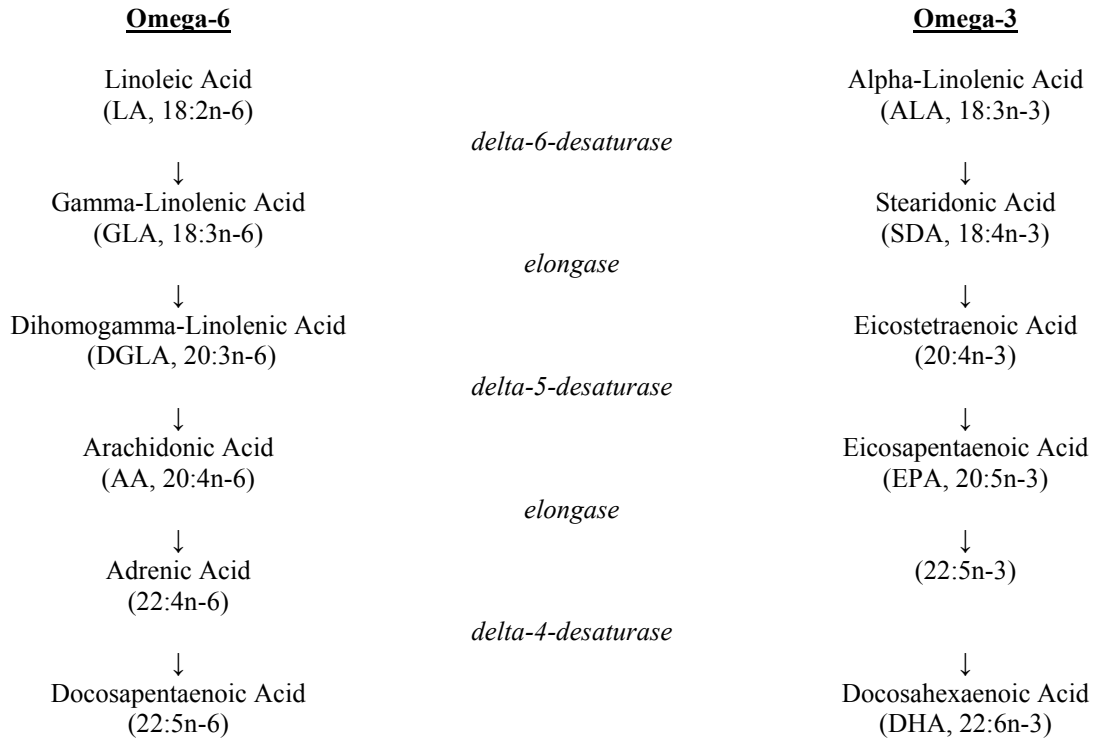
Essential fatty acids are needed for a number of important physiological processes including normal growth, skin and hair growth, cholesterol metabolism and reproductive performance. Like other fatty acids, they can also be oxidized to produce energy or incorporated into cell membranes (outer walls that surround cells). Essential fatty acids help maintain proper cell membrane structure and function, contributing properties of fluidity and flexibility. Omega-3 fatty acids are most abundant in the cell membranes of the brain, retina and the testes and are necessary for proper neural, visual and reproductive function. Omega-6 fatty acids on the other hand, are abundant in the liver and in platelets. It is very important to consume adequate amounts of essential fatty acids during gestation and infancy, when tissues are rapidly developing.

Essential fatty acids are also used by the body to produce eicosanoids. Eicosanoids are a group of hormone-like substances (prostaglandins, leukotrienes, thromboxanes, prostacyclins, lipoxins) that are involved in the regulation of several bodily functions including pain, swelling and inflammation, water retention, blood clotting, nerve transmission, allergic response, steroid production and hormone synthesis among others. If inadequate amounts of essential fatty acids are consumed, abnormal eicosanoid production may result. Abnormal eicosanoid production is implicated in a number of disorders including heart disease, diabetes, cancer and rheumatoid arthritis. Essential fatty acid deficiency can also cause a number of other symptoms including impaired growth, infertility, dermatitis (scaly, dry skin) and defective immune response. It is necessary to consume at least 1-4 % of calories as essential fatty acids to avoid deficiency.

Omega-3 and Omega-6 Fatty Acids

There are two categories of polyunsaturated fatty acids, the omega-6 and the omega-3, which differ in the positioning of their double bonds. The positioning of these bonds causes the fatty acids to have different shapes and functions. Omega-6 fatty acids are far more prominent in the conventional North American diet than omega-3 fatty acids. The precursor fatty acids of the omega-6 and omega-3 series, linoleic acid (LA) and alpha-linolenic acid (ALA) respectively, can be elongated and desaturated (have more double bonds added) in the body and converted into the other members of their group and eventually, into various eicosanoids. In healthy individuals, consuming adequate amounts of LA and ALA should be sufficient to maintain proper fatty acid metabolism and eicosanoid production. Therefore, they are the only polyunsaturated fatty acids that are truly essential in the diet. However, highly unsaturated, long chain polyunsaturated fatty acids (like gamma-linolenic acid, eicosapentaenoic acid and docosahexaenoic acid) often provide benefits that the precursor essential fatty acids do not and in some cases, may be essential in the diet as well.

Essential Fatty Acid Metabolism



Is Borage Oil a Good Source of Good Fat?

Borage oil contains a significant amount of the precursor omega-6 polyunsaturated fatty acid linoleic acid (LA), a moderate amount of monounsaturated fat and very little saturated fat. It is the content of gamma-linolenic acid (GLA) in borage oil however, that separates it from other vegetable oils. Borage oil is nature's richest source of GLA, containing approximately 23 g per 100 g oil.

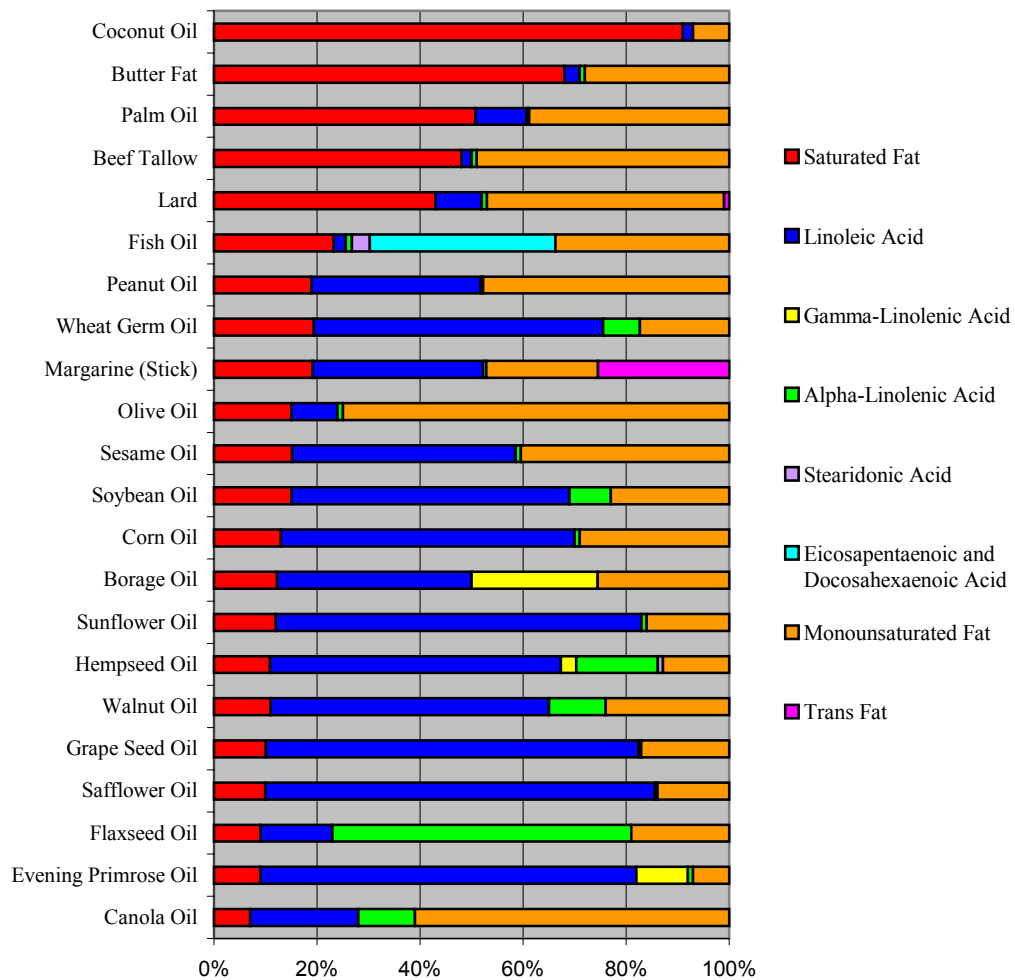
Fatty Acid Content of Borage Oil

<u>Fatty Acid</u>	<u>% of Total Fatty Acids</u>
Saturated	14.9
Monounsaturated	16.6
Polyunsaturated	68.5
<i>Omega-6</i>	
Linoleic Acid	37.3
Gamma-Linolenic Acid	22.9
Other	8.3

Gamma-Linolenic Acid (GLA)

Borage oil is the best source of gamma-linolenic acid (GLA), an omega-6 fatty acid that is not obtained in significant amounts in the conventional diet. In healthy individuals, some of the linoleic acid (LA) that is consumed in the diet is converted into GLA by an enzyme called delta-6-desaturase. GLA is further metabolized into dihomo-gammalinolenic acid (DGLA), arachidonic acid (AA) and eventually into various eicosanoids. The delta-6-desaturase reaction is the rate-limiting (slowest) step in the conversion of LA to long-chain omega 6-fatty acids and is further inhibited by a number of factors including excessive alcohol consumption, high intakes of other fatty acids (saturated, trans and omega-3 fatty acids), stress, aging, gender (males require more essential fatty acids than females), high cholesterol levels, diabetes, smoking and deficiencies in zinc, calcium, magnesium, vitamin C, B vitamins (biotin and pyridoxine) and other minerals and vitamins (Horrobin, 1992a). By providing dietary GLA, the delta-6-desaturase reaction can be bypassed, resulting in more efficient production of long-chain omega-6 fatty acids and eicosanoids. Whereas the DGLA-derived prostaglandin E1 (PGE1) has potent vasodilatory, anti-atherogenic and anti-inflammatory properties, AA-derived eicosanoids (series 2 eicosanoids) are generally considered harmful. GLA supplementation has been shown to increase the production of beneficial DGLA-derived eicosanoids like PGE1 without elevating harmful AA metabolites, exerting an overall beneficial effect (Johnson et al, 1997).

Fatty Acid Content of Fats and Oils



HEALTH BENEFITS

Borage Oil and Rheumatoid Arthritis

Rheumatoid arthritis is a chronic disease characterized by defective regulation of inflammation and the immune response, causing pain, swelling and tenderness of the joints. Dietary administration of GLA has been shown to increase the production of PGE1, a potent anti-inflammatory eicosanoid (Johnson et al, 1997). As a source of GLA, borage oil may be an effective treatment for rheumatoid arthritis.

Can Borage Oil be Used to Treat Rheumatoid Arthritis?

Borage oil may be useful in the treatment of rheumatoid arthritis without producing the gastrointestinal complications characteristic of traditional anti-rheumatic medications (DeLuca et al, 1995). Clinical studies have demonstrated an improvement in rheumatoid arthritis symptoms (joint pain, swelling and tenderness) and decreased need for non-steroidal anti-inflammatory drugs with GLA supplementation of 1.1-2.8 g GLA per day (approximately 4.5-12 g borage oil) for periods of 3 months to 1 year (Pullman-Moar et al, 1990; Leventhal et al, 1993; Rothman et al, 1995; Zurier et al, 1996). Although an optimal dose has yet to be determined (Johnson et al, 1997), it appears as though at least 1.0 to 2.4 g GLA must be taken per day (Calder and Zurier, 2001) for 6-12 weeks for effective treatment (Leventhal et al, 1993). Further research is required to determine an optimal dose and duration of treatment for borage oil.

Borage Oil and Atopic Eczema

Atopic eczema is a common chronic inflammatory condition with symptoms including dry, itchy, scaly skin and increased tendency for skin infection. Although the precise cause of atopic disease is uncertain, it has been proposed that defective delta-6-desaturase function and abnormal eicosanoid synthesis may be involved (Manku et al, 1982). Supplementation with GLA may therefore restore proper eicosanoid production and help treat atopic eczema.

Can Borage Oil be Used to Treat Atopic Eczema?

The results of the few studies using borage oil as the source of GLA in the treatment of atopic eczema are inconclusive (Andreassi et al, 1997; Henz et al, 1999). In a 1997 study, supplementation with 548 mg of GLA (2 x 274 mg) from borage oil for 12 weeks resulted in significant improvement (subjective and dermatologist's assessment) in the symptoms of atopic eczema (Andreassi et al, 1997). On the other hand, supplementation with 500 mg of borage oil (100-125 mg GLA) daily for 24 weeks resulted in no overall significant improvement in symptoms of 60 patients with atopic eczema in a 1999 double blind, placebo-controlled study (Henz et al, 1999). However, a small subgroup of the population studied (those with increased red blood cell DGLA levels) did show significant improvement, suggesting that further studies of this type with borage oil are warranted (Henz et al, 1999).

Borage Oil and Cardiovascular Disease

It has been suggested that people with cardiovascular disease may have a reduced ability to convert LA into GLA and its metabolites (Horrobin, 1993a). GLA consumption has been shown to favourably alter parameters associated with cardiovascular disease including blood cholesterol levels and blood pressure. As a source of GLA, borage oil may be of benefit to those at risk of cardiovascular disease.

Does Borage Oil Reduce Cholesterol?

Excessive low-density lipoprotein (LDL) cholesterol is a major risk factor for atherosclerosis, a condition that often precedes heart disease. Atherosclerosis is characterized by the presence of fatty deposits on the inner arterial walls, which may result in blockage of the artery and restricted blood flow to the heart. Increasing the intake of polyunsaturated fatty acids has been shown to reduce cholesterol levels and may therefore help reduce the risk of cardiovascular disease (Mattson and Grundy, 1985). Although evening primrose oil (another source of GLA) has been shown to reduce harmful LDL cholesterol levels in humans (Horrobin and Manku, 1983; Chaintreuil et al, 1984; Ishikawa et al, 1989; Guivernau et al, 1994; Fukushima et al, 1997) and animals (Sugano et al, 1986), this effect has yet to be investigated adequately with borage oil. In a recent study however, borage oil prevented an increase in serum cholesterol in rats consuming a high cholesterol diet (Fukushima et al, 2001).

Does Borage Oil Reduce Blood Pressure?

Hypertension (high blood pressure) is another one of the main risk factors for heart disease. It is generally recommended that non-drug therapies be used to reduce borderline/mildly high blood pressure before drug intervention is considered. A dietary regimen to reduce blood pressure normally includes a reduced intake of salt (sodium), caffeine, alcohol and red meat and an increased intake of vegetables and whole grains (complex carbohydrates, fibre, potassium, magnesium, calcium, vitamins C and B₆).

Several studies have suggested that GLA supplementation may also reduce blood pressure (Singer et al, 1984; Soma et al, 1985; Venter et al, 1988; Mills et al, 1989; Engler et al, 1992; Engler et al, 1993; Mtabaji et al, 1993; Engler et al, 1998), many of which used borage oil as the source of GLA (Mills et al, 1989; Engler et al, 1992; Engler et al, 1993; Engler et al, 1998). In a 1998 study, dietary borage oil enhanced the amount of omega-6 fatty acids in the plasma, liver and vascular tissue of hypertensive rats, which may contribute to its ability to reduce blood pressure (Engler and Engler, 1998). Further research is needed in humans to confirm the beneficial effects of GLA observed in animal studies.

Borage Oil and Diabetes

Approximately half of diabetics will have to undergo treatment for diabetic neuropathy, a condition characterized by the loss of peripheral nerve function. In severe cases, amputation of the affected area may be necessary. Although strict diabetic control may help prevent neuropathy, it is common even in those who properly control their diabetes (Horrobin, 1993b). It has been shown that diabetics have impaired conversion of LA to its metabolites (Jones et al, 1983), which may be due to impaired delta-6-desaturase function (Poisson, 1989). Since GLA and other LA metabolites are required for normal neuronal structure and to control the microcirculation, their deficiency may contribute to the development of neuropathy (Horrobin, 1992b). Diabetics may therefore benefit from GLA supplementation with borage oil.

Does Borage Oil Prevent Diabetic Neuropathy?

Very few studies have investigated the potential benefits of borage oil in diabetic neuropathy. In a 1996 study, borage oil consumption improved peripheral nerve conduction velocity in diabetic rats, suggesting that it may be effective in preventing or delaying diabetic neuropathy (Dines et al, 1996). It was however, less effective than an equal dose of evening primrose oil, another GLA-containing oil.

Borage Oil and Alcoholism

It has been hypothesized that many of the short and long-term behavioural consequences and adverse effects on the heart, brain, liver and other tissues associated with chronic alcohol intake may be due in part to the effects of alcohol on essential fatty acid metabolism (Horrobin, 1980a; Horrobin 1980b;

Horrobin, 1987). Dietary supplementation with borage oil may restore normal levels of essential fatty acids in alcoholics and help prevent alcohol-related complications.

Can Borage Oil be Used to Treat Alcohol-Related Disorders?

Cirrhosis is an inflammatory disease of the liver that is caused by chronic alcoholism, among other factors. In two preliminary animal studies, supplementation with borage oil prevented an alcohol-induced decrease in arachidonic acid (AA) in platelets, which may be of benefit in the prevention of cirrhosis (Engler et al, 1991). Further research is required to investigate these effects in human subjects however.

Borage Oil and Obesity

The incidence of obesity, defined as excess in body weight (>30 % body fat for women and 25 % for men), has been increasing steadily in North America. Obesity has been associated with an increased risk for cardiovascular disease, several types of cancer, adult-onset diabetes and osteoarthritis (Pi-Sunyer, 1991). By adjusting physical activity and dietary fat, carbohydrate, protein and alcohol intake so that energy expenditure exceeds energy intake, body weight will be reduced. Diets rich in fruits, vegetables, whole grains and dried legumes are often recommended for weight loss, since these foods typically take long to eat and induce satiety (fullness) at a low energy intake (Duncan et al, 1983). Since fat is higher in calories than an equal weight of carbohydrate (9 kcal calories per gram compared to 4 kcal per gram), it is generally recommended that its intake be limited to lose weight (Prentice, 1998).

Several studies have suggested that types of dietary fat may differ in their effects on fat accumulation in the body. Compared to saturated fats, monounsaturated (Jones et al, 1985; De Lany et al, 2000) and polyunsaturated fats (Cunnane et al, 1986; Jones and Schoeller, 1988; Shimomura et al, 1990; Pan et al, 1994; DeLany et al, 2000) favourably alter a number of parameters associated with body weight and may therefore help promote weight loss. However, many studies have reported contradictory results (Ikemoto et al, 1996; Tsunoda et al, 1998), indicating that further research is necessary before any conclusions regarding the role of fat in a weight-reducing diet can be made.

Does Borage Oil Promote Weight Loss?

In a recent study, rats fed diets containing borage oil had decreased body fat mass compared to rats fed a safflower oil-containing diet, suggesting that GLA may attenuate body fat accumulation (Takahashi et al, 2000). Studies with evening primrose oil, another GLA-containing oil, have yielded inconsistent results (Haslett et al, 1982; Mir et al 1982; Haslett et al, 1983). Further research into the relationship between fatty acids and weight reduction is necessary before any conclusions can be made.

Future Research

Most studies investigating the nutritional benefits of GLA have used evening primrose oil as the source of GLA. Evening primrose oil has been investigated for use in the treatment and prevention of a number of illnesses including attention deficit hyperactivity disorder (ADHD), Alzheimer's disease, cancer, irritable bowel syndrome, mastalgia, menopausal flushing, migraine, multiple sclerosis, osteoporosis, premenstrual syndrome, psoriatic arthritis, Raynaud's phenomenon, Sjogren's syndrome, schizophrenia, systemic sclerosis, ulcerative colitis and uremic pruritis. Many of these applications have not yet been substantiated by significant scientific evidence however.

Borage oil contains much more GLA than an equal dose of evening primrose oil, and may therefore have more pronounced effects. Since borage oil has been investigated in only a small number of studies however, it is still unclear whether or not it is more effective than evening primrose oil. In a 1992 study, GLA from borage oil was absorbed and metabolized equally as well as that from evening primrose oil in rats (Raederstorff and Moser, 1992). On the other hand, several studies have shown that borage oil is

no more effective than evening primrose oil in correcting abnormalities in essential fatty acid metabolism (Dines et al, 1996). Borage oil contains more monounsaturated and saturated fatty acids and less polyunsaturated fatty acids (linoleic acid) than evening primrose oil, which may interfere with the metabolism of GLA, reducing its beneficial effects (Dines et al, 1996).

Anecdotal Evidence

Borage flowers and leaves have been used traditionally to treat a wide variety of ailments including melancholy, stress, fever, skin rash, colds, cough, sore throat, bronchitis, corns, diarrhoea, ulcers, kidney stones, nervous tension, premenstrual syndrome, inflammation, abnormal adrenal function and insect bites. There is no scientific evidence supporting any of these claims however.

SAFETY AND SIDE EFFECTS

Is it Safe to Consume Borage Oil?

Borage oil is generally considered safe to use. However, there is a lack of scientific data regarding its safety. There are some safety concerns associated with the excessive consumption of borage oil, primarily due to its high content of polyunsaturated fatty acids. Although polyunsaturated fatty acids are beneficial when consumed in the recommended amounts (8-10 % of total calories), they can be harmful when consumed in excess (>10% of total calories).

Blood Thinning

A high intake of polyunsaturated fatty acids may reduce blood clotting (Eritsland, 2000). It is not recommended that large amounts of borage oil be consumed while taking other blood thinning agents (prescription anti-coagulants like warfarin, over the counter pain relievers like aspirin or ibuprofen, vitamin E), in the 2-3 weeks prior to surgery or if you who have a blood clotting disorder. Other herbs/nutraceuticals that may alter blood clotting include garlic, ginseng, ginkgo, ginger, feverfew, fish oil, flaxseed oil, hempseed oil and evening primrose oil.

GLA and Seizures

People with epilepsy should avoid consuming borage oil as GLA may lower the seizure threshold (Miller, 1998). As a source of GLA, borage oil may also cause harmful interactions with anticonvulsant drugs (such as phenobarbitals) or with drugs that lower the seizure threshold (tricyclic antidepressants and phenothiazines).

Lipid Peroxidation

A main safety concern associated with a high intake of polyunsaturated fatty acids is their high susceptibility to peroxidation (Eritsland, 2000). Peroxidation refers to oxidative damage of lipids (fats) by free radicals. Free radicals are molecules with an unpaired electron, which are for the most part, highly unstable. They cause damage to the DNA, carbohydrates, lipids and proteins in the body (oxidative stress) that is believed to be involved in the aging process and in the development of heart disease, cancer and neurodegenerative diseases (Halliwell, 1994; Jenner, 1994).

Polyunsaturated fatty acids are more susceptible to peroxidation than other fatty acids because of their greater number of double bonds. To reduce oxidative damage to the body, it is often recommended that a high intake of polyunsaturated fatty acids be accompanied by a high antioxidant intake. Antioxidants are compounds that are capable of neutralizing highly reactive molecules (like free radicals), thereby reducing oxidative damage. Vitamin E, a fat-soluble vitamin with antioxidant properties, is particularly important in protecting fatty acids from oxidation. The daily requirement for vitamin E is approximately

15 mg ATE* /day for adults. With increased intakes of polyunsaturated fatty acids however, it is recommended that vitamin E intake also be increased. An optimal ratio of vitamin E /polyunsaturated fat has yet to be agreed upon, but a dose of 0.6 mg ATE of vitamin E/g polyunsaturated fatty acid is often recommended (Valk and Hornstra, 2000).

Glycemic Control

Supplementation with omega-3 fatty acids has been associated with deterioration of glycemic control in subjects with type II (non-insulin dependant) diabetes (Eritsland, 2000). Since this effect has not been consistently demonstrated however, it is unclear how omega-3 fatty acids influence glycemic control

Weight Gain

Another safety concern associated with long-term consumption of large doses of borage oil is weight gain. Although borage oil fat is considered “good fat”, it is still capable of causing weight gain when consumed in excess. Like all fatty acids, polyunsaturated fatty acids are energy dense, providing approximately 9 kcal of energy per gram (1 tablespoon of borage oil provides approximately 126 kcal). To prevent weight gain with consumption of large amounts of borage oil, fat intake from other sources, preferably those high in harmful saturated and trans fatty acids, should be reduced. If borage oil is taken in normal doses (3 g per/day), it will not cause any significant weight gain.

What are Pyrrolizidine Alkaloids?

Reports in the 1980’s demonstrated that borage contains trace amounts of toxic pyrrolizidine alkaloids (PA), which may cause cancer and liver damage. It is recommended that PA intake not exceed 1 µg per day and therefore, PA-containing borage leaves, flowers and stems are considered unsafe for human consumption (Tyler, 1996; Klepser and Klepser 1999). Since refined borage seed oil contains negligible amounts of PA (<4 µg/kg), it generally poses no health risks in this regard.

Does Borage Oil Cause any Side Effects?

Short-term side effects of supplementation with borage oil may include loose stools and minor stomach complications (belching, abdominal bloating) (De Luca et al, 1995) and may be minimized by consuming it with food. Although borage oil has been used for many years, its long-term effects have yet to be investigated thoroughly. Long- term consumption of high doses of borage oil should therefore be approached with caution.

What is an Optimal Dose of Borage Oil?

An optimal dose and length of treatment for borage oil has not been established. Manufacturers recommend a dose of approximately 3 g of borage oil per day, providing approximately 700 mg of GLA. However, higher doses are often used in the treatment of some ailments (like rheumatoid arthritis). A few weeks to several months of supplementation may be necessary before results are noticeable.

For GLA supplementation to produce optimal effects, borage oil should supplement an already balanced diet that provides adequate amounts of vitamins and minerals and the proper amounts of calories and fat. Vitamin C, pyridoxine (vitamin B6), biotin, zinc, calcium and magnesium are all involved in fat metabolism and should be included in the diet. Since different types of fatty acids interfere with each other when metabolized, it is also important to consume the right amounts of different types of fat.

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Written by Eric Paas and Dr. Grant Pierce.

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