InterClinical Wellness

**Marine Phytoplankton –
Improve vitality; support healthy skin and eyes; enhance immunity, natural detoxification and general well being**

Dunaliella salina – Marine Phytoplankton

***Dunaliella salina* is a health-enhancing, powerful functional food and natural medicine. It is a potent natural source of antioxidants, carotenoids, vitamins, minerals, amino acids, polysaccharides, essential fatty acids, chlorophyll and phytonutrients.**

Ancient Healthcare

Micro algae (also known as phytoplankton) have been used as a nutrient rich food and medicine for thousands of years by the Aztecs, some African and Asian peoples and South Pacific Islanders.

In nature, *Dunaliella salina* is an important source of nutrition for many birds, insects, fish and crustaceans, which benefit from the phytoplankton's health promoting properties.

Dunaliella salina marine phytoplankton can be taken daily as a natural multi-nutrient supplement, as it provides many nutrients required to support health and vitality.

Botany

Dunaliella salina (also called *Dunaliella bardawil*)[1] is a single-celled soft walled, edible, marine phytoplankton that lives in coastal waters and salt water lakes.

Phytoplanktons are autotrophic microscopic organisms – the producers in the food chain. Autotrophs obtain energy from the environment (i.e. sunlight or inorganic compounds) and utilise it to create carbon-based organic molecules. The rich source of concentrated nutrients found in marine phytoplankton provides many health benefits to humans.

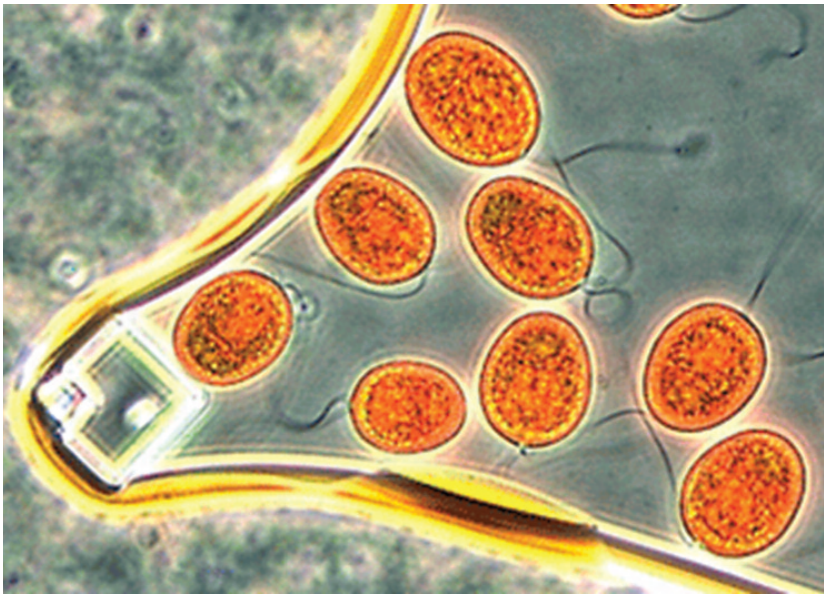

DIAGRAM 1 *Dunaliella salina* single celled phytoplankton

Dunaliella salina is a very primitive organism belonging to a division of eukaryotes that evolved over 1.5 billion million years ago[2] (see diagram 1). It is a unique species of micro-algae that has evolved to live in extreme environmental conditions. It is classed as an extremophile.[3] It is one of the most salt tolerant life forms known and has adapted to very high ultra violet (UV) radiation. To protect itself in these harsh conditions, *Dunaliella salina* naturally produces high levels of carotenoids and antioxidant molecules. *Dunaliella salina* sits at the base of the food chain and is one of the most productive organisms on the planet, using light approximately three times more efficiently than higher plants.[4]

The genus Dunaliella is an order of Chlorophyceae, one of the classes of green algae.[5] *Dunaliella salina* and *Dunaliella bardawil* are considered to be the same species.[6]

Dunaliella salina's orange-red colour is due to its high content of beta-carotene and mixed carotenoids, even though it is extremely rich in chlorophyll. It is sometimes referred to as red marine phytoplankton.

Growth, Storage and Handling

Areas with high UV sunlight and low rainfall provide a perfect environment for growth of *Dunaliella salina*. For greatest nutritional benefit, the phytoplankton should be grown in clean, mineral-rich marine waters and harvested and dried mechanically without the use of chemicals or solvents.

Dunaliella salina should be stored in dry airtight containers, as carotenoids oxidise on exposure to air (oxygen) and light.

Bio available active constituents

On a gram for gram basis, *Dunaliella salina* may be the most nutrient dense food on earth.[7] In its natural state, each *Dunaliella salina* cell supplies a holistic balance of vitamins, minerals and phytonutrients. (See fig 1 and fig 2). It has minimal indigestible structures in contrast to other microalgae, eg spirulina and chlorella, and also higher plants and animals – which typically have less than half their dry weight being nutritionally useful.[8]

Carotenoids

The potent antioxidant activity of *Dunaliella salina* phyto-plankton is due to its high content of mixed carotenoids, a class of yellow, orange and red pigments synthesised by plants, algae and photosynthetic micro-organisms. Of the approximately 600 carotenoids identified in nature, over 500 have been found in *Dunaliella salina*.

Nature's richest source of dietary beta-carotene

Dunaliella salina is extremely rich in antioxidant carotenoids beta-carotene, alpha-carotene, lutein, zeaxanthin, and cryptoxanthin. Significantly, it is nature's richest known source of dietary beta-carotene[9]. (See Table 1)

The colour imparted to animals and birds by the carotenoids in Dunaliella phytoplankton is believed to be used for sexual signalling and play a role in natural selection as the animals with the most colour are likely to be the healthiest and the most likely to attract a mate.[8]

Minerals

Whole dried *Dunaliella salina* is very rich in minerals, including magnesium, potassium, zinc, iron, manganese, boron, selenium and lithium. It's magnesium content is particularly high. (See Table 2)

Minerals, "the spark plugs of life" are necessary for a diverse range of biochemical processes – including enzyme functions, nerve conduction, muscle contraction, acid-alkali balance, healthy function of the nervous system and structural support in formation of bones, teeth and blood. Ocean water contains the full spectrum of minerals and trace elements on which marine phytoplankton feed. The minerals and electrolytes in *Dunaliella salina* are essential for optimum function and health in the human body.

Vitamins

Dunaliella salina contains a range of vitamins including Vitamin E, various B group vitamins; B1, B3, B5, B6, B12, folic acid; and pro-vitamin A (natural beta-carotene).

Amino Acids

Dunaliella salina is a source of complete protein, containing all the essential amino acids (see Table 3). Amino acids are the basic building blocks of life, required for synthesis of muscles, skin, connective tissues, hormones, enzymes and neurotransmitters.

Polysaccharides

Polysaccharides are complex carbohydrates with diverse biological functions. A number of polysaccharides with biological activities, including anti-virus, anti-tumour, and anti-inflammatory are present in *Dunaliella salina*.[11,12]

Chlorophyll

Dunaliella salina contains a significant amount of chlorophyll, a powerful cleansing agent, blood builder and natural antibiotic which is able to chelate heavy metals and toxins from the body. The chemical structure of chlorophyll is similar to haemoglobin, the oxygen carrying protein of red blood cells. The basic difference between haemoglobin and chlorophyll is the metallic atom in the centre of each molecule – chlorophyll molecules have magnesium where haemoglobin has iron. Chlorophyllin, the active ingredient in chlorophyll has antioxidant, anti-tumour and anti mutagenic properties[13].

Human Health Benefits

Dunaliella salina can be used to :

- Help reduce the risk of premature ageing and chronic diseases[8,14,15]
- Support health ageing (as an anti-ageing nutritional medicine)[16,17,18,19]
- Help maintain healthy skin[14,20]
- Help maintain eye health[14,20,21,22]
- Improves protection against UV radiation[19,23]
- Help maintain a healthy immune system[14,21]
- Help reduce the risk of viral infections[14]
- Help maintain and restore vitality[14]
- Improve antioxidant and free radical scavenging activities in the body[14,24]
- Provide a source of antioxidant nutrients that help protect cells from free radical damage[7,14,24]
- Provide a rich source of natural mixed carotenoids and daily nutrients important for long-term health and wellbeing[14]
- Supports the body's natural detoxification processes[14,19,23]
- Help reduce the risk and protect from cardiovascular disease[14,15]
- Help reduce the risk of cancer[14,15,25,26,27]

Comparison with other cell foods

Dunaliella salina has a much higher content of bioavailable nutrients than other cell foods, such as spirulina and chlorella. Gram per gram, *Dunaliella salina* can have more than twice the chlorophyll up to eight times the mineral content and ten times the antioxidant content of spirulina. Research shows the

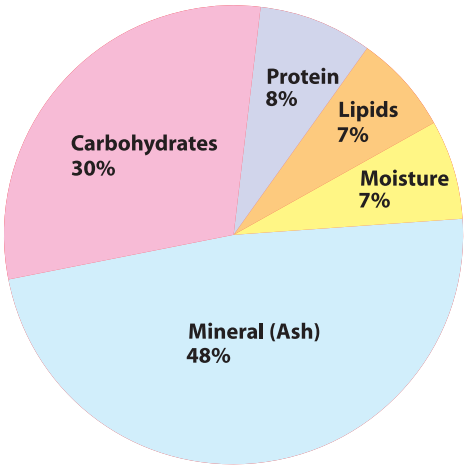

FIGURE 1. *Dunaliella salina* whole dried typical analysis.
Source: Inman and Farrell Pty Ltd. Australia

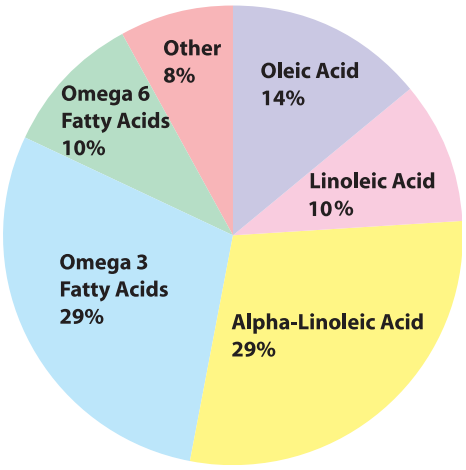

FIGURE 2. *Dunaliella salina* whole dried total unsaturated fatty acids

Comparative characteristics of *Dunaliella salina*, spirulina and chlorella

Dunaliella Salina,	spirulina and chlorella
Soft wall microalgae	Fibrous or hard wall microalgae
Easy breakdown maximising nutrient absorption	Difficult breakdown limiting nutrient absorption
Grown in a nutrient rich marine (brine) environment	Grown in a nutrient poor freshwater environment
Mineral rich	Contains much lower levels of minerals
Carotenoid rich	Contains much lower levels of carotenoids

carotenoids from Dunaliella phytoplankton are well absorbed.[28] *Dunaliella salina* has a soft cell wall structure rather than a hard cell wall that makes it far more easily digestible by the human gut compared to other algae.[29]

Research also indicates carotenoids from *Dunaliella salina* possess better hepatoprotection activity, than those from spirulina[30].

Protective antioxidants

Carotenoids

In plants, carotenoids are essential in photosynthesis and vital for protecting plants from oxidative damage. The red, orange and yellow pigments absorb blue light that is the most damaging part of the light spectrum. In mammals, carotenoids have a similar photo protective effect (ie. protection from oxidative stress that is produced by UV light), as well as antioxidant, immune enhancing and anticarcinogenic activities.

In humans, carotenoids are important fat-soluble antioxidants, and have varied biological roles. Carotenoids have been shown to help protect against oxidative cell damage responsible for premature ageing, cardiovascular disease, cancer and other chronic diseases[14]. Carotenoids quench singlet oxygen, prevent the formation of free radicals, react with or scavenge free radicals, modulate DNA repair mechanisms and inhibit the oxidation of fats (i.e., lipid peroxidation).[24,31]

Beta-carotene:

Beta-carotene is one of the most important carotenoids human health maintenance and prevention of disease. It is the most prevalent carotenoid in plants, and has been described as the most active of the carotenoids. Many of the clinical applications of *Dunaliella salina* are due to its high content of natural beta-carotene.

As well as converting to Vitamin A, beta-carotene is a powerful antioxidant, and may assist with preventing cancer and cardiovascular disease, help maintain a healthy immune system, reduce sunburn and photo-ageing of the skin, assist with asthma, and prevent damage from oxidative stress.

Natural versus synthetic beta-carotene: *Not all beta-carotene is the same in health care*

Beta-carotene has different forms called isomers. Isomers have the same molecular formula but different atomic arrangement, different chemical properties and different pharmacological activities. When using beta-carotene as a nutritional supplement, it is important to note that natural and synthetic forms have different isomeric arrangements.

The beta-carotene 9-cis isomer is one of nature's most powerful antioxidants, whereas the all-trans beta-carotene isomer is more readily converted to Vitamin A than other carotenoids.

Synthetic beta-carotene contains only the all-trans isomer. This form of beta-carotene can be readily converted into vitamin A, but has very little anti-oxidant activity.

Natural beta-carotene, the beta-carotene from *Dunaliella salina*, is composed of approximately equivalent amounts of the all-trans and 9-cis stereoisomers. So *Dunaliella salina* provides much greater bioavailability and anti-oxidant activity than synthetic beta-carotene supplements.[32,33,34]

Many multivitamin supplements contain only the synthetic form of beta-carotene, (ie all-trans) and thus have less antioxidant activity. Studies today suggest that it may be more advantageous to use natural sources of beta-carotene or to increase beta-carotene rich foods, such as carrots, apricots and phytoplankton.[14]

Animal studies show higher accumulation of beta-carotene from algal sources than from synthetic all-trans beta-carotene.[35] Of all the natural carotenoids sources Dunaliella phytoplankton has the highest content of the 9-cis stereoisomer.[36]

Some multivitamin supplements use natural beta-carotene produced from Dunaliella phytoplankton through extraction processes.

Recently, advances in production technology have allowed the whole dried *Dunaliella salina* biomass, with its full range of botanical nutrients and minerals intact, to become commercially available in supplement form for the first time.

Source of Vitamin A (Pro-Vitamin A)

In the body, beta-carotene (all-trans) is converted into vitamin A, as needed, by an enzyme found in the intestinal mucosa and liver this means it is safe and non toxic even when given at high doses for long periods of time.

Vitamin A plays an essential role in vision, growth, reproduction and regulation of the immune system. It also helps maintain the health and integrity of the skin and mucous membranes. However, while high doses of Vitamin A can be toxic, beta-carotene is only converted to Vitamin A as needed, by the body as required, thus making it non-toxic even when given at high doses for long periods of time.

Beta-carotene, alpha-carotene, and beta-cryptoxanthin are provitamin A carotenoids. Other carotenoids, xanthophylls such as lutein, zeaxanthin and lycopene have no vitamin A activity, but are important fat-soluble antioxidants.[32]

Health promoting benefits

Skin, vision, photosensitivity and photoprotection.

Dunaliella salina contains proteins and essential fatty acids, the basic building materials required to make cells, skin and connective tissue. Beta-carotene and vitamin A promote healthy skin and vision and may help to prevent skin conditions, cataracts and night blindness. The mixed carotenoid content in *Dunaliella salina* is especially important for photo protection as the red, orange and yellow pigments preferentially absorb UV light.

Lutein and zeaxanthin are the predominant carotenoids of the retina and are considered to act as photoprotectants preventing retinal degeneration.

Table 1. Typical analysis of *Dunaliella salina*, spirulina and carrots[16]

Nutrient	*Dunaliella salina* (per 100g)	*Dunaliella salina* (per 1g)	Spirulina (per 100g)	Spirulina (per 1g)	Carrots (per 100g)	Carrots (per 1g)
Protein	7.4g	74mg	57g	570mg	1.0g	10mg
Fat (total)	7.0g	70mg	8.0g	80mg	0.0	0.0
Carbohydrates	29.7g	297mg	24g	240mg	10g	100mg
Fibre	0.4g	4mg	4.0g	40mg	3.0g	30mg
Minerals (ash)	49g	490mg	6.2g	62mg	1.0g	10mg
Energy	893kj	8.93kj	1214kj	12.14kj	180kj	1.8kj
Beta-carotene	1,100–2,100mg	11–21mg	0.342mg	0.00342mg	5.8mg	0.058mg
Alpha-carotene	53.1–102.4mg	0.531–1,024mg	0.0mg	0.0mg	2.8mg	0.028mg
Lutein & Zeaxanthin	54.3–97.6mg	0.543-0.976mg	0.00mg	0.00mg	0.2mg	0.002mg
Cryptoxanthin	23.4–46.5mg	0.234–0.465mg	0.00mg	0.00mg	0.1mg	0.001mg
Chlorophyll	2210mg	22.1mg	1000mg	10mg	n/a	n/a

Source: Dunaliella salina National Measurement Institute (Australia) and Craft Technologies Inc. (USA)
Spirulina and Carrot data, USDA National Nutrient Database for standard references, release 18 (USA)

Table 2. Comparison of minerals in green and functional foods

Mineral (mg/100g)	Whole dried *D.salina*	Spirulina	Chlorella	Kelp	Wheat grass	Green barley
Calcium	148	547	201	1443	937	384
Magnesium	6402	330	211	796	83	186
Potassium	6.5	5	5	7	6	6
Copper	0.3	1.1	0.1	0.2	0.4	0.6
Zinc	1	2	1	3	2	2
Phosphorus	76.5	857	1040	106	290	281
Iron	27.3	50.5	214	26.9	13.7	8.4
Manganese	9.1	2.62	4.06	3.87	5.08	3.85
Chromium	0.35	0.53	0.06	0.23	0.09	0.11
Selenium	1.48	0.03	0.01	0.69	0.04	0.15
Boron	27.81	0.25	0.03	11.13	0.33	1.05
Cobalt	0.03	0.131	0.038	0.045	0.005	0.004
Molybdenum	0.04	0.105	0.042	0.094	0.05	0.066
Sulfur	2731	<2000	<2000	2426	<2000	<2000
Lithium	0.92	0.093	0.01	0.068	0.008	0.023

Source: Trace Elements Inc. (USA)
NB: Nutrient levels will vary from batch to batch.

Table 3. Amino Acid Profile *Dunaliella salina*

Alanine	Methionine
Arginine	Phenylalanine
Aspartic acid	Proline
Cysteine	Serine
Glutamic acid	Threonine
Glycine	Tryptophan
Histidine	Tyrosine
Isoleucine	Valine
Leucine	Lysine

Source: Australian Proteome Analysis Facility Ltd

Beta-carotene within the skin acts as a cellular screen against sunlight-induced free-radical damage, and is used in the treatment of photosensitivity disorders (skin rashes caused by the sun). Natural beta-carotene from *Dunaliella salina* is a useful oral sun protectant and supplementation protects against UV-induced erythema formation (sunburn).[23,37] Supplementation with beta carotene before UV-exposure, combined with topical sunscreens is more effective than sunscreen cream alone.[19]

Immunity

Dunaliella salina helps to stimulate the immune system's natural defences and its response to infection. Beta-carotene stimulates thymus gland and immune function. Vitamin A assists in viral illnesses, helps to maintain non-specific host defences, enhances white blood cell function and antibody response, and stimulates anti-tumour activity.[14,21]

Natural Detoxification

As well as chlorophyll and beta-carotene, *Dunaliella salina* contains other vitamins, amino acids, and minerals such as selenium, sulphur and magnesium that aid in detoxification.

The powerful antioxidant properties of the numerous carotenoids in *Dunaliella salina* are also vital for the detoxification of harmful substances in the body. Dietary supplementation with beta carotene enhances the liver's ability to withstand toxic challenge.[38]

Research shows the mixed carotenoids obtained from Dunaliella phytoplankton have a higher antihepatotoxic effect than both beta-carotene extracted from a natural source, and from synthetic beta-carotene. Research suggests this is due to presence of both cis and trans isomeric forms of beta-carotene, as well as other carotenoids (xanthophylls) in Dunaliella phytoplankton.[31,39,40]

Hepatoprotection is essential for enhancing liver function and improving detoxification capacity, as the liver has multiple roles in the body's detoxification processes (blood filtering; bile synthesis and secretion; enzymatic processes for neutralisation of toxins). Supporting functioning of the liver is fundamental for health status, due to its continual role in elimination of toxic substances (eg chemicals, drugs, heavy metals, microbial pathogens) known to cause serious health problems.

An initial cohort study found supplementation of whole dried *Dunaliella salina* (3 grams/day for 14 weeks) significantly reduced hair tissue levels of various toxic metals.[41]

Energy and vitality

Dunaliella salina contains the macro and micro nutrients required by our bodies for energy production and to synthesise muscles, skin and connective tissues, hormones, enzymes and neurotransmitters. It contains vitamins and minerals such as cobalamin (vitamin B12) and magnesium that are necessary cofactors in cellular energy production. The rich electrolyte content of *Dunaliella salina* is also important for maintaining energy and stamina. Magnesium in particular is important for healthy cellular metabolism, energy production and nerve and muscle function.

Vitality- the capacity to live, grow and develop – can be enhanced and restored by the natural antioxidants and Vitamin A precursor carotenoids in *Dunaliella salina*. Vitamin A is essential for growth and development, due to its roles in cellular differentiation and gene expression. Antioxidants function to advance cellular health and immunity, thus improving the body's ability and efficacy in survival, growth , recovery and development.

Cardiovascular disease

Dunaliella salina contains antioxidant nutrients that inhibit damage to cholesterol and help to protect against cardiovascular disease. Studies show that high natural beta-carotene intake is associated with a lower risk of developing cardiovascular disease[14]and supplementation with beta-carotene may reduce the risk of cardiovascular events in patients with coronary artery disease[25].

Dried Dunaliella powder, containing 9-cis and all-trans beta-carotene isomers, may have the potential to inhibit atherogenesis in humans. In animal models using high-fat diet-fed LDL receptor knockout mice, Dunaliella powder inhibited atherogenesis and significantly reduced plasma cholesterol, atherosclerotic lesions and mRNA levels of inflammatory genes. Liver inflammation and liver fat accumulation was also reduced[42].

Dunaliella salina also contains essential fatty acids that reduce blood lipid levels and inflammation and help prevent heart disease.

Cancer

High intake of natural beta- and alpha-carotene from food has been associated with up to a 63% reduction in many cancers[15], in particular those involving epithelial tissues (eg lung, skin, cervix, gastrointestinal tract).[14]

Research with *Dunaliella salina* has been positive and warrants further investigation.

In rats with laboratory-induced fibrosarcoma, supplementation with *Dunaliella salina* resulted in regenerative and regressive alterations to tumours.[25]

In human lung cancer cells an ethanol extract of *Dunaliella salina* was shown to have anti-proliferative effects and induce cell cycle arrest and apoptosis.[26]

Studies on supplementation with synthetic beta-carotene, however, have produced mixed results. Two studies involving heavy smokers found an increased risk of lung cancer with supplementation of synthetic beta-carotene[14,43]. This association has not been found with natural dietary beta-carotene from plant sources. Observational epidemiological studies have consistently shown dietary beta-carotene intake correlates with a decrease in risk of various cancers.[27]

Healthy Ageing

Antioxidants have a role in modulating oxidative stress associated with ageing.[17] Free radicals and oxidative stress have been recognised as important factors in the biology of ageing and many age associated degenerative diseases. The free radical theory of ageing explains how organisms age because free radical damage to cells increases over time. Free radicals are extremely reactive molecules that have unpaired electrons, a configuration that makes them likely to take part in a chemical reaction. Free radicals are often associated with cell damage, mutations and even malignancies.

Oxidative damage is deemed to contribute to deteriorating processes associated with ageing and health disorders that occur more frequently in older people such as cardiovascular disease, cognitive disorders, cancer and diabetes mellitus. An adequate supply of dietary antioxidants is important, as there is an age-related decrease in the activities of antioxidant enzymes.[18] Adequate levels of antioxidants from adulthood may be useful to attain healthy ageing, especially in cases of premature ageing.[16]

The role of carotenoids as dietary antioxidants has been

Dunaliella salina growth ponds

suggested to be the major mechanism for their preventative effects against cancer and inflammatory disorders. Many nutrients in *Dunaliella salina,* including chlorophyll, beta-carotene, mixed carotenoids (lutein, xanthein, cryptoxanthin) sulphur, and selenium, display antioxidant activity.

Long term supplementation with beta-carotene has benefits to brain function, resulting in significant improvements in general cognition and short term memory (verbal memory).[44]

Research also suggests that higher total serum carotenoid concentrations, from natural sources of beta-carotene, are protective against decline in physical ability in older adults.[45,46]

Evidence suggests tissue carotenoid content is the most significant factor in determining maximal life span potential (MLSP) of mammalian species.[47]

Human clinical trials on Dunaliella beta-carotene

Antioxidant protection

A double-blind trial in humans found that a single dose of natural beta-carotene from *Dunaliella salina* reduced the severity of pancreatitis in patients who had undergone endoscopic retrograde cholangiopancreatography (ERCP). The study suggested antioxidants in the natural beta-carotene were protective against oxidative stress, a causative factor in pancreatic injury.[48]

Protection against radiation damage

An evaluation was undertaken of 709 children exposed to long-term doses of radiation during and after the Chernobyl accident. Children were given 40mg capsules of natural 9-cis and all-trans equal-isomer-mixture beta-carotene powder from Dunaliella phytoplankton twice daily for 3 months. After supplementation the children showed reduced serum markers for oxidisation. Beta-carotene acted as a lipophilic antioxidant and in radioprotection.[49]

Normalising high LDL oxidation

Beta-carotene (60mg/day) derived from Dunaliella was given to 20 patients with longstanding non-insulin dependent diabetes mellitus (NIDDM) for 3 weeks. It was found that natural beta-carotene normalised high LDL oxidation in these patients, and the hypothesis was made that it may help to delay accelerated atherosclerosis so common in patients with diabetes.[48]

Protection against exercise induced asthma

In a study of patients with exercise-induced asthma (EIA), all patients receiving placebo showed significant post-exercise reduction of more than 15% in their forced expiration volume in one second (FEV1). However, of the 38 patients who received a daily dose of 64mg beta-carotene from Dunaliella, 20 (53%) were protected against EIA, most likely through its antioxidant effect.[51]

Protection from sun damage

In a twelve week placebo-controlled trial, supplementation with Dunaliella phytoplankton – derived carotenoids (24 mg/day) significantly increased protection from sunburn. In the supplemental group there was a three to fourfold increase in serum beta-carotene concentration after twelve weeks.[23]

Another study showed supplementation with natural carotenoids isolated from *Dunaliella salina* may partially protect human skin from UVA- and UVB- induced erythema. Twenty two subjects were exposed to simulated solar radiation for 24 weeks and serum lipid peroxidation was significantly inhibited (in a dose-dependent manner) during natural carotenoid-supplementation.[37]

Toxicity

Dunaliella phytoplankton is classified as an edible species of phytoplankton (microalgae). No formal human toxicology studies have been carried out on Dunaliella phytoplankton, however no adverse effects from consumption of the whole phytoplankton cells or beta-carotene extract from Dunaliella have been reported in human clinical studies.

Rare

Adverse reactions from algal supplements can include nausea and vomiting.

Excessive amounts of beta-carotene can cause orange or yellow skin (carotenodermia). This is harmless and reversible on discontinuation[52]. Some people may consider this to be a desirable effect and reflect a healthy glow. In some countries this effect is utilised in tanning tablets to produce a natural looking skin tan.

Drug interactions

No known interactions at this time.

Dosage Range

1-3 grams of whole dried *Dunaliella salina* powder (which contains around 1-2% beta carotene) when taken as a supplement.[22]

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